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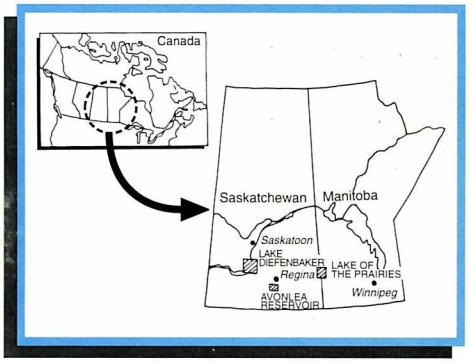
SHORE EROSION AND SLUMPING ON WESTERN CANADIAN LAKES AND RESERVOIRS

A Methodology For Estimating Future Bank Recession Rates

FINAL REPORT



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November, 1993

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EXECUTIVE SUMMARY

In recent years lake and reservoir shore erosion and bank slumping have come under increasing scrutiny owing to their environmental impacts on aquatic and shoreland ecosystems, natural resources, and recreational developments. These impacts create the need for better understanding of shore erosion processes, and the requirement for a methodology that quantitatively predicts shoreline and bluff recession.

This report describes shore erosion processes and the major parameters that influence shore erosion on lakes and reservoirs. An approach for predicting and assessing future shore erosion impacts is outlined, and individual tasks and subtasks are described. This final report and earlier interim reports are intended to serve as reference and working manuals to guide agencies and individuals responsible for assessing shore erosion impacts around lakes and reservoirs on the Canadian Prairies.

The approach recommended comprises five main tasks. These are the following:

- Collection, review, and synthesis of relevant background data.
- Documentation of historical erosion rates.
- The carrying out of field studies.
- Prediction of bluff recession rates and eroded sediment volumes using a numerical model.
- Preparation of a statement on anticipated shore erosion impacts.

This final report incorporates results from eight study phases carried out intermittently since April 1991. The report represents Phase 9. A technology transfer seminar that follows is called Phase 10.

The study builds on earlier shore erosion studies by J D Mollard and Associates Limited, Regina. They include examinations of 30 reservoirs in Saskatchewan, Manitoba, and Alberta that date back to the late 1950s. The approach described here has evolved through this 35 year period. A recent shore erosion study has applied versions of the numerical model presented here. That study dealt with the predication of shore erosion around proposed Wuskwatim reservoir in northern Manitoba. It also serves as a test for the approach recommended here.

Bluff recession rates predicted by the proposed model agree reasonably well with erosion rates measured from airphotos and field surveys. Typical bluff recession rates around Prairie reservoirs range between 0.25 m/yr and 1 m/yr, although rates up to 2 to 3 m/yr are not uncommon along steeper shores exposed to high wave energies. Rates of 5 to 6 m/yr may occur on promontories during the first several years after reservoir impoundment. Long-term erosion rates measured on northern Manitoba reservoirs average about 0.5 to 0.7 m/yr.

Predicted erosion rates at different locations around reservoir shore zones are required to evaluate and manage potential environmental, economic, and social impacts. A good understanding of shore erosion and bluff-wasting processes is therefore needed to design and

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implement erosion mitigative and preventive measures. Shore erosion understanding and prediction are challenging tasks, demanding the consideration of the many factors.

The numerical model is designed to predict erosion rates along shore zones where water levels have been raised on lakes and older reservoirs, and where new reservoirs have been created in recent years or are proposed. The model considers three stages of shore erosion: early, intermediate, and advanced. During early stages of shore erosion, bluff mass-wasting processes and bluff toe processes dominate. Over time, however, beach slope downcutting becomes increasingly important in controlling the rate of erosion.

Further research is required to integrate the model with erosion models developed for the Great Lakes, where beach slope processes tend to dominate. A second area for further research is computer automation of the numerical model. Such automation requires the adaptation of existing wave hindcasting software, development of routines for wave energy calculation, input of shore zone and erodibility parameters, and the estimation of volumetric erosion rates. Other applications of computer technology include automated measurement of fetch lengths and shore zone geometry parameters, and presentation of land use, terrain, and erosion impact data using geographic information system (GIS) technologies.

Results of this study may be used to assist governmental agencies and others responsible for reservoir and shore zone planning, management, and operation. The approach outlined in this report will aid land-use zoning, land acquisition, environmental assessment and management, erosion hazard mitigation, and improved communication with landowners and other residents around Prairie reservoirs. We also anticipate that our study results will assist park officials, resort developers, and consultants responsible for planning and designing shoreland structures and erosion protection measures. Better estimates of future bluff retreat rates are used to guide recommended safe setback distances for temporary and permanent structures around existing and proposed lakes and reservoirs.

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1. INTRODUCTION

In recent years shore erosion and bank slumping have come under increasing scrutiny owing to potential environmental impacts on aquatic and shoreland ecosystems, natural resources, and recreational developments. These impacts create the need for better understanding of shore erosion processes, and a methodology for quantitatively predicting shore and bank recession. Objectives of this study address these needs.

Continuing wave action and bluff mass-wasting cause ongoing evolution and landward retreat of the shore zone profile. Progressive flattening and lowering of the beach and landward recession of the bluff occur together as waves attack the shore zone. Rates of beach erosion and bluff recession vary with the wave energy, the soil and rock material being eroded, the shore zone geometry and stratigraphy, water level fluctuation, seasonal storm activity, and weathering activity.

Long-term shore erosion rates around Prairie lakes and reservoirs typically range from 0.25 to 1 m/yr. In places the initial erosion rates around young reservoirs exceed 2 m/yr, and can reach 5 to 6 m/yr on exposed promontories in high wave energy settings.

This study addresses shore erosion modelling in both qualitative and quantitative terms. Development of a quantitative approach to shore erosion assessment provides an improved means for predicting future shore erosion rates and accompanying sediment loads in lakes and reservoirs.

The procedure developed for assessing shore erosion impacts includes five main tasks:

- Review of existing erosion data for the water bodies in question, and for other water bodies having similar shore zone material, geometry, and wave energy characteristics.

- Documentation of historical erosion rates, including examining several sets of sequential airphotos that span intervals of time up to 50 years, and measuring erosion rates at sites representing a variety of shore zone materials, wave energy environments, and shore zone geometries in plan and profile.

- Field studies necessary to document the erodibility characteristics of different shore zone materials and stratigraphies, shore zone geometries that affect incoming wave energies, offshore and nearshore features (islands, shoals, slopes) that influence wave energy dissipation, groundwater seepage, slope instability features, among other parameters.

- Estimation of future erosion and eroded sediment volumes using a calibrated numerical model that takes into account wave energy and shore zone material and geometry, as well as other parameters, such as long-term weathering (wetting and drying, and freezing and thawing) of beach and bluff slopes, recurring slump activity and other mass movements, bank stratigraphy, groundwater sapping, reservoir water level fluctuation, thawing of frozen ground, and the effects of major storms.

- Preparation of a statement on anticipated shore erosion impacts, including maps showing predicted bluff recession distances and rates, and classified shore zone segments related to shore erosion potential.

  This report summarizes results from nine study phases carried out from April 1991 to December 1993. The study was performed by J D Mollard and Associates Limited of Regina under contract to the Water Resources Branch of Environment Canada in Regina.

2. SUMMARY OF STUDY PHASES

This study comprises ten phases, which when completed span the three-year period starting April 1991 and ending March 1994. Study results are documented in seven separate reports as outlined below.

Phase 1. Phase 1 included collection and review of the pertinent scientific literature, and development of a preliminary shore erosion model and methodology. Our Phase 1 report is dated August 1991.

Phase 2. Phase 2 entailed acquiring and interpreting several ages and scales of airphotos showing each of three reservoirs selected for study. These three reservoirs are Lake of the Prairies in western Manitoba, and Avonlea Reservoir and Lake Diefenbaker in southern Saskatchewan. Airphotos were used to measure shore erosion rates around each reservoir, and to provide data on shore zone geology and geometry. Available field data and accompanying reports prepared by governmental agencies were obtained for each reservoir. In addition, the Phase 2 report describes a working model for evaluating shore erosion processes and for estimating future erosion rates on small, intermediate, and large reservoirs. Phase 2 also included a review of additional scientific literature to supplement the Phase 1 literature review. Our Phase 2 report is dated March 1992.

Phase 3. Phase 3 involved field investigation. A total of 74 shore sites were visited on the reservoirs selected for study. The shore zone profile was surveyed from water level to the top of bank at each site. The geologic material and stratigraphy were described for each site, as well as the beach slope material, the nature of bluff slope failure, and bluff debris characteristics and bluff degradation. Field work was carried out in July 1992, and was summarized in a letter report dated August 6, 1992.

Phase 4. Phase 4 entailed measuring historical bank recession rates around Avonlea Reservoir from 1:5000 scale airphotos acquired in May 1992, and previous large-scale airphotos acquired in 1972 (1:7000 scale) and 1981 (1:5000 scale).

Phase 5. Field data collected during Phase 3 were summarized and analyzed in Phase 5. Results of Phases 4 and 5 are documented in a report dated March 1993.

Phase 6. Phase 6 involved calculating the average annual deepwater and effective wave energy for each shoreline site visited on Lake Diefenbaker, Avonlea Reservoir, and Lake of the Prairies. Calculated wave energy values were integrated with field data to verify the proposed erosion model, and to establish empirical erodibility coefficients for various bank materials.

Phase 7. Phase 7 entailed reviewing the proposed model and methodology to evaluate shore erosion impacts around Prairie lakes and reservoirs based on work in Phases 1 to 6. Results of Phases 6 and 7 are documented in a report dated June, 1993.

Phase 8. Phase 8 entailed selecting sites for long-term shore erosion monitoring and suggesting a program for collection and analysis of data, along with evaluation of results and continued erosion model development. This work also included return field visits to Avonlea Reservoir and Lake Diefenbaker to re-examine certain shore zone sites. Our Phase 8 report is dated November 1993.

Phase 9. Phase 9 involved writing this final report, dated November 1993. This report describes shore erosion processes and presents a methodology for shore erosion assessment and prediction.

Phase 10. Phase 10 has yet to be completed. It involves presentation of the study results at a technology transfer seminar in Regina.

In addition to these ten study phases, a paper by Penner et al., 1992, was presented at the November 2-4, 1992 conference in Regina titled "Erosion—Causes to Cures." The paper summarized results to that time. It incorporated data from this study as well as results from a recent study carried out for Manitoba Hydro, Winnipeg.

3. REVIEW OF SHORE EROSION PROCESSES

Shore erosion is defined as the loss of sediment from the shore area. Such erosion is caused by several interacting processes: wave erosion of the bluff toe, beach flattening and downcutting by current and wave action, mass wasting of the shore bluff from weathering, periodic topple failure of the bluff, removal of failed bluff slope debris by wave action, and offshore and alongshore transport of eroded sediment.

In this report we consider the shore zone to extend from the top of shore bluff to a point on the underwater slope below minimum water level elevation. A shore zone profile and terminology are illustrated in Figure 1.

Continued wave action and bluff mass-wasting cause ongoing evolution and modification of the shore zone profile. These processes result in progressive flattening and downcutting of the beach slope and related landward recession of the bluff toe. Shore erosion tends to be cyclic, particularly so where shore zones are subject to fluctuating water levels in lakes and reservoirs. This is the case around western Canadian reservoirs designed for power development, water supply, flood control, and irrigation.

When water levels are relatively high, wave erosion at the bluff toe and across the beach slope dominate shore evolution. This commonly results in accompanying topple failures along the upper bluff slope. When water levels are low, debris shed during bluff mass-wasting accumulates at the toe-of-bluff, frequently above the temporary reach of incoming waves. The dominant wave erosion process at times of low water level is therefore progressive downcutting and flattening of the beach slope.

High water levels following a period of low water level results in removal of the disintegrating toppled bluff debris. Debris removal is followed by continued erosion of the beach slope. Washing by waves reworks coarser sediment accumulated on the beach surface. If the water level remains high for a long enough time, virtually all bluff debris will be removed and wave erosion of the bluff toe will take place, producing further topple failures. As water levels drop, debris shed from the bluff begins once again to accumulate at the toe; and nearly all of it remains there until the next rise in water level and incursion of waves.

Topple failures are common in cohesive till bluffs, which usually contain several vertical fracture sets as well as occasional horizontal parting planes. These structural discontinuities in the till result in the development of vertical bluff slopes, as blocks of bluff material separate along vertical fracture planes and topple over. Open fractures (fissures) a short distance back from bluff faces mark the location of the next topple failure.

For purpose of modelling, shore erosion is visualized in three stages representing early, intermediate, and advanced stages of evolution. The early stage occurs when waves wash and erode previously non-flooded slopes around new reservoirs, and where water levels are raised in existing lakes and reservoirs. Initially a narrow beach slope forms, backed by an adjoining bluff face. During this early stage, erosion of the toe-of-bluff and bluff mass-wasting dominate the shore erosion process. However, as erosion continues into an intermediate stage, the beach slope widens and the bluff face heightens. The evolving bluff height depends on topography of the pre-erosion shore zone. During this intermediate stage, beach erosion becomes increasingly important, although toe-to-bluff erosion and bluff mass-wasting are still significant.

With continued erosion, the beach slope widens and flattens. Beach slope downcutting begins to dominate the erosion process. Bluff mass-wasting continues, but is largely independent of wave erosion effects except for periodic removal of bluff debris by wave action during times of high water levels. Toe-of-bluff erosion is also restricted to periods of high water level. Shore zones reaching an advanced stage of evolution are uncommon around relatively young Prairie reservoirs—say, less than 50 years old. Examples of advanced erosion occur around large lakes, such as Lake Winnipeg and the Great Lakes.

The duration of each erosion stage (and associated change in bank recession rate, bluff height, bluff slope, beach width, and beach slope angle) depends largely on the sensitivity of the shore zone area to wave erosion. This sensitivity, moreover, is a function of the wave energy environment, shore zone material, and the shore zone profile prior to erosion—although other factors can also be important at some locations along a shore.

The numerical model developed in this study defines the three erosion stages in quantitative terms. The model illustrated in Figure 2 is described in the following section.

4. PROCEDURE FOR EVALUATING SHORE ZONE EROSION PROCESSES AROUND PRAIRIE LAKES AND RESERVOIRS AND PREDICTING FUTURE BANK RECESSION RATES AND ERODED SEDIMENT VOLUME

A methodology for assessing environmental impacts of shore erosion processes is presented in this section. It includes a numerical model for predicting future bluff recession rates around shore zones on reservoirs recently created by the construction of dams and other hydraulic structures.

The methodology involves a multistage approach, in which there are five main tasks and a number of related subtasks.

TASK 1: Collect, review, and synthesize relevant data available in published and unpublished maps, reports, and scientific papers.

Acquisition and synthesis of pertinent data on shore erosion is essential to ensure that any assessment of impacts is based on up-to-date information. Information should be collected for the shore zones under investigation and for others having similar climatic, geographic, geologic, and wave energy conditions and settings. This is particularly important when predicting future shore erosion impacts for proposed reservoirs.

The format, type and amount of data available and relevant usually varies from study location to location. In most shore erosion study areas, additional field and airphoto detail will be required. Where the data required are not available, simplifying assumptions may be necessary to estimate maximum and minimum future erosion rates with acceptable accuracy.

Following is a checklist of desired background data:

- Surficial geology and geologic materials around the reservoir, both above and below full supply level.
- Local drillhole and stratigraphic data at points along the shore zone.
- Location of springs along the shoreline.
- Geotechnical properties of shore zone materials (e.g., composition, density, permeability, strength parameters, typical grain-size distribution, etc.)
- Slope stability conditions in the shore zone, and in the area behind the shore bluff.
- Map showing land use and cultural features on land around new reservoirs, including the locations of pipelines, transmission lines, roads, railroads, buildings, and agricultural land, residential, industrial and recreational areas that may be impacted.
- Records of past and anticipated future reservoir operating curves.

- Historical wind frequency data from Environment Canada's weather station closest to the reservoir area, as well as weather data from independently operated weather stations.

- Historical erosion rate data, as well as field data from which shore erosion rates can be calculated (i.e., surveyed profiles).

- The latest and largest scales of stereoscopic airphotos showing lake and reservoir shore zones.

- All older airphoto sets from different years. Include sets of airphotos showing eroding shore zones around lakes and reservoirs having similar geologic and hydrographic characteristics. Airphotos taken on different years, especially widely separated years, are required to measure bank recession distances and thus rates. Better scales for measuring historical erosion rates from airphotos are 1:5,000 and larger. Scales as small as 1:30,000, however, can often provide useful supplementary data. Scales smaller than 1:30,000 seldom provide reliable quantitative data on shore erosion rates. Yet these airphotos may be useful for identifying higher erosion locations along shorelines. Airphotos are also used routinely to map surficial geology and terrain conditions in the shore zone, and for qualitative assessment of shore zone geometry and wave energy environments.

- Historical data on reservoir water levels to correlate with field data and information interpreted from aerial photographs.

- Topographic maps of the shore zone and adjoining land area. Maps having a contour interval less than 1 to 3 metres are preferred for numerical model applications. The smaller the contour interval the better.

TASK 2: Document historical erosion rates

Historical shore erosion rates around existing lakes and reservoirs are used to provide a first estimate of future erosion rates. Therefore, all relevant erosion rate data and field data should be obtained for analysis.

Historical erosion rates may appear in published and unpublished reports. In places erosion rates may have to be estimated from surveyed shore profiles. Potential data sources include the scientific literature and reports held by private utility companies and governmental agencies (e.g., Prairie Farm Rehabilitation Administration, Environment Canada, Saskatchewan Water Corporation, and SaskPower in Saskatchewan). These agencies often release very helpful data when requests are properly made.

In addition to data contained in available reports, historical erosion rates can often be measured from two sets of stereoscopic airphotos, preferably airphotos taken several years apart. To measure bluff recession rates, top of bluff positions are traced from airphoto sets to overlays. Scales of the two compared datasets must be the same. Annual erosion rates are determined by dividing the measured horizontal setback distance of the top of bluff by the number of years between the two dates of aerial photography. Airphotos are available from federal and provincial government libraries. Although scales are sometimes small, they are usually helpful during an initial inspection and assessment of shore erosion. Specially flown airphotos at a large scale will be necessary for certain projects. This depends in large measure on project requirements. Airphotos ranging in scale from 1:5,000 to 1:80,000 were used in this study. The information derived is determined by photo scale and what can be confidently interpreted.

Reported erosion rates in the literature and those measured during our study are tabulated along with descriptions of shore material and shore and reservoir geometry (Figure 3). In addition to those parameters shown in Figure 3, other conditions may be recorded— e.g., groundwater seepage, slope instability features, etc.

Relationships among parameters affecting shore erosion and erosion rates are used with the numerical model to improve the accuracy of erosion estimates (see TASK 4).

TASK 3: Field studies

Field studies of lake and reservoir shore zone areas provide knowledge and data on shore zone materials and geometry, wave energy setting, land use, vegetation cover and other data needed to assess shore erosion processes and predict future impacts.

When assessing future shore erosion impacts around existing lakes and reservoirs, visible characteristics of the shore zone area in question and its response to wave attack provide helpful data for evaluation of future changes. When assessing impacts around a proposed reservoir, data from comparable lakes and reservoirs should be evaluated. The erodibility characteristics of similar earth materials around comparable lakes and reservoirs are useful for predicting how these same materials will behave around a new reservoir.

The amount of field work may be controlled by accessibility, budget, time constraints, and equipment. On small water bodies like Avonlea Reservoir, it may be feasible to walk along and inspect the entire shoreline. On large lakes like Lake Diefenbaker, field sites may be limited to carefully chosen sites. In any event, it is important that field sites represent common geologic materials, shore zone geometry, and wave energy settings around a lake or reservoir.

Field studies should collect information that assists prediction of shore erosion impacts. Recommended main field activities and parameters to be measured and described are listed below.

- Survey profiles of shore zones from some distance behind (landward from) the top of shore bluff to below minimum water level.
- Measure recession of the toe and top of bluff where shorelines and bluff positions have been measured previously.
- Measure (or estimate) the depth of vertical downcutting of the beach slope.
- Measure beach slope gradient and width.
- Measure bluff face angle and height.
- Record thickness and composition of eroded debris on the beach.
- Make an initial qualitative assessment of erodibility characteristics of identified and classified shore materials.
- Collect samples of shore materials for laboratory analyses (grain-size distribution, moisture content and density, Atterberg limits).

- Classify nearshore sediments subject to erosion.
- Record any physical condition that is believed to accelerate or retard erosion: nearshore submergent and emergent vegetation, root mats that reduce the impact of erosion, loose gravel and boulders on the beach.
- Describe the wave energy setting: shorelines that are exposed, protected, straight, promontories, coves, bays, etc.
- Document measured sites by taking ground photographs.
- Summarize shore geology, hydrography, bathymetry, hydrogeology, earth materials, and topography from airphotos, maps and field data.
- Determine the water level elevation on the days field visits are made and show this on shore profiles.
- Record physical features associated with water level fluctuation—e.g., stepped shore erosion terracettes.
- Record high water mark indicators, such as lines of debris, rows of cobbles or boulders, erosion niches along the base of bluff slopes.

In assessing material erodibility, document parameters that influence erosion rates. They include the following characteristics:

- Fracture spacing and the orientation of fractures with respect to bank orientation.
- Ease of bluff ravelling and sloughing, estimated by scraping away loose bluff material with a spade or geologic pick.
- Shore zone material characteristics: lithology, layering, hardness, density, cohesion, etc.
- Bank orientation with respect to sun exposure, and its relation to desiccation and case-hardening of exposed faces.
- Mechanical composition of bluff materials: percentage of clay, silt, sand, gravel, cobbles, boulders.
- Different ages and diagnostic features of till.
- Presence of granular layers in dominantly cohesive material. Sand and gravel are abrasive when washed back and forth on the beach, operating like sandpaper in removal of surface material.
- Presence and density of boulders on the beach and along the toe-of-bluff.
- Bluff weathering and erodibility, evidenced by debris accumulated along the base of bluff cliffs.
- Visible nearshore detail, such as submerged and emergent vegetation, rocky shoals, sand and gravel shoals—each tending to dissipate wave energy.

Recorded field observations should be summarized in tables. Site locations should be shown on a map. An example of a field data summary table is shown in Figure 4. Ground photographs should be indexed on a map, numbered, and described in a brief caption.

Recently flown aerial photographs and 1:50,000 NTS topographic maps are useful for locating access trails to lakes and reservoirs and for accurate plotting of field data.

TASK 4: Predicting future bluff recession rates and eroded sediment volumes

Most shore erosion impacts are related to bluff recession and reservoir sedimentation. The ability to predict bluff recession rates and eroded sediment volumes is required in order to assess future erosion impacts.

A major effort in this study has been devoted to developing a rational numerical model for predicting rates of bank recession and eroded sediment volumes. Quantifying a highly complex natural process that incorporates the effects of many parameters is a challenge. Certain input parameters can be fairly well defined and have a good degree of reliability. Other parameters, however, are not so easily defined, and a range of numerical values is common. Moreover, numerical values for some parameters may have to be based on judgement owing to insufficient field data.

A step-by-step methodology for applying the numerical model is described below.

Task 4.1: Classification of the shore zone

Material in the shore zone is classified in terms of origin, mechanical composition, and relative erodibility. Airphoto interpretation is a useful and highly efficient technique for mapping terrain types and conditions along long stretches of shore zone. Mapping from airphotos should be correlated with data in published and unpublished maps and reports, and then confirmed by field examination at selected representative sites.
Terrain mapping along the shore of proposed reservoirs can be facilitated by accurate transfer of the full supply elevation contour from good topographic maps to large scale airphotos. Terrain is then classified, typed and outlined on both sides of the full supply elevation contour.

Factors affecting shore material erodibility are listed in Task 3. They should be referred to when developing the terrain legend and planning field inspection visits.

Task 4.2: Mapping foreshore and backshore slope angles

Foreshore and backshore slope angles are measured at a representative number of sites along the shore. The foreshore slope is the underwater gradient immediately below still water shoreline. The backshore slope is the gradient immediately above still water shoreline. For purposes of predicting erosion, these slopes are usually measured above and below the long-term mean water surface elevation.

Two options for selecting shore zone slope measurement sites are presented. One option involves maintaining a uniform horizontal distance between measured sites. A second option involves making a certain number of measurements in each terrain unit. The rationale behind the second option is that distinctive slope angles commonly develop in different geologic materials.

Initial foreshore and backshore slopes may be the same around the shore of recently impounded reservoirs. Along actively eroding shores, differences in slope on the foreshore and backshore depend on beach width and water elevation. Foreshore and backshore slopes angles are typically much the same where beach slopes are wide and gentle and the water surface is well below the toe-of-bluff. Where water levels are located at or near the bluff toe the submerged beach slope forms the foreshore slope and the bluff slope forms the backshore.

A convenient way to identify measured foreshore and backshore slopes on airphotos and topographic maps is to mark selected site locations with a line crossing the shoreline at right angles. The backshore slope angle is then recorded at the landward end of this line, with the foreshore slope angle shown at the opposite end.

Measured slopes on the foreshore are classified as relatively high, medium and low, with ranges for each category. This classification simplifies calculation of wave energy at selected sites around lakes and reservoirs.

Task 4.3: Calculation of wave energies at representative shore zone sites

Wave energy for representative shore zone sites is calculated in two steps. First, the total wave energy at each site is calculated based on wind climate and fetch data. What is referred to here as the "effective wave energy" is then calculated. It is taken to be the product of the total wave energy and a wave energy reduction factor that takes into account wave energy dissipation across the sloping foreshore. The following tasks describe the procedure.

4.3.1: Measure the fetch lengths for each calculated wave energy site

Fetch lengths are measured along seven lines that radiate outward from each shore site (Figure 5). Three radial lines are drawn on each side of a line normal to a shoreline tangent. Each radial line is 22 $^1/_2{}^\circ$ from its nearest neighbour line. Fetch direction, total fetch length, fetch approach angle (ø), and $\cos^2\text{ø}$ are recorded in appropriate columns in a wave energy calculation table (Figure 6).

4.3.2: Determine effective fetch lengths for each wave energy calculation site

Reservoir width perpendicular to each of the seven fetch directions measured in 4.3.1, above, is measured. Effective fetch length for each fetch direction is then determined using Figure 7. The data are recorded in a wave analysis table (Figure 6).

4.3.3: Determine wind velocity classes for the reservoir in question

Velocity classes are selected to match those shown on Environment Canada wind data records. Environment Canada can also generate customized datasets from their computer files. Over-land wind velocity ranges are recorded in the wave energy analysis table for all fetch directions (Figure 6). Over-land velocities are converted to over-water velocities using the relationship shown in Figure 8 and tabulated in Figure 6. Two alternative relationships between over-land and over-water wind speed are shown in Figure 9. Hopkinson (1991) reports that a fetch length of 6 km is required for complete adjustment of the wind velocity from over-land to over-water.

4.3.4: Calculate wind durations

Wind duration for each velocity class and each wind direction during the open water season is determined from recorded data. Environment Canada produces two types of wind data records. Wind normal tables list monthly wind duration and mean monthly wind speed as a percentage frequency for 16 compass directions. For example, wind normal tables for the Regina A station indicate that north winds blow 5% of the time during July (Figure 10). These tables also show that the average velocity of north winds in July is 15.6 km/hr.

A second type of wind record summarizes wind data as percentage frequencies by direction and speed. This information is required to determine the average duration of winds for a range of velocity classes in a variety of directions. An example illustrating such a table for the Regina A station is shown in Figure 11.

Wind normal data and percentage frequency by direction and speed data are integrated to estimate the length of time during the open water season that wind blows from a particular direction within a given velocity range. An example for the Regina A station is shown below.

Duration of north winds blowing at 7 to 12 miles/hour during the open water season April 1 to October 31

1. Length of time the wind blows from the north during the open water season is 993082 seconds as shown below. (Refer also to Figure 10.)

Month	*Percent frequency of north wind*	*Total number of seconds during month*	*Number of seconds wind blows from the north*
April	5.9	2592000	152928
May	6.8	2678400	182131
June	5.4	2592000	139968
July	5.0	2678400	133920
August	5.4	2678400	144634
September	4.9	2592000	127008
October	4.2	2678400	112493
			993082

2. Percentage frequency by direction and speed (Figure 11).

Duration of north wind as a percentage of total time during the year _____ 4.43%

Duration of north winds blowing at 7 to 12 mph as a percentage of total time during the year _____ 1.62%

Duration of north winds blowing at 7 to 12 mph as a percentage of total time that north winds blow _____ 1.62/4.43 = 36.6%

3. Duration in seconds of north winds blowing at 7 to 12 mph during the open water season.

- Total number of seconds that winds blow from the north is 993082 seconds
- Percentage of time the north winds blow at 7 to 12 mph is 36.6%
- The duration of 7 to 12 mph north winds is calculated as 993082 s x 36.6% = 363159 s.
- In this way wind durations are calculated for all directions and speed classes.

4.3.5: Estimating significant and equivalent wave heights and wave periods

The U S Corps of Engineers (1977) published a series of wave hindcasting charts for estimating wave heights and wave periods in deep water and shallow water. Deepwater conditions occur where the ratio of water depth to wave length is greater than one-half. Shallow water conditions occur where the water depth to wave length ratio is less than 1/25. Transitional conditions occur where the water depth to wave length ratio is 1/2 to 1/25. A wave hindcasting chart for shallow water conditions in a water depth of 25 feet (7.6 m) is shown in Figure 12. A complete set of hindcasting curves is included in Appendix 1.

Use of these charts is straightforward. First, several water depth to wave length ratio values are calculated to determine whether shallow water or deepwater conditions apply. The appropriate chart is then selected and the wave height and wave period are read from the chart for all calculated combinations of wind speed and effective fetch. These values are then recorded in the wave energy analysis table (Figure 6).

Equivalent wave height is calculated as 0.71 times the significant wave height. An equivalent wave is a single wave having energy equal to the sum of energies of all real waves.

Computer programs are commercially available for wave hindcasting. One procedure is referred to as "Parametric Hindcasting of Effective Waves" (PHEW) (Fleming et al., 1984). This technique was developed as part of the Canadian Coastal Sediment Study under the direction of the National Research Council of Canada Committee for Research on Shoreline Erosion and Sedimentation. Integration of the PHEW procedure and the numerical model procedure presented here warrants further investigation.

4.3.6: Calculate total wave energy

Average annual wave energy in foot-pounds/foot of shoreline is calculated using the formula:

$$E = \frac{\rho g^2}{32\pi} \times He^2 T t \cos^2 ø$$

where: ρ = mass density of water in lbs^2/ft^4
g = acceleration due to gravity in ft/s^2
$ø$ = angle between the wind direction and a line normal to the shore line
He = equivalent wave height in feet
T = wave period in seconds
t = wind duration during one open water season in seconds

(See, also, USCE 1961, 1966, and 1977; Penner and Swedlo, 1974; and Newbury and McCullough, 1984.) Wave energy in metric units of tonne-metre per metre of shoreline per year is calculated by dividing the imperial units by 2205 lb/tonne. Wave energy is calculated for each speed class in each of seven wind directions. These values are then summed to give the total wave energy at a specific shoreline site.

The formula above applies to deepwater conditions. Alternative equations involving wave velocity as a function of water depth are used for transitional and shallow water conditions (see Phase 1 report, Appendix 2, for derivation of the wave energy equation).

4.3.7: Calculate effective wave energy

A portion of the total offshore wave energy is dissipated as the wave base intersects the nearshore and foreshore underwater slopes. The percentage of total offshore wave energy available for shore erosion depends on the underwater slope angle, determined here using a postulated parabolic relationship between wave energy dissipation and underwater slope angle (Figure 13). Effective wave energy is calculated as the product of total wave energy and the wave energy dissipation factor obtained from Figure 13.

Task 4.4: Calculate volumetric erosion rate

The annual volumetric erosion rate (V) is calculated as the product of effective wave energy (Ee) in tonne-metre/metre of shoreline/year, and the material erodibility coefficient (Ke) in cubic metres/tonne-metre or square metres/tonne, as shown below:

$$V = Ke \bullet Ee$$

The shore material erodibility coefficient, also called the erosion index, is an empirical value based on correlation of material properties and wave energy conditions. Newbury and McCullough (1984) and Kachugin (1961) report erodibility coefficients for a variety of geologic materials (see below).

Newbury and McCullough (1984, northern Manitoba)

Frozen glaciolacustrine clay and silt: Ke = 0.00028 to 0.00043 m^2/t; with an average value of 0.00035 m^2/t

Kachugin (1961, former USSR)

1. Fine-grained sand, clayey loessial sand: Ke = 0.003 m^2/t

2. Medium-grained sand and mixed sand sizes, porous and friable sandy clay, light sandy clay and clayey sand with rubble: Ke = 0.003 to 0.001 m^2/t

3. Heavy sandy clay, clayey sand with boulders, clay, and sand with pebbles and cobbles: Ke = 0.001 to 0.0005 m^2/t

4. Sandstone, clayey gravel with sand and boulders, clay with opaline layers: Ke = 0.0005 to 0.00025 m^2/t

5. Weathered calcareous and siliceous sandstone, limestone, mudstone, massive volcanic rocks: Ke = 0.00025 m^2/t.

Kachugin adds that for bluff slopes less than 30 m high, Ke must be multiplied by a shore height factor of 0.025 for friable rocks and a factor of 0.05 for dense rocks.

Erodibility coefficients derived in this study for soil and soft rock materials around the shores of Lake Diefenbaker, Avonlea Reservoir and Lake of the Prairies are given in Table 1.

TABLE 1

ERODIBILITY COEFFICIENTS FOR DIFFERENT MATERIALS AROUND LAKE DIEFENBAKER, AVONLEA RESERVOIR, AND LAKE OF THE PRAIRIES

Material Type	Erodibility coefficient (m^2/t)
Till with a sand or gravel surficial overlay	0.0004
Soft till	0.0002
Hard till	0.00004
Till with a dense cover of surface boulders	0.00002
Sandstone, siltstone, or shale covered by till	0.00005 to 0.0002

Task 4.5: Calculate total volume of sediment eroded

The total volume of sediment that will be eroded from the shore zone over a given time period along a unit length of shore is the product of the annual volumetric erosion rate and number of years. Eroded volume in cubic metres is then obtained by multiplying the volume per unit length of shore zone by the total length of shore represented by each calculation site. The eroded volume of sediment contributed by all classified shore zone segments is summed to calculate the total volume of sediment entering the reservoir annually from its entire shore.

Task 4.6: Calculate the bluff retreat distance and recession rate

Bluff retreat distance is based on pre-erosion and anticipated post-erosion cross-sectional geometries of the shore zone site, as well as the sediment volume expected to be removed from the site by shore erosion during a given period.

A graphical approach is used in which the horizontal recession distance is determined by superimposing the anticipated post-erosion bluff and beach geometry on the pre-erosion shore zone profile. Position of the beach and bluff slopes are incrementally adjusted until the area between the pre-erosion and post-erosion profiles equals the anticipated eroded volume per unit length of shore zone, as calculated in Task 4.5. Total bluff recession rate is calculated by dividing the bluff recession distance by the number of years considered. This technique is repeated for a number of representative calculation sites around the lake or reservoir shore.

A prerequisite for predicting the post-erosion shore zone profile shape is knowledge of beach slope and bluff slope angles that commonly form in different kinds of shore material. References include papers by Peters and Towle (1979) and by Morgan (1982 and 1983). Tables 2 and 3 summarize beach slope angles in a variety of shore materials at Lake Diefenbaker and Avonlea Reservoir, respectively.

Field observations around Lake Diefenbaker, Avonlea Reservoir and Lake of the Prairies indicate that bluff slopes eroded in cohesive till, sandstone, siltstone, and shale are commonly nearly vertical. Exceptions are highly weathered till containing closely spaced joint fractures, where continual ravelling and sloughing of debris creates slopes ranging from nearly vertical to 1V:3H. Bluff slope angles in sand develop at the angle of repose of 30° to 35° (approximately 1V:1.5H to 1V:2H). Bluff slope angles developed in varved glaciolacustrine clay and silt around Wuskwatim Lake in northern Manitoba range from about 1V:0.5H to 1V:2H.

An alternative to the graphical approach described above is to use a numerical approach for estimating bluff recession. Equations relating bluff recession distance to the geometry of pre-erosion cross-sectional geometry were developed in Phase 1. They are presented in Appendix 3 of our Phase 1 report. Computer modelling of numerical shore erosion data warrants further evaluation.

TABLE 2

SUMMARY OF ERODED BEACH SLOPE MATERIAL AND CORRESPONDING BEACH SLOPE ANGLES MEASURED AT LAKE DIEFENBAKER

Eroded Beach Slope Material	Angle V:H
Till	1:13, 1:15, 1:16, 1:15, 1:16, 1:15, 1:14. 1:12, 1:8, 1:9, 1:19, 1:13, 1:10, 1:8, 1:9, 1:10, 1:7
Till with dense boulder lag	1:9, 1:8, 1:9
Silt and sand	1:33, 1:32, 1:32
Sand and gravel	1:6, 1:6
Sand	1:22, 1:25
Deformed till and clay	1:9
Deformed till and gravel	1:11
Sandstone	1:11, 1:9, 1:10, 1:12

TABLE 3

SUMMARY OF ERODED BEACH SLOPE MATERIAL AND CORRESPONDING BEACH SLOPE ANGLES MEASURED AT AVONLEA RESERVOIR

Eroded Beach Slope Material	Beach Slope Angle V:H
Till	1:8, 1:8, 1:9, 1:8
Till with stratified sand in bluff	1:12, 1:10
Sandstone	1:8, 1:12, 1:13, 1:10, 1:10, 1:12, 1:17, 1:15, 1:9, 1:13, 1:14, 1:4, 1:10, 1:11, 11:9, 1:11
Siltstone	1:12, 1:9, 1:10, 1:9, 1:14, 1:9
Interbedded siltstone, sandstone, shale	1:8, 1:9

Task 4.7: Plotting bluff recession distances and recession rates

Calculated bluff recession distances and recession rates are plotted on a map to display the anticipated bluff crest position at selected times in the future. Variation in shore recession rates around lakes and reservoirs can also be readily displayed on a map. A continuous bluff recession line is constructed by interpolating between adjacent shore zone calculation sites based on classification of the shore zone by material type, wave energy environment, and pre-erosion shore zone slope, as determined by Tasks 4.1, 4.2 and 4.3. These parameters can appear on a final map that shows bluff recession distances for various times in the future. Bluff recession lines are usually plotted on airphoto mosaics and on topographic base maps.

Task 4.8: Additional factors to consider

4.8.1: Erosion during storm events

Storm events can cause accelerated shore erosion in a short time. Erosion caused by single and multiple storm events can be predicted using the wave energy approach described in Tasks 4.3 to 4.6. Input data are storm duration, wind speed and direction, shore zone configuration in plan and profile, erodibility of shore material, fetch length, and water surface elevation.

The impact of storm events in the numerical model is accounted for by incorporating the full range of wind velocities and durations reported in Environment Canada wind data tables.

4.8.2: Water level fluctuation

Erosion can be estimated around lakes and reservoirs where there are known or predictable water level fluctuations based on the duration of water levels at different elevations or, alternatively, within certain elevation ranges. Information in Tasks 4.3 to 4.6 can be used to predict horizontal bluff recession distances for each water level elevation interval. Calculated bluff recession is measured from the midpoint of each interval. The resulting stepped profile is plotted on shore profiles to determine the total recession distance for a particular site.

4.8.3: Shore zone classification

The shore zone is divided into segments around the shoreline and classified. The classification is based on foreshore and backshore slopes, material in the shore zone, exposure to wind, shore configuration in plan, and vegetation. Wave energy and erodibility characteristics are determined for each segment and used to estimate erosion rates and recession distances. The resulting recession line represents the behaviour of each segment as a whole, although local erosion rates may vary within particular segments.

4.8.4: Impact of large bluff movements

Shore erosion, pore-water pressure, and freeze-thaw of bluff material are important factors causing large slope movements. Other factors affecting slope stability are bluff stratigraphy, groundwater regime, rate and magnitude of water level fluctuations, removal of debris from the toe of slide-prone bluffs, infiltration of precipitation, and the impact of domestic and commercial developments constructed along the shore. Past and present slope instability features are recorded in airphotos. Geological and geotechnical investigations are carried out to identify conditions conducive to slope instability. Vallejo and Edil (1979) have developed design charts to determine the ultimate angle of stable bluff slopes under a range of groundwater and soil conditions.

4.8.5: Bank recession from freezing and thawing

Reid (1984) found that about 20% of the total bank recession around Orwell Lake, Minnesota, was due to degradation and spalling of bluffs related to freeze-thaw cycles. In the work described here, the effect of frost action is incorporated in an empirically determined erodibility coefficient. Erodibility coefficients are based on total bluff recession, which includes frost action effects. Debris loosened by frost action accumulates along the toe-of-bluff, where in time it is removed by waves.

4.8.6: Decreasing erosion with time

Shore erosion rates generally decline over time. The rate of decrease, however, is seldom known owing to lack of reliable data. A common assumption is that the erosion rate will decrease exponentially with time (Reid et al., 1988; Pollock, 1981; Kachugin, 1966).

Where erosion-resistant rock in Canadian Shield is buried beneath a thin cover of unconsolidated soil material the rate of erosion is nearly constant until hard rock is encountered. At that point the erosion stops (Newbury and McCullough, 1984).

Factors affecting erosion that are difficult to quantify are type and density of forest vegetation and the effect of the root mat in the shore zone. Newbury and McCullough (1984) noted that it took several years for trees and the root mat to disappear around the shore of Southern Indian Lake in northern Manitoba.

For purposes of numerical modelling we assume three phases of shore erosion, representing early, intermediate, and advanced stages. The duration of each stage reflects the sensitivity of the shore zone to wave erosion, and therefore depends in large measure on wave energy. However, shore material and shore profile can also be very important.

The predictive numerical model developed in this study is an attempt to quantify the volume of sediment eroded along shores, the rate of erosion, and bluff recession for selected periods of time after initial reservoir impoundment. The numerical model is illustrated in Figure 2. Dimensions shown in that figure are based on an erosion study of Wuskwatim Lake in northern Manitoba. Terminology of shore zone profile components are defined in Figure 1.

Shore erosion is assumed to begin at the point where the wave base depth intersects the foreshore slope. Depth of the wave base is determined using a graphical relationship published by the U S Corps of Engineers (1977). Stage 1 erosion involves removal of shore material, beginning at the point where the wave base depth intercepts the non-eroded underwater slope. At a given reservoir water level, erosion will continue until the foreshore attains an essentially stable slope angle. At that water level the foreshore slope extends landward from the initial point of erosion to the point of maximum wave runup. Under lower water levels, part of the previously submerged foreshore slope will be exposed to form a backshore. Maximum wave runup is calculated using the following relationship reported by Brown and Baird (1980):

$$Ru = 2.3H^{0.5}T\tan \propto$$

where: Ru = wave runup (feet)
H = wave height (feet)
T = wave period (seconds)
$\propto$ = beach slope angle

The procedure for estimating bluff recession during Stage 1 erosion is described in Tasks 4.3 to 4.6 and is illustrated diagrammatically in Figure 2. Duration of Stage 1 depends on the volumetric erosion rate and the total volume of material that must be eroded to attain a stable beach slope angle.

Stage 2 involves continued erosion of the beach slope and bluff, similar to that described by Nairn (1992) for the Great Lakes, and represents landward migration of the Stage 1 beach slope. Vertical downcutting of the beach during Stage 2 exposes the bluff toe to continued erosion, resulting in further bluff recession. Stage 2 erosion in silty to clayey till around the Great Lakes has formed beach slopes of 3 to 5%. As the beach profile moves landward, the inshore slope flattens and becomes submerged to form a wide nearshore underwater slope having a slope angle of 1% or flatter. Penner and Swedlo (1974) report nearshore underwater slopes of 1% and foreshore slopes of about 10% around Lake Winnipeg in Manitoba.

Using typical shore zone profiles from the Great Lakes and Lake Winnipeg as examples, we define the end of the Stage 2 profile. We assume the nearshore will attain a slope of approximately 1% and will extend landward from the original point of erosion to a point where the water depth is equal to 40% of the wave base depth. The horizontal distance between these two points is taken to be 80% of the distance between the original point of erosion and the bluff toe at the end of Stage 2. The eroded beach slope is completed by extending the nearshore slope to the highest expected water level along a curved line that reaches a 4% slope angle near the toe of the bluff. The beach slope angle selected depends on the mechanical composition of shore material. As an example, beaches developed in clay till in Saskatchewan typically have beach slope angles of 7 to 10%. The predicted shore zone profile is completed by drawing a bluff slope that extends from the top of the beach slope to the original ground surface (Figure 2).

The length of time required to reach the end of Stage 2 erosion is determined by dividing the graphically determined volume of eroded material by the calculated annual volumetric erosion rate. The volumetric erosion rate for Stage 2 erosion will be less than the rate during Stage 1 erosion because the effective wave energy decreases as the nearshore slope becomes progressively flatter and waves break farther and farther from the shoreline.

Erosion that continues beyond the end of Stage 2 is designated Stage 3 erosion. Long-term Stage 3 erosion rates are expected to be relatively low, owing to continued flattening of the nearshore slope. Measured long-term average erosion rates on Wuskwatim and Sipiwesk lakes in northern Manitoba are estimated to be in the range of 0.5 to 0.7 m/yr. Calculations using our predictive model yield exponentially decreasing erosion rates for these lakes, with long-term values of 0.6 to 0.8 m/yr (Figure 2).

TASK 5: Prepare a statement on anticipated shore erosion impacts

The preparation of a statement on anticipated shore erosion impacts requires informed judgement based on knowledge of the literature, documented historical erosion rates, adequate field data, and numerical modelling results. Information in this report deals largely with numerical modelling of shore erosion processes. Indeed, the development of a numerical shore erosion model has been an important component of this ten phase study. While the model presented here is intended to evaluate shore erosion impacts, any numerical model that may be developed is only as reliable as the data that is input and the necessarily simplifying assumptions.

Wherever possible, erosion rates predicted by the numerical model should be correlated with historical rates. They must also satisfy a subjective test based on experience, intuition, and common sense. Are the rates predicted reasonable? If not, additional or better input data may be required. Do model parameters adequately reflect the shore erosion process? Are there certain characteristics that are unique to a specific site or a particular reservoir, thereby necessitating special consideration?

After outstanding questions have been appropriately and adequately considered, an erosion impact assessment statement may be prepared. A map showing anticipated bluff recession distances and recession rates should accompany a written assessment. Such a map should present the best estimate possible of bluff recession for use by environmental managers, reservoir operators, land use planners as well as local residents and land owners that might be affected by lake and reservoir operation.

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5. CONCLUSIONS

In recent years lake and reservoir shore erosion and bank slumping have come under increasing scrutiny owing to their environmental impacts on aquatic and shoreland ecosystems, natural resources, and recreational developments. These impacts create the need for better understanding of shore erosion processes, and the requirement for a methodology that quantitatively predicts shoreline and bluff recession.

This report describes shore erosion processes and the major parameters that influence shore erosion on lakes and reservoirs. An approach for predicting and assessing future shore erosion impacts is outlined, and individual tasks and subtasks are described. This final report and earlier interim reports are intended to serve as reference and working manuals to guide agencies and individuals responsible for assessing shore erosion impacts around lakes and reservoirs on the Canadian Prairies.

The approach recommended comprises five main tasks. These are the following:

- Collection, review, and synthesis of relevant background data.
- Documentation of historical erosion rates.
- The carrying out of field studies.
- Prediction of bluff recession rates and eroded sediment volumes using a numerical model.
- Preparation of a statement on anticipated shore erosion impacts.

This final report incorporates results from eight study phases carried out intermittently since April 1991. The report represents Phase 9. A technology transfer seminar that follows is called Phase 10.

The study builds on earlier shore erosion studies by J D Mollard and Associates Limited, Regina. They include examinations of 30 reservoirs in Saskatchewan, Manitoba, and Alberta that date back to the late 1950s (Mollard,1986). The approach described here has evolved through this 35 year period. A recent shore erosion study has applied versions of the numerical model presented here. That study dealt with the prediction of shore erosion around proposed Wuskwatim reservoir in northern Manitoba. It also serves as a test for the approach recommended here.

Bluff recession rates predicted by the proposed model agree reasonably well with erosion rates measured from airphotos and field surveys. Typical shore recession rates around Prairie reservoirs range between 0.25 m/yr and 1 m/yr, although rates up to 2 to 3 m/yr are not uncommon along steeper shores exposed to high wave energies. Rates of 5 to 6 m/yr may occur on promontories during the first several years after reservoir impoundment. Long-term erosion rates measured on northern Manitoba reservoirs average about 0.5 to 0.7 m/yr.

Predicted erosion rates at different locations around reservoir shore zones are required to evaluate and manage potential environmental, economic, and social impacts. A good understanding of shore erosion and bluff-wasting processes is therefore needed to design and

implement erosion mitigative and preventive measures. Shore erosion understanding and prediction are challenging tasks, demanding the consideration of the many factors.
The numerical model is designed to predict erosion rates along shore zones where water levels have been raised on lakes and older reservoirs, and where new reservoirs have been created in recent years or are proposed. The model considers three stages of shore erosion: early, intermediate, and advanced. During early stages of shore erosion, bluff mass-wasting processes and bluff toe processes dominate. Over time, however, beach slope downcutting becomes increasingly important in controlling the rate of erosion.

Further research is required to integrate the model with erosion models developed for the Great Lakes, where beach slope processes tend to dominate. A second area for further research is computer automation of the numerical model. Such automation requires the adaptation of existing wave hindcasting software, development of routines for wave energy calculation, input of shore zone and erodibility parameters, and the estimation of volumetric erosion rates. Other applications of computer technology include automated measurement of fetch lengths and shore zone geometry parameters, and presentation of land use, terrain, and erosion impact data using geographic information system (GIS) technologies.

Results of this study may be used to assist governmental agencies and others responsible for reservoir and shore zone planning, management, and operation. The approach outlined in this report will aid land-use zoning, land acquisition, environmental assessment and management, erosion hazard mitigation, and improved communication with landowners and other residents around Prairie reservoirs. We also anticipate that our study results will assist park officials, resort developers, and consultants responsible for planning and designing shoreland structures and erosion protection measures. Better estimates of future bluff retreat rates are used to guide recommended safe setback distances for temporary and permanent structures around existing and proposed lakes and reservoirs.

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Phase 2: March, 1992
Phase 3: August, 1992
Phase 4 and 5: March, 1993
Phase 6 and 7: June, 1993
Phase 8: November, 1993

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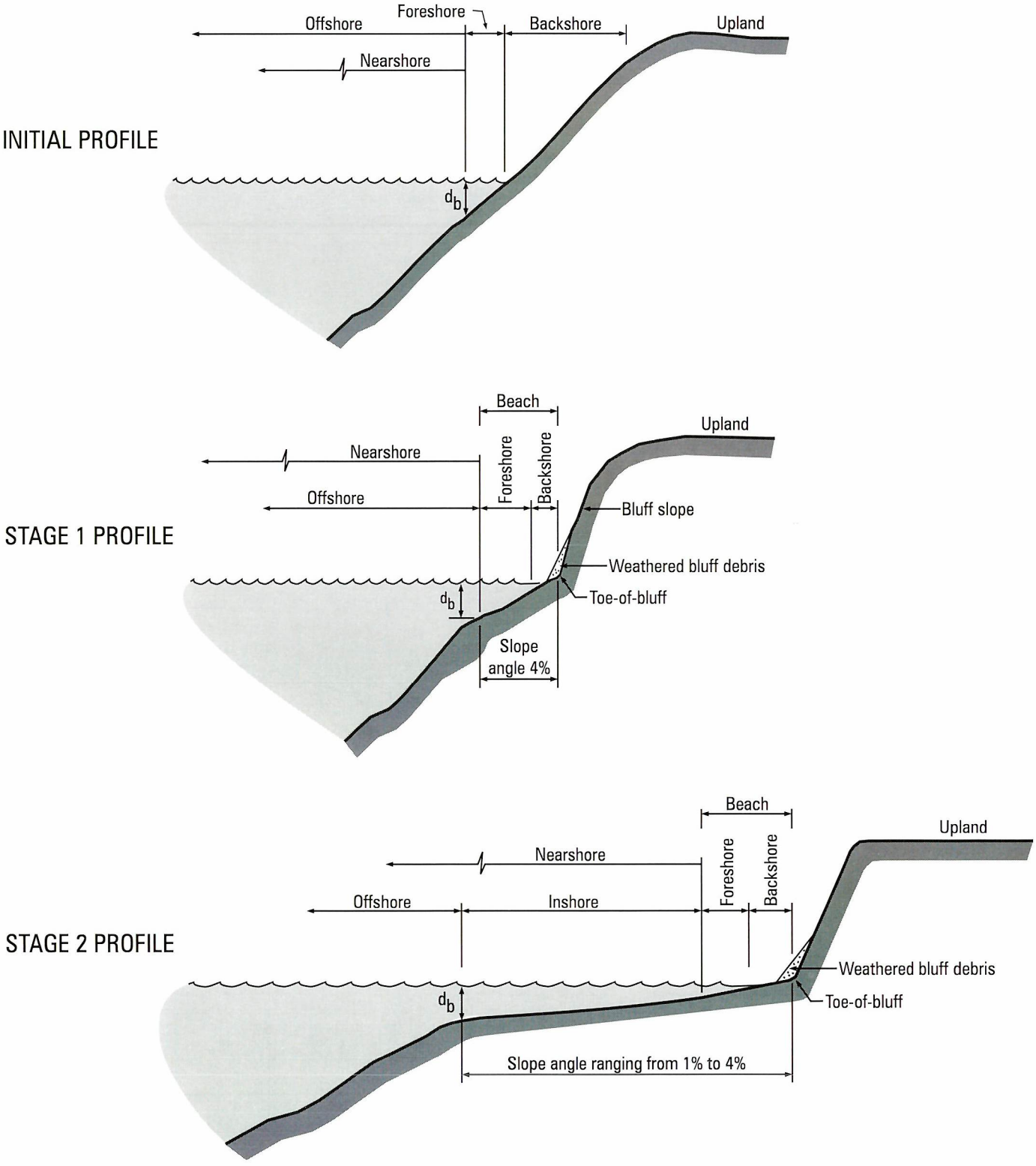
FIGURES



Shore zone profile evolution and related terms (after USCE, 1977). Nearshore and beach slope angles shown are typical for erosion in fine-grained glacial lake sediment around the Great Lakes and Lake Winnipeg.

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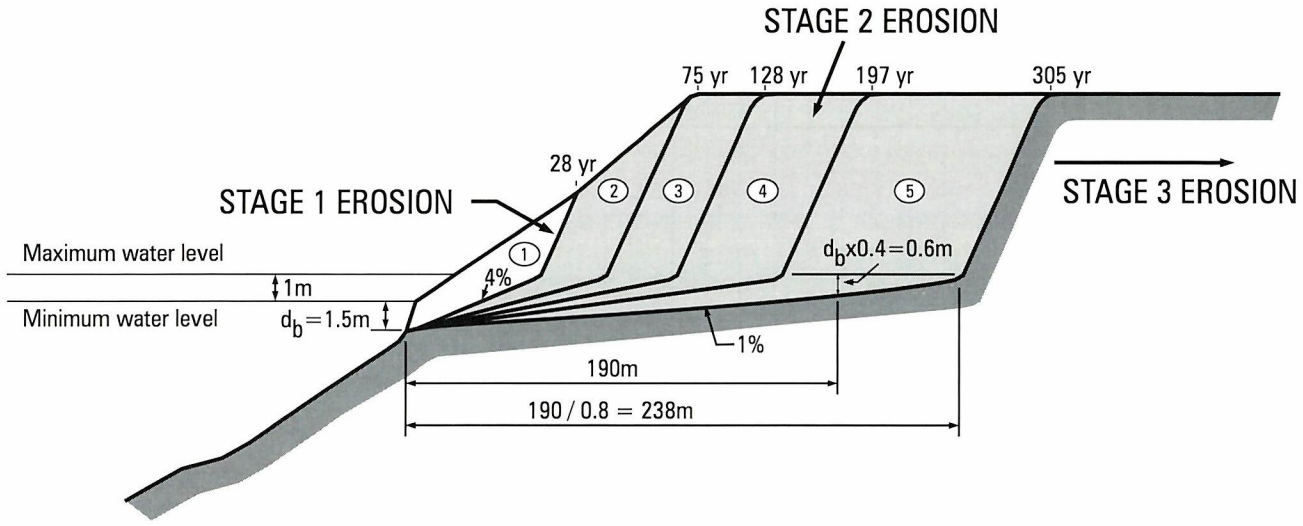
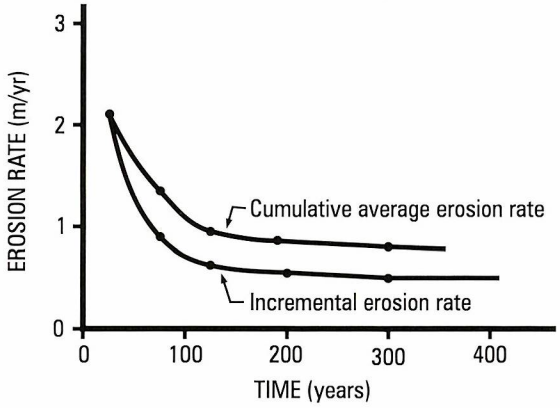
FIGURE 1



Example calculation from the Wuskwatim Lake study

Assume :
- Moderate wave energy
- Volumetric erosion rate = 4.8 m^3/m/yr
- Upland elevation 8m above minimum water level

DECLINING EROSION RATE WITH TIME



Proposed three-stage erosion model and an example of an erosion rate versus time calculation from a study of Wuskwatim Lake in northern Manitoba.

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FIGURE 2

EXAMPLE TABLE FOR RECORDING HISTORICAL SHORE EROSION RATES AND RELATED PARAMETERS

Site Number	Pre-impoundment erosion rate	Post-impoundment erosion rate	Slope above FSL (%)	Nearshore slope (%)	Shore zone material[1]	Shore zone planform[2]	Shoreline orientation[3]	Fetch normal[4]		Wind duration[5]	Maximum fetch		Wind duration[5]	Deepwater wave energy	Effective wave energy[6]	Shore erosion measurements by different individuals			
								Length (Km)	Orientation		Length (Km)	Orientation							

1 Shore material letter symbols:

2 Shore zone planform
- S Straight
- H Headland
- C Cove

3 Orientation of a line tangent to the shoreline

4 Fetch normal is the fetch length perpendicular to the shoreline tangent

5 Wind duration is average number of days that the wind blows from the fetch normal direction during the open water season

6 Wave energy causing erosion

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FIGURE 3

TABLE

FIELD DATA AND WAVE ENERGY SUMMARY

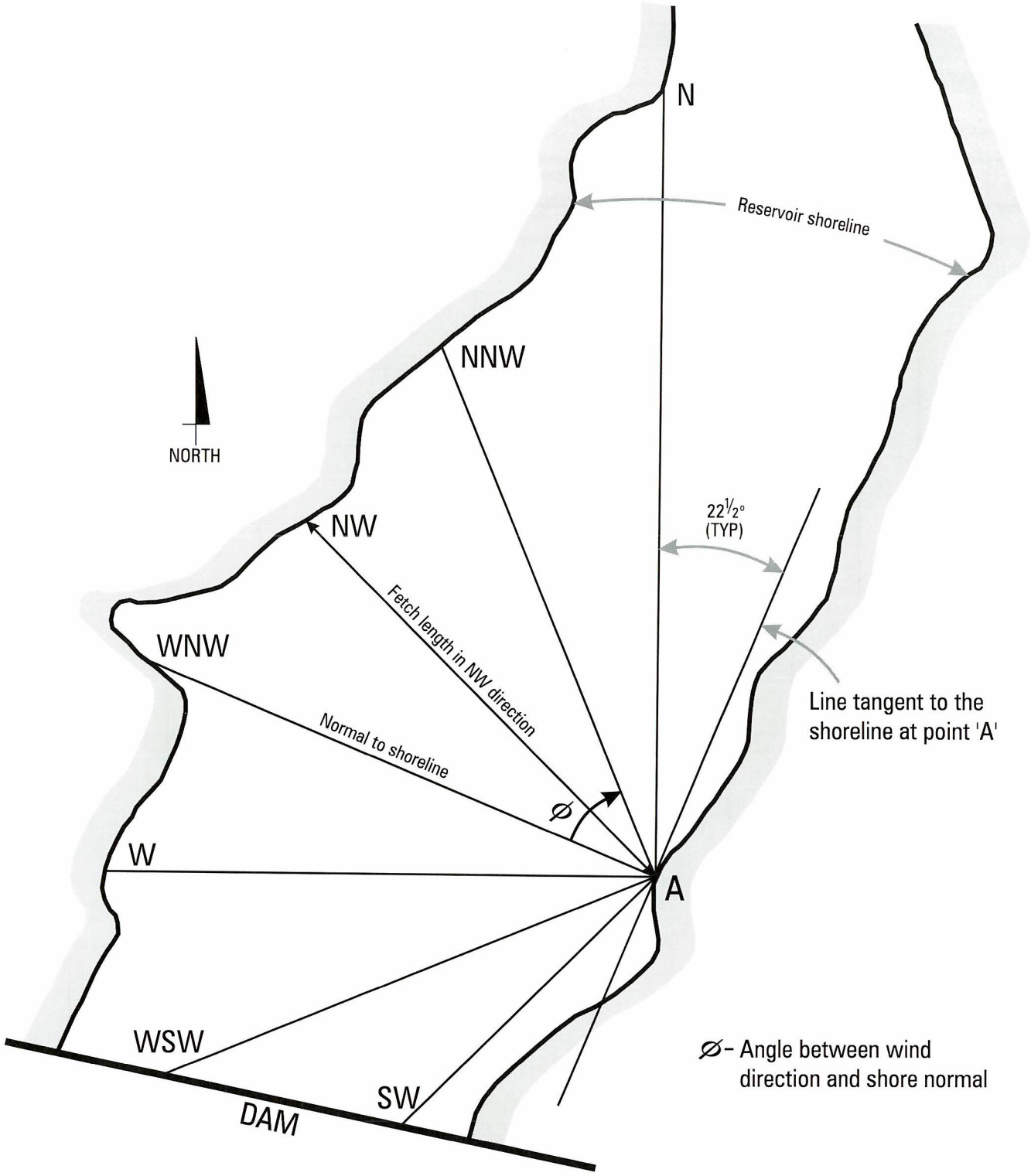
RESERVOIR NAME:

Profile Number	Beach material	Beach slope V:H	Bank material	Bank height (m)	Pre-impoundment valley-side slope V:H	Horizontal bank recession (m)	Recession rate (m/yr)	Volume of sediment eroded (m^3)	Volumetric erosion rate (m^3/yr)	Deep water wave energy (t x m/yr)	Effective wave energy (t x m/yr)	
											(1)*	(2)*

* (1) Based on pre-impoundment valley-side slope
(2) Based on field measured beach slope

EXAMPLE FIELD DATA AND WAVE ENERGY SUMMARY SHEET

J.D. Mollard and Associates Limited
November, 1993
FIGURE 4



SKETCH ILLUSTRATING MEASUREMENT OF FETCH FOR CALCULATION OF WAVE ENERGY

J.D. Mollard and Associates Limited
November, 1993
FIGURE 5

WAVE ENERGY ANALYSIS TABLE

LOCATION: _____ SITE NUMBER: _____

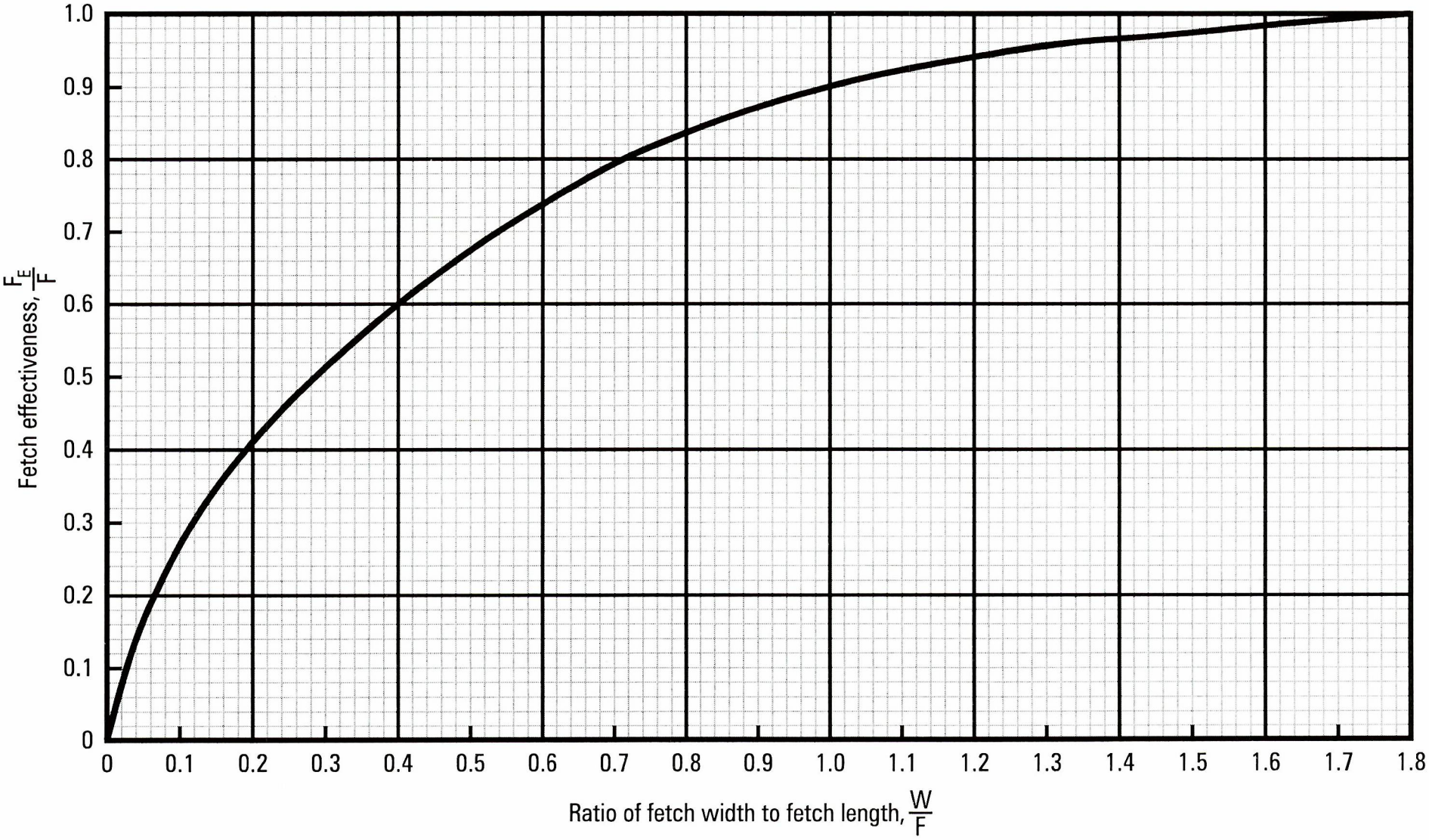
Wind direction	Fetch		Approach angle		Wind speed			Significant wave height (Hs)	Significant wave period (Ts)	Equivalent wave height (He)	Wind duration (t)	Deep water wave energy (E_1)	Deep water wave energy (E_2)
	F	F eff	∅	$Cos^2∅$	V_k	V_k	Vw						
	miles	miles			kph	mph	mph	feet	seconds	feet	seconds	ft-lbs/yr/ft	t-m/yr/m
1	2	3	4	5	6	7	8	9	10	11	12	13	14
					15.5	10							
					25.5	16							
					35.5	22							
					45.5	28							
					55.5	34							
					65.5	41							
					75	46							
					15.5	10							
					25.5	16							
					35.5	22							
					45.5	28							
					55.5	34							
					65.5	41							
					75	46							
					15.5	10							
					25.5	16							
					35.5	22							
					45.5	28							
					55.5	34							
					65.5	41							
					75	46							
					15.5	10							
					25.5	16							
					35.5	22							
					45.5	28							
					55.5	34							
					65.5	41							
					75	46							
					15.5	10							
					25.5	16							
					35.5	22							
					45.5	28							
					55.5	34							
					65.5	41							
					75	46							

Total deep water energy ($E_w = \Sigma E_2$)	Slope of site	% deep water wave energy causing erosion	Effective energy (ΣE_2 eff.)	Erodibility coefficient (Ke)	Volume of material removed (Qe)	Volume of material removed during erosion period (Qe x t)	Bank retreat distance during erosion period
t-m/yr/m		percent	t-m/yr/m	m^3/t-m	m^3/m/yr	m^3/m	m
15	16	17	18	19	20	21	22

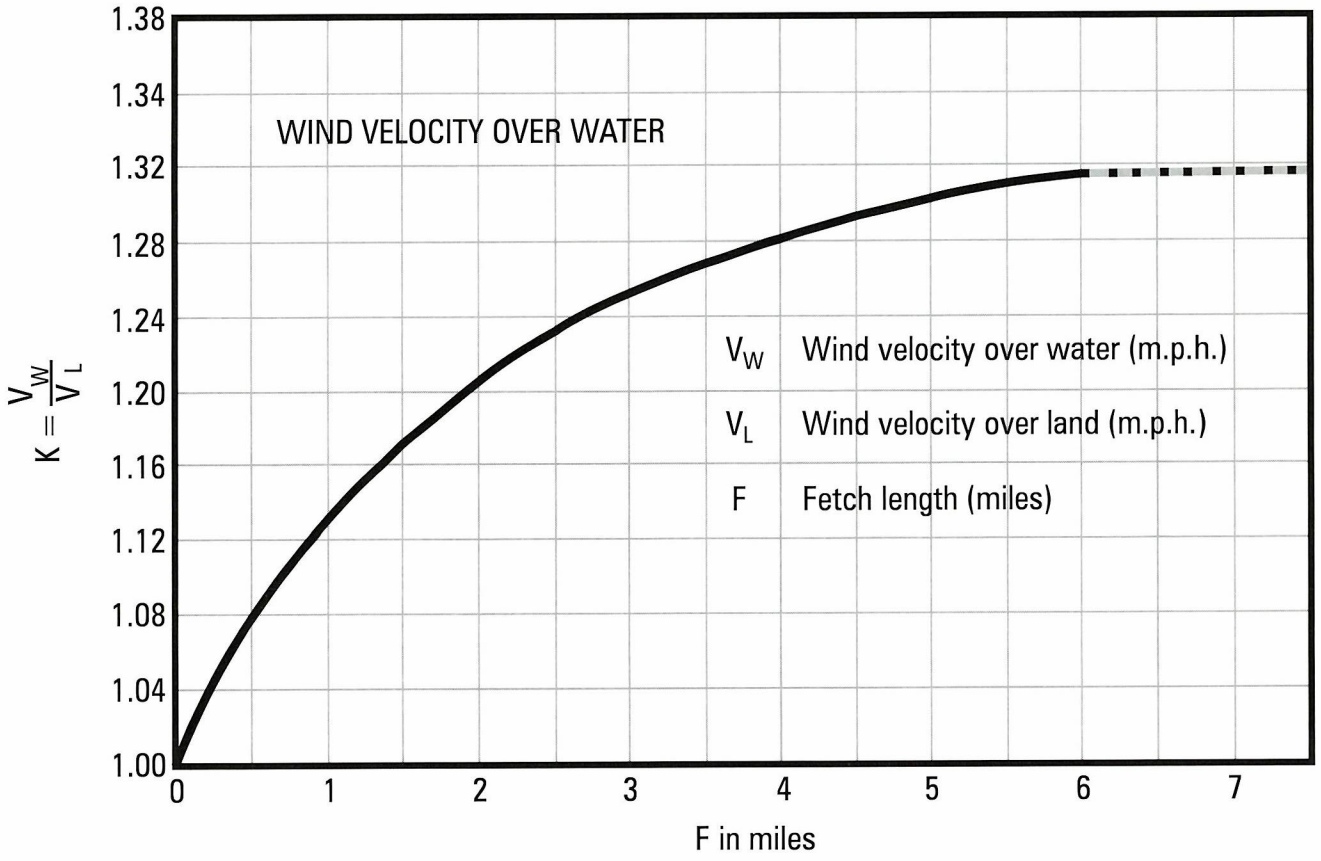
EXAMPLE OF TABLE USED TO CALCULATE BANK RECESSION USING THE WAVE ENERGY APPROACH

J.D. Mollard and Associates Limited
November, 1993
FIGURE 6

RELATION OF EFFECTIVE FETCH TO WIDTH-LENGTH RATIO FOR RECTANGULAR FETCHES
(USCE,1977)

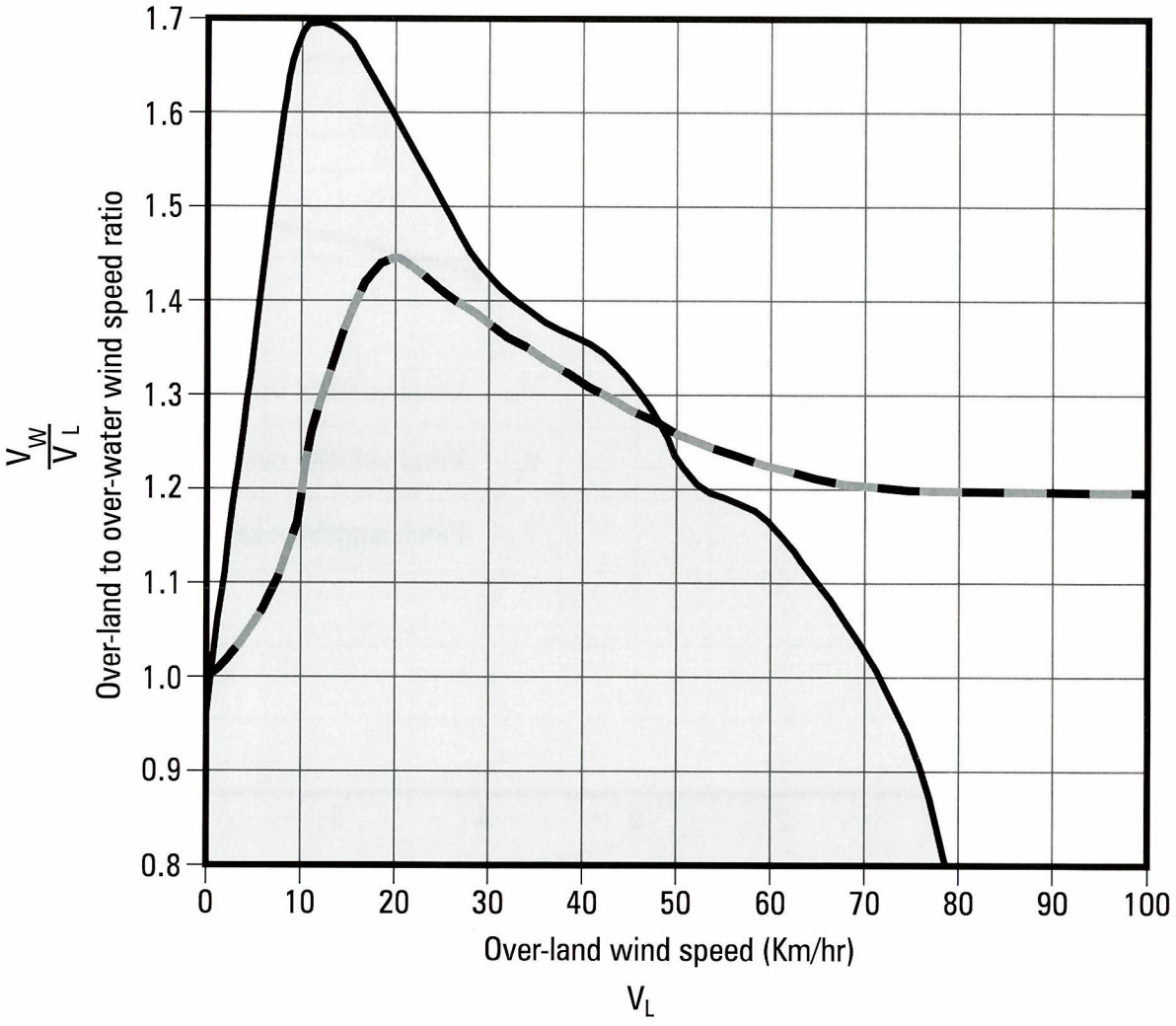


J.D. Mollard and Associates Limited
November, 1993
FIGURE 7



RELATIONSHIP OF OVER-LAND TO OVER-WATER WIND SPEED
(from Hart, 1973; see also McKay, 1966, and Hopkinson, 1991)

J.D. Mollard and Associates Limited
November, 1993
FIGURE 8



TWO ALTERNATIVE RELATIONSHIPS OF OVER-LAND TO OVER-WATER WIND SPEED
(from Baird et al., 1986)

J.D. Mollard and Associates Limited
November, 1993
FIGURE 9

REGINA A SASK.

Lat. 50°26'N Long. 104°40'W

PERIOD 1955-80 PERIODE

Elevation 577 m Altitude

	JAN JANV	FEB FEV	MAR MARS	APR AVR	MAY MAI	JUN JUIN	JUL JUIL	AUG AOUT	SEP SEPT	OCT OCT	NOV NOV	DEC DEC	YEAR ANNUEL	
PERCENTAGE FREQUENCY														FREQUENCE EN %
N	3.5	3.8	4.8	5.9	6.8	5.4	5.0	5.4	4.9	4.2	4.0	2.5	4.7	N
NNE	1.1	1.5	1.9	3.8	3.9	3.2	2.6	2.7	2.3	1.6	1.3	1.1	2.2	NNE
NE	0.9	1.2	1.3	3.0	3.4	3.2	2.3	2.7	1.8	1.4	1.1	0.8	1.9	NE
ENE	0.9	1.0	1.5	3.4	3.3	3.3	2.2	3.1	2.5	1.3	1.1	1.3	2.1	ENE
E	4.0	5.9	5.6	8.3	8.0	7.3	6.6	6.8	5.1	3.8	3.7	4.9	5.8	E
ESE	9.0	11.0	10.9	9.8	9.0	8.0	7.9	9.4	7.8	7.2	6.4	8.7	8.8	ESE
SE	16.4	19.0	18.0	14.3	12.4	9.9	11.2	13.0	12.2	13.0	14.5	18.3	14.4	SE
SSE	4.8	5.6	6.7	7.2	7.1	6.6	6.4	6.3	6.7	6.6	7.4	5.9	6.4	SSE
S	2.5	3.0	3.5	4.8	5.5	5.3	4.9	4.4	5.5	5.6	5.2	3.0	4.4	S
SSW	1.4	1.6	1.7	3.0	3.4	3.4	2.8	2.7	3.4	3.2	3.1	1.8	2.6	SSW
SW	2.6	2.6	2.5	3.5	3.5	4.3	3.9	3.6	3.9	4.5	4.0	2.9	3.5	SW
WSW	4.2	3.4	3.4	3.5	4.2	5.2	5.2	5.0	5.2	5.7	5.0	4.6	4.6	WSW
W	12.5	10.2	9.8	6.4	6.6	9.7	10.9	8.3	10.7	11.3	11.7	11.9	10.0	W
WNW	12.7	9.6	8.1	6.3	5.8	8.6	9.1	7.6	9.3	10.9	11.3	12.6	9.3	WNW
NW	13.6	11.1	10.7	8.2	7.4	7.6	8.7	8.7	9.0	10.4	11.2	11.2	9.8	NW
NNW	7.2	6.7	7.6	6.7	7.1	6.3	7.3	6.9	7.1	6.8	6.9	5.9	6.9	NNW
Calm	2.7	2.8	2.0	1.9	2.6	2.7	3.0	3.4	2.6	2.5	2.1	2.6	2.6	Calme
MEAN WIND SPEED IN KILOMETRES PER HOUR VITESSE MOYENNE DES VENTS EN KILOMÈTRES PAR HEURE														
N	19.4	19.0	21.2	20.6	21.7	17.8	15.6	15.5	18.9	18.9	18.6	17.8	18.8	N
NNE	15.3	18.2	19.3	20.2	19.5	17.7	14.5	14.8	16.8	16.1	15.8	14.8	16.9	NNE
NE	14.6	14.5	20.1	21.1	20.1	16.3	14.4	14.7	16.3	16.1	16.8	15.6	16.7	NE
ENE	18.3	18.4	21.9	23.0	20.3	19.6	17.1	16.6	19.6	19.5	17.4	20.8	19.4	ENE
E	17.3	20.2	21.2	22.0	21.0	19.4	17.7	16.7	18.2	17.8	18.6	18.8	19.1	E
ESE	21.5	24.2	24.6	23.2	22.1	20.9	18.9	19.1	19.7	19.1	20.0	20.7	21.2	ESE
SE	24.5	26.2	25.7	25.6	24.9	22.6	19.7	21.1	22.1	22.0	23.1	25.0	23.5	SE
SSE	21.0	20.7	22.5	23.9	24.8	22.3	19.4	20.6	22.0	21.1	21.4	20.4	21.7	SSE
S	13.3	13.9	16.5	19.1	21.2	18.7	16.0	16.2	17.5	18.5	16.4	13.6	16.7	S
SSW	13.7	13.3	15.7	19.1	20.4	19.3	14.6	16.0	17.9	18.5	16.5	14.5	16.6	SSW
SW	17.7	16.2	17.0	21.1	19.6	18.9	15.3	17.0	17.7	18.5	17.6	17.5	17.8	SW
WSW	21.0	18.0	18.1	22.0	22.7	20.6	18.5	18.6	20.8	19.7	18.9	19.3	19.9	WSW
W	20.7	19.5	19.1	22.5	23.2	21.0	18.5	18.6	20.7	19.6	19.8	20.5	20.3	W
WNW	25.8	23.7	23.7	25.1	25.9	23.2	21.0	21.9	24.5	24.7	25.0	25.5	24.2	WNW
NW	25.8	24.6	23.8	25.2	24.3	20.8	19.3	20.8	24.5	24.8	26.2	26.9	23.9	NW
NNW	24.7	24.1	24.1	24.0	23.4	19.8	18.7	19.1	23.2	23.9	22.5	24.4	22.7	NNW
All Directions														Toutes directions
	21.8	21.6	22.0	22.6	22.1	19.9	17.7	18.1	20.4	20.5	20.9	21.7	20.8	
Maximum Hourly Speed														Vitesse horaire maximale
	97	89	77	84	84	97	80	72	71	142	85	89	142	
	W	NW	W	WSW	WSW	WNW	NW	WNW	SVL	SE	NW	SVL	SE	
Maximum Gust Speed														Vitesse maximale des rafales
	122	122	95	126	135	153	137	137	117	127	132	105	153	
	W	NW	NW	SE	WSW	WNW	SE	SSW	WNW	WNW	NW	WNW	WNW	

Height of anemometer 10.1m hauteur de l'anémomètre

STATION INFORMATION

The U2A wind eqipment is mounted on a 10 m mast 1 km west-southwest of terminal building at the airport. There is no obstruction to the wind flow in any direction. The topography is fairly flat in all directions with the airport in a shallow vally oriented NW-SE.

DONNEES RELATIVES A LA STATION

L'appareil U2A est fixé sur un mât de 10m de hauteur situe à 1 km a l'ouest-sud-ouest de l'aérogare. Le courant de vent ne rencontre d'obstacle dans aucune direction. Le relief est assez piat de tous côtes.

J.D. Mollard and Associates Limited
November, 1993

ENVIRONMENT CANADA WIND NORMAL TABLE FOR REGINA A STATION

FIGURE 10

PERCENTAGE FREQUENCIES BY DIRECTION AND SPEED

REGINA A SASK. 25005

TOTAL FILE 1953-1972

PROJECT 01174

FOR HOURS WITH
WIND SPEED AND DIRECTION

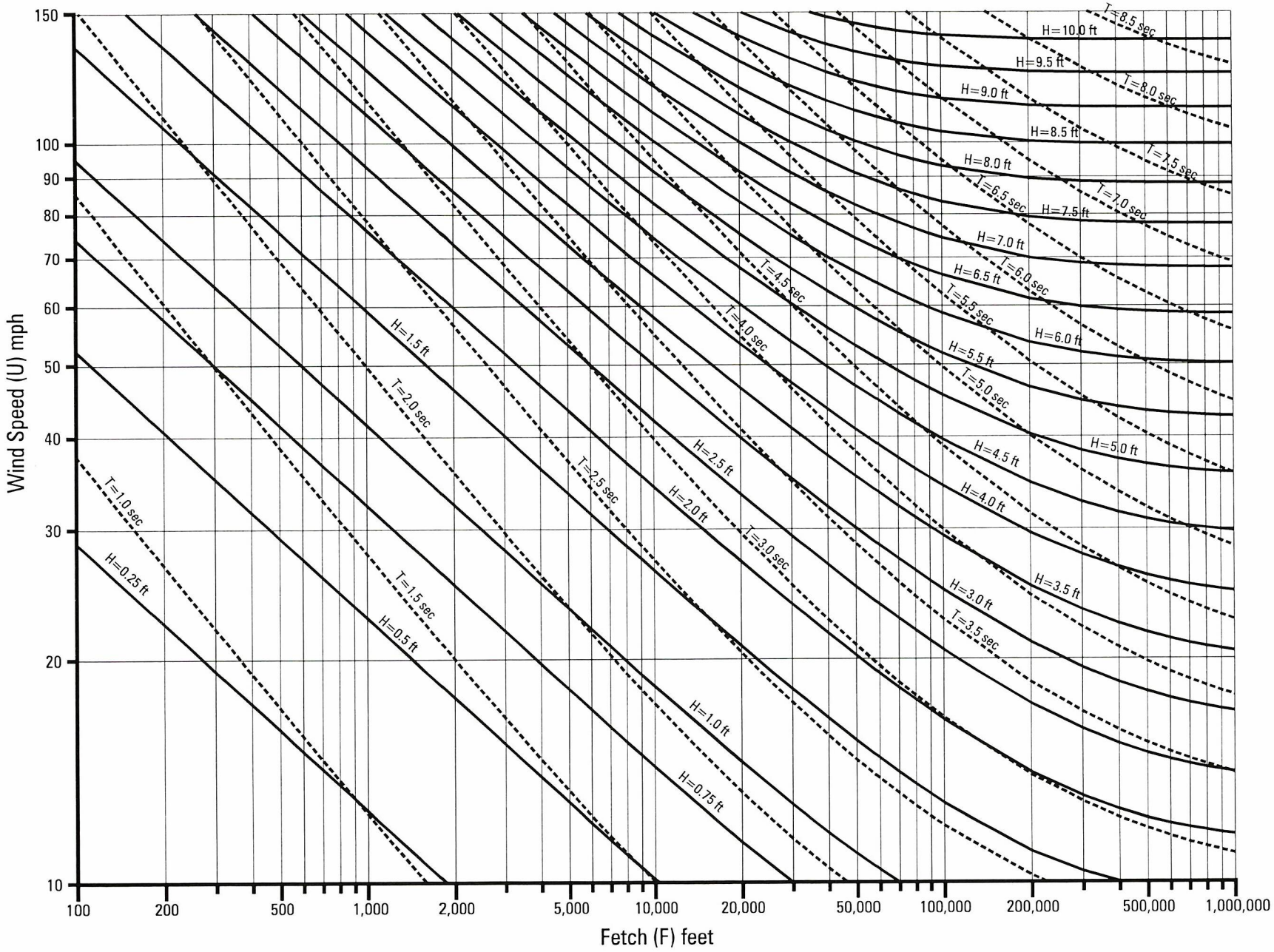
	Total	Speed (mph)	1-3	4-6	7-12	13-17	18-23	24-29	30-35	36-40	41-46	Percent	Mean	Speed limit	Percent above limit
Calm	3,208											1.83			
NNE	4,190		0.14	0.49	0.93	0.45	0.31	0.07	0.01			2.39	11.0	46	
NE	3,708		0.12	0.47	0.82	0.40	0.23	0.07	0.01	0.00		2.11	10.9	46	
ENE	4,150		0.07	0.37	0.86	0.55	0.40	0.10	0.01	0.00	0.00	2.37	12.5	46	
E	10,099		0.19	0.91	2.18	1.31	0.92	0.22	0.03	0.00		5.76	12.2	46	
ESE	15,294		0.14	0.92	3.22	2.08	1.62	0.56	0.15	0.03	0.01	8.72	13.7	46	
SE	25,927		0.22	1.23	4.45	3.71	3.40	1.37	0.35	0.05	0.00	14.79	15.0	46	0.00
SSE	10,778		0.18	0.76	2.00	1.36	1.25	0.46	0.12	0.01	0.01	6.15	13.9	46	
S	7,698		0.28	0.85	1.73	0.83	0.54	0.13	0.03	0.00		4.39	11.1	46	
SSW	4,741		0.18	0.47	1.07	0.56	0.32	0.09	0.01	0.01		2.70	11.2	46	
SW	6,847		0.22	0.75	1.40	0.82	0.53	0.14	0.03	0.01	0.00	3.91	11.7	46	0.00
WSW	7,961		0.19	0.65	1.55	1.03	0.73	0.28	0.08	0.03	0.01	4.54	13.1	46	0.01
W	16,663		0.34	1.32	3.61	1.90	1.48	0.56	0.19	0.07	0.02	9.50	13.1	46	0.01
WNW	16,737		0.19	0.86	2.80	2.13	2.13	0.95	0.34	0.10	0.03	9.55	15.5	46	0.01
NW	18,080		0.27	1.04	2.99	2.22	2.28	0.98	0.39	0.10	0.02	10.31	15.2	46	0.01
NNW	11,467		0.18	0.79	2.04	1.41	1.37	0.55	0.16	0.03	0.01	6.54	14.3	46	0.00
N	7,772		0.24	0.92	1.62	0.83	0.58	0.19	0.04	0.01	0.00	4.43	11.6		
Total	175,320		3.13	12.80	33.27	21.59	18.09	6.73	1.95	0.45	0.12	100.00	13.4		0.04

Total before selection 175,320*

* Percentages computed using this total

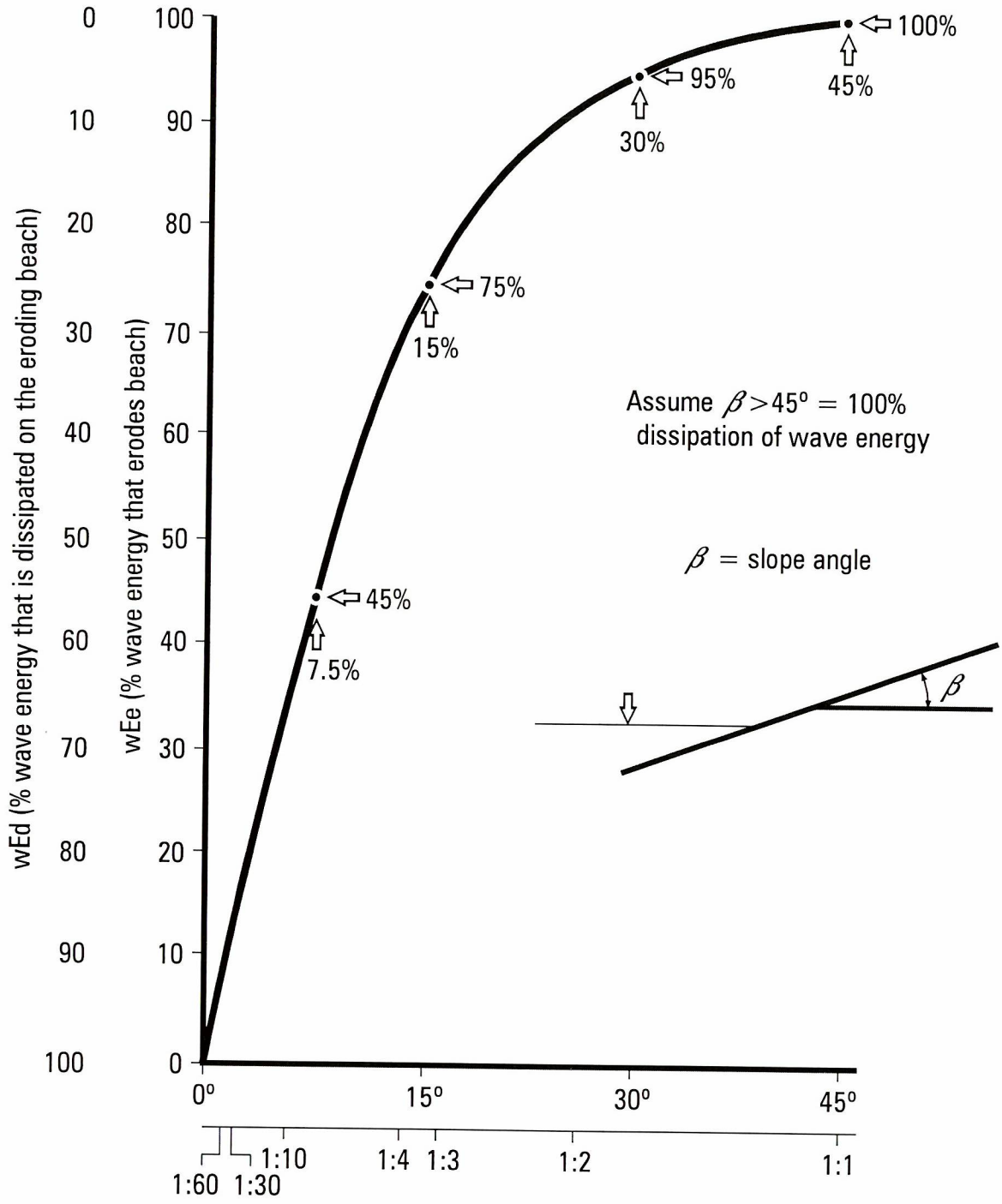
ENVIRONMENT CANADA PERCENTAGE FREQUENCIES BY DIRECTION AND SPEED FOR WINDS AT REGINA A STATION

J.D. Mollard and Associates Limited
November, 1993
FIGURE 11



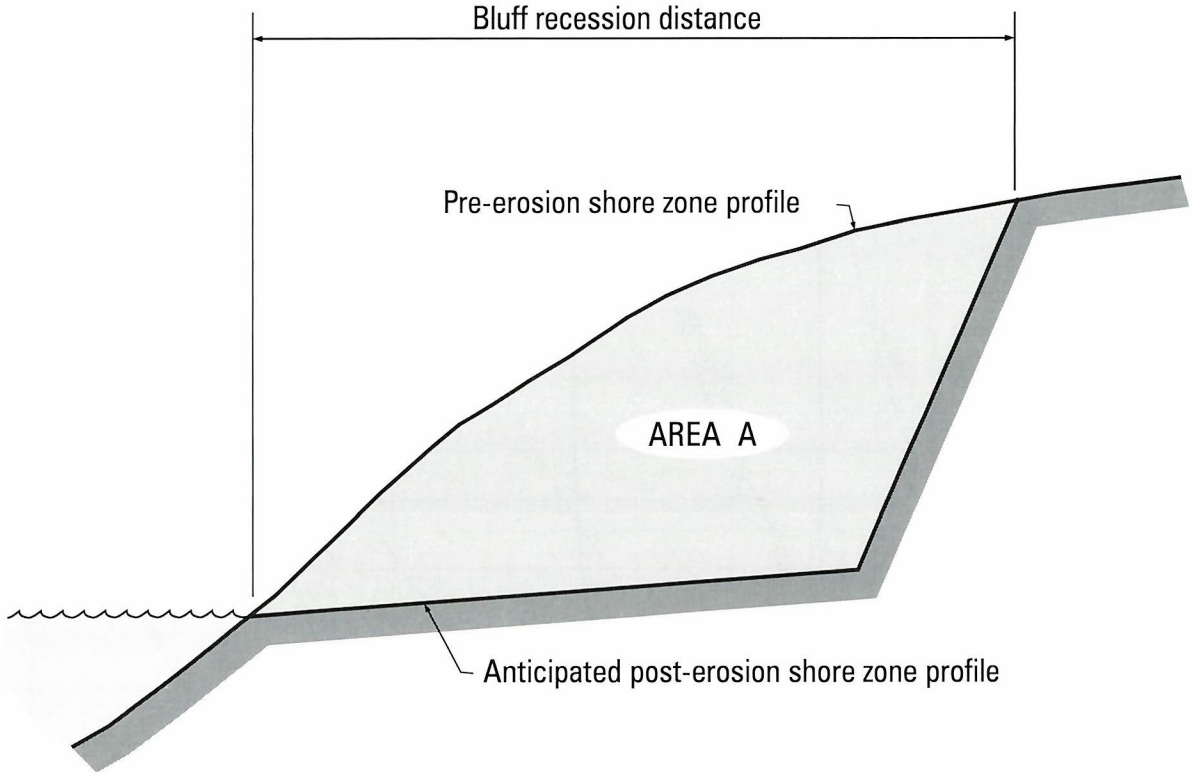
WAVE HINDCASTING CURVE FOR SHALLOW WATER WAVES
FOR A CONSTANT WATER DEPTH OF 25 FEET
(USCE, 1977)

J.D. Mollard and Associates Limited
November, 1993
FIGURE 12



POSTULATED PARABOLIC RELATIONSHIP BETWEEN PERCENTAGE OF WAVE ENERGY DISSIPATION AND FORESHORE SLOPE ANGLE.

J.D. Mollard and Associates Limited
November, 1993
FIGURE 13



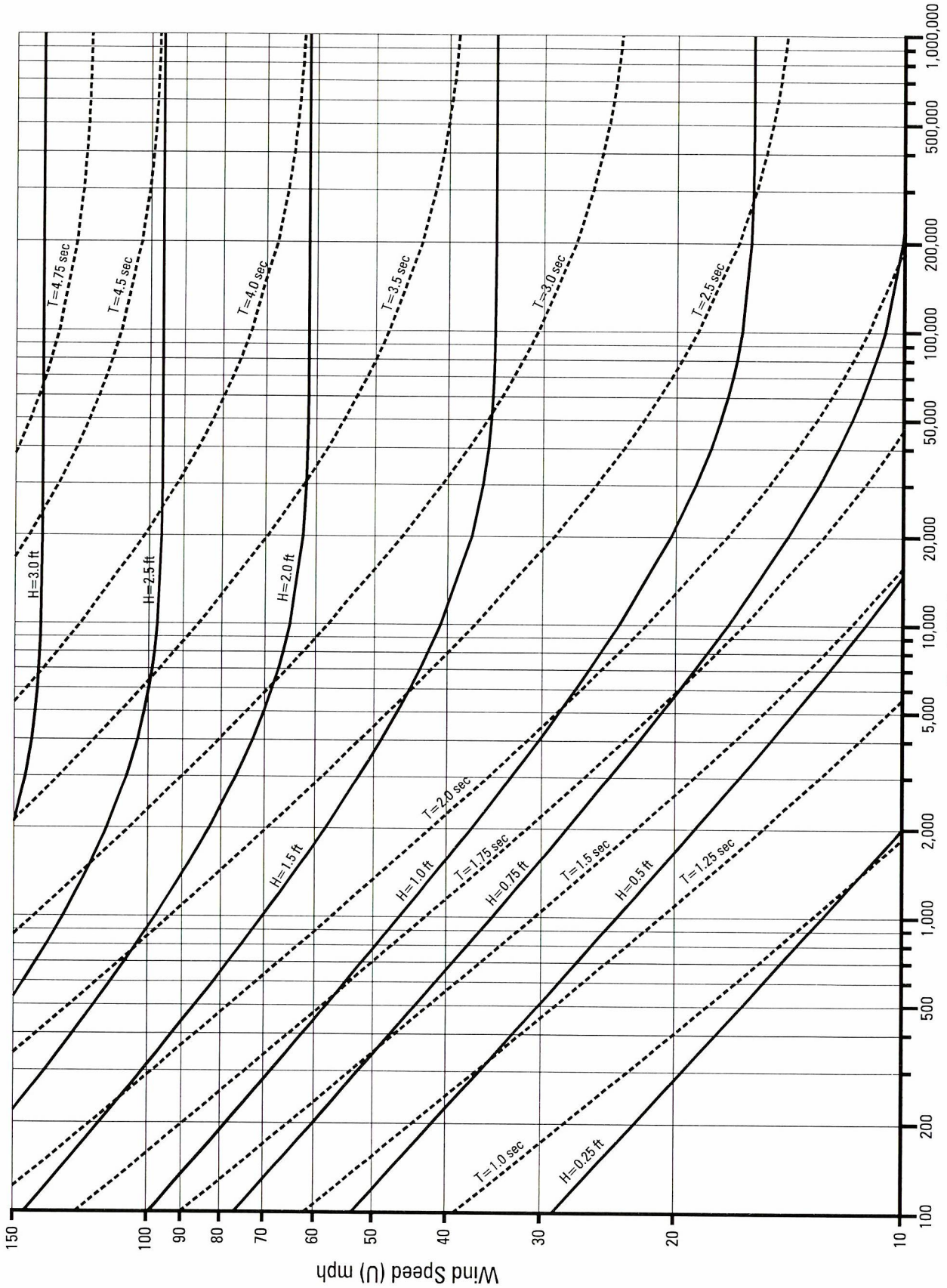
Position of the anticipated post-erosion shore zone profile is adjusted until Area A equals the calculated eroded volume per unit length of shore zone as calculated in TASK 4.5. Bluff recession distance is then measured.

GRAPHICAL DETERMINATION OF ANTICIPATED BLUFF RECESSION DISTANCE

J.D. Mollard and Associates Limited
November, 1993
FIGURE 14

APPENDIX 1

WAVE HINDCASTING CHARTS



Forecasting Curve for Shallow-Water Waves.
(USCE, 1977)

Constant Depth = 5 feet

J.D. Mollard and Associates Limited
November, 1993

Chart Data - Wind Speed (mph)

Constant Depth = 5 feet

1 of 1

Wave Period (seconds)

Fetch (feet)	1.00	1.25	1.50	1.75	2.00	2.50	3.00	3.50	4.00	4.50	4.75
100	39.03	61.75	90.07	124.22							
122					150.00						
200	27.95	44.29	64.74	89.50	118.76						
300	23.03	36.53	53.47	74.02	98.38						
343						150.00					
400	20.10	31.90	46.72	64.76	86.17	139.87					
500	18.10	28.73	42.11	58.41	77.80	126.57					
600	16.63	26.39	38.70	53.72	71.61	116.71					
700	15.49	24.57	36.05	50.07	66.79	109.02					
800	14.56	23.10	33.91	47.12	62.89	102.80					
865							150.00				
900	13.80	21.89	32.13	44.67	59.65	97.63	147.49				
1,000	13.16	20.86	30.63	42.59	56.91	93.26	141.06				
1,100	12.60	19.98	29.33	40.81	54.55	89.48	135.51				
1,200	12.12	19.21	28.21	39.25	52.49	86.18	130.66				
1,300	11.70	18.53	27.21	37.87	50.67	83.27	126.37				
1,400	11.32	17.92	26.32	36.65	49.04	80.66	122.54				
1,500	10.98	17.38	25.52	35.54	47.58	78.32	119.09				
1,600	10.67	16.89	24.80	34.54	46.26	76.20	115.97				
1,700	10.40	16.44	24.14	33.63	45.05	74.27	113.12				
1,800	10.14	16.03	23.54	32.80	43.95	72.50	110.51				
1,860	10.00										
1,900		15.66	22.99	32.03	42.93	70.87	108.11				
2,000		15.31	22.48	31.33	41.99	69.36	105.88				
2,106								150.00			
3,000		12.87	18.87	26.31	35.33	58.64	90.06	131.04			
4,000		11.42	16.72	23.32	31.34	52.21	80.54	117.79			
5,000		10.45	15.26	21.28	28.62	47.79	74.00	108.67			
5,355									150.00		
5,592		10.00									
6,000			14.19	19.78	26.61	44.53	69.15	101.91	144.47		
7,000			13.36	18.61	25.04	41.98	65.37	96.63	137.45		
8,000			12.70	17.67	23.78	39.92	62.31	92.36	131.76		
9,000			12.15	16.90	22.74	38.22	59.77	88.81	127.05		
10,000			11.69	16.24	21.86	36.77	57.62	85.81	123.05		
15,689			10.00								
16,702										150.00	
20,000				12.75	17.12	28.94	45.90	69.44	101.33	143.74	
30,000				11.26	15.06	25.49	40.70	62.18	91.76	131.68	
37,842											150.00
40,000				10.39	13.86	23.45	37.61	57.87	86.12	124.65	148.61
46,383				10.00							
50,000					13.05	22.07	35.52	54.96	82.32	119.97	143.50
60,000					12.47	21.06	34.00	52.84	79.57	116.59	139.85
70,000					12.03	20.29	32.82	51.21	77.46	114.04	137.09
80,000					11.67	19.68	31.88	49.91	75.80	112.03	134.93
90,000					11.39	19.17	31.11	48.84	74.44	110.41	133.20
100,000					11.15	18.75	30.46	47.95	73.31	109.07	131.78
191,154					10.00						
200,000						16.58	27.13	43.40	67.65	102.57	124.97
300,000						15.71	25.80	41.62	65.53	100.25	122.63
400,000						15.24	25.07	40.66	64.43	99.11	121.50
500,000						14.93	24.61	40.07	63.77	98.45	120.85
600,000						14.73	24.29	39.68	63.33	98.03	120.45
700,000						14.57	24.06	39.39	63.03	97.74	120.18
800,000						14.46	23.89	39.18	62.81	97.54	119.99
900,000						14.37	23.76	39.02	62.64	97.39	119.85
1,000,000						14.30	23.65	38.89	62.52	97.27	119.75

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

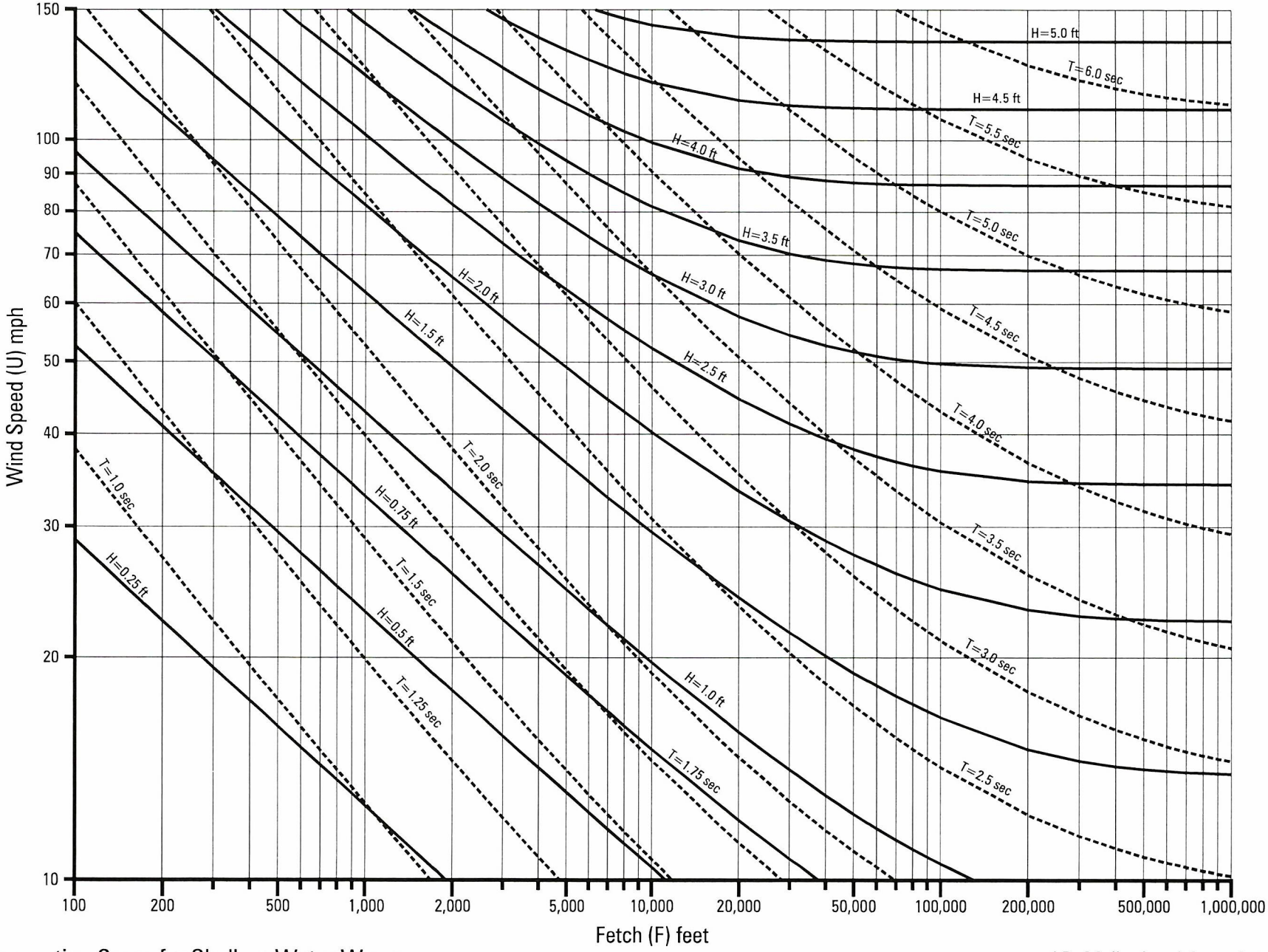
Constant Depth = 5 feet

1 of 1

Wave Height (feet)

Fetch (feet)	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00
100	28.95	53.25	76.49	99.36	145.10			
200	22.59	41.69	60.11	78.40	115.52			
219						150.00		
300	19.55	36.16	52.28	68.39	101.42	136.46		
400	17.64	32.70	47.38	62.13	92.64	125.41		
500	16.30	30.25	43.92	57.72	86.46	117.66		
531							150.00	
600	15.28	28.40	41.30	54.37	81.78	111.83	145.49	
700	14.47	26.92	39.21	51.71	78.07	107.23	140.19	
800	13.80	25.71	37.50	49.52	75.04	103.47	135.89	
900	13.24	24.69	36.06	47.68	72.48	100.33	132.33	
1,000	12.76	23.81	34.82	46.10	70.30	97.65	129.32	
1,100	12.34	23.05	33.73	44.73	68.40	95.34	126.72	
1,200	11.96	22.37	32.78	43.52	66.73	93.30	124.47	
1,300	11.63	21.77	31.93	42.43	65.24	91.51	122.49	
1,400	11.34	21.23	31.16	41.46	63.91	89.90	120.74	
1,500	11.07	20.74	30.47	40.58	62.70	88.45	119.17	
1,600	10.82	20.29	29.84	39.78	61.60	87.14	117.76	
1,700	10.59	19.88	29.26	39.04	60.60	85.94	116.48	
1,800	10.38	19.50	28.72	38.36	59.67	84.85	115.32	
1,900	10.19	19.14	28.22	37.73	58.82	83.84	114.27	
2,000	10.01	18.82	27.76	37.15	58.02	82.91	113.30	
2,007	10.00							
2,081								150.00
3,000		16.44	24.41	32.91	52.34	76.39	106.77	144.99
4,000		14.95	22.32	30.28	48.89	72.62	103.29	142.31
5,000		13.91	20.85	28.45	46.54	70.15	101.19	140.88
6,000		13.12	19.75	27.07	44.80	68.42	99.83	140.04
7,000		12.50	18.87	25.98	43.46	67.14	98.91	139.52
8,000		11.99	18.16	25.10	42.39	66.17	98.26	139.19
9,000		11.57	17.56	24.36	41.52	65.42	97.78	138.97
10,000		11.20	17.05	23.73	40.80	64.82	97.43	138.81
14,711		10.00						
20,000			14.21	20.31	37.23	62.39	96.32	138.43
30,000			12.94	18.84	36.00	61.85	96.16	138.40
40,000			12.20	18.01	35.45	61.67	96.13	138.39
50,000			11.71	17.48	35.16	61.60	96.12	138.39
60,000			11.36	17.12	34.99	61.57	96.12	138.39
70,000			11.10	16.86	34.90	61.55	96.11	138.39
80,000			10.89	16.66	34.83	61.55	96.11	138.39
90,000			10.74	16.52	34.79	61.54	96.11	138.39
100,000			10.61	16.40	34.77	61.54	96.11	138.39
200,000			10.05	15.97	34.70	61.54	96.11	138.39
300,000				15.89	34.70	61.54	96.11	138.39
400,000				15.86	34.70	61.54	96.11	138.39
500,000				15.85	34.70	61.54	96.11	138.39
600,000				15.85	34.70	61.54	96.11	138.39
700,000				15.85	34.70	61.54	96.11	138.39
800,000				15.85	34.70	61.54	96.11	138.39
900,000				15.85	34.70	61.54	96.11	138.39
1,000,000				15.85	34.70	61.54	96.11	138.39

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph



Forecasting Curve for Shallow-Water Waves.
(USCE, 1977)

Constant Depth = 10 feet

J.D. Mollard and Associates Limited
November, 1993

Chart Data - Wind Speed (mph)

Constant Depth = 10 feet

1 of 2

Wave Period (seconds)

Fetch (feet)	1.00	1.25	1.50	1.75	2.00	2.50	3.00	3.50	4.00	4.50	5.00
100	38.20	60.10	87.18	119.58							
110					150.00						
200	27.24	42.89	62.28	85.52	112.72						
292						150.00					
300	22.39	35.25	51.22	70.38	92.84	148.07					
400	19.51	30.70	44.61	61.34	80.96	129.30					
500	17.54	27.59	40.10	55.16	72.84	116.45					
600	16.09	25.30	36.77	50.59	66.83	106.95					
671							150.00				
700	14.96	23.52	34.18	47.03	62.15	99.55	147.07				
800	14.06	22.08	32.10	44.17	58.38	93.57	138.35				
900	13.31	20.90	30.37	41.79	55.25	88.61	131.12				
1,000	12.68	19.89	28.90	39.78	52.61	84.41	124.99				
1,100	12.14	19.03	27.64	38.05	50.33	80.79	119.70				
1,200	11.66	18.28	26.55	36.54	48.34	77.63	115.09				
1,300	11.25	17.61	25.58	35.21	46.58	74.84	111.01				
1,400	10.88	17.03	24.72	34.02	45.02	72.36	107.37				
1,416								150.00			
1,500	10.55	16.50	23.94	32.96	43.61	70.12	104.10	146.23			
1,600	10.25	16.02	23.24	31.99	42.34	68.09	101.14	142.14			
1,692	10.00										
1,700		15.58	22.61	31.11	41.18	66.25	98.44	138.41			
1,800		15.18	22.02	30.31	40.11	64.56	95.96	134.99			
1,900		14.82	21.49	29.57	39.14	63.00	93.69	131.85			
2,000		14.48	20.99	28.89	38.24	61.56	91.58	128.93			
2,854									150.00		
3,000		12.11	17.51	24.07	31.85	51.38	76.64	108.26	146.91		
4,000		10.72	15.44	21.20	28.05	45.29	67.69	95.85	130.43		
4,736		10.00									
5,000			14.05	19.25	25.46	41.12	61.55	87.33	119.10		
5,673										150.00	
6,000			13.02	17.82	23.55	38.04	57.01	81.02	110.70	146.77	
7,000			12.23	16.71	22.07	35.65	53.47	76.09	104.15	138.33	
8,000			11.60	15.82	20.88	33.72	50.61	72.11	98.84	131.50	
9,000			11.08	15.09	19.90	32.12	48.24	68.81	94.44	125.82	
10,000			10.64	14.47	19.07	30.77	46.24	66.01	90.70	121.00	
11,526											150.00
11,829			10.00								
20,000				11.20	14.64	23.49	35.35	50.76	70.30	94.67	124.64
28,298				10.00							
30,000					12.74	20.30	30.54	43.97	61.19	82.88	109.83
40,000					11.64	18.43	27.69	39.93	55.74	75.83	100.98
50,000					10.91	17.18	25.76	37.18	52.03	71.01	94.94
60,000					10.39	16.26	24.35	35.16	49.29	67.46	90.49
69,630					10.00						
70,000						15.56	23.26	33.59	47.17	64.71	87.04
80,000						15.01	22.39	32.34	45.47	62.50	84.28
90,000						14.55	21.67	31.30	44.06	60.67	82.00
100,000						14.17	21.07	30.44	42.88	59.13	80.08
200,000						12.22	17.95	25.86	36.61	51.00	69.96
300,000						11.44	16.66	23.95	33.98	47.58	65.76
400,000						11.00	15.94	22.86	32.48	45.65	63.40
500,000						10.73	15.48	22.16	31.51	44.40	61.89
600,000						10.53	15.15	21.67	30.82	43.52	60.84
700,000						10.39	14.90	21.30	30.31	42.87	60.06
800,000						10.28	14.72	21.01	29.91	42.37	59.47
900,000						10.19	14.57	20.78	29.60	41.97	59.00
1,000,000						10.12	14.45	20.59	29.34	41.64	58.63

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 10 feet

2 of 2

Wave Period (seconds)

Fetch (feet)	5.50	6.00
100		
200		
300		
400		
500		
600		
700		
800		
900		
1,000		
1,100		
1,200		
1,300		
1,400		
1,500		
1,600		
1,700		
1,800		
1,900		
2,000		
3,000		
4,000		
5,000		
6,000		
7,000		
8,000		
9,000		
10,000		
20,000		
25,381	150.00	
30,000	142.96	
40,000	132.13	
50,000	124.76	
60,000	119.34	
70,000	115.15	
70,350		150.00
80,000	111.80	146.19
90,000	109.03	142.93
100,000	106.71	140.21
200,000	94.59	126.14
300,000	89.64	120.53
400,000	86.91	117.50
500,000	85.18	115.61
600,000	83.99	114.33
700,000	83.12	113.41
800,000	82.47	112.73
900,000	81.96	112.20
1,000,000	81.55	111.78

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 10 feet

1 of 2

Wave Height (feet)

Fetch (feet)	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
100	28.77	52.51	74.81	96.32	137.97						
166						150.00					
200	22.41	40.94	58.41	75.30	108.18	140.52					
300	19.37	35.41	50.56	65.24	93.93	122.28					
304							150.00				
400	17.46	31.95	45.65	58.95	85.01	110.88	136.92				
500	16.12	29.50	42.18	54.51	78.71	102.83	127.19				
521								150.00			
600	15.10	27.64	39.54	51.13	73.94	96.72	119.81	143.44			
700	14.28	26.17	37.45	48.45	70.13	91.86	113.95	136.62			
800	13.62	24.95	35.73	46.24	67.01	87.87	109.13	131.02			
868									150.00		
900	13.05	23.93	34.27	44.38	64.38	84.51	105.08	126.31	148.38		
1,000	12.57	23.05	33.03	42.78	62.12	81.62	101.60	122.27	143.82		
1,100	12.15	22.28	31.94	41.39	60.15	79.11	98.57	118.76	139.85		
1,200	11.78	21.61	30.98	40.16	58.41	76.89	95.90	115.66	136.35		
1,300	11.45	21.00	30.12	39.06	56.85	74.91	93.51	112.90	133.24		
1,400	11.15	20.46	29.35	38.08	55.46	73.12	91.37	110.41	130.44		
1,458										150.00	
1,500	10.88	19.97	28.65	37.18	54.19	71.51	89.43	108.17	127.91	148.86	
1,600	10.64	19.52	28.01	36.36	53.03	70.03	87.66	106.12	125.61	146.33	
1,700	10.41	19.10	27.43	35.61	51.97	68.68	86.03	104.24	123.50	144.02	
1,800	10.20	18.72	26.88	34.92	50.99	67.43	84.53	102.51	121.56	141.89	
1,900	10.01	18.37	26.38	34.28	50.08	66.28	83.14	100.91	119.77	139.92	
1,904	10.00										
2,000		18.04	25.92	33.68	49.24	65.20	81.85	99.42	118.10	138.10	
2,629											150.00
3,000		15.65	22.52	29.33	43.09	57.39	72.50	88.67	106.12	125.09	145.81
4,000		14.16	20.40	26.61	39.26	52.53	66.71	82.06	98.82	117.26	137.64
5,000		13.11	18.91	24.70	36.56	49.11	62.66	77.46	93.79	111.93	132.17
6,000		12.32	17.77	23.24	34.51	46.54	59.61	74.02	90.06	108.03	128.25
7,000		11.69	16.88	22.09	32.89	44.49	57.21	71.33	87.17	105.05	125.30
8,000		11.18	16.14	21.15	31.56	42.82	55.25	69.15	84.85	102.70	123.01
9,000		10.75	15.52	20.35	30.45	41.42	53.61	67.34	82.95	100.79	121.18
10,000		10.38	14.99	19.67	29.49	40.23	52.22	65.81	81.35	99.21	119.70
11,210		10.00									
20,000			12.02	15.84	24.11	33.56	44.61	57.70	73.26	91.67	113.16
30,000			10.66	14.06	21.61	30.53	41.29	54.40	70.30	89.26	111.38
37,835			10.00								
40,000				12.99	20.10	28.73	39.40	52.65	68.87	88.24	110.73
50,000				12.26	19.07	27.52	38.18	51.60	68.09	87.74	110.44
60,000				11.72	18.30	26.64	37.34	50.92	67.63	87.46	110.30
70,000				11.31	17.72	25.98	36.73	50.45	67.34	87.31	110.22
80,000				10.98	17.25	25.47	36.28	50.13	67.15	87.21	110.18
90,000				10.71	16.87	25.06	35.92	49.89	67.02	87.15	110.16
100,000				10.49	16.56	24.72	35.65	49.72	66.93	87.12	110.14
131,182				10.00							
200,000					15.00	23.20	34.59	49.17	66.70	87.03	110.11
300,000					14.46	22.76	34.37	49.09	66.68	87.03	110.11
400,000					14.21	22.59	34.31	49.08	66.67	87.02	110.11
500,000					14.08	22.51	34.29	49.07	66.67	87.02	110.11
600,000					14.00	22.47	34.28	49.07	66.67	87.02	110.11
700,000					13.95	22.45	34.27	49.07	66.67	87.02	110.11
800,000					13.92	22.43	34.27	49.07	66.67	87.02	110.11
900,000					13.90	22.42	34.27	49.07	66.67	87.02	110.11
1,000,000					13.88	22.42	34.27	49.07	66.67	87.02	110.11

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 10 feet

2 of 2

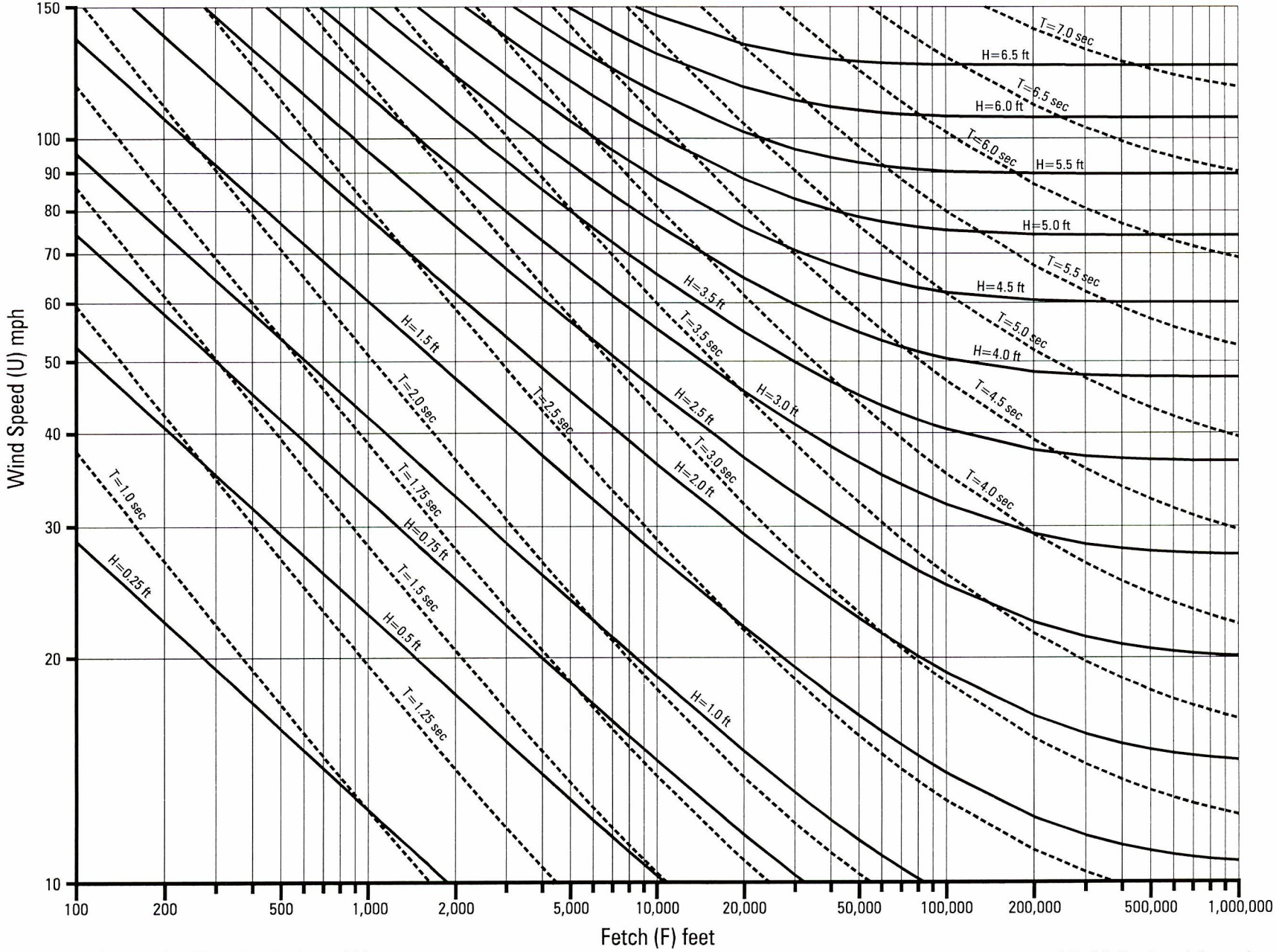
Wave Height (feet)

Fetch (feet)	5.00
100	
200	
300	
400	
500	
600	
700	
800	
900	
1,000	
1,100	
1,200	
1,300	
1,400	
1,500	
1,600	
1,700	
1,800	
1,900	
2,000	
3,000	
4,000	
5,000	
6,000	
6,323	150.00
7,000	148.20
8,000	146.07
9,000	144.42
10,000	143.11
20,000	137.79
30,000	136.60
40,000	136.21
50,000	136.06
60,000	136.00
70,000	135.96
80,000	135.95
90,000	135.94
100,000	135.93
200,000	135.92
300,000	135.92
400,000	135.92
500,000	135.92
600,000	135.92
700,000	135.92
800,000	135.92
900,000	135.92
1,000,000	135.92

Data Limits

Fetch 100 to 1,000,000 feet

Wind Speed 10 to 150 mph



Forecasting Curve for Shallow-Water Waves.
(USCE, 1977)

Constant Depth = 15 feet

J.D. Mollard and Associates Limited
November, 1993

Chart Data - Wind Speed (mph)

Constant Depth = 15 feet

1 of 2

Wave Period (seconds)

Fetch (feet)	1.00	1.25	1.50	1.75	2.00	2.50	3.00	3.50	4.00	4.50	5.00
100	37.88	59.48	86.11	117.85							
107					150.00						
200	26.98	42.36	61.36	84.05	110.50						
276						150.00					
300	22.16	34.78	50.38	69.04	90.82	144.02					
400	19.28	30.26	43.84	60.08	79.07	125.50					
500	17.33	27.17	39.36	53.97	71.04	112.84					
600	15.89	24.90	36.06	49.45	65.10	103.47					
614							150.00				
700	14.77	23.13	33.50	45.93	60.48	96.18	141.09				
800	13.87	21.71	31.43	43.10	56.76	90.30	132.53				
900	13.13	20.53	29.72	40.75	53.67	85.42	125.44				
1,000	12.50	19.54	28.27	38.77	51.06	81.29	119.42				
1,100	11.97	18.68	27.03	37.06	48.81	77.74	114.25				
1,200	11.50	17.94	25.94	35.57	46.85	74.63	109.73				
1,246								150.00			
1,300	11.09	17.28	24.99	34.25	45.12	71.89	105.73	147.10			
1,400	10.72	16.70	24.14	33.08	43.58	69.45	102.17	142.20			
1,500	10.39	16.17	23.37	32.03	42.20	67.26	98.97	137.79			
1,600	10.10	15.70	22.68	31.08	40.94	65.27	96.08	133.80			
1,635	10.00										
1,700		15.27	22.05	30.21	39.80	63.46	93.44	130.17			
1,800		14.88	21.48	29.42	38.76	61.80	91.02	126.84			
1,900		14.52	20.95	28.69	37.80	60.28	88.79	123.77			
2,000		14.18	20.46	28.02	36.91	58.87	86.73	120.93			
2,375									150.00		
3,000		11.85	17.02	23.27	30.64	48.89	72.16	100.82	135.33		
4,000		10.47	14.99	20.46	26.91	42.94	63.43	88.77	119.37		
4,364										150.00	
4,471		10.00									
5,000			13.62	18.55	24.37	38.87	57.47	80.52	108.43	141.62	
6,000			12.61	17.14	22.50	35.87	53.06	74.41	100.32	131.21	
7,000			11.84	16.06	21.06	33.54	49.62	69.65	94.00	123.09	
7,887											150.00
8,000			11.22	15.19	19.90	31.67	46.86	65.80	88.89	116.52	149.14
9,000			10.71	14.47	18.94	30.12	44.56	62.61	84.64	111.06	142.31
10,000			10.29	13.87	18.13	28.80	42.62	59.91	81.05	106.43	136.51
10,781			10.00								
20,000				10.70	13.83	21.76	32.13	45.25	61.47	81.19	104.81
24,415				10.00							
30,000					12.00	18.70	27.51	38.75	52.75	69.89	90.60
40,000					10.95	16.91	24.79	34.89	47.55	63.14	82.08
50,000					10.25	15.71	22.95	32.27	44.00	58.52	76.25
54,702					10.00						
60,000						14.84	21.61	30.35	41.39	55.11	71.94
70,000						14.18	20.58	28.86	39.37	52.47	68.60
80,000						13.65	19.75	27.67	37.74	50.34	65.90
90,000						13.23	19.08	26.69	36.40	48.59	63.67
100,000						12.87	18.51	25.87	35.27	47.10	61.79
200,000						11.04	15.58	21.55	29.29	39.19	51.73
300,000						10.31	14.38	19.75	26.75	35.82	47.41
372,632						10.00					
400,000							13.71	18.72	25.31	33.88	44.92
500,000							13.28	18.06	24.36	32.60	43.28
600,000							12.97	17.59	23.68	31.68	42.11
700,000							12.74	17.24	23.17	30.99	41.23
800,000							12.57	16.96	22.78	30.46	40.54
900,000							12.43	16.74	22.46	30.02	39.98
1,000,000							12.31	16.56	22.19	29.67	39.53

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 15 feet

2 of 2

Wave Period (seconds)

Fetch (feet)	5.50	6.00	6.50	7.00
100				
200				
300				
400				
500				
600				
700				
800				
900				
1,000				
1,100				
1,200				
1,300				
1,400				
1,500				
1,600				
1,700				
1,800				
1,900				
2,000				
3,000				
4,000				
5,000				
6,000				
7,000				
8,000				
9,000				
10,000	143.17	150.00		
20,000	132.82			
26,851		150.00		
30,000	115.33	144.63		
40,000	104.85	131.97		
50,000	97.67	123.30		
54,614			150.00	
60,000	92.36	116.90	146.17	
70,000	88.23	111.92	140.28	
80,000	84.91	107.91	135.53	
90,000	82.16	104.60	131.61	
100,000	79.84	101.80	128.31	
136,420				150.00
200,000	67.41	86.85	110.73	139.82
300,000	62.08	80.48	103.30	131.36
400,000	59.02	76.83	99.08	126.61
500,000	57.01	74.44	96.34	123.55
600,000	55.57	72.74	94.41	121.42
700,000	54.49	71.47	92.97	119.85
800,000	53.64	70.49	91.86	118.65
900,000	52.97	69.70	90.98	117.70
1,000,000	52.41	69.06	90.27	116.93

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 15 feet

1 of 2

Wave Height (feet)

Fetch (feet)	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
100	28.73	52.33	74.40	95.59	136.30						
156						150.00					
200	22.36	40.76	58.00	74.56	106.49	137.46					
276							150.00				
300	19.32	35.23	50.15	64.50	92.22	119.18	145.73				
400	17.42	31.77	45.24	58.21	83.30	107.75	131.89				
448								150.00			
500	16.07	29.32	41.76	53.76	76.99	99.67	122.10	144.48			
600	15.05	27.46	39.13	50.38	72.20	93.54	114.68	135.80			
688									150.00		
700	14.24	25.98	37.03	47.70	68.39	88.66	108.77	128.90	149.15		
800	13.57	24.77	35.31	45.49	65.26	84.65	103.92	123.23	142.69		
900	13.01	23.75	33.86	43.63	62.62	81.27	99.83	118.45	137.25		
1,000	12.53	22.87	32.61	42.03	60.36	78.37	96.32	114.35	132.57		
1,022										150.00	
1,100	12.11	22.10	31.52	40.63	58.38	75.84	93.26	110.77	128.50	146.52	
1,200	11.74	21.42	30.56	39.40	56.63	73.60	90.55	107.62	124.90	142.50	
1,300	11.41	20.82	29.70	38.30	55.08	71.61	88.14	104.80	121.70	138.91	
1,400	11.11	20.28	28.93	37.31	53.67	69.82	85.97	102.26	118.81	135.69	
1,492											150.00
1,500	10.84	19.78	28.23	36.42	52.40	68.19	84.00	99.97	116.20	132.77	149.75
1,600	10.59	19.33	27.59	35.60	51.24	66.70	82.20	97.87	113.81	130.10	146.82
1,700	10.37	18.92	27.00	34.85	50.17	65.34	80.55	95.94	111.62	127.66	144.13
1,800	10.16	18.54	26.46	34.15	49.19	64.08	79.02	94.17	109.60	125.40	141.65
1,881	10.00										
1,900		18.18	25.96	33.51	48.28	62.91	77.61	92.52	107.73	123.31	139.35
2,000		17.86	25.49	32.91	47.43	61.82	76.30	90.99	105.98	121.37	137.22
3,000		15.46	22.09	28.55	41.25	53.92	66.74	79.85	93.34	107.28	121.76
4,000		13.97	19.97	25.83	37.38	48.98	60.78	72.92	85.48	98.54	112.20
5,000		12.93	18.47	23.90	34.66	45.50	56.58	68.03	79.95	92.41	105.52
6,000		12.13	17.34	22.45	32.59	42.86	53.40	64.34	75.77	87.80	100.50
7,000		11.51	16.44	21.29	30.95	40.76	50.87	61.41	72.47	84.15	96.55
8,000		10.99	15.71	20.34	29.60	39.04	48.80	59.01	69.77	81.18	93.34
9,000		10.56	15.09	19.55	28.47	37.59	47.06	56.99	67.50	78.69	90.65
10,000		10.20	14.56	18.86	27.50	36.35	45.56	55.27	65.57	76.57	88.38
10,606		10.00									
20,000			11.58	15.00	21.99	29.32	37.14	45.58	54.78	64.87	75.99
30,000			10.23	13.21	19.40	26.02	33.20	41.10	49.87	59.67	70.67
32,367			10.00								
40,000				12.13	17.82	23.99	30.79	38.39	46.96	56.66	67.67
50,000				11.39	16.72	22.58	29.13	36.54	44.99	54.68	65.78
60,000				10.85	15.91	21.54	27.90	35.18	43.58	53.29	64.48
70,000				10.43	15.28	20.72	26.95	34.14	42.51	52.26	63.56
80,000				10.11	14.77	20.07	26.18	33.31	41.67	51.47	62.88
83,772				10.00							
90,000					14.35	19.53	25.55	32.63	41.00	50.86	62.36
100,000					14.00	19.07	25.02	32.07	40.46	50.37	61.96
200,000					12.22	16.71	22.32	29.33	37.98	48.36	60.49
300,000					11.54	15.79	21.31	28.41	37.27	47.90	60.22
400,000					11.20	15.32	20.81	28.00	36.99	47.74	60.14
500,000					11.00	15.05	20.53	27.78	36.86	47.68	60.12
600,000					10.87	14.87	20.36	27.66	36.80	47.65	60.11
700,000					10.79	14.76	20.25	27.59	36.77	47.64	60.10
800,000					10.73	14.68	20.18	27.55	36.75	47.63	60.10
900,000					10.68	14.62	20.13	27.52	36.73	47.63	60.10
1,000,000					10.65	14.57	20.09	27.50	36.73	47.63	60.10

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 15 feet

2 of 2

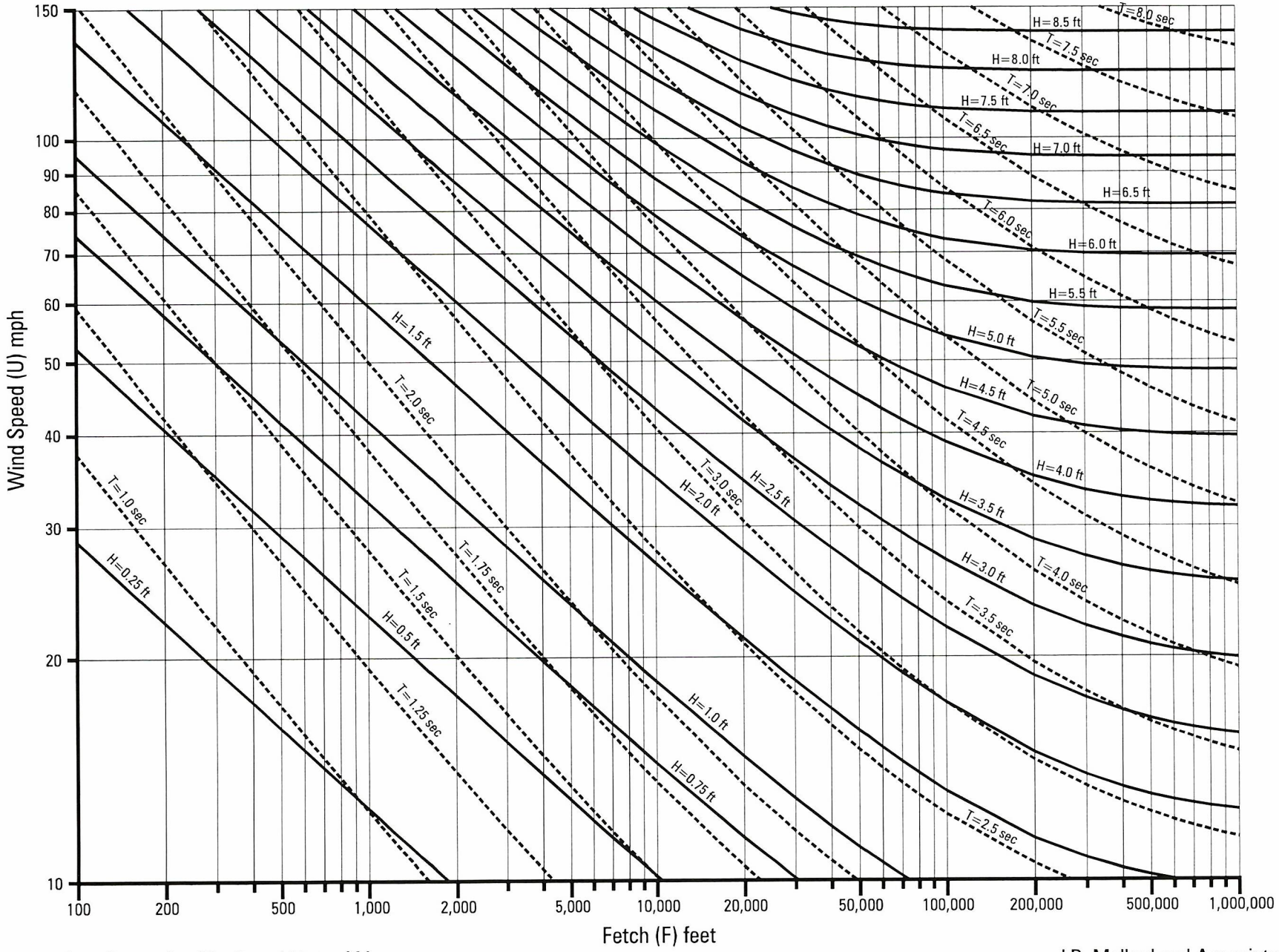
Wave Height (feet)

Fetch (feet)	5.00	5.50	6.00	6.50	7.00
100					
200					
300					
400					
500					
600					
700					
800					
900					
1,000					
1,100					
1,200					
1,300					
1,400					
1,500					
1,600					
1,700					
1,800					
1,900					
2,000					
2,170	150.00				
3,000	136.85				
3,202		150.00			
4000	126.53	141.62			
4,931			150.00		
5,000	119.35	133.99	149.53		
6,000	113.97	128.31	143.61		
7,000	109.76	123.88	139.02		
8,000	106.34	120.31	135.34		
8,480				150.00	
9,000	103.51	117.36	132.31	148.49	
10,000	101.10	114.87	129.78	145.96	
20,000	88.29	101.90	116.96	133.58	
30,000	83.01	96.84	112.28	129.39	
40,000	80.17	94.25	110.03	127.51	
50,000	78.44	92.76	108.80	126.55	
60,000	77.30	91.83	108.07	126.01	
70,000	76.53	91.21	107.62	125.69	
80,000	75.97	90.80	107.32	125.50	
90,000	75.57	90.51	107.12	125.37	
100,000	75.27	90.29	106.98	125.28	
200,000	74.28	89.68	106.62	125.08	
300,000	74.14	89.61	106.59	125.06	
400,000	74.11	89.60	106.58	125.06	
500,000	74.10	89.59	106.58	125.06	
600,000	74.09	89.59	106.58	125.06	
700,000	74.09	89.59	106.58	125.06	
800,000	74.09	89.59	106.58	125.06	
900,000	74.09	89.59	106.58	125.06	
1,000,000	74.09	89.59	106.58	125.06	

Data Limits

Fetch 100 to 1,000,000 feet

Wind Speed 10 to 150 mph



Forecasting Curve for Shallow-Water Waves.
(USCE, 1977)

Constant Depth = 20 feet

J.D. Mollard and Associates Limited
November, 1993

Chart Data - Wind Speed (mph)

Constant Depth = 20 feet

1 of 2

Wave Period (seconds)

Fetch (feet)	1.00	1.25	1.50	1.75	2.00	2.50	3.00	3.50	4.00	4.50	5.00
100	37.72	59.15	85.53	116.92							
105					150.00						
200	26.84	42.08	60.87	83.26	109.32						
267						150.00					
300	22.03	34.52	49.94	68.33	89.74	141.88					
400	19.16	30.02	43.42	59.42	78.06	123.49					
500	17.22	26.95	38.97	53.33	70.08	110.92					
587							150.00				
600	15.78	24.68	35.69	48.84	64.18	101.64	148.44				
700	14.67	22.92	33.14	45.34	59.60	94.41	137.95				
800	13.77	21.51	31.08	42.53	55.90	88.58	129.48				
900	13.03	20.34	29.38	40.20	52.84	83.75	122.46				
1,000	12.41	19.35	27.94	38.23	50.24	79.66	116.52				
1,100	11.88	18.50	26.70	36.53	48.01	76.13	111.40				
1,167								150.00			
1,200	11.41	17.76	25.62	35.05	46.07	73.06	106.93	148.04			
1,300	11.00	17.11	24.67	33.74	44.35	70.35	102.99	142.62			
1,400	10.64	16.53	23.83	32.58	42.82	67.93	99.47	137.79			
1,500	10.31	16.00	23.07	31.54	41.45	65.76	96.31	133.44			
1,600	10.02	15.53	22.38	30.59	40.21	63.79	93.45	129.51			
1,607	10.00										
1,700		15.11	21.76	29.74	39.08	62.00	90.84	125.93			
1,800		14.72	21.19	28.95	38.04	60.36	88.45	122.64			
1,900		14.36	20.66	28.23	37.09	58.85	86.25	119.62			
2,000		14.03	20.18	27.56	36.21	57.46	84.22	116.83			
2,168									150.00		
3,000		11.71	16.77	22.86	30.00	47.60	69.85	97.03	129.48		
3,850										150.00	
4,000		10.35	14.76	20.07	26.31	41.72	61.26	85.19	113.83	147.49	
4,341		10.00									
5,000			13.40	18.18	23.80	37.72	55.38	77.08	103.10	133.75	
6,000			12.40	16.79	21.96	34.76	51.05	71.09	95.16	123.57	
6,645											150.00
7,000			11.64	15.72	20.53	32.47	47.68	66.42	88.97	115.64	146.73
8,000			11.03	14.86	19.39	30.62	44.96	62.65	83.98	109.23	138.71
9,000			10.53	14.16	18.44	29.09	42.71	59.53	79.83	103.90	132.05
10,000			10.11	13.56	17.65	27.80	40.80	56.89	76.32	99.39	126.40
10,289			10.00								
20,000				10.45	13.43	20.89	30.53	42.56	57.24	74.82	95.59
22,712				10.00							
30,000					11.64	17.90	26.03	36.24	48.76	63.85	81.80
40,000					10.61	16.16	23.38	32.49	43.71	57.30	73.54
48,881					10.00						
50,000						15.00	21.60	29.95	40.28	52.84	67.90
60,000						14.16	20.30	28.09	37.75	49.54	63.73
70,000						13.52	19.30	26.65	35.80	46.99	60.49
80,000						13.01	18.51	25.51	34.23	44.93	57.88
90,000						12.60	17.86	24.56	32.94	43.23	55.72
100,000						12.25	17.32	23.77	31.85	41.80	53.90
200,000						10.50	14.51	19.63	26.10	34.18	44.14
264,059						10.00					
300,000							13.36	17.91	23.68	30.92	39.94
400,000							12.73	16.94	22.30	29.05	37.50
500,000							12.32	16.31	21.39	27.81	35.89
600,000							12.03	15.86	20.74	26.93	34.73
700,000							11.81	15.53	20.26	26.26	33.85
800,000							11.64	15.27	19.88	25.73	33.16
900,000							11.51	15.06	19.57	25.31	32.60
1,000,000							11.40	14.89	19.32	24.96	32.14

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 20 feet

2 of 2

Wave Period (seconds)

Fetch (feet)	5.50	6.00	6.50	7.00	7.50	8.00
100						
200						
300						
400						
500						
600						
700						
800						
900						
1,000						
1,100						
1,200						
1,300						
1,400						
1,500						
1,600						
1,700						
1,800						
1,900						
2,000						
3,000						
4,000						
5,000						
6,000						
7,000						
8,000						
9,000						
10,000						
11,315	150.00					
19,301		150.00				
20,000	119.87	148.01				
30,000	102.91	127.53				
33,607			150.00			
40,000	92.74	115.23	141.39			
50,000	85.78	106.80	131.35			
60,000	80.62	100.56	123.93			
61,505				150.00		
70,000	76.62	95.71	118.15	144.34		
80,000	73.39	91.79	113.48	138.87		
90,000	70.71	88.55	109.62	134.34		
100,000	68.45	85.81	106.35	130.51		
125,502					150.00	
200,000	56.31	71.05	88.77	109.93	135.03	
300,000	51.05	64.65	81.15	101.04	124.85	
342,500						150.00
400,000	48.00	60.93	76.73	95.91	119.00	146.62
500,000	45.97	58.45	73.80	92.51	115.15	142.34
600,000	44.51	56.67	71.69	90.07	112.40	139.31
700,000	43.40	55.32	70.09	88.24	110.35	137.05
800,000	42.53	54.26	68.84	86.80	108.74	135.31
900,000	41.83	53.40	67.83	85.65	107.46	133.91
1,000,000	41.24	52.70	67.00	84.70	106.41	132.78

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 20 feet

1 of 2

Wave Height (feet)

Fetch (feet)	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
100	28.71	52.25	74.23	95.28	135.62						
153						150.00					
200	22.35	40.69	57.83	74.26	105.80	136.21					
266							150.00				
300	19.30	35.15	49.98	64.20	91.53	117.93	143.75				
400	17.40	31.69	45.07	57.90	82.60	106.49	129.89				
423								150.00			
500	16.05	29.24	41.59	53.46	76.29	98.40	120.09	141.53			
600	15.03	27.39	38.96	50.08	71.50	92.27	112.66	132.83			
634									150.00		
700	14.22	25.91	36.86	47.39	67.69	87.39	106.74	125.91	145.00		
800	13.55	24.69	35.14	45.18	64.56	83.37	101.88	120.23	138.51		
900	12.99	23.67	33.68	43.32	61.92	79.99	97.78	115.44	133.04		
912										150.00	
1,000	12.51	22.79	32.44	41.72	59.65	77.08	94.26	111.32	128.35	145.42	
1,100	12.09	22.02	31.35	40.33	57.67	74.55	91.19	107.73	124.25	140.83	
1,200	11.72	21.35	30.39	39.09	55.92	72.31	88.48	104.56	120.64	136.78	
1,275											150.00
1,300	11.39	20.74	29.53	37.99	54.36	70.31	86.06	101.73	117.41	133.16	149.03
1,400	11.09	20.20	28.76	37.01	52.96	68.52	83.88	99.18	114.51	129.91	145.44
1,500	10.82	19.71	28.06	36.11	51.69	66.88	81.91	96.88	111.87	126.96	142.18
1,600	10.57	19.26	27.42	35.29	50.52	65.39	80.10	94.77	109.47	124.26	139.21
1,700	10.35	18.84	26.83	34.54	49.46	64.03	78.45	92.83	107.26	121.79	136.48
1,800	10.14	18.46	26.29	33.84	48.47	62.77	76.92	91.04	105.22	119.51	133.96
1,871	10.00										
1,900		18.11	25.79	33.20	47.56	61.60	75.50	89.39	103.33	117.40	131.62
2,000		17.78	25.32	32.60	46.71	60.51	74.18	87.85	101.58	115.43	129.45
3,000		15.39	21.92	28.24	40.52	52.58	64.59	76.63	88.80	101.13	113.67
4,000		13.90	19.80	25.51	36.65	47.63	58.59	69.63	80.82	92.21	103.84
5,000		12.85	18.30	23.59	33.92	44.13	54.35	64.69	75.19	85.92	96.92
6,000		12.06	17.17	22.13	31.85	41.47	51.14	60.94	70.93	81.16	91.68
7,000		11.43	16.27	20.97	30.20	39.37	48.59	57.97	67.55	77.39	87.53
8,000		10.92	15.53	20.02	28.85	37.63	46.50	55.52	64.77	74.29	84.13
9,000		10.49	14.91	19.23	27.71	36.18	44.73	53.47	62.43	71.69	81.28
10,000		10.13	14.38	18.54	26.74	34.93	43.22	51.70	60.43	69.46	78.84
10,382		10.00									
20,000			11.41	14.68	21.20	27.82	34.63	41.71	49.11	56.89	65.12
30,000			10.06	12.89	18.60	24.47	30.58	37.00	43.79	51.03	58.78
30,612			10.00								
40,000				11.81	17.01	22.40	28.08	34.10	40.53	47.46	54.95
50,000				11.07	15.90	20.96	26.33	32.08	38.27	45.00	52.33
60,000				10.54	15.08	19.89	25.03	30.57	36.59	43.17	50.41
70,000				10.13	14.44	19.05	24.00	29.38	35.27	41.76	48.94
73,644				10.00							
80,000					13.93	18.37	23.17	28.43	34.21	40.63	47.76
90,000					13.51	17.81	22.49	27.63	33.34	39.70	46.81
100,000					13.16	17.33	21.90	26.96	32.60	38.92	46.01
200,000					11.37	14.84	18.82	23.41	28.75	34.96	42.15
300,000					10.69	13.85	17.56	21.98	27.25	33.51	40.86
400,000					10.35	13.33	16.89	21.21	26.47	32.80	40.28
500,000					10.15	13.01	16.48	20.75	26.02	32.42	39.99
600,000					10.02	12.80	16.21	20.45	25.74	32.18	39.82
617,541					10.00						
700,000						12.66	16.02	20.25	25.55	32.04	39.73
800,000						12.56	15.88	20.10	25.42	31.94	39.66
900,000						12.48	15.78	19.99	25.32	31.88	39.62
1,000,000						12.42	15.70	19.91	25.26	31.83	39.60

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

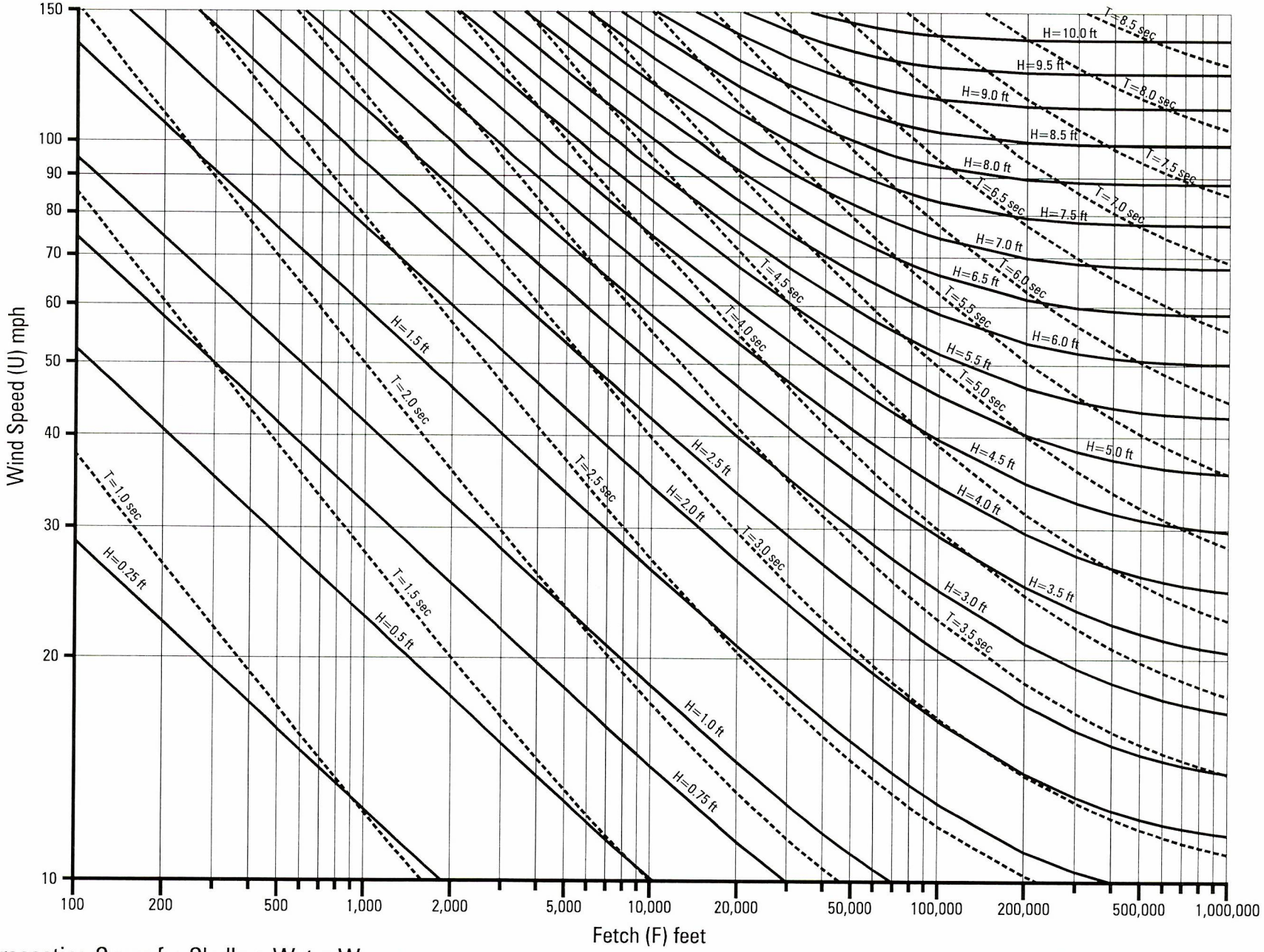
Constant Depth = 20 feet

2 of 2

Wave Height (feet)

Fetch (feet)	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50
100								
200								
300								
400								
500								
600								
700								
800								
900								
1,000								
1,100								
1,200								
1,300								
1,400								
1,500								
1,600								
1,700								
1,748	150.00							
1,800	148.60							
1,900	146.05							
2,000	143.68							
2,371		150.00						
3,000	126.47	139.56						
3,205			150.00					
4,000	115.76	128.00	140.60					
4,354				150.00				
5,000	108.23	119.88	131.93	144.40				
6,000	102.53	113.76	125.40	137.49				
6,012					150.00			
7,000	98.03	108.92	120.25	132.05	144.38			
8,000	94.35	104.97	116.05	127.63	139.75			
8,599						150.00		
9,000	91.25	101.66	112.53	123.93	135.90	148.49		
10,000	88.61	98.83	109.54	120.79	132.63	145.12		
13,264							150.00	
20,000	73.85	83.15	93.07	103.68	115.05	127.23	140.30	
25,448								150.00
30,000	67.11	76.09	85.80	96.30	107.67	119.97	133.25	147.58
40,000	63.09	71.94	81.60	92.13	103.61	116.10	129.64	144.28
50,000	60.37	69.18	78.86	89.47	101.09	113.78	127.55	142.44
60,000	58.40	67.21	76.94	87.65	99.42	112.27	126.24	141.32
70,000	56.90	65.73	75.53	86.35	98.25	111.25	125.38	140.62
80,000	55.72	64.59	74.46	85.38	97.40	110.54	124.79	140.15
90,000	54.78	63.69	73.63	84.64	96.77	110.02	124.38	139.83
100,000	54.00	62.96	72.97	84.07	96.29	109.63	124.08	139.60
200,000	50.42	59.80	70.31	81.94	94.65	108.41	123.20	138.99
300,000	49.35	58.98	69.72	81.54	94.39	108.25	123.10	138.93
400,000	48.92	58.68	69.53	81.42	94.32	108.21	123.08	138.92
500,000	48.72	58.56	69.46	81.38	94.30	108.20	123.07	138.92
600,000	48.61	58.50	69.43	81.37	94.29	108.20	123.07	138.91
700,000	48.56	58.47	69.41	81.36	94.29	108.20	123.07	138.91
800,000	48.52	58.45	69.40	81.35	94.29	108.20	123.07	138.91
900,000	48.50	58.44	69.40	81.35	94.29	108.20	123.07	138.91
1,000,000	48.49	58.43	69.40	81.35	94.29	108.19	123.07	138.91

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph



Forecasting Curve for Shallow-Water Waves.
(USCE, 1977)

Constant Depth = 25 feet

J.D. Mollard and Associates Limited
November, 1993

Chart Data - Wind Speed (mph)

Constant Depth = 25 feet

1 of 2

Wave Period (seconds)

Fetch (feet)	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
100	37.61	85.16									
103			150.00								
200	26.75	60.56	108.57								
262				150.00							
300	21.95	49.65	89.06	140.52							
400	19.09	43.15	77.42	122.23							
500	17.14	38.72	69.47	109.72							
570					150.00						
600	15.71	35.45	63.60	100.48	146.41						
700	14.60	32.90	59.04	93.30	135.99						
800	13.71	30.86	55.36	87.50	127.58						
900	12.98	29.16	52.31	82.69	120.61						
1,000	12.35	27.73	49.73	78.63	114.71						
1,100	11.82	26.50	47.51	75.13	109.63						
1,120						150.00					
1,200	11.36	25.42	45.58	72.07	105.19	145.22					
1,300	10.95	24.48	43.87	69.38	101.28	139.85					
1,400	10.59	23.63	42.35	66.98	97.79	135.06					
1,500	10.26	22.88	40.98	64.82	94.65	130.75					
1,590	10.00										
1,600		22.19	39.75	62.87	91.81	126.86					
1,700		21.57	38.62	61.09	89.23	123.31					
1,800		21.00	37.59	59.46	86.86	120.05					
1,900		20.48	36.65	57.96	84.68	117.06					
2,000		20.00	35.77	56.58	82.67	114.29					
2,050							150.00				
3,000		16.61	29.60	46.80	68.42	94.71	125.91				
3,571								150.00			
4,000		14.61	25.94	40.97	59.91	82.99	110.45	142.54			
5,000		13.26	23.45	37.00	54.10	74.98	99.87	129.00			
6,000		12.28	21.62	34.07	49.81	69.06	92.04	118.98			
6,013									150.00		
7,000		11.52	20.21	31.80	46.48	64.45	85.94	111.17	140.39		
8,000		10.91	19.07	29.97	43.79	60.74	81.02	104.86	132.51		
9,000		10.42	18.14	28.46	41.57	57.66	76.93	99.63	125.97		
9,910										150.00	
10,000		10.00	17.35	27.19	39.69	55.05	73.48	95.19	120.42	149.43	
10,003			10.00								
16,174											150.00
20,000			13.18	20.37	29.57	40.95	54.72	71.07	90.21	112.39	137.86
30,000			11.42	17.43	25.14	34.74	46.41	60.33	76.72	95.82	117.85
40,000			10.41	15.72	22.55	31.07	41.47	53.93	68.66	85.88	105.84
45,788			10.00								
50,000				14.58	20.80	28.59	38.11	49.56	63.15	79.08	97.62
60,000				13.75	19.53	26.77	35.65	46.35	59.08	74.06	91.53
70,000				13.13	18.56	25.37	33.74	43.86	55.92	70.15	86.79
80,000				12.63	17.78	24.25	32.22	41.86	53.38	67.00	82.97
90,000				12.23	17.15	23.33	30.96	40.21	51.28	64.40	79.80
100,000				11.89	16.62	22.56	29.90	38.81	49.50	62.19	77.12
200,000				10.19	13.89	18.55	24.33	31.41	40.02	50.36	62.69
221,749				10.00							
300,000					12.79	16.89	21.99	28.27	35.94	45.23	56.41
400,000					12.18	15.96	20.66	26.46	33.58	42.25	52.74
500,000					11.78	15.35	19.78	25.27	32.01	40.26	50.29
600,000					11.51	14.92	19.16	24.41	30.89	38.83	48.52
700,000					11.30	14.60	18.69	23.77	30.03	37.74	47.17
800,000					11.14	14.35	18.33	23.26	29.36	36.88	46.10
900,000					11.01	14.15	18.03	22.85	28.81	36.18	45.24
1,000,000					10.90	13.99	17.79	22.51	28.36	35.60	44.52

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 25 feet

2 of 2

Wave Period (seconds)

Fetch (feet)	6.50	7.00	7.50	8.00	8.50
100					
200					
300					
400					
500					
600					
700					
800					
900					
1,000					
1,100					
1,200					
1,300					
1,400					
1,500					
1,600					
1,700					
1,800					
1,900					
2,000					
3,000					
4,000					
5,000					
6,000					
7,000					
8,000					
9,000					
10,000					
20,000					
26,453	150.00				
30,000	143.10				
40,000	128.81				
44,001		150.00			
50,000	119.01	143.56			
60,000	111.75	135.03			
70,000	106.10	128.38			
76,087			150.00		
80,000	101.54	123.01	147.71		
90,000	97.76	118.57	142.54		
100,000	94.56	114.80	138.17		
142,377				150.00	
200,000	77.29	94.46	114.55	137.94	
300,000	69.75	85.58	104.25	126.16	
318,804					150.00
400,000	65.34	80.38	98.24	119.31	144.04
500,000	62.39	76.91	94.22	114.75	138.95
600,000	60.26	74.40	91.33	111.47	135.30
700,000	58.63	72.49	89.13	108.99	132.54
800,000	57.35	70.98	87.40	107.04	130.39
900,000	56.31	69.76	86.00	105.47	128.65
1,000,000	55.44	68.74	84.83	104.17	127.23

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 25 feet

1 of 2

Wave Height (feet)

Fetch (feet)	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50
100	28.70	52.22	74.15	95.12	135.26						
151						150.00					
200	22.34	40.65	57.74	74.10	105.44	135.57					
261							150.00				
300	19.29	35.11	49.89	64.04	91.17	117.28	142.72				
400	17.39	31.65	44.98	57.74	82.24	105.84	128.86				
411								150.00			
500	16.04	29.20	41.50	53.30	75.93	97.75	119.06	140.02			
600	15.02	27.35	38.87	49.92	71.14	91.61	111.62	131.32			
609									150.00		
700	14.21	25.87	36.77	47.23	67.32	86.73	105.70	124.39	142.90		
800	13.54	24.65	35.05	45.02	64.19	82.71	100.84	118.70	136.41		
864										150.00	
900	12.98	23.63	33.60	43.16	61.55	79.33	96.74	113.91	130.93	147.87	
1,000	12.50	22.75	32.35	41.56	59.28	76.42	93.21	109.79	126.23	142.60	
1,100	12.08	21.99	31.26	40.17	57.30	73.89	90.14	106.19	122.12	138.00	
1,185											150.00
1,200	11.71	21.31	30.30	38.93	55.56	71.65	87.43	103.02	118.50	133.94	149.37
1,300	11.38	20.70	29.44	37.83	54.00	69.65	85.00	100.18	115.27	130.31	145.36
1,400	11.08	20.16	28.67	36.84	52.59	67.85	82.82	97.63	112.36	127.05	141.75
1,500	10.81	19.67	27.97	35.95	51.32	66.22	80.85	95.32	109.72	124.09	138.48
1,600	10.56	19.22	27.33	35.13	50.15	64.73	79.04	93.21	107.31	121.39	135.49
1,700	10.34	18.80	26.74	34.37	49.09	63.36	77.38	91.27	105.09	118.90	132.75
1,800	10.13	18.42	26.20	33.68	48.10	62.10	75.85	89.48	103.05	116.61	130.22
1,867	10.00										
1,900		18.07	25.70	33.03	47.19	60.93	74.43	87.82	101.16	114.49	127.87
2,000		17.74	25.23	32.44	46.34	59.84	73.11	86.28	99.39	112.52	125.69
3,000		15.35	21.83	28.07	40.15	51.90	63.50	75.04	86.57	98.14	109.80
4,000		13.86	19.71	25.35	36.28	46.94	57.49	68.01	78.56	89.17	99.88
5,000		12.81	18.21	23.43	33.54	43.44	53.25	63.05	72.90	82.83	92.89
6,000		12.02	17.08	21.97	31.47	40.78	50.03	59.29	68.60	78.03	87.58
7,000		11.40	16.18	20.81	29.82	38.67	47.47	56.29	65.19	74.21	83.37
8,000		10.88	15.44	19.86	28.47	36.93	45.37	53.84	62.39	71.08	79.92
9,000		10.46	14.82	19.06	27.33	35.47	43.60	51.77	60.04	68.44	77.01
10,000		10.09	14.29	18.38	26.35	34.22	42.08	49.99	58.01	66.18	74.52
10,274		10.00									
20,000			11.33	14.52	20.81	27.09	33.44	39.90	46.52	53.35	60.40
29,814			10.00								
30,000				12.73	18.21	23.73	29.35	35.12	41.09	47.29	53.75
40,000				11.65	16.61	21.65	26.82	32.16	37.73	43.55	49.66
50,000				10.92	15.50	20.20	25.05	30.09	35.38	40.94	46.82
60,000				10.39	14.69	19.12	23.72	28.54	33.61	38.98	44.69
69,532				10.00							
70,000					14.05	18.27	22.68	27.32	32.23	37.45	43.03
80,000					13.54	17.59	21.84	26.33	31.10	36.21	41.69
90,000					13.12	17.02	21.13	25.50	30.16	35.17	40.57
100,000					12.77	16.54	20.54	24.80	29.37	34.29	39.63
200,000					11.00	14.03	17.36	21.02	25.08	29.60	34.64
300,000					10.33	13.04	16.05	19.44	23.28	27.65	32.62
398,918					10.00						
400,000						12.51	15.34	18.57	22.29	26.59	31.56
500,000						12.19	14.90	18.02	21.67	25.94	30.91
600,000						11.98	14.60	17.66	21.25	25.50	30.50
700,000						11.84	14.40	17.39	20.96	25.20	30.22
800,000						11.73	14.24	17.20	20.74	24.98	30.02
900,000						11.65	14.13	17.05	20.57	24.82	29.87
1,000,000						11.59	14.04	16.94	20.45	24.69	29.77

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

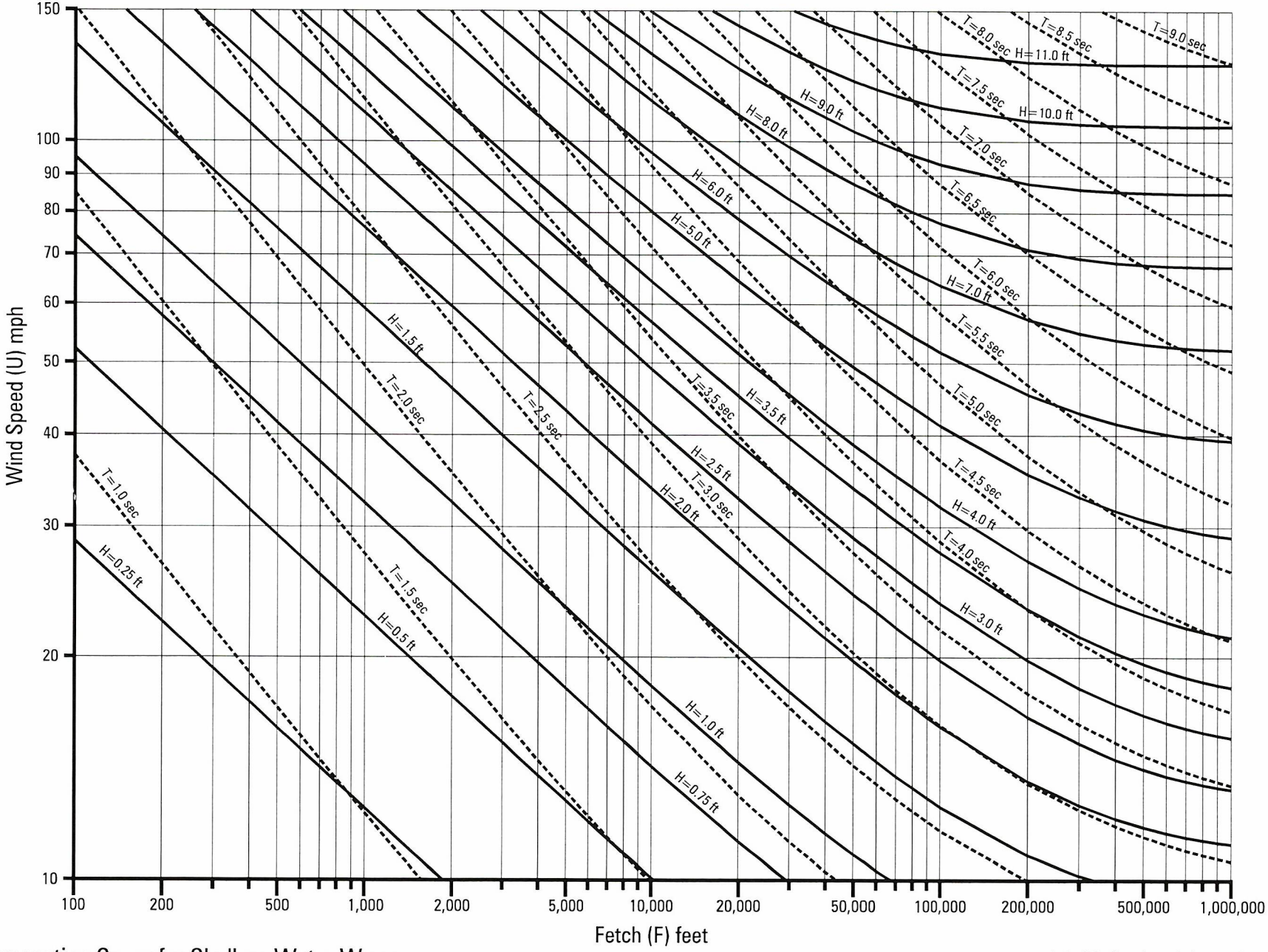
Constant Depth = 25 feet

2 of 2

Wave Height (feet)

Fetch (feet)	5.00	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00
100											
200											
300											
400											
500											
600											
700											
800											
900											
1,000											
1,100											
1,200											
1,300											
1,400											
1,500											
1,589	150.00										
1,600	149.65										
1,700	146.65										
1,800	143.88										
1,900	141.32										
2,000	138.93										
2,094		150.00									
2,728			150.00								
3,000	121.57	133.47	145.53								
3,529				150.00							
4,000	110.73	121.74	132.93	144.32							
4,553					150.00						
5,000	103.09	113.47	124.05	134.85	145.89						
5,889						150.00					
6,000	97.30	107.21	117.34	127.70	138.31	149.21					
7,000	92.71	102.25	112.02	122.03	132.32	142.90					
7,684							150.00				
8,000	88.94	98.18	107.66	117.39	127.42	137.75	148.41				
9,000	85.77	94.76	104.00	113.50	123.31	133.43	143.90				
10,000	83.06	91.83	100.86	110.17	119.79	129.75	140.05				
10,205								150.00			
14,005									150.00		
20,000	67.71	75.32	83.25	91.55	100.23	109.33	118.89	128.94	139.52		
20,497										150.00	
30,000	60.52	67.63	75.11	83.00	91.34	100.17	109.53	119.45	129.98	141.14	
35,278											150.00
40,000	56.11	62.94	70.18	77.87	86.06	94.80	104.11	114.05	124.65	135.95	147.97
50,000	53.06	59.71	66.80	74.39	82.52	91.23	100.57	110.57	121.29	132.74	144.95
60,000	50.79	57.32	64.32	71.85	79.96	88.69	98.08	108.18	119.01	130.61	142.99
70,000	49.02	55.46	62.41	69.92	78.03	86.79	96.25	106.44	117.39	129.12	141.65
80,000	47.59	53.98	60.89	68.39	76.52	85.33	94.86	105.14	116.20	128.06	140.71
90,000	46.41	52.76	59.65	67.16	75.31	84.18	93.78	104.15	115.31	127.27	140.03
100,000	45.42	51.74	58.62	66.14	74.33	83.25	92.92	103.37	114.62	126.67	139.52
200,000	40.27	46.56	53.57	61.34	69.90	79.26	89.43	100.39	112.14	124.64	137.90
300,000	38.28	44.67	51.85	59.84	68.64	78.25	88.64	99.79	111.70	124.33	137.67
400,000	37.26	43.76	51.08	59.21	68.16	77.89	88.38	99.62	111.58	124.25	137.62
500,000	36.68	43.26	50.68	58.91	67.94	77.74	88.28	99.55	111.54	124.22	137.61
600,000	36.31	42.96	50.45	58.75	67.83	77.67	88.24	99.53	111.52	124.21	137.60
700,000	36.07	42.78	50.32	58.66	67.77	77.63	88.22	99.51	111.51	124.21	137.60
800,000	35.91	42.66	50.23	58.60	67.74	77.61	88.21	99.51	111.51	124.21	137.60
900,000	35.79	42.57	50.18	58.57	67.72	77.60	88.20	99.50	111.51	124.21	137.60
1,000,000	35.71	42.52	50.14	58.55	67.71	77.60	88.20	99.50	111.51	124.21	137.60

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph



Forecasting Curve for Shallow-Water Waves.
(USCE, 1977)

Constant Depth = 30 feet

J.D. Mollard and Associates Limited
November, 1993

Chart Data - Wind Speed (mph)

Constant Depth = 30 feet

1 of 2

Wave Period (seconds)

Fetch (feet)	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
100	37.53	84.90									
103			150.00								
200	26.68	60.34	108.04								
259				150.00							
300	21.89	49.46	88.59	139.59							
400	19.04	42.97	76.98	121.35							
500	17.10	38.55	69.05	108.89							
559					150.00						
600	15.67	35.28	63.20	99.68	145.01						
700	14.56	32.74	58.65	92.53	134.64						
800	13.67	30.70	54.98	86.75	126.27						
900	12.94	29.01	51.94	81.97	119.33						
1,000	12.32	27.58	49.37	77.92	113.46						
1,090						150.00					
1,100	11.78	26.35	47.16	74.43	108.41	149.33					
1,200	11.32	25.28	45.23	71.39	103.99	143.28					
1,300	10.92	24.34	43.53	68.71	100.10	137.94					
1,400	10.55	23.50	42.02	66.32	96.63	133.18					
1,500	10.23	22.75	40.66	64.17	93.51	128.91					
1,578	10.00										
1,600		22.07	39.43	62.23	90.69	125.03					
1,700		21.45	38.31	60.46	88.12	121.51					
1,800		20.88	37.28	58.84	85.76	118.28					
1,900		20.36	36.34	57.35	83.60	115.31					
1,974							150.00				
2,000		19.88	35.47	55.97	81.60	112.56	149.09				
3,000		16.50	29.33	46.25	67.44	93.11	123.48				
3,395								150.00			
4,000		14.51	25.69	40.45	58.99	81.49	108.16	139.19			
5,000		13.17	23.21	36.51	53.23	73.55	97.67	125.80			
5,627									150.00		
6,000		12.19	21.39	33.60	48.97	67.68	89.92	115.88	145.77		
7,000		11.44	19.99	31.35	45.67	63.12	83.89	108.16	136.15		
8,000		10.83	18.86	29.53	43.00	59.44	79.02	101.93	128.37		
9,000		10.34	17.93	28.03	40.80	56.39	74.98	96.76	121.91		
9,090										150.00	
9,816		10.00									
10,000			17.15	26.77	38.94	53.81	71.57	92.38	116.44	143.96	
14,457											150.00
20,000			13.02	20.01	28.92	39.87	53.04	68.58	86.67	107.49	131.26
30,000			11.28	17.11	24.55	33.75	44.85	58.01	73.40	91.20	111.60
40,000			10.28	15.42	21.99	30.13	39.99	51.71	65.47	81.44	99.81
43,876			10.00								
50,000				14.30	20.27	27.68	36.69	47.43	60.06	74.77	91.74
60,000				13.49	19.02	25.90	34.27	44.27	56.07	69.85	85.78
70,000				12.87	18.06	24.52	32.40	41.83	52.98	66.02	81.13
80,000				12.39	17.30	23.43	30.90	39.87	50.49	62.93	77.39
90,000				11.99	16.68	22.53	29.67	38.25	48.43	60.38	74.29
100,000				11.66	16.16	21.77	28.63	36.89	46.70	58.23	71.66
199,356				10.00							
200,000					13.50	17.85	23.19	29.66	37.43	46.66	57.54
300,000					12.43	16.24	20.92	26.60	33.46	41.66	51.39
400,000					11.83	15.34	19.63	24.85	31.16	38.75	47.80
500,000					11.45	14.75	18.78	23.69	29.64	36.81	45.39
600,000					11.18	14.33	18.18	22.86	28.55	35.41	43.65
700,000					10.98	14.02	17.73	22.24	27.72	34.34	42.33
800,000					10.82	13.78	17.37	21.75	27.06	33.50	41.28
900,000					10.70	13.59	17.09	21.35	26.53	32.82	40.43
1,000,000					10.59	13.43	16.86	21.02	26.10	32.26	39.72

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 30 feet

2 of 2

Wave Period (seconds)

Fetch (feet)	6.50	7.00	7.50	8.00	8.50	9.00
100						
200						
300						
400						
500						
600						
700						
800						
900						
1,000						
1,100						
1,200						
1,300						
1,400						
1,500						
1,600						
1,700						
1,800						
1,900						
2,000						
3,000						
4,000						
5,000						
6,000						
7,000						
8,000						
9,000						
10,000						
20,000						
22,846	150.00					
30,000	134.81					
36,234		150.00				
40,000	120.79	144.60				
50,000	111.18	133.30				
58,408			150.00			
60,000	104.07	124.93	148.62			
70,000	98.53	118.41	141.04			
80,000	94.05	113.15	134.92			
90,000	90.35	108.79	129.84			
97,457				150.00		
100,000	87.21	105.09	125.54	148.81		
173,874					150.00	
200,000	70.28	85.10	102.25	122.01	144.67	
300,000	62.87	76.33	92.03	110.25	131.30	
357,310						150.00
400,000	58.53	71.18	86.02	103.34	123.46	146.72
500,000	55.62	67.72	81.99	98.71	118.21	140.85
600,000	53.51	65.22	79.06	95.35	114.41	136.62
700,000	51.89	63.30	76.83	92.79	111.52	133.41
800,000	50.62	61.78	75.06	90.76	109.24	130.87
900,000	49.58	60.54	73.61	89.11	107.38	128.82
1,000,000	48.71	59.51	72.41	87.74	105.85	127.13

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 30 feet

1 of 2

Wave Height (feet)

Fetch (feet)	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	5.00
100	28.69	52.19	74.09	95.03	135.04						
150						150.00					
200	22.33	40.63	57.69	74.01	105.22	135.18					
258							150.00				
300	19.29	35.09	49.83	63.94	90.95	116.89	142.12				
400	17.38	31.63	44.92	57.65	82.02	105.45	128.25				
405								150.00			
500	16.04	29.18	41.45	53.20	75.71	97.36	118.45	139.13			
595									150.00		
600	15.02	27.32	38.81	49.82	70.92	91.22	111.00	130.42	149.58		
700	14.20	25.85	36.72	47.13	67.11	86.34	105.08	123.50	141.67		
800	13.54	24.63	34.99	44.93	63.97	82.32	100.22	117.80	135.17		
837										150.00	
900	12.98	23.61	33.54	43.06	61.33	78.94	96.12	113.00	129.69	146.23	
1,000	12.49	22.73	32.29	41.46	59.06	76.03	92.59	108.88	124.98	140.95	
1,100	12.07	21.96	31.21	40.07	57.08	73.49	89.52	105.29	120.88	136.35	
1,200	11.70	21.28	30.24	38.84	55.34	71.25	86.80	102.11	117.25	132.28	
1,300	11.37	20.68	29.39	37.74	53.78	69.25	84.38	99.27	114.01	128.65	
1,400	11.07	20.14	28.61	36.75	52.37	67.45	82.20	96.72	111.10	125.38	
1,500	10.81	19.64	27.91	35.85	51.10	65.82	80.22	94.41	108.46	122.42	
1,507											150.00
1,600	10.56	19.19	27.27	35.03	49.93	64.33	78.41	92.29	106.04	119.71	146.96
1,700	10.33	18.78	26.69	34.28	48.87	62.96	76.76	90.35	103.83	117.23	143.96
1,800	10.13	18.40	26.15	33.58	47.88	61.70	75.22	88.56	101.78	114.94	141.18
1,864	10.00										
1,900		18.05	25.64	32.94	46.97	60.53	73.81	86.90	99.89	112.81	138.61
2,000		17.72	25.18	32.34	46.12	59.44	72.48	85.36	98.12	110.83	136.21
3,000		15.33	21.78	27.98	39.92	51.50	62.87	74.11	85.28	96.43	118.79
4,000		13.84	19.65	25.25	36.05	46.54	56.85	67.07	77.25	87.43	107.90
5,000		12.79	18.16	23.33	33.32	43.03	52.60	62.10	71.58	81.07	100.22
6,000		12.00	17.02	21.87	31.25	40.38	49.38	58.33	67.28	76.25	94.39
7,000		11.37	16.12	20.71	29.60	38.26	46.82	55.33	63.85	72.42	89.76
8,000		10.86	15.39	19.76	28.24	36.52	44.71	52.87	61.04	69.27	85.96
9,000		10.44	14.77	18.96	27.10	35.06	42.94	50.80	58.68	66.62	82.76
10,000		10.07	14.24	18.28	26.13	33.81	41.42	49.01	56.65	64.34	80.02
10,216		10.00									
20,000			11.28	14.42	20.58	26.67	32.76	38.89	45.09	51.40	64.44
29,389			10.00								
30,000				12.64	17.98	23.30	28.65	34.08	39.61	45.27	57.07
40,000				11.56	16.38	21.22	26.11	31.10	36.20	41.46	52.52
50,000				10.84	15.28	19.77	24.33	29.01	33.82	38.80	49.34
60,000				10.31	14.46	18.68	23.00	27.44	32.03	36.79	46.95
67,451				10.00							
70,000					13.83	17.84	21.95	26.20	30.61	35.21	45.08
80,000					13.32	17.15	21.10	25.20	29.46	33.93	43.55
90,000					12.90	16.58	20.39	24.36	28.50	32.85	42.28
100,000					12.56	16.10	19.80	23.65	27.69	31.94	41.20
200,000					10.80	13.61	16.60	19.80	23.25	26.97	35.38
300,000					10.15	12.62	15.28	18.18	21.35	24.83	32.92
338,794					10.00						
400,000						12.10	14.57	17.27	20.28	23.63	31.56
500,000						11.79	14.12	16.71	19.60	22.86	30.71
600,000						11.58	13.82	16.32	19.14	22.34	30.14
700,000						11.44	13.61	16.04	18.80	21.96	29.73
800,000						11.33	13.46	15.84	18.55	21.67	29.43
900,000						11.25	13.34	15.68	18.36	21.45	29.21
1,000,000						11.19	13.25	15.56	18.21	21.28	29.04

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

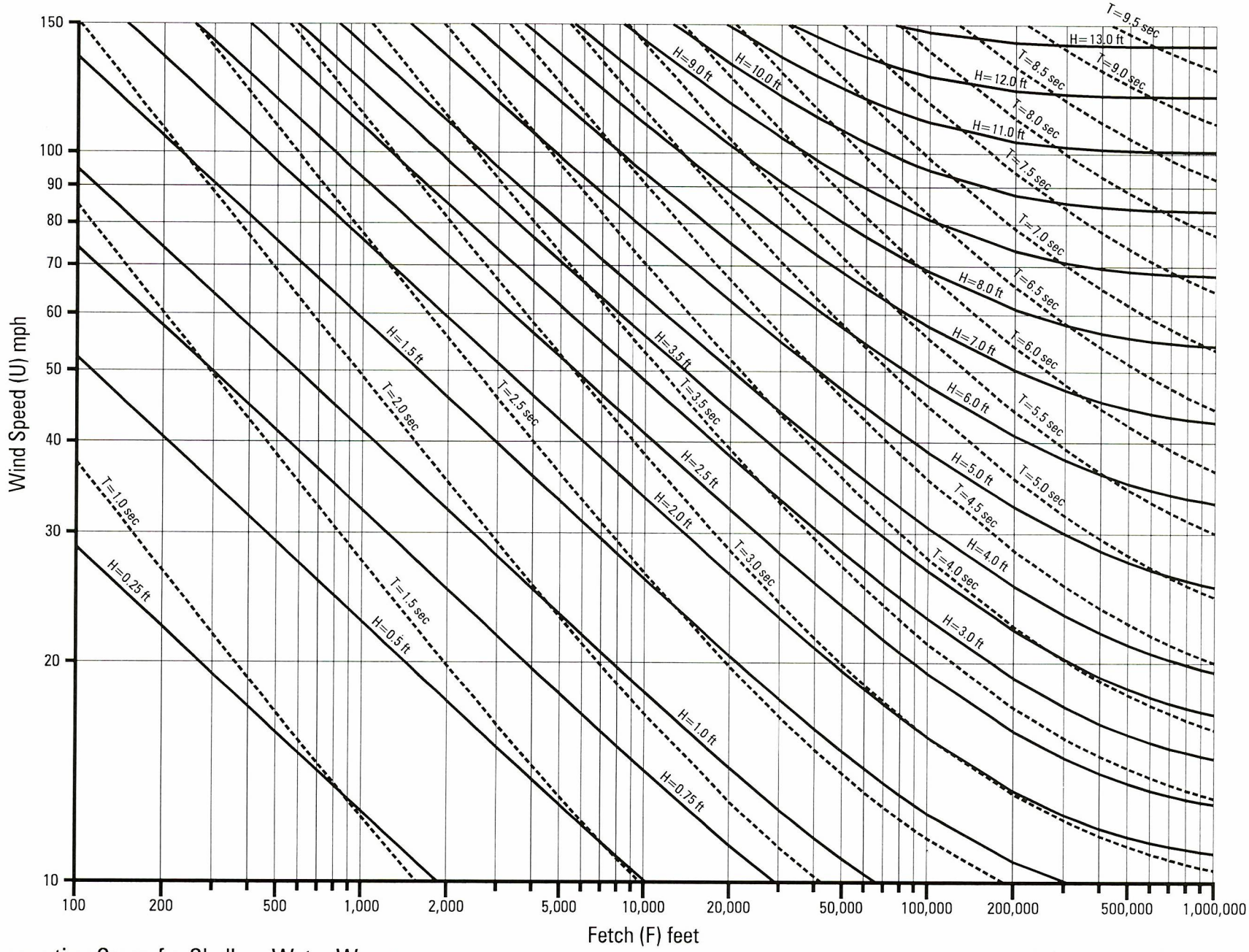
Constant Depth = 30 feet

2 of 2

Wave Height (feet)

Fetch (feet)	6.00	7.00	8.00	9.00	10.00	11.00
100						
200						
300						
400						
500						
600						
700						
800						
900						
1,000						
1,100						
1,200						
1,300						
1,400						
1,500						
1,600						
1,700						
1,800						
1,900						
2,000						
2,507	150.00					
3,000	141.37					
3,990		150.00				
4,000	128.68	149.88				
5,000	119.72	139.71				
6,000	112.93	132.00				
6,234			150.00			
7,000	107.54	125.89	144.93			
8,000	103.12	120.88	139.36			
9,000	99.40	116.67	134.69			
9,812				150.00		
10,000	96.21	113.06	130.69	149.23		
16,181					150.00	
20,000	78.16	92.73	108.28	124.98	142.98	
30,000	69.68	83.25	97.96	113.99	131.52	
30,895						150.00
40,000	64.46	77.47	91.73	107.46	124.85	144.11
50,000	60.83	73.48	87.49	103.09	120.48	139.87
60,000	58.13	70.53	84.39	99.94	117.39	136.95
70,000	56.01	68.24	82.01	97.56	115.11	134.86
80,000	54.30	66.41	80.13	95.71	113.37	133.30
90,000	52.88	64.90	78.59	94.23	112.01	132.11
100,000	51.68	63.63	77.33	93.02	110.92	131.18
200,000	45.36	57.21	71.24	87.62	106.45	127.70
300,000	42.82	54.85	69.26	86.12	105.40	127.02
400,000	41.48	53.71	68.40	85.54	105.05	126.83
500,000	40.69	53.08	67.97	85.29	104.92	126.76
600,000	40.18	52.70	67.74	85.16	104.85	126.73
700,000	39.83	52.47	67.60	85.09	104.82	126.71
800,000	39.59	52.31	67.52	85.05	104.81	126.71
900,000	39.42	52.21	67.47	85.03	104.80	126.71
1,000,000	39.29	52.13	67.43	85.02	104.79	126.70

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph



Forecasting Curve for Shallow-Water Waves.
(USCE, 1977)

Constant Depth = 35 feet

J.D. Mollard and Associates Limited
November, 1993

Chart Data - Wind Speed (mph)

Constant Depth = 35 feet

1 of 2

Wave Period (seconds)

Fetch (feet)	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
100	37.48	84.71									
102			150.00								
200	26.64	60.18	107.66								
256				150.00							
300	21.85	49.31	88.23	138.89							
400	19.00	42.83	76.65	120.70							
500	17.06	38.42	68.74	108.27							
551					150.00						
600	15.63	35.16	62.90	99.09	143.98						
700	14.53	32.63	58.36	91.96	133.64						
800	13.64	30.59	54.70	86.20	125.30						
900	12.91	28.90	51.67	81.43	118.39						
1,000	12.29	27.47	49.11	77.40	112.54						
1,068						150.00					
1,100	11.76	26.25	46.91	73.92	107.51	147.87					
1,200	11.30	25.18	44.98	70.89	103.11	141.86					
1,300	10.89	24.24	43.29	68.22	99.23	136.54					
1,400	10.53	23.40	41.78	65.84	95.78	131.81					
1,500	10.21	22.65	40.42	63.70	92.67	127.55					
1,570	10.00										
1,600		21.97	39.19	61.76	89.86	123.70					
1,700		21.35	38.08	60.00	87.30	120.19					
1,800		20.79	37.05	58.38	84.96	116.98					
1,900		20.27	36.12	56.90	82.80	114.02					
1,920							150.00				
2,000		19.79	35.25	55.53	80.81	111.29	147.15				
3,000		16.42	29.13	45.84	66.72	91.95	121.71				
3,273								150.00			
4,000		14.44	25.50	40.08	58.32	80.40	106.49	136.76			
5,000		13.10	23.04	36.15	52.59	72.51	96.08	123.47			
5,366									150.00		
6,000		12.13	21.23	33.26	48.36	66.68	88.39	113.64	142.63		
7,000		11.38	19.83	31.01	45.07	62.15	82.40	105.99	133.09		
8,000		10.78	18.71	29.21	42.43	58.50	77.57	99.81	125.39		
8,551										150.00	
9,000		10.29	17.78	27.72	40.24	55.47	73.57	94.69	119.00	146.66	
9,686		10.00									
10,000			17.01	26.47	38.39	52.91	70.18	90.35	113.58	140.05	
13,368											150.00
20,000			12.90	19.76	28.45	39.10	51.83	66.80	84.14	104.01	126.59
30,000			11.18	16.88	24.12	33.03	43.73	56.35	71.04	87.94	107.21
40,000			10.19	15.21	21.59	29.45	38.93	50.14	63.22	78.32	95.60
42,584			10.00								
50,000				14.10	19.89	27.04	35.67	45.91	57.89	71.75	87.65
60,000				13.30	18.66	25.28	33.29	42.80	53.96	66.90	81.78
70,000				12.69	17.71	23.92	31.44	40.40	50.92	63.14	77.21
80,000				12.21	16.96	22.84	29.97	38.47	48.47	60.11	73.53
90,000				11.82	16.35	21.96	28.76	36.88	46.45	57.60	70.49
100,000				11.50	15.84	21.22	27.74	35.54	44.74	55.48	67.91
185,574				10.00							
200,000					13.23	17.37	22.40	28.45	35.65	44.13	54.05
300,000					12.18	15.79	20.18	25.46	31.77	39.24	48.02
400,000					11.59	14.91	18.92	23.75	29.53	36.39	44.50
500,000					11.22	14.34	18.10	22.62	28.04	34.50	42.15
600,000					10.95	13.93	17.51	21.82	26.98	33.13	40.44
700,000					10.76	13.63	17.07	21.21	26.17	32.09	39.15
800,000					10.61	13.39	16.73	20.73	25.53	31.27	38.12
900,000					10.48	13.20	16.45	20.35	25.02	30.61	37.28
1,000,000					10.38	13.05	16.22	20.03	24.59	30.06	36.59

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 35 feet

2 of 2

Wave Period (seconds)

Fetch (feet)	6.50	7.00	7.50	8.00	8.50	9.00	9.50
100							
200							
300							
400							
500							
600							
700							
800							
900							
1,000							
1,100							
1,200							
1,300							
1,400							
1,500							
1,600							
1,700							
1,800							
1,900							
2,000							
3,000							
4,000							
5,000							
6,000							
7,000							
8,000							
9,000							
10,000							
20,000							
20,666	150.00						
30,000	129.02						
31,846		150.00					
40,000	115.21	137.34					
49,348			150.00				
50,000	105.75	126.23	149.28				
60,000	98.76	118.00	139.71				
70,000	93.31	111.59	132.26				
77,768				150.00			
80,000	88.91	106.42	126.23	148.57			
90,000	85.27	102.12	121.24	142.81			
100,000	82.19	98.49	117.01	137.94			
126,716					150.00		
200,000	65.56	78.84	94.08	111.50	131.32		
219,764						150.00	
300,000	58.28	70.21	83.99	99.85	118.02	138.75	
400,000	54.02	65.14	78.05	92.98	110.18	129.90	
432,627							150.00
500,000	51.16	61.72	74.05	88.36	104.90	123.95	145.79
600,000	49.09	59.25	71.14	84.99	101.06	119.62	140.98
700,000	47.50	57.35	68.91	82.41	98.12	116.32	137.31
800,000	46.24	55.84	67.14	80.36	95.79	113.70	134.41
900,000	45.22	54.61	65.69	78.69	93.89	111.57	132.04
1,000,000	44.36	53.59	64.48	77.30	92.30	109.79	130.08

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 35 feet

1 of 2

Wave Height (feet)

Fetch (feet)	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	5.00
100	28.69	52.18	74.06	94.97	134.90						
149						150.00					
200	22.33	40.61	57.65	73.94	105.08	134.93					
256							150.00				
300	19.28	35.07	49.80	63.88	90.81	116.64	141.72				
400	17.38	31.61	44.89	57.59	81.88	105.20	127.85				
400								150.00			
500	16.03	29.17	41.41	53.14	75.57	97.11	118.05	138.55			
586									150.00		
600	15.01	27.31	38.78	49.76	70.78	90.97	110.60	129.84	148.78		
700	14.20	25.83	36.68	47.07	66.96	86.08	104.68	122.92	140.87		
800	13.53	24.62	34.96	44.86	63.83	82.07	99.82	117.22	134.37		
820										150.00	
900	12.97	23.59	33.51	43.00	61.19	78.68	95.71	112.42	128.89	145.18	
1,000	12.49	22.71	32.26	41.40	58.92	75.77	92.19	108.30	124.18	139.90	
1,100	12.07	21.95	31.17	40.01	56.94	73.24	89.12	104.70	120.07	135.29	
1,200	11.70	21.27	30.21	38.77	55.19	71.00	86.40	101.52	116.44	131.22	
1,300	11.37	20.66	29.35	37.67	53.63	69.00	83.98	98.69	113.21	127.59	
1,400	11.07	20.12	28.58	36.68	52.23	67.20	81.80	96.13	110.29	124.32	
1,458											150.00
1,500	10.80	19.63	27.88	35.79	50.95	65.57	79.82	93.82	107.65	121.35	148.53
1,600	10.56	19.18	27.24	34.97	49.79	64.07	78.01	91.70	105.23	118.64	145.25
1,700	10.33	18.76	26.65	34.21	48.72	62.71	76.35	89.76	103.02	116.16	142.24
1,800	10.12	18.38	26.11	33.52	47.74	61.44	74.82	87.97	100.97	113.86	139.46
1,863	10.00										
1,900		18.03	25.61	32.88	46.82	60.27	73.40	86.31	99.07	111.73	136.88
2,000		17.70	25.14	32.28	45.97	59.18	72.08	84.76	97.31	109.75	134.49
3,000		15.31	21.74	27.91	39.78	51.24	62.46	73.51	84.45	95.34	117.03
4,000		13.82	19.62	25.19	35.91	46.28	56.44	66.47	76.42	86.32	106.12
5,000		12.78	18.12	23.26	33.17	42.77	52.19	61.49	70.74	79.96	98.41
6,000		11.99	16.99	21.81	31.10	40.11	48.96	57.72	66.43	75.13	92.57
7,000		11.36	16.09	20.65	29.45	38.00	46.40	54.72	63.00	71.28	87.92
8,000		10.85	15.35	19.70	28.10	36.26	44.29	52.25	60.19	68.13	84.11
9,000		10.42	14.74	18.90	26.96	34.80	42.52	50.18	57.82	65.47	80.89
10,000		10.06	14.21	18.22	25.98	33.54	40.99	48.39	55.78	63.19	78.13
10,181		10.00									
20,000			11.25	14.36	20.44	26.40	32.33	38.25	44.20	50.20	62.45
29,141			10.00								
30,000				12.58	17.83	23.03	28.21	33.42	38.69	44.03	55.00
40,000				11.51	16.24	20.94	25.67	30.43	35.27	40.19	50.38
50,000				10.79	15.14	19.49	23.89	28.34	32.87	37.50	47.14
60,000				10.26	14.32	18.41	22.55	26.76	31.06	35.47	44.70
66,274				10.00							
70,000					13.69	17.56	21.50	25.52	29.64	33.87	42.78
80,000					13.18	16.88	20.65	24.51	28.48	32.57	41.21
90,000					12.77	16.31	19.94	23.67	27.51	31.48	39.90
100,000					12.43	15.84	19.34	22.95	26.68	30.55	38.78
200,000					10.69	13.35	16.14	19.08	22.18	25.47	32.66
300,000					10.05	12.38	14.83	17.44	20.24	23.25	30.00
311,781					10.00						
400,000						11.87	14.12	16.54	19.15	21.99	28.47
500,000						11.56	13.68	15.97	18.46	21.18	27.49
600,000						11.35	13.39	15.58	17.98	20.62	26.81
700,000						11.21	13.18	15.30	17.63	20.21	26.31
800,000						11.11	13.02	15.09	17.37	19.90	25.94
900,000						11.03	12.91	14.93	17.16	19.66	25.65
1,000,000						10.97	12.81	14.80	17.00	19.47	25.42

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

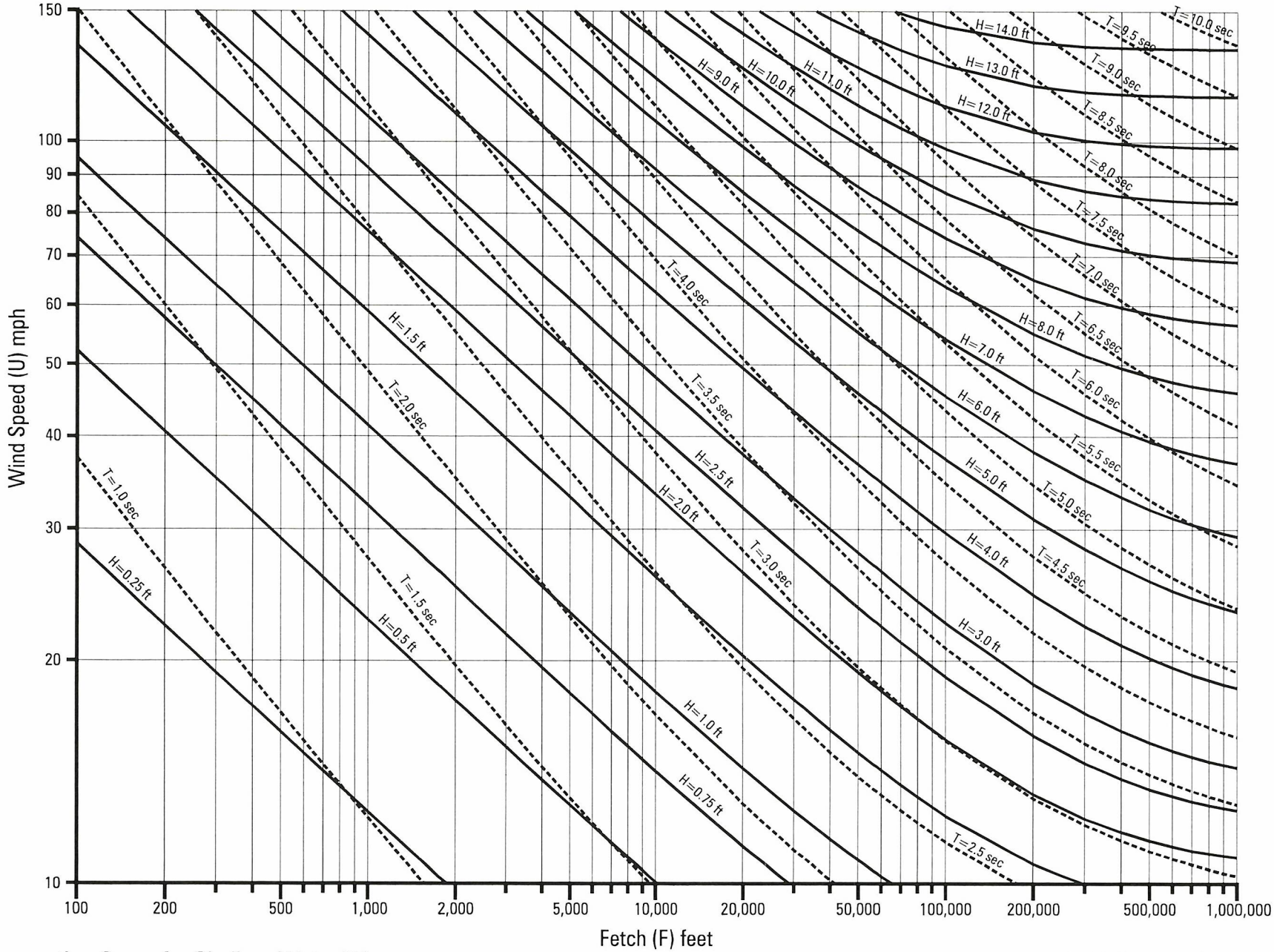
Constant Depth = 35 feet

2 of 2

Wave Height (feet)

Fetch (feet)	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00
100								
200								
300								
400								
500								
600								
700								
800								
900								
1,000								
1,100								
1,200								
1,300								
1,400								
1,500								
1,600								
1,700								
1,800								
1,900								
2,000								
2,382	150.00							
3,000	138.77							
3,695		150.00						
4,000	126.02	146.15						
5,000	117.03	135.91						
5,563			150.00					
6,000	110.21	128.14	146.48					
7,000	104.79	121.98	139.60					
8,000	100.33	116.92	133.95					
8,273				150.00				
9,000	96.59	112.66	129.20	146.30				
10,000	93.37	109.01	125.14	141.84				
12,381					150.00			
19,144						150.00		
20,000	75.12	88.32	102.15	116.72	132.11	148.43		
30,000	66.48	78.57	91.39	105.05	119.66	135.34		
32,350							150.00	
40,000	61.13	72.56	84.79	97.95	112.17	127.57	144.28	
50,000	57.39	68.37	80.23	93.08	107.08	122.35	139.05	
60,000	54.58	65.24	76.83	89.48	103.35	118.59	135.34	
70,000	52.37	62.78	74.18	86.70	100.51	115.76	132.59	
75,512								150.00
80,000	50.57	60.79	72.04	84.48	98.26	113.54	130.48	149.19
90,000	49.07	59.14	70.28	82.65	96.43	111.78	128.82	147.68
100,000	47.79	57.74	68.79	81.13	94.93	110.33	127.49	146.50
200,000	40.86	50.27	61.09	73.53	87.75	103.86	121.91	141.88
300,000	37.90	47.19	58.10	70.83	85.46	102.05	120.55	140.92
400,000	36.23	45.53	56.59	69.56	84.49	101.36	120.09	140.63
500,000	35.18	44.52	55.72	68.89	84.02	101.04	119.90	140.52
600,000	34.46	43.85	55.18	68.50	83.76	100.89	119.81	140.47
700,000	33.94	43.40	54.83	68.26	83.61	100.81	119.77	140.45
800,000	33.56	43.07	54.59	68.10	83.52	100.76	119.74	140.44
900,000	33.28	42.83	54.42	68.00	83.47	100.73	119.73	140.43
1,000,000	33.05	42.65	54.30	67.93	83.43	100.71	119.72	140.43

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph



Forecasting Curve for Shallow-Water Waves.
(USCE, 1977)

Constant Depth = 40 feet

J.D. Mollard and Associates Limited
November, 1993

Chart Data - Wind Speed (mph)

Constant Depth = 40 feet

1 of 2

Wave Period (seconds)

Fetch (feet)	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
100	37.43	84.56									
101			150.00								
200	26.60	60.05	107.36								
254				150.00							
300	21.81	49.20	87.96	138.35							
400	18.97	42.73	76.40	120.20							
500	17.03	38.32	68.50	107.80							
545					150.00						
600	15.61	35.06	62.67	98.64	143.18						
700	14.50	32.53	58.14	91.52	132.87						
800	13.62	30.50	54.49	85.78	124.56						
900	12.88	28.81	51.47	81.02	117.67						
1,000	12.27	27.39	48.91	76.99	111.83						
1,051						150.00					
1,100	11.74	26.17	46.71	73.53	106.81	146.76					
1,200	11.28	25.10	44.79	70.51	102.43	140.76					
1,300	10.87	24.16	43.10	67.84	98.57	135.47					
1,400	10.51	23.33	41.59	65.46	95.12	130.75					
1,500	10.19	22.58	40.24	63.33	92.03	126.51					
1,564	10.00										
1,600		21.90	39.01	61.40	89.23	122.67					
1,700		21.28	37.90	59.64	86.68	119.18					
1,800		20.72	36.88	58.03	84.34	115.98					
1,880							150.00				
1,900		20.20	35.94	56.55	82.19	113.03	149.25				
2,000		19.72	35.08	55.18	80.21	110.31	145.67				
3,000		16.36	28.97	45.53	66.17	91.06	120.35				
3,184								150.00			
4,000		14.38	25.36	39.78	57.81	79.56	105.21	134.91			
5,000		13.05	22.90	35.87	52.10	71.71	94.87	121.71			
5,176									150.00		
6,000		12.08	21.10	32.99	47.89	65.92	87.22	111.94	140.24		
7,000		11.33	19.70	30.76	44.62	61.41	81.27	104.34	130.77		
8,000		10.74	18.59	28.96	41.99	57.78	76.47	98.21	123.13		
8,167										150.00	
9,000		10.25	17.67	27.48	39.81	54.77	72.49	93.12	116.79	143.65	
9,590		10.00									
10,000			16.90	26.23	37.97	52.23	69.13	88.81	111.42	137.09	
12,613											150.00
20,000			12.82	19.56	28.09	38.51	50.92	65.46	82.24	101.41	123.10
30,000			11.10	16.70	23.80	32.49	42.89	55.11	69.27	85.50	103.94
40,000			10.12	15.05	21.29	28.95	38.13	48.96	61.54	76.00	92.47
41,656			10.00								
50,000				13.95	19.60	26.56	34.91	44.78	56.27	69.51	84.63
60,000				13.16	18.38	24.81	32.55	41.71	52.39	64.73	78.84
70,000				12.56	17.45	23.47	30.73	39.33	49.39	61.01	74.33
80,000				12.08	16.71	22.41	29.28	37.43	46.97	58.02	70.70
90,000				11.70	16.11	21.53	28.08	35.86	44.98	55.55	67.70
100,000				11.38	15.61	20.80	27.08	34.54	43.30	53.46	65.16
176,281				10.00							
200,000					13.03	17.01	21.82	27.57	34.35	42.30	51.52
300,000					11.99	15.47	19.64	24.63	30.54	37.49	45.60
400,000					11.42	14.60	18.41	22.95	28.35	34.70	42.15
500,000					11.05	14.04	17.60	21.85	26.89	32.85	39.84
600,000					10.79	13.64	17.03	21.06	25.85	31.51	38.17
700,000					10.60	13.34	16.60	20.47	25.06	30.50	36.90
800,000					10.45	13.11	16.26	20.00	24.44	29.70	35.90
900,000					10.33	12.93	15.99	19.63	23.94	29.05	35.08
1,000,000					10.23	12.78	15.77	19.32	23.52	28.51	34.39

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 40 feet

2 of 2

Wave Period (seconds)

Fetch (feet)	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00
100								
200								
300								
400								
500								
600								
700								
800								
900								
1,000								
1,100								
1,200								
1,300								
1,400								
1,500								
1,600								
1,700								
1,800								
1,900								
2,000								
3,000								
4,000								
5,000								
6,000								
7,000								
8,000								
9,000								
10,000								
19,203	150.00							
20,000	147.46							
29,020		150.00						
30,000	124.72	148.01						
40,000	111.09	132.01						
43,838			150.00					
50,000	101.76	121.05	142.66					
60,000	94.86	112.94	133.23					
66,734				150.00				
70,000	89.49	106.62	125.88	147.44				
80,000	85.16	101.52	119.95	140.61				
90,000	81.57	97.29	115.02	134.94				
100,000	78.53	93.71	110.85	130.13				
103,458					150.00			
165,952						150.00		
200,000	62.16	74.36	88.27	104.05	121.91	142.02		
283,206							150.00	
300,000	55.01	65.87	78.32	92.55	108.74	127.09	147.83	
400,000	50.82	60.87	72.46	85.75	100.96	118.27	137.92	
500,000	48.01	57.51	68.51	81.17	95.70	112.32	131.24	
546,920								150.00
600,000	45.98	55.07	65.63	77.83	91.87	107.97	126.38	147.33
700,000	44.42	53.20	63.42	75.26	88.93	104.64	122.65	143.20
800,000	43.18	51.71	61.66	73.22	86.59	101.99	119.68	139.92
900,000	42.17	50.50	60.23	71.55	84.67	99.83	117.26	137.24
1,000,000	41.34	49.49	59.03	70.16	83.08	98.02	115.24	135.02

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 40 feet

1 of 2

Wave Height (feet)

Fetch (feet)	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	4.00	5.00	6.00
100	28.69	52.17	74.03	94.92	134.80						
148						150.00					
200	22.32	40.60	57.63	73.90	104.98	134.75					
255							150.00				
300	19.28	35.06	49.77	63.84	90.71	116.46	141.44				
397								150.00			
400	17.38	31.60	44.86	57.54	81.78	105.02	127.57	149.62			
500	16.03	29.15	41.39	53.09	75.47	96.93	117.77	138.15			
600	15.01	27.30	38.75	49.71	70.68	90.79	110.33	129.44			
700	14.20	25.82	36.66	47.03	66.87	85.91	104.41	122.51			
800	13.53	24.60	34.93	44.82	63.73	81.89	99.54	116.82			
809									150.00		
900	12.97	23.58	33.48	42.96	61.09	78.50	95.44	112.02	144.45		
1,000	12.49	22.70	32.23	41.36	58.82	75.60	91.91	107.89	139.17		
1,100	12.07	21.94	31.15	39.96	56.84	73.06	88.84	104.29	134.56		
1,200	11.70	21.26	30.18	38.73	55.09	70.82	86.12	101.12	130.49		
1,300	11.37	20.65	29.33	37.63	53.53	68.82	83.70	98.28	126.85		
1,400	11.07	20.11	28.55	36.64	52.13	67.02	81.52	95.73	123.58		
1,426										150.00	
1,500	10.80	19.62	27.85	35.74	50.86	65.39	79.54	93.41	120.61	147.36	
1,600	10.55	19.17	27.21	34.92	49.69	63.90	77.73	91.30	117.91	144.08	
1,700	10.33	18.75	26.63	34.17	48.62	62.53	76.07	89.36	115.42	141.07	
1,800	10.12	18.37	26.09	33.48	47.64	61.26	74.54	87.56	113.12	138.28	
1,862	10.00										
1,900		18.02	25.58	32.83	46.72	60.09	73.12	85.90	110.99	135.71	
2,000		17.69	25.12	32.23	45.87	59.00	71.80	84.36	109.01	133.31	
2,302											150.00
3,000		15.30	21.72	27.87	39.68	51.06	62.17	73.09	94.59	115.83	137.00
4,000		13.81	19.59	25.14	35.81	46.10	56.16	66.05	85.57	104.91	124.24
5,000		12.77	18.10	23.22	33.07	42.59	51.90	61.08	79.20	97.19	115.22
6,000		11.98	16.96	21.76	31.00	39.93	48.68	57.30	74.36	91.34	108.38
7,000		11.35	16.07	20.61	29.35	37.82	46.11	54.30	70.51	86.68	102.94
8,000		10.84	15.33	19.66	28.00	36.08	44.00	51.83	67.35	82.86	98.47
9,000		10.42	14.71	18.86	26.86	34.62	42.23	49.75	64.69	79.64	94.71
10,000		10.05	14.18	18.17	25.88	33.36	40.70	47.97	62.41	76.87	91.48
10,159		10.00									
20,000			11.23	14.32	20.34	26.22	32.03	37.81	49.39	61.12	73.12
28,989			10.00								
30,000				12.54	17.73	22.84	27.92	32.98	43.20	53.63	64.40
40,000				11.48	16.14	20.76	25.37	29.99	39.35	48.98	58.98
50,000				10.76	15.04	19.31	23.58	27.89	36.64	45.71	55.18
60,000				10.23	14.23	18.23	22.25	26.31	34.61	43.24	52.32
65,561				10.00							
70,000					13.60	17.38	21.20	25.06	33.00	41.30	50.06
80,000					13.10	16.70	20.35	24.05	31.68	39.71	48.22
90,000					12.68	16.13	19.64	23.21	30.58	38.37	46.68
100,000					12.34	15.66	19.04	22.49	29.65	37.24	45.36
200,000					10.62	13.19	15.85	18.61	24.51	30.98	38.13
297,252					10.00						
300,000						12.23	14.54	16.98	22.27	28.21	34.95
400,000						11.72	13.84	16.08	20.99	26.61	33.11
500,000						11.42	13.41	15.51	20.16	25.57	31.92
600,000						11.22	13.12	15.12	19.59	24.84	31.08
700,000						11.08	12.91	14.84	19.17	24.30	30.47
800,000						10.97	12.76	14.64	18.85	23.88	30.00
900,000						10.90	12.64	14.48	18.60	23.56	29.64
1,000,000						10.84	12.55	14.35	18.40	23.30	29.35

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

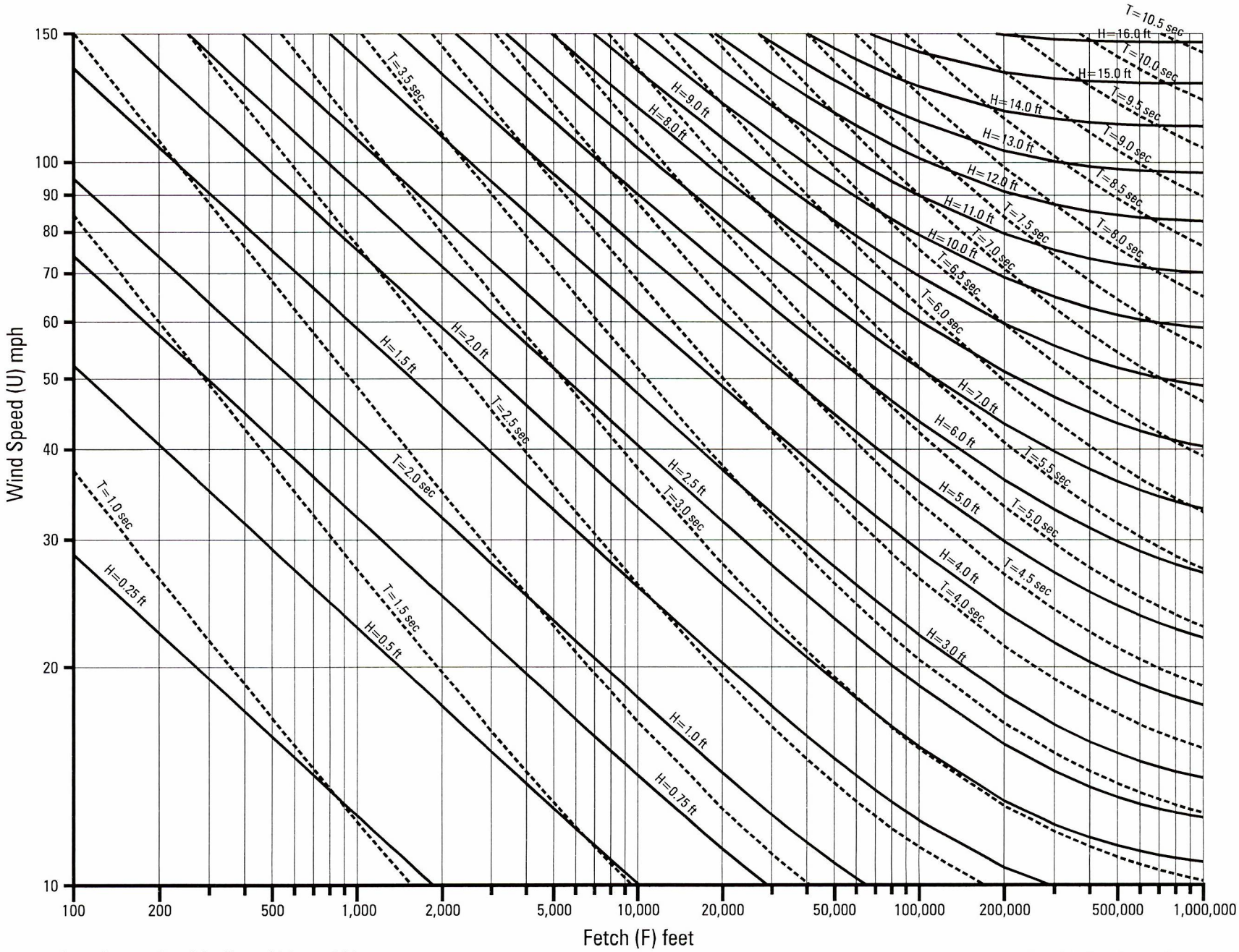
Constant Depth = 40 feet

2 of 2

Wave Height (feet)

Fetch (feet)	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00
100								
200								
300								
400								
500								
600								
700								
800								
900								
1,000								
1,100								
1,200								
1,300								
1,400								
1,500								
1,600								
1,700								
1,800								
1,900								
2,000								
3,000								
3,515	150.00							
4,000	143.65							
5,000	133.37							
5,180		150.00						
6,000	125.58	143.02						
7,000	119.38	136.09						
7,475			150.00					
8,000	114.30	130.40	146.85					
9,000	110.01	125.62	141.58					
10,000	106.34	121.51	137.06					
10,700				150.00				
15,406					150.00			
20,000	85.46	98.23	111.49	125.32	139.77			
22,748						150.00		
30,000	75.57	87.24	99.48	112.36	125.96	140.37		
35,736							150.00	
40,000	69.45	80.46	92.09	104.44	117.59	131.62	146.63	
50,000	65.16	75.72	86.96	98.97	111.84	125.68	140.56	
60,000	61.93	72.17	83.13	94.91	107.61	121.34	136.19	
66,690								150.00
70,000	59.39	69.38	80.14	91.75	104.35	118.02	132.88	149.02
80,000	57.32	67.12	77.71	89.22	101.74	115.40	130.29	146.53
90,000	55.59	65.23	75.71	87.13	99.61	113.27	128.22	144.56
100,000	54.12	63.64	74.01	85.37	97.83	111.52	126.53	142.97
200,000	46.10	55.03	65.07	76.37	89.04	103.19	118.90	136.18
300,000	42.63	51.42	61.49	72.98	85.98	100.55	116.72	134.46
400,000	40.66	49.44	59.61	71.30	84.57	99.44	115.88	133.86
500,000	39.40	48.21	58.50	70.36	83.83	98.89	115.50	133.61
600,000	38.53	47.39	57.78	69.79	83.41	98.60	115.31	133.49
700,000	37.91	46.81	57.30	69.42	83.15	98.44	115.21	133.43
800,000	37.44	46.39	56.97	69.18	82.99	98.34	115.15	133.39
900,000	37.08	46.08	56.73	69.02	82.89	98.27	115.11	133.37
1,000,000	36.80	45.84	56.55	68.90	82.81	98.23	115.09	133.36

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph



Forecasting Curve for Shallow-Water Waves.
(USCE, 1977)

Constant Depth = 45 feet

J.D. Mollard and Associates Limited
November, 1993

Chart Data - Wind Speed (mph)

Constant Depth = 45 feet

1 of 2

Wave Period (seconds)

Fetch (feet)	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
100	37.40	84.44									
101			150.00								
200	26.57	59.95	107.12								
253				150.00							
300	21.79	49.11	87.75	137.93							
400	18.95	42.64	76.19	119.80							
500	17.01	38.24	68.31	107.42							
540					150.00						
600	15.59	34.99	62.49	98.28	142.54						
700	14.48	32.46	57.96	91.17	132.26						
800	13.60	30.43	54.32	85.44	123.96						
900	12.87	28.75	51.30	80.69	117.09						
1,000	12.25	27.32	48.74	76.67	111.27						
1,038						150.00					
1,100	11.72	26.10	46.55	73.21	106.26	145.87					
1,200	11.26	25.04	44.63	70.20	101.89	139.89					
1,300	10.86	24.10	42.94	67.54	98.04	134.61					
1,400	10.50	23.26	41.44	65.17	94.60	129.91					
1,500	10.18	22.52	40.09	63.04	91.51	125.68					
1,559	10.00										
1,600		21.84	38.87	61.11	88.72	121.86					
1,700		21.22	37.76	59.36	86.18	118.38					
1,800		20.66	36.74	57.75	83.85	115.19					
1,849							150.00				
1,900		20.14	35.80	56.28	81.71	112.25	148.07				
2,000		19.67	34.94	54.91	79.73	109.54	144.50				
3,000		16.31	28.85	45.28	65.74	90.35	119.28				
3,114								150.00			
4,000		14.34	25.24	39.55	57.40	78.90	104.20	133.45			
5,000		13.01	22.79	35.65	51.71	71.08	93.90	120.31			
5,032									150.00		
6,000		12.04	21.00	32.78	47.51	65.31	86.29	110.60	138.36		
7,000		11.30	19.61	30.56	44.26	60.82	80.37	103.04	128.95		
7,880										150.00	
8,000		10.70	18.49	28.77	41.64	57.21	75.60	96.94	121.35	148.98	
9,000		10.22	17.58	27.29	39.47	54.22	71.65	91.88	115.06	141.29	
9,517		10.00									
10,000			16.81	26.05	37.64	51.68	68.30	87.60	109.72	134.78	
12,057											150.00
20,000			12.75	19.41	27.81	38.04	50.20	64.41	80.76	99.38	120.39
30,000			11.04	16.57	23.54	32.07	42.23	54.14	67.90	83.61	101.41
40,000			10.07	14.93	21.05	28.55	37.51	48.04	60.23	74.20	90.06
40,961			10.00								
50,000				13.84	19.38	26.18	34.32	43.90	55.02	67.78	82.30
60,000				13.05	18.17	24.45	31.98	40.86	51.18	63.05	76.57
70,000				12.46	17.25	23.13	30.18	38.51	48.20	59.37	72.12
80,000				11.99	16.52	22.07	28.74	36.62	45.82	56.42	68.53
90,000				11.60	15.92	21.21	27.56	35.07	43.85	53.97	65.57
100,000				11.29	15.42	20.48	26.57	33.77	42.18	51.91	63.06
169,628				10.00							
200,000					12.88	16.74	21.38	26.89	33.36	40.90	49.61
300,000					11.86	15.22	19.23	24.00	29.61	36.17	43.78
400,000					11.29	14.36	18.02	22.35	27.45	33.43	40.39
500,000					10.93	13.81	17.23	21.27	26.03	31.61	38.12
600,000					10.67	13.42	16.67	20.50	25.01	30.30	36.48
700,000					10.48	13.13	16.24	19.91	24.23	29.31	35.24
800,000					10.34	12.90	15.92	19.46	23.63	28.52	34.25
900,000					10.22	12.72	15.65	19.09	23.14	27.88	33.45
1,000,000					10.12	12.57	15.43	18.79	22.73	27.36	32.78

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 45 feet

2 of 2

Wave Period (seconds)

Fetch (feet)	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50
100									
200									
300									
400									
500									
600									
700									
800									
900									
1,000									
1,100									
1,200									
1,300									
1,400									
1,500									
1,600									
1,700									
1,800									
1,900									
2,000									
3,000									
4,000									
5,000									
6,000									
7,000									
8,000									
9,000									
10,000									
18,150	150.00								
20,000	143.92								
27,045		150.00							
30,000	121.41	143.74							
40,000	107.92	127.92							
40,130			150.00						
50,000	98.69	117.09	137.61						
59,677				150.00					
60,000	91.87	109.07	128.30	149.70					
70,000	86.56	102.83	121.04	141.34					
80,000	82.28	97.79	115.18	134.59					
89,628					150.00				
90,000	78.74	93.61	110.32	128.99	149.78				
100,000	75.74	90.08	106.20	124.25	144.36				
137,362						150.00			
200,000	59.60	70.99	83.91	98.51	114.93	133.33			
218,250							150.00		
300,000	52.56	62.62	74.11	87.15	101.91	118.54	137.24		
369,871								150.00	
400,000	48.44	57.71	68.32	80.44	94.20	109.79	127.38	147.17	
500,000	45.68	54.40	64.43	75.91	88.99	103.87	120.71	139.73	
600,000	43.67	51.99	61.59	72.60	85.19	99.54	115.84	134.30	
700,000	42.14	50.15	59.41	70.06	82.27	96.22	112.10	130.12	
712,870									150.00
800,000	40.93	48.69	57.67	68.03	79.94	93.56	109.12	126.80	146.85
900,000	39.94	47.49	56.26	66.38	78.03	91.39	106.67	124.08	143.86
1,000,000	39.11	46.50	55.07	64.99	76.43	89.58	104.63	121.82	141.36

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 45 feet

1 of 2

Wave Height (feet)

Fetch (feet)	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	4.00	5.00	6.00
100	28.68	52.16	74.01	94.89	134.73						
148						150.00					
200	22.32	40.59	57.61	73.87	104.91	134.62					
254							150.00				
300	19.28	35.06	49.76	63.81	90.64	116.33	141.24				
395								150.00			
400	17.37	31.59	44.84	57.51	81.71	104.89	127.37	149.33			
500	16.03	29.15	41.37	53.06	75.40	96.80	117.57	137.86			
600	15.01	27.29	38.74	49.68	70.61	90.66	110.12	129.15			
700	14.20	25.81	36.64	47.00	66.79	85.78	104.20	122.22			
800	13.53	24.60	34.92	44.79	63.66	81.76	99.34	116.52			
801									150.00		
900	12.97	23.57	33.46	42.92	61.02	78.38	95.23	111.72	143.92		
1,000	12.49	22.69	32.22	41.33	58.75	75.47	91.71	107.60	138.64		
1,100	12.07	21.93	31.13	39.93	56.77	72.93	88.63	104.00	134.03		
1,200	11.70	21.25	30.17	38.70	55.02	70.69	85.92	100.82	129.96		
1,300	11.37	20.65	29.31	37.60	53.46	68.69	83.49	97.99	126.32		
1,400	11.07	20.10	28.54	36.61	52.06	66.89	81.31	95.43	123.05		
1,403										150.00	
1,500	10.80	19.61	27.84	35.71	50.78	65.26	79.33	93.12	120.08	146.52	
1,600	10.55	19.16	27.20	34.89	49.62	63.77	77.53	91.00	117.37	143.24	
1,700	10.33	18.75	26.61	34.14	48.55	62.40	75.87	89.06	114.89	140.22	
1,800	10.12	18.37	26.07	33.44	47.57	61.13	74.33	87.27	112.59	137.44	
1,861	10.00										
1,900		18.01	25.57	32.80	46.65	59.96	72.91	85.61	110.46	134.86	
2,000		17.68	25.10	32.20	45.80	58.87	71.59	84.06	108.48	132.46	
2,247											150.00
3,000		15.29	21.70	27.84	39.61	50.93	61.97	72.80	94.05	114.98	135.74
4,000		13.81	19.58	25.11	35.74	45.97	55.95	65.75	85.03	104.04	122.96
5,000		12.76	18.08	23.19	33.00	42.46	51.70	60.78	78.65	96.32	113.93
6,000		11.97	16.95	21.73	30.93	39.80	48.47	57.00	73.81	90.46	107.08
7,000		11.35	16.05	20.57	29.28	37.69	45.90	54.00	69.96	85.80	101.63
8,000		10.84	15.31	19.62	27.92	35.95	43.79	51.53	66.80	81.97	97.16
9,000		10.41	14.70	18.83	26.79	34.48	42.02	49.45	64.14	78.74	93.39
10,000		10.05	14.17	18.14	25.81	33.23	40.49	47.66	61.85	75.97	90.15
10,146		10.00									
20,000			11.22	14.29	20.27	26.09	31.82	37.50	48.82	60.19	71.72
28,892			10.00								
30,000				12.52	17.66	22.71	27.70	32.67	42.61	52.68	62.96
40,000				11.45	16.07	20.63	25.15	29.67	38.75	48.00	57.50
50,000				10.73	14.97	19.18	23.37	27.57	36.04	44.72	53.67
60,000				10.21	14.16	18.10	22.03	25.99	34.00	42.24	50.78
65,111				10.00							
70,000					13.54	17.25	20.98	24.74	32.38	40.27	48.49
80,000					13.04	16.57	20.13	23.73	31.07	38.67	46.63
90,000					12.63	16.01	19.42	22.88	29.96	37.33	45.06
100,000					12.28	15.53	18.82	22.16	29.02	36.18	43.72
200,000					10.58	13.08	15.64	18.29	23.86	29.85	36.33
288,671					10.00						
300,000						12.13	14.35	16.66	21.60	27.03	33.03
400,000						11.63	13.66	15.77	20.32	25.40	31.11
500,000						11.33	13.23	15.20	19.49	24.32	29.84
600,000						11.13	12.94	14.82	18.91	23.57	28.94
700,000						10.99	12.74	14.55	18.48	23.01	28.27
800,000						10.89	12.59	14.34	18.16	22.58	27.76
900,000						10.81	12.47	14.18	17.91	22.24	27.36
1,000,000						10.76	12.38	14.06	17.71	21.97	27.03

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

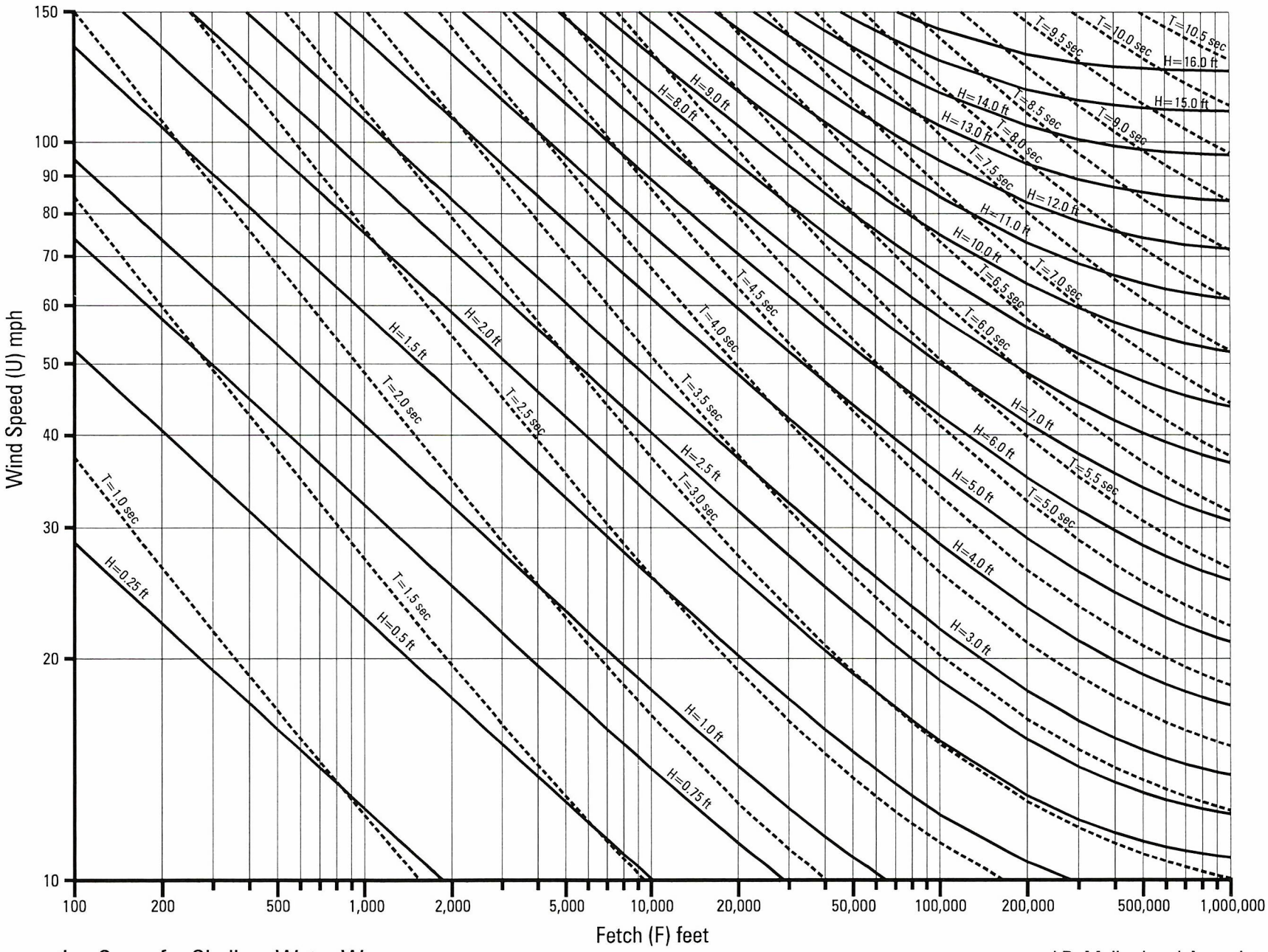
Constant Depth = 45 feet

2 of 2

Wave Height (feet)

Fetch (feet)	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
100										
200										
300										
400										
500										
600										
700										
800										
900										
1,000										
1,100										
1,200										
1,300										
1,400										
1,500										
1,600										
1,700										
1,800										
1,900										
2,000										
3,000										
3,395	150.00									
4,000	141.88									
4,934		150.00								
5,000	131.58	149.33								
6,000	123.76	140.58								
6,988			150.00							
7,000	117.55	133.63	149.92							
8,000	112.45	127.92	143.62							
9,000	108.15	123.11	138.31							
9,753				150.00						
10,000	104.47	118.98	133.76	148.84						
13,542					150.00					
18,912						150.00				
20,000	83.48	95.54	107.94	120.73	133.97	147.71				
26,963							150.00			
30,000	73.51	84.42	95.73	107.49	119.77	132.62	146.09			
40,000	67.32	77.53	88.18	99.34	111.06	123.41	136.45			
40,294								150.00		
50,000	62.98	72.70	82.91	93.66	105.02	117.06	129.84	143.44		
60,000	59.70	69.07	78.95	89.41	100.52	112.35	124.98	138.48		
67,451									150.00	
70,000	57.11	66.20	75.83	86.08	97.01	108.70	121.23	134.68	149.12	
80,000	55.00	63.87	73.30	83.38	94.17	105.77	118.24	131.68	146.15	
90,000	53.23	61.92	71.19	81.13	91.83	103.36	115.80	129.25	143.77	
100,000	51.72	60.25	69.40	79.24	89.85	101.34	113.77	127.24	141.83	
187,500										150.00
200,000	43.40	51.15	59.69	69.11	79.53	91.05	103.75	117.70	132.95	149.51
300,000	39.71	47.17	55.55	64.95	75.49	87.25	100.30	114.67	130.37	147.40
400,000	37.57	44.90	53.24	62.71	73.41	85.40	98.72	113.38	129.36	146.63
500,000	36.16	43.43	51.79	61.35	72.20	84.38	97.91	112.76	128.90	146.30
600,000	35.17	42.41	50.81	60.46	71.44	83.77	97.44	112.42	128.66	146.14
700,000	34.44	41.67	50.11	59.84	70.94	83.39	97.16	112.23	128.54	146.06
800,000	33.88	41.11	49.59	59.41	70.59	83.13	96.99	112.11	128.46	146.01
900,000	33.45	40.68	49.21	59.09	70.35	82.96	96.87	112.04	128.42	145.99
1,000,000	33.10	40.34	48.91	58.85	70.18	82.84	96.79	111.99	128.39	145.97

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph



Forecasting Curve for Shallow-Water Waves.
(USCE, 1977)

Constant Depth = 50 feet

J.D. Mollard and Associates Limited
November, 1993

Chart Data - Wind Speed (mph)

Constant Depth = 50 feet

1 of 2

Wave Period (seconds)

Fetch (feet)	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
100	37.37	84.34									
101			150.00								
200	26.55	59.87	106.92								
252				150.00							
300	21.77	49.03	87.57	137.57							
400	18.93	42.58	76.03	119.47							
500	16.99	38.17	68.15	107.11							
536					150.00						
600	15.57	34.92	62.34	97.98	142.02						
700	14.47	32.40	57.82	90.88	131.76						
800	13.58	30.37	54.18	85.16	123.48						
900	12.85	28.69	51.16	80.42	116.62						
1,000	12.24	27.27	48.61	76.41	110.81						
1,028						150.00					
1,100	11.71	26.05	46.42	72.95	105.81	145.15					
1,200	11.25	24.99	44.51	69.94	101.45	139.18					
1,300	10.84	24.05	42.82	67.29	97.60	133.92					
1,400	10.49	23.22	41.32	64.92	94.18	129.23					
1,500	10.16	22.47	39.97	62.80	91.10	125.01					
1,556	10.00										
1,600		21.79	38.75	60.88	88.31	121.19					
1,700		21.18	37.64	59.13	85.77	117.72					
1,800		20.61	36.62	57.52	83.45	114.54					
1,824							150.00				
1,900		20.10	35.69	56.05	81.31	111.61	147.10				
2,000		19.62	34.83	54.69	79.33	108.90	143.54				
3,000		16.28	28.75	45.08	65.38	89.78	118.40				
3,059								150.00			
4,000		14.31	25.15	39.36	57.06	78.36	103.38	132.26			
4,918									150.00		
5,000		12.98	22.71	35.47	51.39	70.57	93.12	119.18	148.86		
6,000		12.01	20.91	32.61	47.21	64.82	85.54	109.51	136.84		
7,000		11.27	19.53	30.39	43.96	60.35	79.65	101.98	127.47		
7,656										150.00	
8,000		10.68	18.42	28.61	41.35	56.75	74.90	95.91	119.92	147.03	
9,000		10.19	17.51	27.14	39.19	53.76	70.96	90.88	113.65	139.39	
9,460		10.00									
10,000			16.74	25.90	37.37	51.25	67.63	86.63	108.35	132.92	
11,630											150.00
20,000			12.69	19.29	27.58	37.66	49.62	63.56	79.56	97.74	118.21
30,000			11.00	16.46	23.34	31.72	41.70	53.36	66.79	82.10	99.38
40,000			10.03	14.83	20.86	28.23	37.01	47.30	59.19	72.76	88.13
40,424			10.00								
50,000				13.74	19.20	25.88	33.84	43.19	54.01	66.40	80.44
60,000				12.97	18.00	24.16	31.52	40.18	50.21	61.71	74.77
70,000				12.37	17.09	22.85	29.74	37.85	47.26	58.07	70.36
80,000				11.91	16.36	21.80	28.31	35.98	44.90	55.14	66.81
90,000				11.53	15.77	20.94	27.14	34.45	42.94	52.72	63.88
100,000				11.22	15.28	20.23	26.16	33.15	41.30	50.68	61.40
164,651				10.00							
200,000					12.76	16.53	21.03	26.35	32.58	39.80	48.11
300,000					11.75	15.02	18.91	23.50	28.88	35.14	42.36
400,000					11.19	14.18	17.71	21.88	26.76	32.44	39.02
500,000					10.83	13.64	16.93	20.81	25.35	30.65	36.79
600,000					10.58	13.25	16.38	20.05	24.35	29.36	35.18
700,000					10.39	12.96	15.97	19.48	23.59	28.38	33.95
800,000					10.25	12.74	15.64	19.04	23.00	27.61	32.98
900,000					10.13	12.56	15.38	18.67	22.51	26.99	32.19
1,000,000					10.04	12.41	15.17	18.38	22.11	26.47	31.54

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 50 feet

2 of 2

Wave Period (seconds)

Fetch (feet)	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50		
100											
200											
300											
400											
500											
600											
700											
800											
900											
1,000											
1,100											
1,200											
1,300											
1,400											
1,500											
1,600											
1,700											
1,800											
1,900											
2,000											
3,000											
4,000											
5,000											
6,000											
7,000											
8,000											
9,000											
10,000											
17,355	150.00										
20,000	141.09										
25,584		150.00									
30,000	118.76	140.34									
37,460			150.00								
40,000	105.40	124.67	146.08								
50,000	96.26	113.94	133.62								
54,772				150.00							
60,000	89.50	106.01	124.40	144.81							
70,000	84.25	99.83	117.23	136.55							
80,000	80.01	94.85	111.43	129.88							
80,462					150.00						
90,000	76.51	90.72	106.62	124.34	143.99						
100,000	73.55	87.23	102.56	119.65	138.64						
119,658						150.00					
182,038							150.00				
200,000	57.60	68.37	80.54	94.22	109.54	126.64	145.67				
288,024								150.00			
300,000	50.65	60.11	70.85	83.00	96.67	112.01	129.17	148.31			
400,000	46.59	55.26	65.15	76.37	89.05	103.34	119.39	137.36			
488,633									150.00		
500,000	43.87	52.01	61.30	71.89	83.90	97.47	112.77	129.95	149.20		
600,000	41.90	49.64	58.50	68.62	80.13	93.18	107.92	124.52	143.17		
700,000	40.39	47.82	56.35	66.11	77.23	89.87	104.18	120.34	138.54		
800,000	39.20	46.38	54.64	64.11	74.92	87.23	101.20	117.01	134.85		
900,000	38.23	45.20	53.24	62.47	73.03	85.07	98.76	114.28	131.82		
1,000,000	37.42	44.22	52.07	61.10	71.44	83.26	96.71	111.99	129.29		

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Constant Depth = 50 feet

1 of 2

Wave Height (feet)

Fetch (feet)	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	4.00	5.00	6.00
100	28.68	52.15	74.00	94.87	134.68						
148						150.00					
200	22.32	40.59	57.59	73.84	104.86	134.53					
253							150.00				
300	19.28	35.05	49.74	63.78	90.58	116.24	141.09				
393								150.00			
400	17.37	31.59	44.83	57.49	81.66	104.79	127.22	149.11			
500	16.03	29.14	41.36	53.04	75.34	96.71	117.42	137.64			
600	15.01	27.28	38.72	49.66	70.55	90.56	109.97	128.93			
700	14.20	25.81	36.63	46.97	66.74	85.68	104.05	122.00			
795									150.00		
800	13.53	24.59	34.90	44.76	63.61	81.66	99.18	116.30	149.68		
900	12.97	23.57	33.45	42.90	60.96	78.28	95.08	111.50	143.53		
1,000	12.49	22.69	32.20	41.30	58.69	75.37	91.56	107.38	138.24		
1,100	12.07	21.92	31.11	39.91	56.72	72.83	88.48	103.78	133.63		
1,200	11.70	21.24	30.15	38.67	54.97	70.59	85.76	100.60	129.56		
1,300	11.36	20.64	29.30	37.57	53.41	68.59	83.34	97.77	125.92		
1,386										150.00	
1,400	11.07	20.10	28.52	36.58	52.00	66.79	81.16	95.21	122.65	149.48	
1,500	10.80	19.60	27.82	35.69	50.73	65.16	79.18	92.90	119.68	145.89	
1,600	10.55	19.15	27.18	34.87	49.56	63.67	77.37	90.78	116.97	142.60	
1,700	10.33	18.74	26.60	34.11	48.50	62.30	75.71	88.84	114.49	139.59	
1,800	10.12	18.36	26.05	33.42	47.51	61.04	74.18	87.05	112.19	136.80	
1,861	10.00										
1,900		18.01	25.55	32.78	46.60	59.87	72.76	85.38	110.06	134.22	
2,000		17.68	25.09	32.18	45.75	58.77	71.44	83.84	108.08	131.82	
2,207											150.00
3,000		15.29	21.69	27.81	39.55	50.84	61.81	72.57	93.65	114.33	134.80
4,000		13.80	19.56	25.09	35.68	45.87	55.79	65.53	84.62	103.40	122.01
5,000		12.75	18.07	23.17	32.95	42.36	51.54	60.55	78.24	95.67	112.98
6,000		11.97	16.93	21.71	30.87	39.70	48.31	56.77	73.40	89.80	106.12
7,000		11.34	16.04	20.55	29.22	37.59	45.75	53.77	69.55	85.14	100.66
8,000		10.83	15.30	19.60	27.87	35.85	43.64	51.30	66.39	81.31	96.18
9,000		10.41	14.68	18.80	26.73	34.38	41.86	49.22	63.72	78.08	92.41
10,000		10.05	14.16	18.12	25.75	33.13	40.34	47.44	61.43	75.30	89.16
10,137		10.00									
20,000			11.21	14.27	20.21	25.99	31.66	37.27	48.39	59.50	70.70
28,829			10.00								
30,000				12.50	17.61	22.61	27.54	32.43	42.18	51.98	61.90
40,000				11.44	16.02	20.53	24.99	29.43	38.32	47.29	56.43
50,000				10.72	14.92	19.08	23.21	27.33	35.60	43.99	52.58
60,000				10.20	14.12	18.00	21.87	25.75	33.55	41.50	49.67
64,817				10.00							
70,000					13.49	17.16	20.82	24.50	31.94	39.53	47.37
80,000					12.99	16.48	19.97	23.49	30.61	37.92	45.48
90,000					12.58	15.92	19.27	22.64	29.51	36.57	43.91
100,000					12.24	15.44	18.67	21.93	28.57	35.42	42.56
200,000					10.55	13.00	15.50	18.06	23.39	29.04	35.07
283,305					10.00						
300,000						12.06	14.22	16.44	21.13	26.20	31.71
400,000						11.56	13.53	15.55	19.85	24.55	29.73
500,000						11.27	13.10	14.99	19.02	23.46	28.42
600,000						11.07	12.82	14.61	18.44	22.70	27.49
700,000						10.94	12.62	14.34	18.02	22.13	26.80
800,000						10.84	12.47	14.14	17.70	21.69	26.26
900,000						10.76	12.36	13.98	17.45	21.35	25.83
1,000,000						10.70	12.27	13.86	17.25	21.07	25.49

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

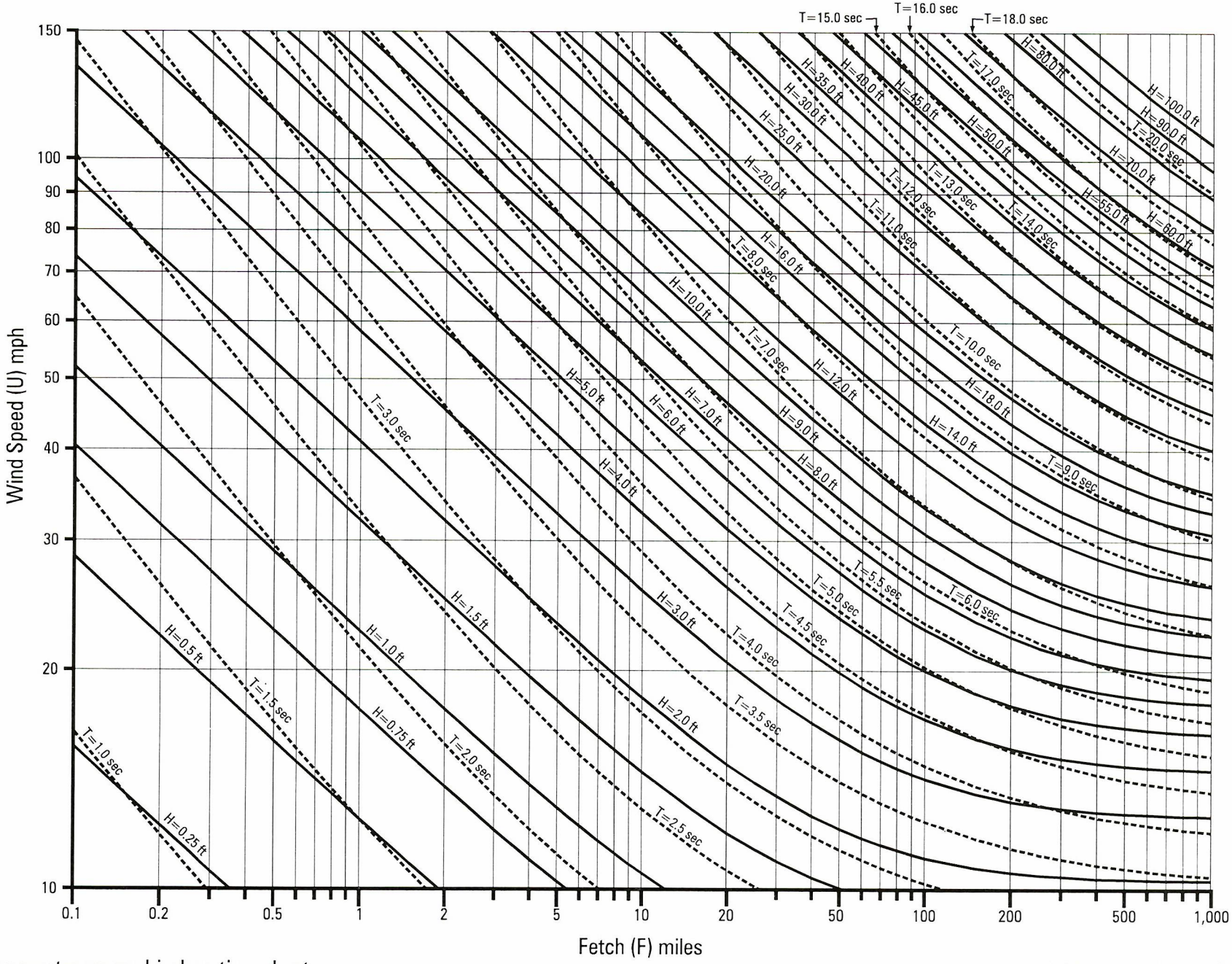
Constant Depth = 50 feet

2 of 2

Wave Height (feet)

Fetch (feet)	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
100										
200										
300										
400										
500										
600										
700										
800										
900										
1,000										
1,100										
1,200										
1,300										
1,400										
1,500										
1,600										
1,700										
1,800										
1,900										
2,000										
3,000										
3,310	150.00									
4,000	140.56									
4,763		150.00								
5,000	130.25	147.57								
6,000	122.43	138.80								
6,663			150.00							
7,000	116.21	131.83	147.58							
8,000	111.09	126.10	141.26							
9,000	106.79	121.28	135.93							
9,148				150.00						
10,000	103.09	117.14	131.36	145.79						
12,426					150.00					
16,829						150.00				
20,000	82.04	93.59	105.38	117.46	129.87	142.64				
22,926							150.00			
30,000	72.03	82.40	93.06	104.06	115.43	127.22	139.47			
31,791								150.00		
40,000	65.80	75.44	85.41	95.76	106.52	117.74	129.47	141.74		
45,788									150.00	
50,000	61.42	70.56	80.05	89.95	100.30	111.15	122.54	134.52	147.16	
60,000	58.11	66.87	76.02	85.59	95.64	106.22	117.38	129.18	141.67	
70,000	55.49	63.96	72.83	82.15	91.98	102.37	113.36	125.03	137.43	
71,675										150.00
80,000	53.35	61.59	70.24	79.36	89.01	99.25	110.13	121.71	134.06	147.24
90,000	51.56	59.59	68.06	77.03	86.54	96.66	107.45	118.98	131.31	144.49
100,000	50.03	57.90	66.21	75.04	84.44	94.47	105.20	116.70	129.02	142.22
200,000	41.53	48.50	56.04	64.24	73.17	82.90	93.53	105.12	117.73	131.41
300,000	37.71	44.30	51.56	59.58	68.44	78.23	89.03	100.88	113.85	127.95
400,000	35.47	41.86	48.99	56.95	65.85	75.76	86.74	98.85	112.09	126.47
500,000	33.98	40.24	47.31	55.28	64.24	74.28	85.44	97.74	111.18	125.75
600,000	32.92	39.10	46.14	54.13	63.17	73.33	84.63	97.08	110.66	125.35
700,000	32.13	38.25	45.28	53.31	62.43	72.68	84.10	96.66	110.35	125.13
800,000	31.52	37.60	44.63	52.70	61.89	72.23	83.74	96.39	110.15	124.99
900,000	31.04	37.09	44.12	52.23	61.48	71.91	83.49	96.21	110.03	124.91
1,000,000	30.64	36.68	43.72	51.87	61.18	71.67	83.31	96.08	109.94	124.85

Data Limits
Fetch 100 to 1,000,000 feet
Wind Speed 10 to 150 mph



Deepwater wave hindcasting chart.
(USCE, 1977)

J.D. Mollard and Associates Limited
November, 1993

Chart Data - Wind Speed (mph)

Deepwater

1 of 3

Wave Period (seconds)

Fetch (miles)	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
0.1	16.41	36.50	64.61	100.76	144.94						
0.15	13.54	29.94	52.90	82.41	118.49						
0.17						150.00					
0.2	11.84	26.05	45.93	71.50	102.74	139.66					
0.25	10.69	23.41	41.19	64.06	92.00	125.03					
0.29	10.00										
0.30							150.00				
0.3		21.46	37.70	58.58	84.09	114.23	149.02				
0.4		18.75	32.82	50.90	72.99	99.10	129.23				
0.48								150.00			
0.5		16.92	29.51	45.68	65.44	88.79	115.74	146.28			
0.6		15.58	27.07	41.84	59.88	81.20	105.80	133.67			
0.7		14.54	25.19	38.86	55.57	75.31	98.08	123.89			
0.73									150.00		
0.8		13.72	23.68	36.47	52.10	70.56	91.87	116.01	142.99		
0.9		13.04	22.43	34.50	49.23	66.64	86.73	109.49	134.93		
1		12.46	21.39	32.83	46.81	63.33	82.39	103.98	128.11		
1.07										150.00	
1.5		10.56	17.87	27.23	38.65	52.15	67.71	85.34	105.05	126.83	
1.51										150.00	
1.73		10.00									
2			15.82	23.94	33.84	45.53	59.02	74.29	91.36	110.22	130.88
2.5			14.44	21.73	30.59	41.06	53.12	66.78	82.05	98.93	117.41
3			13.45	20.11	28.22	37.78	48.79	61.27	75.21	90.62	107.49
4			12.08	17.88	24.93	33.22	42.77	53.59	65.67	79.01	93.63
5			11.17	16.40	22.72	30.15	38.71	48.39	59.20	71.14	84.22
6			10.52	15.32	21.12	27.92	35.74	44.59	54.46	65.37	77.31
7			10.03	14.50	19.89	26.20	33.46	41.66	50.81	60.91	71.97
7.06			10.00								
8				13.85	18.92	24.84	31.64	39.31	47.88	57.34	67.69
9				13.32	18.12	23.72	30.14	37.39	45.47	54.40	64.16
10				12.88	17.45	22.78	28.89	35.77	43.45	51.92	61.19
15				11.44	15.26	19.69	24.73	30.40	36.70	43.65	51.24
20				10.63	14.02	17.92	22.35	27.30	32.80	38.84	45.44
25				10.10	13.21	16.76	20.77	25.24	30.20	35.64	41.56
26.16				10.00							
30					12.63	15.93	19.64	23.77	28.32	33.32	38.75
40					11.85	14.81	18.11	21.76	25.77	30.15	34.91
50					11.34	14.08	17.10	20.44	24.09	28.06	32.36
60					10.98	13.56	16.39	19.49	22.88	26.56	30.53
70					10.71	13.16	15.85	18.78	21.97	25.42	29.14
80					10.50	12.86	15.43	18.23	21.26	24.53	28.05
90					10.34	12.61	15.09	17.77	20.68	23.80	27.16
100					10.20	12.41	14.81	17.40	20.20	23.20	26.42
117.84					10.00						
150						11.76	13.90	16.19	18.64	21.25	24.02
200						11.40	13.40	15.53	17.78	20.16	22.68
250						11.17	13.09	15.10	17.23	19.46	21.82
300						11.02	12.86	14.80	16.84	18.97	21.21
400						10.81	12.57	14.41	16.32	18.31	20.39
500						10.68	12.39	14.15	15.99	17.89	19.87
600						10.59	12.26	13.98	15.76	17.60	19.50
700						10.53	12.17	13.85	15.59	17.38	19.23
800						10.48	12.10	13.76	15.46	17.22	19.02
900						10.44	12.04	13.68	15.36	17.08	18.86
1000						10.41	12.00	13.61	15.27	16.97	18.72

Data Limits

Fetch 0.1 to 1,000 Statute Miles

Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Deepwater

2 of 3

Wave Period (seconds)

Fetch (miles)	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00
0.1											
0.15											
0.2											
0.25											
0.3											
0.4											
0.5											
0.6											
0.7											
0.8											
0.9											
1											
1.5											
2											
2.5											
2.82	150.00										
3	145.63										
4	126.66										
4.85		150.00									
5	113.77	147.86									
6	104.29	135.42									
7	96.96	125.78									
7.84			150.00								
8	91.07	118.03	148.58								
9	86.21	111.63	140.44								
10	82.11	106.24	133.57								
12.07				150.00							
15	68.36	88.08	110.42	135.37							
17.87					150.00						
20	60.31	77.42	96.78	118.40	142.28						
25	54.90	70.23	87.57	106.93	128.30						
25.61						150.00					
30	50.97	65.00	80.85	98.54	118.06	139.44					
35.75							150.00				
40	45.57	57.77	71.55	86.90	103.84	122.37	142.50				
48.78								150.00			
50	41.97	52.95	65.32	79.09	94.27	110.87	128.89	148.34			
60	39.38	49.46	60.80	73.41	87.30	102.48	118.95	136.72			
65.30									150.00		
70	37.41	46.80	57.34	69.06	81.95	96.02	111.30	127.77	145.44		
80	35.85	44.69	54.60	65.59	77.68	90.88	105.19	120.61	137.16		
85.97										150.00	
90	34.58	42.97	52.36	62.76	74.19	86.66	100.17	114.73	130.35	147.03	
100	33.52	41.54	50.49	60.40	71.27	83.13	95.97	109.80	124.63	140.47	
111.57											150.00
150	30.08	36.85	44.35	52.60	61.62	71.42	82.01	93.40	105.59	118.58	132.39
200	28.15	34.21	40.87	48.17	56.12	64.72	73.99	83.94	94.58	105.90	117.92
250	26.90	32.48	38.60	45.26	52.49	60.30	68.69	77.68	87.27	97.46	108.28
300	26.01	31.26	36.98	43.19	49.90	57.13	64.88	73.17	82.00	91.38	101.31
400	24.82	29.61	34.80	40.39	46.40	52.84	59.72	67.05	74.83	83.08	91.79
500	24.05	28.55	33.39	38.57	44.12	50.04	56.34	63.03	70.12	77.61	85.51
600	23.51	27.80	32.39	37.28	42.50	48.04	53.93	60.16	66.75	73.70	81.01
700	23.11	27.24	31.64	36.32	41.28	46.54	52.11	58.00	64.20	70.74	77.60
800	22.80	26.81	31.06	35.56	40.33	45.37	50.69	56.30	62.21	68.41	74.92
900	22.55	26.46	30.59	34.95	39.56	44.42	49.54	54.93	60.59	66.53	72.75
1000	22.35	26.17	30.20	34.45	38.93	43.64	48.59	53.79	59.25	64.96	70.94

Data Limits
Fetch 0.1 to 1,000 Statute Miles
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Deepwater

3 of 3

Wave Period (seconds)

Fetch (miles)	18.00	20.00
0.1		
0.15		
0.2		
0.25		
0.3		
0.4		
0.5		
0.6		
0.7		
0.8		
0.9		
1		
1.5		
2		
2.5		
3		
4		
5		
6		
7		
8		
9		
10		
15		
20		
25		
30		
40		
50		
60		
70		
80		
90		
100		
143.00	150.00	
150	147.01	
200	130.64	
227.59		150.00
250	119.71	144.43
300	111.80	134.46
400	100.98	120.79
500	93.83	111.73
600	88.70	105.20
700	84.81	100.25
800	81.75	96.34
900	79.26	93.17
1000	77.20	90.53

Data Limits

Fetch 0.1 to 1,000 Statute Miles

Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Deepwater

1 of 3

Wave Height (feet)

Fetch (miles)	0.25	0.50	0.75	1.00	1.50	2.00	3.00	4.00	5.00	6.00	7.00
0.1	15.71	28.54	40.48	51.87	73.56	94.27	133.71				
0.14								150.00			
0.15	13.57	24.65	34.95	44.79	63.52	81.40	115.45	147.95			
0.2	12.24	22.22	31.50	40.36	57.24	73.35	104.03	133.31			
0.25									150.00		
0.25	11.30	20.50	29.06	37.23	52.80	67.66	95.96	122.97	149.05		
0.3	10.59	19.20	27.21	34.86	49.43	63.34	89.83	115.11	139.53		
0.35	10.00										
0.38										150.00	
0.4		17.31	24.53	31.42	44.55	57.08	80.95	103.73	125.73	147.13	
0.5		15.98	22.64	28.99	41.10	52.66	74.67	95.68	115.98	135.71	
0.55											150.00
0.6		14.97	21.20	27.15	38.48	49.30	69.91	89.58	108.57	127.04	145.10
0.7		14.17	20.06	25.68	36.40	46.63	66.12	84.72	102.68	120.15	137.22
0.8		13.52	19.13	24.48	34.69	44.43	63.00	80.72	97.84	114.48	130.75
0.9		12.97	18.34	23.47	33.25	42.59	60.38	77.36	93.76	109.71	125.29
1		12.50	17.66	22.60	32.01	41.00	58.12	74.47	90.25	105.61	120.61
1.5		10.86	15.31	19.56	27.68	35.43	50.21	64.32	77.95	91.20	104.16
1.92		10.00									
2			13.85	17.68	24.98	31.96	45.27	57.98	70.26	82.20	93.87
2.5			12.83	16.35	23.08	29.51	41.79	53.50	64.82	75.84	86.60
3			12.07	15.36	21.65	27.66	39.14	50.11	60.70	71.01	81.09
4			10.99	13.94	19.59	25.00	35.33	45.20	54.74	64.02	73.10
5			10.25	12.96	18.15	23.13	32.64	41.74	50.53	59.09	67.46
5.43			10.00								
6				12.23	17.07	21.72	30.62	39.12	47.35	55.36	63.19
7				11.67	16.23	20.62	29.01	37.05	44.82	52.39	59.79
8				11.21	15.55	19.72	27.70	35.35	42.75	49.96	57.01
9				10.84	14.98	18.97	26.61	33.93	41.01	47.92	54.67
10				10.53	14.50	18.33	25.67	32.71	39.52	46.16	52.66
12.15				10.00							
15					12.89	16.16	22.45	28.49	34.35	40.06	45.65
20					11.97	14.89	20.51	25.92	31.17	36.30	41.33
25					11.36	14.04	19.19	24.16	28.98	33.69	38.31
30					10.94	13.44	18.23	22.86	27.35	31.75	36.05
40					10.39	12.63	16.93	21.06	25.07	29.00	32.86
50					10.04	12.12	16.07	19.86	23.54	27.14	30.68
51.54					10.00						
60						11.77	15.47	19.00	22.43	25.79	29.08
70						11.52	15.03	18.36	21.59	24.75	27.85
80						11.33	14.69	17.87	20.94	23.94	26.88
90						11.18	14.42	17.47	20.41	23.28	26.09
100						11.06	14.20	17.14	19.97	22.73	25.43
150						10.71	13.55	16.15	18.61	21.00	23.32
200						10.55	13.23	15.64	17.91	20.08	22.19
250						10.47	13.04	15.34	17.49	19.53	21.49
300						10.41	12.93	15.15	17.21	19.16	21.02
400						10.35	12.79	14.92	16.87	18.70	20.44
500						10.33	12.72	14.80	16.69	18.44	20.11
600						10.31	12.68	14.72	16.57	18.28	19.89
700						10.30	12.66	14.68	16.49	18.17	19.74
800						10.29	12.64	14.64	16.44	18.09	19.64
900						10.29	12.63	14.62	16.40	18.03	19.56
1000						10.29	12.62	14.60	16.37	17.99	19.50

Data Limits
Fetch 0.1 to 1,000 Statute Miles
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Deepwater

2 of 3

Wave Height (feet)

Fetch (miles)	8.00	9.00	10.00	12.00	14.00	16.00	18.00	20.00	25.00	30.00	35.00
0.1											
0.15											
0.2											
0.25											
0.3											
0.4											
0.5											
0.6											
0.7											
0.75	150.00										
0.8	146.70										
0.9	140.58										
1.00		150.00									
1	135.32	149.78									
1.28			150.00								
1.5	116.86	129.34	141.63								
1.98				150.00							
2	105.31	116.56	127.64	149.35							
2.5	97.15	107.53	117.74	137.77							
2.85					150.00						
3	90.96	100.67	110.23	128.98	147.30						
3.92						150.00					
4	82.00	90.74	99.36	116.25	132.75	148.93					
5	75.67	83.73	91.68	107.25	122.47	137.40					
5.19							150.00				
6	70.87	78.41	85.85	100.43	114.67	128.64	142.37				
6.68								150.00			
7	67.05	74.19	81.22	95.00	108.47	121.68	134.67	147.45			
8	63.92	70.72	77.42	90.54	103.38	115.96	128.33	140.51			
9	61.29	67.80	74.21	86.79	99.09	111.14	123.00	134.67			
10	59.03	65.29	71.47	83.57	95.40	107.01	118.41	129.65			
11.37									150.00		
15	51.14	56.54	61.86	72.30	82.50	92.51	102.35	112.05	135.74		
17.57										150.00	
20	46.26	51.11	55.90	65.29	74.47	83.48	92.34	101.07	122.40	143.16	
25	42.85	47.31	51.72	60.36	68.82	77.12	85.29	93.33	113.00	132.14	
25.39											150.00
30	40.29	44.46	48.58	56.65	64.56	72.32	79.96	87.48	105.88	123.78	141.29
40	36.66	40.40	44.09	51.34	58.44	65.42	72.28	79.05	95.60	111.72	127.48
50	34.16	37.59	40.98	47.65	54.18	60.59	66.91	73.14	88.38	103.23	117.75
60	32.32	35.52	38.68	44.90	50.99	56.98	62.88	68.70	82.94	96.82	110.39
70	30.91	33.92	36.89	42.75	48.49	54.14	59.71	65.20	78.64	91.75	104.57
80	29.78	32.64	35.46	41.02	46.47	51.84	57.13	62.35	75.13	87.60	99.81
90	28.85	31.58	34.28	39.59	44.80	49.93	54.99	59.98	72.20	84.13	95.82
100	28.08	30.70	33.29	38.39	43.39	48.31	53.17	57.96	69.71	81.17	92.41
150	25.60	27.84	30.05	34.40	38.66	42.87	47.01	51.11	61.16	70.99	80.62
200	24.25	26.26	28.25	32.14	35.96	39.72	43.42	47.08	56.07	64.85	73.48
250	23.40	25.27	27.11	30.70	34.21	37.65	41.05	44.41	52.64	60.69	68.60
300	22.83	24.60	26.32	29.69	32.98	36.20	39.37	42.49	50.16	57.66	65.03
400	22.12	23.74	25.33	28.40	31.38	34.29	37.14	39.95	46.82	53.52	60.10
500	21.70	23.24	24.73	27.61	30.39	33.10	35.74	38.33	44.66	50.82	56.86
600	21.43	22.91	24.34	27.09	29.73	32.29	34.78	37.23	43.17	48.93	54.56
700	21.24	22.68	24.06	26.72	29.26	31.71	34.10	36.43	42.07	47.52	52.85
800	21.11	22.51	23.86	26.45	28.91	31.28	33.58	35.82	41.23	46.45	51.52
900	21.01	22.39	23.71	26.24	28.64	30.95	33.18	35.35	40.57	45.59	50.47
1000	20.93	22.29	23.60	26.08	28.43	30.69	32.86	34.97	40.05	44.91	49.62

Data Limits
Fetch 0.1 to 1,000 Statute Miles
Wind Speed 10 to 150 mph

Chart Data - Wind Speed (mph)

Deepwater

3 of 3

Wave Height (feet)

Fetch (miles)	40.00	45.00	50.00	55.00	60.00	70.00	80.00	90.00	100.00
0.1									
0.15									
0.2									
0.25									
0.3									
0.4									
0.5									
0.6									
0.7									
0.8									
0.9									
1									
1.5									
2									
2.5									
3									
4									
5									
6									
7									
8									
9									
10									
15									
20									
25									
30									
34.96	150.00								
40	142.93								
46.36		150.00							
50	131.99	146.00							
59.70			150.00						
60	123.72	136.82	149.74						
70	117.16	129.55	141.75						
75.09				150.00					
80	111.79	123.58	135.20	146.66					
90	107.29	118.57	129.70	140.68					
92.61					150.00				
100	103.44	114.29	124.99	135.55	145.98				
134.45						150.00			
150	90.09	99.42	108.62	117.70	126.68	144.36			
186.03							150.00		
200	81.97	90.33	98.58	106.74	114.80	130.68	146.28		
248.15								150.00	
250	76.39	84.06	91.64	99.13	106.54	121.14	135.49	149.62	
300	72.28	79.43	86.49	93.48	100.39	114.01	127.41	140.60	
321.69									150.00
400	66.58	72.97	79.29	85.54	91.72	103.92	115.92	127.75	139.42
500	62.80	68.66	74.44	80.17	85.83	97.02	108.03	118.88	129.60
600	60.10	65.55	70.94	76.27	81.55	91.96	102.22	112.33	122.32
700	58.07	63.21	68.29	73.31	78.28	88.08	97.74	107.26	116.67
800	56.50	61.39	66.21	70.98	75.69	85.00	94.16	103.20	112.13
900	55.24	59.92	64.54	69.09	73.60	82.49	91.24	99.87	108.40
1000	54.21	58.72	63.16	67.54	71.88	80.41	88.81	97.09	105.28

Data Limits
Fetch 0.1 to 1,000 Statute Miles
Wind Speed 10 to 150 mph

NOTES

Notes