Technical Memorandum:

Delta Risk Management Strategy (DRMS) Phase 1

Topical Area:

Wind-Wave Hazard

Final

Prepared by:

URS Corporation/Jack R. Benjamin & Associates, Inc.

Prepared for:
California Department of Water Resources (DWR)

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Subject: Delta Risk Management Strategy
Final Phase 1 Technical Memorandum – Wind-Wave Hazard

Dear Mr. Bagheban:

We are providing the final Wind-Wave Hazard Technical Memorandum (TM) (dated May 22, 2008) for Phase 1 of the Delta Risk Management Strategy (DRMS) project. Members of the Steering Committee's Technical Advisory Committee and agency staff reviewed the draft TM, and their comments were incorporated before the CALFED Independent Review Panel (IRP) review of the June 26, 2007, draft of the Risk Analysis Report. This final version of this TM addresses the IRP comments provided on the wind-wave hazard sections of the Risk Analysis Report.

This TM was prepared by Nick Garrity, Matthew Brennan, Bob Battalio, Annika Fain, Damien Kunz, and Francis Ludwig (all of Phillip Williams and Associates) and reviewed by Dr. Said Salah-Mars and Mr. Philip Mineart (both of URS) and Dr. Marty McCann (JBA). Internal peer review was provided in accordance with URS' quality assurance program, as outlined in the DRMS project management plan.

Sincerely,

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Topical Area: Wind-Wave Hazard

Preamble

In response to Assembly Bill (AB) 1200 (Laird, chaptered, September 2005), the California Department of Water Resources (DWR) authorized the Delta Risk Management Strategy (DRMS) project to perform a Risk Analysis of the Sacramento–San Joaquin Delta (Delta) and Suisun Marsh (Phase 1) and to develop a set of improvement strategies to manage those risks (Phase 2).

AB 1200 amends Section 139.2 of the Water Code to read: "The department shall evaluate the potential impacts on water supplies derived from the Sacramento–San Joaquin Delta based on 50-, 100-, and 200-year projections for each of the following possible impacts on the Delta:

1. Subsidence
2. Earthquakes
3. Floods
4. Changes in precipitation, temperature, and ocean levels
5. A combination of the impacts specified in paragraphs (1) to (4) inclusive."

AB 1200 also amended Section 139.4 to read: "(a) The Department and the Department of Fish and Game shall determine the principal options for the Delta. (b) The Department shall evaluate and comparatively rate each option determined in subdivision (a) for its ability to do the following:

1. Prevent the disruption of water supplies derived from the Sacramento–San Joaquin Delta.
2. Improve the quality of drinking water supplies derived from the Delta.
3. Reduce the amount of salts contained in Delta water and delivered to, and often retained in, our agricultural areas.
4. Maintain Delta water quality for Delta users.
5. Assist in preserving Delta lands.
6. Protect water rights of the "area of origin" and protect the environments of the Sacramento–San Joaquin river systems.
7. Protect highways, utility facilities, and other infrastructure located within the Delta.
8. Preserve, protect, and improve Delta levees.…"

To meet the requirements of AB 1200, the DRMS project has been divided into two parts. Phase 1 involves the development and implementation of a Risk Analysis to evaluate the impacts of various stressing events on the Delta. Phase 2 evaluates the risk reduction potential of alternative options and develops risk management strategies for the long-term management of the Delta.

As part of the Phase 1 work, 12 technical memoranda (TMs), which address individual topical areas, and one risk report have been prepared. This TM addresses the wind-wave hazard issues that are considered in Phase 1. The TMs and the topical areas covered in the Phase 1 Risk Analysis are as follows:

1. Geomorphology of the Delta and Suisun Marsh
2. Subsidence of the Delta and Suisun Marsh
3. Seismology of the Delta and Suisun Marsh
4. Climate Change in the Delta and Suisun Marsh
5. Flood Hazard of the Delta and Suisun Marsh
6. Wind-Wave Hazard of the Delta and Suisun Marsh
7. Levee Vulnerability of the Delta and Suisun Marsh
8. Emergency Response and Repair of the Delta and Suisun Marsh Levees
9. Hydrodynamics, Water Quality, and Management and Operation of the Delta and Suisun Marsh (Water Analysis Module)*
10. Ecosystem Impacts to the Delta and Suisun Marsh
11. Impact to Infrastructure of the Delta and Suisun Marsh
12. Economic Consequences to the Delta and Suisun Marsh

*Two separate topical areas—the Hydrodynamics topical area and the Water Management topical area—were combined into one TM because of the strong interaction between them. The resulting TM is referred to as the Water Analysis Module (WAM).

The work products described in all of the TMs are integrated in the DRMS Risk Analysis. The results of the Risk Analysis are presented in a technical report referred to as:

13. Risk Analysis Report

Taken together, the Phase 1 TMs and the Risk Analysis Report constitute the full documentation of the DRMS Risk Analysis.

The Business-as-Usual Delta and Suisun Marsh: Assumptions and Definitions

To carry out the DRMS Phase 1 analysis, it was important to establish some assumptions about the future "look" of the Delta. To address the challenge of predicting the impacts of stressing events on the Delta and Suisun Marsh under changing future conditions, DRMS adopted the approach of evaluating impacts absent major future changes in the Delta as a baseline. Thus, the Phase 1 work did not incorporate or examine proposals for Delta improvements. Rather, Phase 1 identified the characteristics and problems of the current Delta (as of 2005), with its practices and uses. This approach, which allows for consideration of pre-existing agreements, policies, funded projects, and practices, is referred to as the "business-as-usual" (BAU) scenario. Defining a BAU Delta is necessary because one of the objectives of this project is to estimate whether the current practices of managing the Delta (i.e., BAU) are sustainable for the foreseeable future. The results of the Phase 1 Risk Analysis based on the BAU assumption not only maintained continuity with the existing Delta, but also served as the baseline for evaluating the risk reduction measures considered in Phase 2.

The existing procedures and policies developed to address "standard" emergencies in the Delta, as covered in the BAU scenario, do not cover some of the major (unprecedented) events in the Delta that are evaluated in the Risk Analysis. In these instances, prioritization of actions is based on (1) existing and expected future response resources and (2) the highest value of recovery/restoration given available resources.

This study relied solely on available data. In other words, the effects of stressing events (changing future earthquake frequencies, future rates of subsidence given continued farming practices, the change in the magnitude and frequency of storm events, and the potential effects of global warming) on the Delta and Suisun Marsh levees were estimated using readily available engineering and scientific tools or based on a broad and current consensus among practitioners. Using the current state of knowledge, the DRMS project team made estimates of the future magnitude and frequency of occurrence of the stressing events 50, 100, and 200 years from now to evaluate the change in Delta risks into the future.

Because of the limited time available to complete this work, no investigation or research was conducted to supplement the current state of knowledge.

Perspective

The analysis results presented in this TM do not represent the full estimate of risk for the Delta and Suisun Marsh. The full estimate of risk is the probable outcome of the hazards (earthquake, floods, climate change, subsidence, wind waves, and sunny day failures) combined with the conditional probability of the subject outcome (levee failures, emergency response, water management, hydrodynamic response of the Delta and Suisun Marsh, ecosystem response, and economic consequences) given the stressing events. A full characterization of risk is presented in the Risk Analysis Report. In that report, the integration of the initiating (stressing) events, the conditional probable response of the Delta levee system, and the expected probable consequences are integrated to develop a complete assessment of risk to the Delta and Suisun Marsh. In this context, the subject of this TM is one element of the Risk Analysis.

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DRMS Wind Wave Analysis Data Output CD, PWA
<Note: CD not provided with electronic submittal.>

List of Acronyms and Abbreviations

CEM	Coastal Engineering Manual
CI	confidence intervals
CIMIS	California Irrigation Management Information System
Delta	Sacramento-San Joaquin River Delta
DRMS	Delta Risk Management Strategy
DWR	California Department of Water Resources
ERR	emergency response and repair
GEV	Generalized Extreme Value Distribution
km/hr	kilometers/hour
m	meter(s)

m/s	meters/second
NARR	North American Regional Reanalysis
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PMF	probability mass function
SPM	Shore Protection Manual
Suisun Marsh	Suisun Bay and Marsh
WOCSS	Winds on Critical Streamline Surface

1.0 Introduction

This report presents the results of a wind and wind-wave analysis performed for the Sacramento–San Joaquin River Delta (Delta) and Suisun Bay and Marsh (Suisun Marsh) region of California (Figure 1). This analysis was conducted as part of the Delta Risk Management Strategy (DRMS) project, which is an effort funded by the California Department of Water Resources (DWR) and sponsored by DWR, the California Department of Fish and Game, and the U.S. Army Corps of Engineers.

The purpose of DRMS is to analyze the risk of levee failure in the Delta and Suisun Marsh and to develop alternative risk management strategies. In Phase 1 of the DRMS, probabilistic models are being developed to assess the risk to the Delta and the state of California to various hazards. Among the hazards to be considered are winds that generate waves in the Delta. These wind-generated waves can lead to levee erosion and potential breaching. Islands in the Delta are typically subsided to elevations below sea level and are protected from inundation by earth levees with varying degrees of repair, engineering, and armoring.

To evaluate the likelihood and severity of winds and wind waves, wind data were collected from multiple locations in the Delta and Suisun Marsh for this study. The wind data were analyzed to estimate the probability of extreme winds and their patterns, seasonal wind occurrences, and a range of wave conditions that may be caused by these winds. The methods and results of this study are meant for use in conjunction with other parts of the DRMS analyses, such as the risk analysis, emergency response and repair (ERR), levee vulnerability, and flood hazard.

Wind and wind waves pose a hazard to Delta levees. Winds blowing over water in Delta sloughs can generate waves that break on the waterside (outboard) slopes of Delta levees. However, the exterior erosion of the waterside slopes of the levees was not included as a failure mode in the risk analysis because the waterside levee slopes are protected by rip rap. This attribute, combined with emergency response and flood fighting, has prevented failures due to wave erosion in the past.

In the event that a levee surrounding a Delta island breaches along a Delta slough as a result of other failure modes, the island would be flooded and winds blowing over the length of the flooded island would generate waves. These waves may have the potential to erode the inner slopes (inboard side) of the levee, which are not armored. Inboard levee erosion could cause secondary levee breaches to form. Winds can also elevate the water level near barriers (called wind setup). High water levels are somewhat more likely to occur during high winds, and the combined effect (total water level and associated erosion and flooding) is, therefore, more likely than the probabilities associated with each of the forcing parameters considered separately (Garrity et al. 2007; FEMA 2005).

This report addresses wind-wave hazards and their probabilities. The effects of water levels, levee overtopping, and levee erosion and failure are evaluated in other parts of the DRMS project. This study did not analyze wind setup, wave transmission past levees due to wave overtopping, the joint probability of high winds/wind waves and high water levels (residuals or storm surges), or the probability of the flood response caused by high

wind waves and high water levels (e.g., wave runup, wave overtopping, levee erosion, and levee breaching).

2.0 Approach

A wind-wave analysis was developed with guidance from Jack R. Benjamin & Associates, Inc., to meet the needs of the DRMS risk analysis (Section 2.1). Winds and wind waves were analyzed separately. The wind analysis included both extreme winds that occur infrequently and typical winds that on average occur throughout each season and year. Extreme winds were analyzed using a probabilistic model of extreme wind events and their spatial patterns across the Delta and Suisun Marsh region (Section 2.1). For typical winds, the frequency of occurrence of wind speeds was analyzed in multiple directions (wind roses) for two seasons (fall-winter and spring-summer) and multiple locations. The approach to the wind-wave portion of the analysis is deterministic rather than probabilistic (Section 2.2). Wind-wave height, period, power, and runup were estimated for a range of wind speeds and open-water fetch lengths for use in other DRMS analyses, such as the ERR and levee vulnerability, which will assess levee erosion and failure. Deepwater conditions were assumed and wave transformations were ignored.

2.1 Extreme Wind Probability Model Approach

The extreme wind probability model is consistent with the probabilistic approach to the DRMS risk analysis. DRMS requires a probabilistic assessment of regional extreme wind events that can occur over the spatial dimensions of the Delta, rather than the probability of extreme winds at a particular location independent of other locations. Therefore, wind data and synoptic charts were analyzed in terms of regional wind patterns (meteorologies) that cause high winds. These meteorologies cause winds with relatively consistent seasonal and directional patterns. The following meteorologies were identified:

- *Pacific Low*: an extra-tropical low-pressure storm system moving from the Pacific through or to the north of the San Francisco Bay–Delta region, generally causing high winds from the southeast before frontal passage (and also from the southwest to west after frontal passage and sometimes before southeast frontal winds) in the Delta.
- *Polar Front*: a high-pressure cold front extending from the polar region and Canada coupled with a low-pressure system over the southern Great Basin, generally causing high winds from the north in the Delta.
- *Sea Breeze*: thermal pressure gradient between a cold high-pressure area over the Pacific and a warm low-pressure area inland. Sea breezes generally cause high winds from the west through the straits and over the coastal range and diverge to the northeast and southeast in the Delta.

Figures 2-a to 2-c show example synoptic weather charts for each meteorology.

To model the probability of regional winds, events for each meteorology in the measured regional wind data record were identified. These events were ranked by the highest peak wind speed measured at a particular location or wind station. The data generally showed that, during these events, wind speeds were relatively high throughout the Delta and Suisun region. For a given event, regional wind speeds were typically highest at Travis.

Travis was selected as the reference station to represent the regional probability of extreme wind events. For each meteorology, an extreme value analysis was performed on peak annual wind speeds measured at Travis (i.e., using high-wind events only). The analysis resulted in estimates of extreme "meteorological" wind events and their probabilities for Pacific Lows, Polar Fronts, and Sea Breezes.

To evaluate the wind patterns (speed and direction) throughout the study area, coincident wind data collected at other locations were compared to those collected at Travis. Then, wind data were scaled relative to the Travis data. Winds were estimated at nongauged locations throughout the study area by interpolation. For each meteorology, spatial scaling patterns for wind speed and direction were developed. Using triangulation, wind speeds were interpolated throughout the region for the highest peak wind events measured in each year. Wind direction for several measured high-wind events were interpolated using the Winds on Critical Streamline Surfaces (WOCSS) model (Ludwig et al. 1991). The WOCSS model was also tested for wind speed interpolation, but selected linear interpolation was selected as a more appropriate scheme. The wind speed and direction fields were interpolated for multiple events to estimate typical (mean) patterns of (1) (normalized) wind speed and (2) direction. The normalized wind-speed patterns and wind-direction patterns for each meteorology were used as the spatial scaling patterns. The variability in these patterns was accounted for in the probabilistic model.

Empirical probability distributions were developed for the direction, duration, and month of occurrence of measured high-wind events. These distributions were used to characterize these parameters for extreme wind events.

2.2 Wind-Wave Approach

Simple parametric equations for wind-wave generation and wave runup (USACE 1984, 2003; TAW 2002) were used to develop "look-up tables" for wind-wave height, period, power, and runup. Each look-up table is parameterized by wind speed and fetch length. The range in wind speed covers seasonal and extreme winds, and the range in fetch lengths covers possible fetches in Delta sloughs and islands and Suisun Marsh. Wind-wave conditions are dependent on island shape and fetch orientation, water depth, bed friction, and vegetation. Site-specific assessments to delineate fetches, estimate water depths, or characterize bed and vegetation types were not performed. The look-up tables developed as part of this analysis are based on deepwater conditions, which may be representative of Delta sloughs and deeply-subsided flooded islands. Water depth criteria are provided to allow users to determine whether the assumption of deepwater waves is valid, or whether shallow-water wave conditions are expected. Shallow water (relative to the wave length) limits wind-wave growth (USACE 1984, 2003).

3.0 Wind Analysis

The wind analysis included wind data collection (Section 3.1), development of an extreme wind probability model (Section 3.2), and seasonal winds (Section 3.3).

3.1 Wind Data Collection

Wind data are available from National Oceanic and Atmospheric Administration /National Weather Service (NOAA/NWS), DWR, and the California Irrigation

Management Information System (CIMIS). Wind stations are shown on Figure 1 and available wind data are summarized in Table 1. Wind data gaps were assessed as part of this analysis and are described in other DRMS documentation. Only a few wind stations are actually located in the Delta and Suisun Marsh and these stations are located on the periphery of the Delta and Suisun Marsh. Each agency uses different data collection and quality control procedures. The height of the wind gage at each station and the sampling interval over which winds are measured vary by station and agency. As described below, wind data were corrected to a standard anemometer height of 10 meters (m) and a 1-minute averaging period to give a consistent set of regional wind data.

Within the vicinity of the Delta and Suisun region, long-term data sets (approximately 60 years each) are available from NOAA/NWS for Sacramento Executive Airport (Sacramento), Stockton Metropolitan Airport (Stockton), and Travis Air Force Base/Fairfield (Travis). Other long-term data sets (approximately 30 years each) are available at Concord Buchanan Field Airport (Concord), Concord at Port Chicago, and Livermore Municipal Airport (Livermore). The wind gage height at these stations was changed at different times. The wind speed data were corrected to a 10-m height using procedures described in the USACE Coastal Engineering Manual (CEM) (USACE 2003). The sampling interval of the NOAA/NWS wind speed changed from a 1-minute average to a 2-minute average around July 1, 1996. The recent 2-minute average wind speed data were adjusted to a 1-minute average based on the CEM, which give an adjustment factor of 1.06. NOAA/NWS data are quality controlled. Additional limited checking of high-measured wind data was performed to identify and remove wind data points that appeared to be erroneous (Section 3.2).

Wind data measured from 1983 to 2006 at Stockton, Rio Vista, Martinez, Mallard, and Antioch were obtained from DWR. DWR wind speed data are measured in kilometers per hour and averaged over 15 minutes. The instantaneous wind direction is measured and reported every 15 minutes for 16 discrete compass directions (i.e., precision of 22.5 degrees). Wind gage heights were not available for the DWR data; however, DWR staff indicated that gage heights were approximately 10 meters (Dempsey 2006). DWR has performed some limited quality control of the wind data; however, high wind speed measurements (i.e., above 60 kilometers/hour [km/hr] or 17 meters/second [m/s]), which are of primary interest for the extreme wind analysis, may be suspect (Vayssières 2006).

CIMIS wind data from 1996-2006 at Lodi, Twitchell Island, and Hastings Tract were obtained (CIMIS 2006). The CIMIS wind data sampling interval is a 60-minute average and wind gage heights are 2 m above the ground, which were adjusted using CEM methods. The CIMIS wind data are quality controlled using an automated procedure. As the heights of the CIMIS wind gages are relatively close to the ground, CIMIS wind data are expected to have a greater potential to be affected by adjacent structures, such as buildings. The quality and consistency of the CIMIS wind data relative to the NWS wind data has not been evaluated or verified.

3.2 Extreme Wind Probability Model

To model the regional occurrence of extreme wind events, a probabilistic extreme wind probability model (model) was developed (Section 3.2.1). The model was implemented for the Delta and Suisun Marsh region using the collected wind data (Section 3.2.2).

3.2.1 Model Formulation

The wind model for the Delta can be denoted:

$$P(S(\underline{x}) > s(\underline{x}), \theta(\underline{x}), d, t \mid m_i) \quad (1)$$

where,

$P(\ )$ = annual probability of exceedance distribution

$\underline{x}$ = vector of geographic locations where the wind hazard is defined

$S(\underline{x})$ = wind speed at location $\underline{x}$

$\theta(\underline{x})$ = wind direction at location $\underline{x}$

d = event duration

t = time of year

m_i = meteorological event type (meteorology).

Equation 1 denotes the probability of wind events in the Delta and Suisun Marsh occurring in a direction and duration for a given period of the year. Different meteorologies are assumed to be independent.

Reference wind speed distribution. Given the occurrence of a meteorology m_i, a probability distribution of wind speeds for a reference location can be determined. This distribution can be denoted:

$P(S_R > s \mid m_i)$ where,

S_R = the wind speed at a reference location.

Spatial wind speed distribution. An occurrence of a wind event at a reference location will be accompanied by an associated pattern of coincident winds throughout the Delta. These patterns are spatially correlated due to the fact they are associated with the same wind event. The coincident wind speeds can be expressed:

$$S(\underline{x}, m_i) = S_R(m_i)\, u(\underline{x}, m_i) \quad (2)$$

where,

$u(\underline{x}, m_i)$ = spatial pattern of wind speeds (with respect to a reference location) in the Delta and Suisun Marsh, and defined as a function of meteorology

Given the occurrence of a wind speed at the reference location, the spatial pattern of wind speed will be random and can be expressed:

$$P(u(\underline{x}, m_i))$$

The distribution of this random variability of the spatial wind speed pattern with respect to the reference station is assumed to be lognormal (see Section 3.2.2.2). The distribution parameters are:

$\mu(\underline{x}, m_i)$ = the mean of the natural logarithm of the normalized wind speeds at location $\underline{x}$

$\sigma(\underline{x}, m_i)$ = the standard deviation of the natural logarithm of the normalized wind speeds at location $\underline{x}$; winds are assumed to be perfectly correlated in space.

The extreme tail of the lognormal distribution of the spatial wind speed pattern variability is truncated because real wind speed values are limited and may not reach extreme values in the distribution tail (see Section 3.2.2.2).

The exceedance probability of wind speeds at locations throughout the Delta (x) is a function of two random variables: the wind speed at the reference location (SR) and the random variability of the spatial wind speed pattern (u). The combination of these two random variables can be used to derive the probability distribution on winds at any location in the Delta and Suisun Marsh:

$$P(S(\underline{x}) > s(\underline{x}) \mid m_i) = P(S_R * u(\underline{x}) > s(\underline{x}) \mid u(x), m_i)\, P(u(\underline{x}) \mid m_i) \qquad (3)$$

Spatial wind direction distribution. For each meteorology, a probability mass function (PMF) on wind speed direction was determined from observations. This distribution can be denoted:

$P(\theta(\underline{x}) \mid m_i)$ where,

$\theta(\underline{x})$ = the wind direction for a given event at location $\underline{x}$.

The spatial pattern of wind directions can be denoted:

$\theta(\underline{x}, m_i) = h(\underline{x}, m_i) + \eta(\underline{x}_m, m_i)$ where,

$h(\underline{x}, m_i)$ = mean spatial wind direction pattern in the Delta and Suisun Bay, defined as a function of meteorology, m_i

$\eta(\underline{x}_m, m_i)$ = random variability of wind direction relative to the mean spatial wind direction pattern, represented as a PMF at:

$\underline{x}_m$ = the location of the wind station nearest to $\underline{x}$.

A simplified representation of highly variable data was necessary to develop the spatial wind direction patterns for each meteorology (see Section 3.2.2.3). Wind direction and its variation can be important in determining the appropriate wind fetch, wind-wave conditions, and wind-wave hazards including levee erosion. The wind direction distributions represent the direction of the peak wind speed for a given event, but do not model the temporal variation of wind direction within an event. This simplification can be mitigated somewhat by the way the method is applied. As described below, the wind direction distributions (PMFs) can be applied to give the probability of wind events with peak wind speeds occurring over a range of directions. The directional variability of winds and wind waves can be addressed using directional spreading functions (Goda 1985). An alternative, simplified approach is to select the primary direction for a given location and meteorology if, for example, that wind-wave direction might produce the greatest erosion.

The Pacific Low meteorology includes both southeasterly winds (typically prefrontal winds) and westerly winds (typically following passage of a cold front). Hence, in order to represent both wind conditions, wind speeds for Pacific Low events should be applied for two wind directions. For Pacific Low wind events, the duration of the wind event,

discussed below, can be split between the direction of the prefrontal wind speed and the direction of subsequent winds from the southwest to west.

Wind duration distribution. Observational data can be used to determine a PMF of wind event duration for different meteorological types. This can be denoted:

$$P(S(\underline{x}), d \mid m_i)$$

where,

d = wind speed duration above a given threshold (in hours) for a given wind event.

While the analysis of wind event duration showed that wind speed and wind event duration may be partially correlated (Section3.2.2.4), wind event duration was characterized independently of wind speed as a simplifying assumption. The simplified PMF of wind event duration can then be denoted:

$$P(d \mid m_i)$$

Timing of an event within a year. The timing of a wind event (for a given meteorology) within a year can be denoted by a PMF:

$$P(t \mid m_i)$$

where,

t = the month of occurrence of a wind event.

Probability of wind events. The probability of wind events can be determined from a combination of the various elements identified above. The probability of winds generally in the Delta and Suisun Marsh for events of a given meteorology can be expressed:

$$P(S(\underline{x}) > s(\underline{x}), \theta(\underline{x}), d, t \mid m_i) = P(S(\underline{x}) > s(\underline{x}) \mid m_i)\, P(\theta(\underline{x}) \mid m_i)\, P(d \mid m_i)\, P(t \mid m_i)$$

Uncertainty. Given there is epistemic uncertainty in the elements of the model, there is uncertainty in the estimate of the probability of wind events, (S(x), θ(x), d). Based on an analysis of these uncertainties and propagating them through the analysis, the uncertainty can be denoted:

$$\{P(S(x) > s(x), \theta(x), d|mi)j, pj\}$$

where,

pj = the probability weight associated with the jth wind model.

The epistemic uncertainty of the model is discussed in Section 5.1.

3.2.2 Model Implementation

The model was implemented by sorting data for high wind events by wind meteorology (Section 3.2.2.1), fitting extreme value probability distributions to the reference wind speed data (Section 3.2.2.2), developing spatial wind patterns and distributions (Section 3.2.2.3), and developing empirical probability distributions of wind event duration (Section 3.2.2.4) and month of occurrence (Section 3.2.2.5).

3.2.2.1 Extreme Wind Meteorologies

Three meteorologies were identified (Pacific Low, Polar Front, and Sea Breeze) that cause high winds, based on an assessment of measured wind direction patterns for high wind events and synoptic charts of weather and pressure systems from the National Centers for Environmental Prediction (NCEP) (2006) North American Regional Reanalysis (NARR) data and NOAA Central Library U.S. Daily Weather Maps Project (2006a). The wind data were first sorted by direction at Travis (reference station) to get an initial set of peak annual wind speeds for each meteorology. The directional sectors were:

- Pacific Low: 80 to 195 degrees from north, representing a “southeast” sector from approximately east-northeast to south
- Sea Breeze: 195 to 310 degrees from north, representing a “southwest” sector from approximately south to northwest
- Polar Front: 310 to 80 degrees from north, representing a “north” sector from approximately northwest to east-northeast.

The meteorology classification of each peak annual event was checked based wind speed and direction patterns at Travis, Sacramento, and Stockton and the time of year of each event. For events in which this information did not conform to the general pattern for the meteorology, synoptic charts were checked to confirm or re-classify the event meteorology. The peak wind speed and direction for certain events appeared to be erroneous. These wind events were not included in the extreme wind data sets as a quality control measure.

The time series of wind directions and wind event duration for Pacific Lows are complex. Wind directions during Pacific Low events may shift from southeast to west at a given location as the storm front moves through the region. During Pacific Low wind events, high wind speeds typically occur for a duration of approximately 12 hours. A Pacific Low storm system may have multiple storm fronts or may be a series of storms. Thus, these 12-hour wind events may be preceded or followed by wind events of similar duration in which the peak wind speed is less. Analyzing the time series of wind events and series of multiple events was not evaluated in this study. Sections 3.2.2.3 and 3.2.2.4 include additional discussion of wind direction and wind event duration, respectively, for Pacific Lows.

3.2.2.2 Reference Wind Speed Distribution

Travis was selected as the reference wind station because it has the longest data record and the wind speed at Travis is often the highest during high wind events (i.e., winds speeds at Travis are higher than at other stations for more than 80 percent of the peak annual wind events from 60 years of data record). As the spatial wind speed patterns are normalized, any station could be chosen as the reference station and the results are not expected to vary significantly due to which station is chosen.

Two different probability distributions were tested for the reference wind speed:

1. Gumbel (Extreme Value Type I) Distribution

2. Generalized Extreme Value Distribution (GEV)

The distributions were fit to annual maximum wind speed data for each meteorology. The Gumbel Distribution fit is discussed in Section 5.0. The GEV was used to develop the spatial wind speed distributions discussed below. As discussed in Section 5.0, wind speed estimates from the Gumbel distribution are approximately 10 percent higher than estimates from the GEV for extreme probabilities of approximately 0.002 or a 500-year return period.

The WAFO toolbox was used in Matlab (WAFO Group 2000) to fit the GEV using the maximum likelihood estimation procedure. The GEV parameters are k, μ, and σ. WAFO provides 95 percent confidence intervals (CI) for each parameter. The CI for the GEV were estimated by calculating the GEV CI for all combinations of parameter CI and selecting the widest interval from all combinations. These CI are expected to be equal to or "wider" than the 95 percent CI on the GEV. WAFO also provides plots that compare the GEV predictions to the measured data (comparison plots). Figures 3-a to 3-c show the GEV with the 95 percent CIs, the empirical data distribution, and comparison plots for each meteorology.

3.2.2.3 Spatial Wind Distribution

The WOCSS model was tested as a method for spatially interpolating wind speed and direction for this study. Triangulation was selected as a wind speed interpolation method over the WOCSS model. The WOCSS model results were used to interpolate wind direction patterns and develop a spatial wind direction pattern.

WOCSS Model

The WOCSS model interpolates wind speed and direction in space using an inverse distance interpolation scheme between data points (wind stations) and imposes physical constraints on the interpolation to account for the effects of topography and atmospheric layering (Ludwig et al. 1991; Ludwig and Sinton 1998). The physical principles of the WOCSS model are intended primarily to account for complex physical terrain and atmospheric stratification. The physical principles are based on a two-dimensional non-divergence constraint to force flow interaction with topography and atmospheric layers. The WOCSS model is not an atmospheric model and does not solve differential equations for the conservation of momentum.

Model setup. A WOCSS model was set up and test calculations performed for the Delta and Suisun Marsh. WOCSS model setup and input parameters included topography, atmospheric sounding data, and wind speed and direction data at station locations. A 1-kilometer resolution digital elevation model was generated from USGS data[1]. This topographic grid covered the region in UTM Zone 10S from approximately 4300 km to the north, 4134 km to the south, 540 km to the east, and 676 km to the west. Vertical profile data of wind and potential temperature from the Oakland Airport (NOAA Integrated Global Radiosonde Archive) (NOAA 2006b) were used for atmospheric

[1] Data available from U.S. Geological Survey, EROS Data Center, Sioux Falls, SD.

layering input, as specified for the WOCSS model. Wind station data from the Delta and Suisun Marsh region were also used.

Model runs. Test runs for the WOCSS model for the Delta and Suisun Marsh were performed. In the first set of runs, all available wind station data were input. In the second set, only the NWS wind data from Travis, Sacramento, Stockton, Livermore, and Concord were input. Both sets of runs were performed for 15 wind events (five from each meteorology). For each event, the model runs included 4 hours before the time of the peak wind and 4 hours after the peak wind (9 hours total). For one event, the model was also tested using only the inverse distance interpolation, without the physical adjustment.

Model results. Figure 4 shows selected results of the Delta and Suisun Marsh WOCSS model test runs. For the set of runs that included all available wind station data, the model results showed wind speed peaks at the location of each station and areas of lower wind speed between each station. The results for the runs using only NWS wind stations showed more spatially uniform wind speed patterns, with fewer areas of low wind speed between the stations and more gradual wind speed gradients. This result is likely due to two factors:

1. Wind speed measurements at the DWR and CIMIS stations tend to be lower than at the NWS stations, and
2. The WOCSS model's interpolation method appears to interpolate wind speeds between stations that may be lower than the wind speed at either station.

When interpolating any type of data, it is typical to test several different interpolation methods (e.g., linear, nearest neighbor, kriging, etc.) and select the method that gives the most representative results. Instead of using the WOCSS wind speed interpolation results, a triangulation method was selected to interpolate wind speeds for the more uniform wind conditions expected for the relatively flat, open topography of the Delta and Suisun Marsh. Other studies have shown that the WOCSS interpolation method significantly affects model results. Also, the WOCSS model has been shown to give better results when wind data from only one source with consistent measurement methods (e.g., a single agency) are used, rather than using data from multiple sources (Ludwig 2006). This is presumably due to differences in the wind data and data quality that cannot be accounted for by standard corrections for the duration of wind speed measurements and anemometer height.

A source of uncertainty in this analysis is the modeling of spatial wind patterns. This uncertainty is attributable to the period of record of the wind dataset and the number and spatial distribution of wind stations. An alternative to implementing and empirical, as used in this analysis, would be to develop atmospheric models and/or to collect additional Delta-specific wind data.

The WOCSS model's interpolation of wind direction does not appear to show the same "station biasing" as wind speed. The wind direction model results were used to develop the spatial wind direction patterns.

Spatial Wind Speed Distribution

Wind speed exceedance probability distributions were developed at selected locations throughout the Delta and Suisun Marsh region using normalized spatial wind speed patterns, applying these patterns to scale the reference wind speed distributions in space, and accounting for the variability in the spatial wind speed patterns.

Wind speed patterns. Normalized spatial wind speed patterns (mean and standard deviation) were developed from the peak annual wind events for each meteorology. For each event, wind speed at each NWS station (Travis, Sacramento, Stockton, Livermore, and Concord) was normalized by the wind speed at the reference station (Travis). The normalized wind speeds were mapped and normalized winds speeds were interpolated throughout the region using triangulation with cubic interpolation. Compared to triangle-based linear interpolation, triangle-based cubic interpolation produces a smooth surface between triangulation points. For each meteorology, the wind speed patterns for each peak annual event were averaged to give a mean normalized spatial wind speed pattern. The standard deviation of the normalized wind speeds was also calculated at each station The same interpolation method was used to give the variation of the wind pattern. The wind speed patterns were extended to the west of Travis and Concord and to the south of Livermore and Stockton to provide coverage of the western part of Suisun Marsh and the far south Delta, respectively. The patterns were extended by applying values from Stockton to a point south of Stockton and applying values from Travis and Concord to points west of these locations. Figures 5-a to 5-c show the normalized spatial wind speed scaling patterns (mean and standard deviation) for each meteorology.

Wind speed distributions. The probability of exceeding a wind speed at a particular location was represented in space as a function of wind speed at the reference station and the variation in the spatial wind speed pattern. The mean normalized spatial wind speed pattern was used to spatially scale the reference wind speed distribution for each meteorology. PMFs of the direction of the peak annual wind speed were calculated at each NWS station for each meteorology (Figures 6-a to 6-c). The variation in the spatial pattern was assumed to be log-normally distributed. The log-normal distributions of spatial pattern variability were truncated to account for physical limitations in spatial wind speed variability expected in the tail of the distribution. Depending on location, the distributions were truncated to two or three standard deviations ($\pm 2\sigma$ or $\pm 3\sigma$), which span most of the empirical data distribution (Figures 6-a to 6-c). The joint probability distribution of the independent parameters of reference wind speed (S_R) and the spatial wind speed variability (u) was then integrated to get a single-parameter exceedance probability distribution for wind speed at a particular location.

Judgment is required to select the truncation point for the lognormal distributions of spatial pattern variability. In locations where the standard deviation is high (e.g., in the vicinity of Stockton and Livermore in the south Delta), truncation at three standard deviations ($\pm 3\sigma$) would give wind speed estimates for low probabilities (e.g., less than approximately 0.02 to 0.01) that are higher than wind speed estimates at Travis with the same probabilities. Two standard deviations were therefore selected as the truncation points for south Delta locations (Jones Tract and Clifton Court Forebay) and three standard deviations were selected for other locations. Figures 7-a to 7-f show the

resulting wind speed exceedance probability distributions for each meteorology at six locations.

In general, ±2σ may give more reasonable results for south Delta locations (i.e., locations closer to Stockton and Livermore), while ±3σ may be acceptable for the central and north Delta and Suisun Marsh. As a general guideline, truncation at ±3σ can be used for locations where the standard deviation of the natural logarithm of the normalized wind speed (i.e., Figures 5-aii, 5-bii, and 5-cii) is less than approximately 0.3, and ±2σ when this parameter is greater than approximately 0.3.

Spatial Wind Direction Distribution

Wind direction exceedance probability distributions were developed at locations throughout the Delta and Suisun Marsh region using mean spatial wind direction patterns and PMFs of wind direction at each NWS station.

Wind direction patterns. For each wind event modeled with WOCSS (9 hours modeled per event), the wind direction results were averaged to give a spatial map of wind direction for each event. For the five events modeled for each meteorology, the wind event direction maps were averaged to give mean spatial wind direction patterns for each meteorology. Figures 8-a to 8-c show the mean spatial wind direction patterns for each meteorology. The range in wind direction was also calculated at several locations for each event and meteorology. These calculations generally indicate that wind direction varies by up to approximately ±30 degrees from the mean direction for a given event or meteorology.

Figure 9 shows the estimated wind speed and direction in the Delta and Suisun Marsh for the 100-year return period (0.01 annual exceedance probability) wind events from each meteorology based on the reference wind speed distributions, normalized median spatial wind speed patterns, and median spatial wind direction patterns. (Note: these maps do not account for the randomness in wind speeds, which is included in Figures 7-a to 7-f.).

Wind direction distributions. For each meteorology and each NWS station, PMFs of wind direction corresponding to the peak wind speed for peak annual wind events were developed (Figures 10-a to 10-e). In general, the range in wind direction for each meteorology at each station is typically 60 degrees or more. Wind direction distributions can be estimated by applying the peak wind direction PMFs (Figures 10-a to 10-e) to the mean spatial wind direction patterns (Figure 9). For a given location and meteorology, the wind direction PMF from the nearest NWS station and the wind speed exceedance curve at that location can be multiplied to give distributions of wind direction and wind speed exceedance. For locations and meteorologies where the mean spatial wind direction is different than the wind direction at the nearest NWS station, this difference in wind direction can be used to adjust or shift the wind direction PMF from the NWS station for that location. This adjustment is most important for the Sea Breezes, where the wind direction pattern is more variable throughout the Delta.

As an alternative to applying the wind direction distributions, the longest fetch within the direction range can be selected as discussed in Section 3.2.1. The longest fetch within this directional range can be used in the wind-wave look-up tables (Section 4) to estimate wind-wave conditions. Choosing the longest fetch within ±30 degrees of the mean wind

direction is consistent with analyses of the directional spreading of wave spectra. The Mitsuyasu-type directional spreading function discussed in Goda (1985) is based on field measurements and indicates that "about 85 percent of the wave energy is contained in the angular range of ±30 degrees." The simplified approaches to wind direction represent only the direction of the peak wind speed for the event. Using a directional spreading function can also account for the variation of winds and wind waves within an event.

For Pacific Lows, peak wind speeds typically occur within a range of directions centered around southeast (approximately 120 to 180 degrees or east-southeast to south for some locations), but may shift towards the southwest or west following the peak wind event and frontal passage. Therefore, for Pacific Low wind events, the peak wind speed should be applied to the range of directions (or the longest fetch within the range) from southwest to west in addition to the direction of the peak frontal wind speed. The duration of the wind event, discussed below, can be split between the direction of the peak prefrontal wind speed and the direction of subsequent winds from the southwest to west.

3.2.2.4 Duration

The duration of wind speeds above 11 m/s were plotted against wind speed for the peak annual wind events from each meteorology (Figure 11). Wind event duration and wind speed appear to be partially correlated for Polar Fronts and Sea Breezes, but not for Pacific Lows. This could be explained by the fact that Polar Fronts and Sea Breezes may be characterized by meteorological conditions (i.e., pressure systems) that persist for more than a day, whereas Pacific Low storm systems may tend to move through the region within a day.

PMFs of wind event duration were calculated for each meteorology using wind data from the reference station (Travis) (Figure 12), without consideration of wind speed. If the potential correlation with wind speed is not included as a simplifying assumption, the wind event duration PMFs could be applied to wind speed exceedance distributions at any location to give distributions of wind event duration and wind speed exceedance. This may tend to underestimate the probability of longer duration events associated with higher wind speeds, and overestimate the probability of longer durations for lower, bur more frequent wind speeds.

The wind event durations could be applied by assuming wind speeds increases from 11 m/s to the estimate peak wind speed, and then decreases back to 11 m/s over the event duration. For Pacific Lows, this may not account for multiple storm fronts or a series of storm fronts.

3.2.2.5 Month of Occurrence

PMFs for the month of occurrence of peak annual wind events from each meteorology were calculated using wind data at the reference station (Travis) (Figure 13). The wind speed exceedance distributions (or other distributions) at a particular location can be multiplied by the probability of occurrence for a month to give the probability of a wind event (wind of a given speed) occurring during a year. Figure 14 shows an example of these distributions for Twitchell Island.

3.3 Seasonal Winds

WRPLOT was used to create seasonal wind roses for the fall-winter season (October to March), spring-summer season (April to September), and the entire year for the period from 1997 to 2005 at each wind data station (NWS, DWR, and CIMIS). The wind roses give the percent occurrence of wind speeds (from low to high) in eight compass directions. For other DRMS analyses using the seasonal wind rose data (e.g., ERR) at a given location, the wind rose for the nearest NWS station can be used, as the NWS data are consistent and are expected to provide the most reliable data. Figures 15a to 15-e show the seasonal wind roses for the NWS stations (Travis, Sacramento, Stockton, Livermore, and Concord). Appendix A contains seasonal wind percent occurrence tables corresponding to the wind roses for the NWS stations. Figure 16 shows an example seasonal wind percent occurrence table. Appendix B contains seasonal wind roses and percent occurrence tables for the DWR and CIMIS wind stations.

4.0 Wind-Wave Analysis

Wind-wave calculations were performed to develop look-up tables (Tables 2 to 6) for wind-wave height and period (Section 4.1), wave power (Section 4.2), and wave runup (Section 4.3). These look-up tables can be used to estimate deepwater wind-wave heights and periods, power, and runup for seasonal or extreme winds and any fetch of interest in other DRMS analyses.

4.1 Wind-Wave Generation

Wind-wave heights and periods were calculated for a range of fetch lengths and wind speeds using the procedures and parametric deepwater wave equations for fetch-limited wave growth from the Shore Protection Manual (SPM) (USACE 1984). The SPM equations are similar to the CEM equations and differences are discussed in Section 5.2.

Wind speeds estimated in the wind analysis are based on wind speed data measured over land (and are corrected to a 10-m wind gage height and 1-minute averaging period). The over-land wind speeds were increased by a factor of 1.2 to estimate wind speeds over water, based on corrections provided in the CEM. The CEM recommends a correction factor of 1.2 for fetches less than 10 miles (16,000 m). For longer fetches, the CEM gives this correction factor as a function of wind speed based on a Great Lakes study and provides additional correction factors for air-sea temperature difference and the stability of the atmospheric boundary layer. The factor of 1.2 was used for all fetches for consistency and simplicity.

For fetch-limited wave growth conditions in sheltered waters, the wind blows steadily in a constant direction for a sufficient amount of time to achieve steady-state fetch-limited wave conditions. Wind-wave generation requires a sustained input of wind energy. The adjusted 1-minute average wind speeds represent sustained winds with durations of 1 minute. (Note that the sustained wind duration is different than the wind event duration analyzed in Section 3.2.2.4.) The duration of the sustained wind speed that gives steady-state fetch-limited wave conditions may be longer (or shorter) than 1 minute. For each 1-minute wind speed estimate, wind speeds corresponding to a range of durations using SPM equations were calculated and these combinations of wind speed-duration were

tested in the wave growth equations. The wind speed-duration equations from the SPM are:

$$\frac{U_t}{U_{3600}} = 1.277 + 0.296 \tanh\left\{0.9 \log_{10} \frac{45}{t}\right\} \quad for \quad 1 < t \le 3{,}600\, s$$

$$\frac{U_t}{U_{3600}} = -0.15 \log_{10} t + 1.5334 \quad for \quad 3{,}600 < t < 36{,}000\, s$$

where,

U_t = the sustained wind speed corresponding to duration t

U_{3600} = the sustained wind speed corresponding to a duration of one hour.

The wind speeds decrease in magnitude with a longer-averaging time.

The SPM wave-growth equations are functions of the wind stress factor. The wind stress factor is obtained from the adjusted wind speeds using the equation:

$$U_A = 0.71 U^{1.23}$$

where,

U = wind speed in m/s.

In the SPM wave growth equations, locally generated wind-wave height and period depend on wind speed, wind duration, fetch length, and water depth. The dimensionless forms of the SPM deepwater wave equations give spectral wave heights, peak periods of the wave spectrum, and durations as:

$$\frac{gH_{mo}}{U_A^2} = 1.6 \times 10^{-3} \left(\frac{gF}{U_A^2}\right)^{\frac{1}{2}}$$

$$\frac{gT_m}{U_A} = 2.857 \times 10^{-1} \left(\frac{gF}{U_A^2}\right)^{\frac{1}{3}}$$

$$\frac{gt}{U_A} = 6.88 \times 10^{1} \left(\frac{gF}{U_A^2}\right)^{\frac{2}{3}}$$

where,

H_{mo} = the spectrally based significant wave height

T_m = the period of the peak of the wave spectrum

F = the fetch (miles)

t = the duration

U_A = the wind-stress factor

g = acceleration due to gravity.

An automated computer code was used to find the wind-speed duration combination giving fetch-limited conditions. The code first calculates the duration for the highest wind speed-shortest wind duration combination to see if the calculated duration is sufficient to develop a fetch limited condition. If not, the code selects the next wind speed and repeats the calculation. When the calculated duration for a given wind speed and fetch length is greater than the corresponding wind duration, the corresponding wind stress factor is used to calculate deepwater wave heights and periods. This is considered to be the largest fetch limited condition.

Tables 2 and 3 contain the calculated deepwater wave heights and periods, respectively, for wind speeds (35 m/s, which has an exceedance probability of less than 0.002 for all meteorologies) and fetch lengths of interest.

The above analysis assumes that deepwater wave conditions exist on the flooded islands or in the sloughs. The deepwater assumption is satisfied when the depth of water is greater than the half the wave length of the wind generated wave. Table 4 contains the water depth for which the ratio of water depth to wave length (d/L) is equal to 0.5. The deepwater assumption is valid for all depths greater than the values in Table 4. The depths less then the values in Table 4 would be considered intermediate depths and the simplifying assumptions of deepwater (or shallow water) waves would not be strictly valid. For the shallow water assumption to be valid the ratio of depth to wave length would need to be less than 1/20. This condition would never be met for any conditions of importance to the risk analysis. In intermediate depth water, wave energy is partially dissipated by bottom friction. For a given wind speed, wave heights and periods would be less than in deepwater. Using the deepwater wave heights and periods from the look-up table for intermediate water conditions would therefore provide a conservative estimate of wind-wave conditions.

4.2 Wave Power

Wave power is a measure of the rate of wave energy transmitted to a surface, such as a coastal structure or levee. As defined in the CEM, wave power refers to “the average wave energy flux per unit wave crest width transmitted across a vertical plane perpendicular to the direction of wave advance.” Wave power is an indicator of potential work done toward levee erosion and generally provides an indication of intensity. Given that waves are dissipated over time and space, the actual work done on a surface depends on the shape of that surface and, hence, the antecedent wave conditions. Erosion is affected by the sequence of wave power, water levels, and event duration and is more accurately modeled in terms of a time series of waves and erosion.

For each combination of wave height and period in the wind-wave generation look-up table, deep wave power per unit crest in the direction of propagation, as defined by linear wave theory, is calculated by the following equation:

$$P = \frac{\gamma g H^2 T}{32\pi}$$ where,

γ = unit weight of water

g = acceleration due to gravity

H = wave height

T = wave period.

Table 5 is the wave power look-up table, parameterized by wind speed and fetch length, and gives the wave power calculated for each wave height and period from the wind-wave generation look-up table.

4.3 Wave Runup

Figure 17 shows a schematic of wave runup and associated wave processes for a coastal structure. Potential wave runup height is the height above the still water level that a wave breaking on a structure slope will reach as it travels up the slope, assuming the slope extends above the runup height. The actual wave runup height or elevation depends on the water level and structure crest elevation, which may limit runup height. However, potential wave runup is an indicator of water velocity on the structure slope, wave overtopping of the structure, and the potential for erosion of both the outboard levee slope and inboard levee slope (due to wave overtopping and head-cutting).

For each combination of wave height and period in the wind-wave generation look-up table, potential wave runup heights were calculated using the TAW method (2002) as described in the FEMA (2005) Guidelines for Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States (FEMA Guidelines). Wave runup is a function of the surf similarity parameter, which is calculated as:

$$\xi_o = \frac{m}{\sqrt{\frac{2\pi H_{mo}}{g T_{m-1.0}^2}}}$$

where,

m = structure slope

g = acceleration due to gravity

H_{mo} = spectral significant wave height at the structure toe

$T_{m\text{-}1.0}$ = spectral wave period.

The spectral wave period is related to the peak wave period estimated in the wind-wave generation look-up tables (T_p) as follows:

$$T_{m-1.0} = \frac{T_p}{1.1}$$

The TAW wave runup equation is:

$$R_{2\%} = H_{mo} \begin{cases} 1.77\gamma_r\gamma_b\gamma_\beta\gamma_P\xi_o & 0.5 \le \gamma_b\xi_o < 1.8 \\ \gamma_r\gamma_b\gamma_\beta\gamma_P\left(4.3 - \frac{1.6}{\sqrt{\xi_o}}\right) & 1.8 \le \gamma_b\xi_o \end{cases}$$

where,

$R_{2\%}$ = the 2% or 2σ runup height above the still water level

γ_r = reduction factor for influence of surface roughness

γ_b = reduction factor for influence of berm

γ_β = reduction factor for influence of angled wave attack

γ_P = reduction factor for influence of structure permeability

The TAW method and other wave runup methods give the wave runup height that is exceeded 2 percent of the time during a given wave event. This 2 percent wave runup height was calculated for each wind-wave height and period. The 2 percent wave runup height is otherwise not related to the probability of a given wind speed or wind-wave condition. Wave runup height calculated from the TAW method includes the super-elevation of the still water level due to wave setup (static and dynamic) caused by the wave conditions input into the equation. Note that in real situations, larger waves can break farther offshore of the slope and induce greater setup, which can, in turn, increase the local wave height and wave runup height elevation. The analysis accomplished here assumes the hindcast wave impinges on the slope and the wave runup includes all wave setup.

Wave runup heights were calculated for two structure slopes:

- 1 vertical to 1.5 horizontal (1:1.5) to represent relatively steep upper slopes of outboard and inboard levees that typically result in relatively high wave runup heights
- 1 vertical on 5 horizontal (1:5) to represent less steep lower slopes or average (composite) slopes of inboard levees

The TAW method includes wave runup reduction factors for surface roughness, the influence of a berm, oblique wave incidence, and structure permeability. The FEMA Guidelines and TAW (2002) provide guidance on estimating wave runup reduction factors. These reduction factors were not included in wave runup calculations, and assumed smooth levee surfaces, the absence of a berm, perpendicular wave attack, and an impermeable structure (i.e., all reduction factors equal to one). For armored levees, a roughness reduction factor of 0.55 to 0.6 can be applied for levees with one layer of rock armoring, where the rock diameter (D) is one to three times the significant wave height (H_s / D = 1 to 3) (FEMA 2005).

Tables 6a and 6b are the wave runup height look-up tables, parameterized by wind speed and fetch length, and give the potential wave runup power calculated for levee slopes of 1:1.5 and 1:5, respectively, for each wave height and period from the wind-wave generation look-up table.

5.0 Epistemic Uncertainty

5.1 Extreme Wind Hazard Probability Model

The availability of wind data and/or atmospheric models for the Delta and Suisun Marsh contributes to the uncertainty in the assessment of winds and wind waves. Estimates of

winds and wind waves within the Delta and Suisun Marsh are uncertain regardless of probabilistic, spatial analysis, interpolation, and analytic methods due to the lack of wind data. Figure 18 shows the logic tree for the epistemic uncertainty of the extreme wind hazard probability model. Figures 19-a to 19-c show the Gumbel Distribution fit to the annual maximum wind speed data for each meteorology using the plotting position procedure and a linear regression. Figures 20-a to 20-c compare the Gumbel and GEV Distributions for wind speed exceedance. Wind speed estimates from the Gumbel distribution are approximately 10 percent higher than estimates from the GEV for extreme probabilities of approximately 0.002 or a 500-year return period. Confidence intervals on the distributions and the distribution parameters can be used to assign probabilities to model estimates using each distribution.

The probabilistic approach to the wind hazard model is different than more common engineering approaches to wind and wind-wave analysis, which typically use data from only the nearest wind measurement station(s) to estimate extreme winds and wind waves at a single location. Figures 21-a and 21-b compare the results of the spatial wind hazard model at Sacramento and Stockton to the wind speed exceedance curves determined from the NWS wind data measured at Sacramento and Stockton.

5.2 Wind Waves

The deepwater wave generation equations from the SPM and CEM are in terms of different wind parameters. In the process of calculating deepwater wave heights and periods, the SPM method uses a parameter defined as the wind stress factor, and the CEM uses a term defined as the wind friction velocity. The SPM and CEM methods have been compared in a separate case study (PWA 2004). The results of this case study showed that deepwater wave heights obtained from the SPM equations were 10 to 25 percent higher than the CEM calculated deepwater wave heights. SPM calculated deepwater wave periods were 22 to 30 percent higher than the calculated CEM deepwater wave periods.

5.3 Example Wind-Wave Hindcast

A wind and wind-wave hindcast was performed for the January 1, 2006, storm event at Twitchell Island. This event is typical of a Pacific Low and caused high winds to blow from the southeast over the San Joaquin River, generating wind waves incident to the southern levee of Twitchell Island. A video of the event provides visual observations of wind-wave conditions (CALFED 2006). Comparing the hindcast results to the visual observations from the video provides a check on the accuracy of the analysis. Table 7 summarizes the wind and wind-wave hindcast. Visual observations suggest wind and wind-wave conditions during the January 1, 2006, storm event were more severe than conditions hindcast using the wind-wave analysis approach. A wind speed of 60 mph (27 m/s) was reported in the video (however, the source of this estimate is not known), which is higher than the peak wind speed measured at Travis. No wind data are available from Twitchell Island during the event. Observed wave heights appear to be approximately 1 m (3 ft), with a period of approximately 3 seconds.

Table 7
Example Wind-Wave Hindcast at Twitchell Island
for the January 1, 2006, Storm Event

Peak wind speed at reference station (Travis)	18 m/s (40 mph)
Mean normalized spatial wind speed pattern scaling factor for Pacific Low at Twitchell Island	0.896
Wind speed at Twitchell Island estimated by applying the scaling factor to the reference wind speed	16 m/s (36 mph)
Estimated annual probability of wind event at Twitchell Island	0.4 (2.5-year return period)
Mean spatial wind direction for Pacific Low at Twitchell Island	~150 degrees
Range of wind directions	~120 to 180 degrees
Longest fetch length within the range of wind directions	3,200 m (2.0 mi)
Estimated deepwater wind wave height	0.64 m (2.1 ft)
Estimated deepwater wind wave period	2.6 s
Water depth criteria for deepwater wave conditions	5.1 m (17 ft)
Estimated wave power	997 J/s
Estimated potential wave runup height on smooth levee slope of 1:1.5	2.1 m (6.9 ft)
Wave runup reduction factor for levee armoring	0.6
Reduced estimate of potential wave runup height	1.3 m (4.1 ft)

5.4 Summary

WOCSS model test runs were performed using wind speeds measured at all available locations, including locations within the Delta and Suisun Marsh where limited data are available (Section 3.2.2.3). These limited data and the model test runs indicated that wind speeds measured within the Delta and Suisun Marsh by DWR and CIMIS were typically lower than wind speeds measured at NWS stations on the periphery of the Delta and Suisun Marsh. This finding suggests that the spatial wind hazard model using only the NWS wind data may over-estimate wind speeds within the Delta or that the DWR and CIMIS wind data are not accurate. Using deduction, wind speeds within the Delta could also be assumed greater than wind speeds around the periphery, due to the open topography of the Delta. The comparison of the wind-wave hindcast and observed wind-wave conditions for the January 1, 2006, storm event appear to support the deductive reasoning that winds in the Delta may be higher than measured at the periphery. This suggests that the spatial wind hazard model and the wind-wave analysis may under-predict wind-wave conditions in the Delta. Based on these assessments, the model and results may be biased towards predicting more or less severe wind-wave conditions.

6.0 References

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Tables

Table 1. Summary of Delta and Suisun Bay Wind Data

Agency	Data Type/QC	Station	Years of Record
NOAA/NWS	Wind Speed & Direction (daily)	Concord Buchanan	1973-2006
		Concord	1973-2006
		Livermore	1978-2006
		Sacramento	1948 - 2006
		Stockton	1941-1946, 1948-1955, 1963-2006
		Travis	1943-1970, 1973-2006
		Oakland	1943 only
NOAA NDBC	Wind Speed, Direction & Gust (hourly)	Port Chicago	1994-present
DWR	Wind Direction&Velocity	Antioch	1983 - 2006
		Mallard	1984 - 2006
		Martinez	1983 - 2006
		Rio Vista	1983 - 2006
CIMIS	Wind Speed & Direction (hourly)	Dixon	1994-2006
		Hastings	1995-2006
		Lodi	2000-2006
		Twitchell	1997-2006

Table 2. Wind Wave Height Look-Up Table

Wave Height (m)

Wind Speed (m/s) \ Fetch (m)	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000	17000	18000	19000	20000	21000	22000	23000	24000	25000	26000	27000	28000	29000	30000
2.5	0.03	0.05	0.06	0.06	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.16	0.16
5	0.08	0.11	0.13	0.15	0.17	0.18	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.29	0.30	0.31	0.31	0.32	0.33	0.34	0.34	0.35	0.35	0.36	0.36	0.37	0.37
7.5	0.13	0.19	0.23	0.25	0.28	0.31	0.33	0.35	0.37	0.38	0.40	0.42	0.43	0.45	0.46	0.48	0.48	0.50	0.51	0.53	0.53	0.55	0.56	0.57	0.58	0.59	0.60	0.61	0.62	0.63
10	0.19	0.26	0.32	0.37	0.40	0.44	0.48	0.50	0.53	0.56	0.59	0.60	0.62	0.65	0.67	0.68	0.70	0.72	0.74	0.75	0.77	0.79	0.80	0.82	0.84	0.84	0.86	0.88	0.89	0.91
12.5	0.24	0.35	0.42	0.49	0.53	0.58	0.63	0.67	0.69	0.73	0.77	0.80	0.82	0.85	0.88	0.91	0.94	0.95	0.98	1.00	1.02	1.05	1.06	1.08	1.10	1.12	1.15	1.17	1.18	1.19
15	0.31	0.43	0.53	0.61	0.69	0.73	0.79	0.84	0.89	0.92	0.96	1.00	1.05	1.09	1.10	1.14	1.17	1.21	1.24	1.25	1.28	1.31	1.34	1.37	1.40	1.41	1.44	1.46	1.49	1.51
17.5	0.38	0.52	0.64	0.74	0.83	0.88	0.95	1.01	1.08	1.13	1.16	1.21	1.26	1.31	1.36	1.37	1.42	1.46	1.50	1.54	1.58	1.59	1.62	1.66	1.69	1.73	1.76	1.79	1.80	1.83
20	0.45	0.62	0.76	0.87	0.98	1.07	1.12	1.19	1.27	1.34	1.40	1.43	1.49	1.55	1.60	1.65	1.67	1.72	1.77	1.81	1.86	1.90	1.94	1.95	1.99	2.03	2.07	2.11	2.15	2.19
22.5	0.52	0.71	0.87	1.01	1.13	1.24	1.29	1.38	1.47	1.55	1.62	1.66	1.72	1.79	1.85	1.91	1.97	2.02	2.04	2.09	2.15	2.20	2.25	2.30	2.34	2.35	2.40	2.44	2.48	2.52
25	0.59	0.81	0.99	1.15	1.29	1.41	1.52	1.57	1.67	1.76	1.85	1.93	1.96	2.03	2.10	2.17	2.24	2.30	2.37	2.38	2.44	2.50	2.56	2.61	2.66	2.72	2.73	2.78	2.83	2.87
27.5	0.66	0.91	1.12	1.30	1.45	1.58	1.71	1.77	1.88	1.98	2.08	2.17	2.26	2.29	2.37	2.44	2.52	2.59	2.66	2.73	2.75	2.81	2.87	2.94	3.00	3.06	3.12	3.17	3.18	3.23
30	0.74	1.02	1.24	1.44	1.61	1.76	1.91	1.97	2.09	2.20	2.31	2.41	2.51	2.61	2.63	2.72	2.80	2.88	2.96	3.04	3.12	3.13	3.20	3.27	3.33	3.40	3.47	3.53	3.59	3.65
32.5	0.82	1.12	1.37	1.59	1.78	1.94	2.10	2.25	2.30	2.43	2.55	2.66	2.77	2.87	2.97	3.00	3.09	3.18	3.27	3.36	3.44	3.52	3.53	3.61	3.68	3.76	3.83	3.90	3.97	4.03
35	0.89	1.23	1.51	1.74	1.94	2.13	2.30	2.46	2.52	2.66	2.79	2.92	3.04	3.15	3.26	3.29	3.39	3.49	3.58	3.68	3.77	3.86	3.94	3.95	4.03	4.11	4.19	4.27	4.34	4.42

Wave Height (ft)

Wind Speed (mph) \ Fetch (mi)	0.62	1.24	1.86	2.49	3.11	3.73	4.35	4.97	5.59	6.21	6.84	7.46	8.08	8.7	9.32	9.94	10.56	11.18	11.81	12.43	13.05	13.67	14.29	14.91	15.53	16.16	16.78	17.4	18.02	18.64
5.59	0.11	0.15	0.19	0.21	0.23	0.25	0.27	0.29	0.3	0.32	0.33	0.34	0.35	0.37	0.38	0.39	0.4	0.4	0.42	0.43	0.44	0.45	0.46	0.46	0.47	0.48	0.49	0.5	0.51	0.51
11.18	0.26	0.37	0.44	0.5	0.55	0.6	0.65	0.68	0.72	0.76	0.79	0.82	0.86	0.88	0.91	0.94	0.96	0.98	1.01	1.03	1.05	1.08	1.1	1.11	1.14	1.16	1.18	1.18	1.2	1.23
16.78	0.43	0.61	0.74	0.83	0.93	1.02	1.07	1.15	1.22	1.26	1.32	1.38	1.41	1.47	1.52	1.57	1.59	1.64	1.68	1.73	1.75	1.79	1.83	1.87	1.91	1.93	1.96	2	2.04	2.07
22.37	0.61	0.86	1.06	1.22	1.32	1.45	1.56	1.63	1.73	1.83	1.92	1.96	2.04	2.12	2.19	2.23	2.3	2.37	2.43	2.46	2.52	2.58	2.64	2.7	2.75	2.77	2.83	2.88	2.93	2.98
27.96	0.8	1.14	1.39	1.61	1.74	1.91	2.06	2.2	2.28	2.4	2.52	2.63	2.69	2.79	2.89	2.98	3.07	3.11	3.2	3.28	3.36	3.44	3.47	3.55	3.62	3.69	3.76	3.83	3.86	3.92
33.55	1.03	1.42	1.74	2.01	2.25	2.39	2.58	2.75	2.92	3.01	3.15	3.29	3.43	3.56	3.61	3.73	3.85	3.96	4.07	4.11	4.21	4.31	4.41	4.5	4.59	4.62	4.71	4.8	4.88	4.96
39.15	1.25	1.72	2.1	2.44	2.72	2.88	3.11	3.33	3.53	3.72	3.81	3.98	4.14	4.3	4.45	4.51	4.65	4.78	4.92	5.04	5.17	5.21	5.32	5.44	5.55	5.66	5.77	5.88	5.9	6
44.74	1.47	2.03	2.48	2.87	3.21	3.51	3.67	3.92	4.16	4.39	4.6	4.69	4.88	5.07	5.25	5.42	5.48	5.64	5.8	5.95	6.09	6.23	6.37	6.41	6.54	6.67	6.8	6.92	7.05	7.17
50.33	1.7	2.34	2.87	3.32	3.71	4.06	4.24	4.54	4.81	5.07	5.32	5.43	5.65	5.86	6.06	6.26	6.45	6.64	6.7	6.87	7.04	7.21	7.37	7.53	7.68	7.71	7.86	8	8.15	8.28
55.92	1.94	2.67	3.26	3.78	4.22	4.62	4.99	5.16	5.48	5.77	6.06	6.33	6.43	6.67	6.9	7.13	7.35	7.56	7.77	7.82	8.02	8.2	8.39	8.57	8.74	8.92	8.95	9.11	9.27	9.43
61.52	2.18	3	3.67	4.25	4.75	5.2	5.61	5.8	6.16	6.49	6.81	7.11	7.4	7.5	7.76	8.02	8.26	8.5	8.74	8.96	9.01	9.22	9.43	9.63	9.83	10.03	10.22	10.41	10.43	10.6
67.11	2.43	3.34	4.08	4.73	5.28	5.78	6.25	6.46	6.85	7.22	7.58	7.92	8.24	8.55	8.64	8.92	9.19	9.46	9.72	9.98	10.22	10.27	10.5	10.72	10.94	11.16	11.37	11.58	11.79	11.99
72.7	2.68	3.68	4.51	5.22	5.83	6.38	6.89	7.37	7.56	7.97	8.36	8.73	9.09	9.43	9.76	9.84	10.15	10.44	10.73	11.01	11.28	11.54	11.58	11.83	12.07	12.32	12.55	12.78	13.01	13.23
78.29	2.93	4.03	4.94	5.71	6.38	6.99	7.55	8.07	8.28	8.73	9.16	9.57	9.96	10.33	10.69	10.78	11.11	11.44	11.75	12.06	12.36	12.65	12.93	12.96	13.23	13.49	13.75	14	14.25	14.49

Table 3. Wind Wave Period Look-Up Table

Wave Period (sec)

Fetch (m)

Wind Speed (m/s)	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000	17000	18000	19000	20000	21000	22000	23000	24000	25000	26000	27000	28000	29000	30000
2.5	0.8	0.99	1.14	1.24	1.33	1.41	1.48	1.55	1.6	1.66	1.71	1.76	1.8	1.84	1.89	1.92	1.96	1.99	2.02	2.06	2.09	2.13	2.16	2.18	2.21	2.24	2.26	2.29	2.32	2.34
5	1.06	1.33	1.51	1.67	1.78	1.89	1.99	2.07	2.15	2.23	2.29	2.36	2.42	2.47	2.53	2.58	2.62	2.67	2.72	2.76	2.8	2.85	2.89	2.92	2.96	3	3.04	3.06	3.1	3.13
7.5	1.25	1.58	1.8	1.97	2.12	2.25	2.35	2.46	2.56	2.63	2.72	2.8	2.86	2.93	3	3.06	3.11	3.17	3.23	3.28	3.32	3.37	3.43	3.47	3.52	3.56	3.6	3.64	3.69	3.73
10	1.41	1.77	2.03	2.24	2.38	2.53	2.67	2.76	2.88	2.98	3.08	3.15	3.23	3.31	3.39	3.44	3.51	3.58	3.65	3.69	3.75	3.81	3.87	3.92	3.98	4.02	4.07	4.12	4.16	4.21
12.5	1.54	1.94	2.22	2.45	2.61	2.78	2.92	3.05	3.15	3.26	3.37	3.47	3.54	3.63	3.71	3.79	3.87	3.92	4	4.07	4.13	4.2	4.24	4.3	4.36	4.42	4.47	4.53	4.56	4.61
15	1.68	2.09	2.4	2.64	2.85	2.99	3.15	3.29	3.42	3.52	3.63	3.74	3.84	3.93	4	4.09	4.17	4.25	4.33	4.38	4.45	4.52	4.59	4.65	4.72	4.76	4.82	4.88	4.94	4.99
17.5	1.79	2.23	2.55	2.81	3.03	3.19	3.35	3.51	3.65	3.78	3.87	3.98	4.09	4.19	4.29	4.35	4.44	4.53	4.61	4.69	4.77	4.82	4.89	4.96	5.03	5.09	5.16	5.22	5.26	5.32
20	1.89	2.36	2.7	2.97	3.2	3.4	3.54	3.7	3.85	3.99	4.12	4.21	4.32	4.43	4.53	4.63	4.69	4.78	4.87	4.95	5.04	5.11	5.19	5.24	5.31	5.38	5.45	5.51	5.58	5.64
22.5	1.98	2.47	2.83	3.12	3.36	3.57	3.72	3.89	4.04	4.19	4.32	4.41	4.53	4.65	4.75	4.86	4.96	5.05	5.11	5.2	5.28	5.37	5.45	5.52	5.6	5.65	5.72	5.79	5.85	5.92
25	2.07	2.58	2.96	3.26	3.51	3.73	3.92	4.06	4.22	4.37	4.51	4.65	4.73	4.85	4.96	5.07	5.17	5.27	5.37	5.43	5.52	5.6	5.69	5.77	5.85	5.93	5.97	6.04	6.11	6.18
27.5	2.15	2.69	3.07	3.39	3.65	3.88	4.08	4.22	4.39	4.54	4.69	4.83	4.96	5.04	5.16	5.27	5.38	5.48	5.59	5.68	5.74	5.83	5.91	6	6.08	6.16	6.24	6.32	6.36	6.43
30	2.23	2.78	3.19	3.51	3.78	4.02	4.23	4.37	4.55	4.71	4.86	5.01	5.14	5.27	5.35	5.46	5.58	5.68	5.79	5.89	5.98	6.04	6.13	6.22	6.3	6.39	6.47	6.55	6.62	6.7
32.5	2.3	2.88	3.29	3.63	3.91	4.15	4.37	4.57	4.7	4.87	5.03	5.17	5.31	5.45	5.57	5.65	5.76	5.87	5.98	6.08	6.18	6.28	6.33	6.42	6.51	6.6	6.68	6.76	6.84	6.92
35	2.38	2.96	3.39	3.74	4.03	4.28	4.5	4.71	4.84	5.02	5.18	5.33	5.48	5.61	5.74	5.82	5.94	6.05	6.17	6.27	6.37	6.47	6.57	6.62	6.71	6.8	6.89	6.97	7.05	7.13

Wave Period (sec)

Fetch (mi)

Wind Speed (mph)	0.62	1.24	1.86	2.49	3.11	3.73	4.35	4.97	5.59	6.21	6.84	7.46	8.08	8.7	9.32	9.94	10.56	11.18	11.81	12.43	13.05	13.67	14.29	14.91	15.53	16.16	16.78	17.4	18.02	18.64
5.59	0.8	0.99	1.14	1.24	1.33	1.41	1.48	1.55	1.6	1.66	1.71	1.76	1.8	1.84	1.89	1.92	1.96	1.99	2.02	2.06	2.09	2.13	2.16	2.18	2.21	2.24	2.26	2.29	2.32	2.34
11.18	1.06	1.33	1.51	1.67	1.78	1.89	1.99	2.07	2.15	2.23	2.29	2.36	2.42	2.47	2.53	2.58	2.62	2.67	2.72	2.76	2.8	2.85	2.89	2.92	2.96	3	3.04	3.06	3.1	3.13
16.78	1.25	1.58	1.8	1.97	2.12	2.25	2.35	2.46	2.56	2.63	2.72	2.8	2.86	2.93	3	3.06	3.11	3.17	3.23	3.28	3.32	3.37	3.43	3.47	3.52	3.56	3.6	3.64	3.69	3.73
22.37	1.41	1.77	2.03	2.24	2.38	2.53	2.67	2.76	2.88	2.98	3.08	3.15	3.23	3.31	3.39	3.44	3.51	3.58	3.65	3.69	3.75	3.81	3.87	3.92	3.98	4.02	4.07	4.12	4.16	4.21
27.96	1.54	1.94	2.22	2.45	2.61	2.78	2.92	3.05	3.15	3.26	3.37	3.47	3.54	3.63	3.71	3.79	3.87	3.92	4	4.07	4.13	4.2	4.24	4.3	4.36	4.42	4.47	4.53	4.56	4.61
33.55	1.68	2.09	2.4	2.64	2.85	2.99	3.15	3.29	3.42	3.52	3.63	3.74	3.84	3.93	4	4.09	4.17	4.25	4.33	4.38	4.45	4.52	4.59	4.65	4.72	4.76	4.82	4.88	4.94	4.99
39.15	1.79	2.23	2.55	2.81	3.03	3.19	3.35	3.51	3.65	3.78	3.87	3.98	4.09	4.19	4.29	4.35	4.44	4.53	4.61	4.69	4.77	4.82	4.89	4.96	5.03	5.09	5.16	5.22	5.26	5.32
44.74	1.89	2.36	2.7	2.97	3.2	3.4	3.54	3.7	3.85	3.99	4.12	4.21	4.32	4.43	4.53	4.63	4.69	4.78	4.87	4.95	5.04	5.11	5.19	5.24	5.31	5.38	5.45	5.51	5.58	5.64
50.33	1.98	2.47	2.83	3.12	3.36	3.57	3.72	3.89	4.04	4.19	4.32	4.41	4.53	4.65	4.75	4.86	4.96	5.05	5.11	5.2	5.28	5.37	5.45	5.52	5.6	5.65	5.72	5.79	5.85	5.92
55.92	2.07	2.58	2.96	3.26	3.51	3.73	3.92	4.06	4.22	4.37	4.51	4.65	4.73	4.85	4.96	5.07	5.17	5.27	5.37	5.43	5.52	5.6	5.69	5.77	5.85	5.93	5.97	6.04	6.11	6.18
61.52	2.15	2.69	3.07	3.39	3.65	3.88	4.08	4.22	4.39	4.54	4.69	4.83	4.96	5.04	5.16	5.27	5.38	5.48	5.59	5.68	5.74	5.83	5.91	6	6.08	6.16	6.24	6.32	6.36	6.43
67.11	2.23	2.78	3.19	3.51	3.78	4.02	4.23	4.37	4.55	4.71	4.86	5.01	5.14	5.27	5.35	5.46	5.58	5.68	5.79	5.89	5.98	6.04	6.13	6.22	6.3	6.39	6.47	6.55	6.62	6.7
72.7	2.3	2.88	3.29	3.63	3.91	4.15	4.37	4.57	4.7	4.87	5.03	5.17	5.31	5.45	5.57	5.65	5.76	5.87	5.98	6.08	6.18	6.28	6.33	6.42	6.51	6.6	6.68	6.76	6.84	6.92
78.29	2.38	2.96	3.39	3.74	4.03	4.28	4.5	4.71	4.84	5.02	5.18	5.33	5.48	5.61	5.74	5.82	5.94	6.05	6.17	6.27	6.37	6.47	6.57	6.62	6.71	6.8	6.89	6.97	7.05	7.13

Table 4. Water Depth Criteria Look-Up Table

Water Depth (m)

Fetch (m)

Wind Speed (m/s)	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000	17000	18000	19000	20000	21000	22000	23000	24000	25000	26000	27000	28000	29000	30000
2.5	0.50	0.76	1.01	1.20	1.38	1.55	1.71	1.87	2.00	2.15	2.28	2.42	2.53	2.64	2.79	2.88	3.00	3.09	3.18	3.31	3.41	3.54	3.64	3.71	3.81	3.92	3.99	4.09	4.20	4.27
5	0.88	1.38	1.78	2.18	2.47	2.79	3.09	3.34	3.61	3.88	4.09	4.35	4.57	4.76	5.00	5.19	5.36	5.56	5.77	5.94	6.12	6.34	6.52	6.65	6.84	7.02	7.21	7.31	7.50	7.65
7.5	1.22	1.95	2.53	3.03	3.51	3.95	4.31	4.72	5.11	5.40	5.77	6.12	6.38	6.70	7.02	7.31	7.55	7.84	8.14	8.40	8.60	8.86	9.18	9.40	9.67	9.89	10.11	10.34	10.63	10.86
10	1.55	2.44	3.22	3.92	4.42	5.00	5.56	5.94	6.47	6.93	7.40	7.74	8.14	8.55	8.97	9.23	9.61	10.00	10.40	10.63	10.97	11.33	11.69	11.99	12.36	12.61	12.93	13.25	13.51	13.83
12.5	1.85	2.94	3.85	4.68	5.32	6.03	6.65	7.26	7.74	8.29	8.86	9.40	9.78	10.28	10.74	11.21	11.69	11.99	12.49	12.93	13.31	13.77	14.03	14.43	14.83	15.25	15.59	16.01	16.23	16.58
15	2.20	3.41	4.50	5.44	6.34	6.98	7.74	8.45	9.13	9.67	10.28	10.92	11.51	12.05	12.49	13.05	13.57	14.10	14.63	14.97	15.45	15.94	16.44	16.87	17.39	17.68	18.13	18.58	19.04	19.43
17.5	2.50	3.88	5.07	6.16	7.16	7.94	8.76	9.61	10.40	11.15	11.69	12.36	13.05	13.70	14.36	14.77	15.38	16.01	16.58	17.17	17.76	18.13	18.66	19.20	19.74	20.22	20.78	21.26	21.59	22.09
20	2.79	4.35	5.69	6.88	7.99	9.02	9.78	10.68	11.57	12.42	13.25	13.83	14.56	15.31	16.01	16.73	17.17	17.83	18.51	19.12	19.82	20.38	21.02	21.43	22.00	22.59	23.18	23.69	24.30	24.82
22.5	3.06	4.76	6.25	7.60	8.81	9.95	10.80	11.81	12.74	13.70	14.56	15.18	16.01	16.87	17.61	18.43	19.20	19.90	20.38	21.10	21.76	22.50	23.18	23.78	24.47	24.91	25.53	26.16	26.71	27.35
25	3.34	5.19	6.84	8.29	9.61	10.86	11.99	12.86	13.90	14.90	15.87	16.87	17.46	18.36	19.20	20.06	20.86	21.67	22.50	23.01	23.78	24.47	25.27	25.98	26.71	27.44	27.81	28.47	29.13	29.80
27.5	3.61	5.65	7.36	8.97	10.40	11.75	12.99	13.90	15.04	16.08	17.17	18.21	19.20	19.82	20.78	21.67	22.59	23.44	24.39	25.18	25.71	26.52	27.26	28.09	28.85	29.61	30.39	31.17	31.57	32.26
30	3.88	6.03	7.94	9.61	11.15	12.61	13.96	14.90	16.16	17.31	18.43	19.59	20.62	21.67	22.34	23.26	24.30	25.18	26.16	27.07	27.91	28.47	29.32	30.19	30.97	31.86	32.67	33.48	34.20	35.03
32.5	4.13	6.47	8.45	10.28	11.93	13.44	14.90	16.30	17.24	18.51	19.74	20.86	22.00	23.18	24.21	24.91	25.89	26.89	27.91	28.85	29.80	30.78	31.27	32.16	33.07	33.99	34.82	35.66	36.51	37.37
35	4.42	6.84	8.97	10.92	12.67	14.30	15.80	17.31	18.28	19.67	20.94	22.17	23.44	24.56	25.71	26.43	27.53	28.56	29.71	30.68	31.67	32.67	33.69	34.20	35.14	36.08	37.05	37.91	38.79	39.67

Water Depth (ft)

Fetch (mi)

Wind Speed (mph)	0.62	1.24	1.86	2.49	3.11	3.73	4.35	4.97	5.59	6.21	6.84	7.46	8.08	8.7	9.32	9.94	10.56	11.18	11.81	12.43	13.05	13.67	14.29	14.91	15.53	16.16	16.78	17.4	18.02	18.64
5.59	1.64	2.51	3.33	3.94	4.53	5.09	5.61	6.15	6.55	7.06	7.49	7.93	8.30	8.67	9.15	9.44	9.84	10.14	10.45	10.86	11.18	11.62	11.95	12.17	12.50	12.85	13.08	13.43	13.78	14.02
11.18	2.88	4.53	5.84	7.14	8.11	9.15	10.14	10.97	11.84	12.73	13.43	14.26	14.99	15.62	16.39	17.04	17.58	18.25	18.94	19.50	20.07	20.80	21.38	21.83	22.43	23.04	23.66	23.97	24.60	25.08
16.78	4.00	6.39	8.30	9.94	11.51	12.96	14.14	15.49	16.78	17.71	18.94	20.07	20.94	21.98	23.04	23.97	24.76	25.73	26.71	27.54	28.22	29.08	30.12	30.83	31.72	32.45	33.18	33.92	34.86	35.62
22.37	5.09	8.02	10.55	12.85	14.50	16.39	18.25	19.50	21.24	22.74	24.29	25.40	26.71	28.05	29.42	30.30	31.54	32.81	34.11	34.86	36.00	37.17	38.35	39.34	40.56	41.38	42.41	43.46	44.31	45.38
27.96	6.07	9.64	12.62	15.37	17.44	19.79	21.83	23.82	25.40	27.21	29.08	30.83	32.08	33.74	35.24	36.78	38.35	39.34	40.97	42.41	43.67	45.16	46.03	47.34	48.67	50.02	51.16	52.54	53.24	54.41
33.55	7.23	11.18	14.75	17.84	20.80	22.89	25.40	27.71	29.95	31.72	33.74	35.81	37.75	39.54	40.97	42.83	44.52	46.25	48.00	49.12	50.70	52.31	53.94	55.36	57.04	58.01	59.48	60.97	62.48	63.75
39.15	8.20	12.73	16.65	20.22	23.51	26.05	28.73	31.54	34.11	36.58	38.35	40.56	42.83	44.95	47.12	48.45	50.47	52.54	54.41	56.32	58.25	59.48	61.22	62.99	64.78	66.33	68.17	69.76	70.84	72.46
44.74	9.15	14.26	18.66	22.58	26.22	29.60	32.08	35.05	37.95	40.76	43.46	45.38	47.78	50.25	52.54	54.89	56.32	58.50	60.72	62.73	65.04	66.86	68.96	70.30	72.19	74.11	76.05	77.73	79.72	81.44
50.33	10.04	15.62	20.51	24.92	28.90	32.63	35.43	38.74	41.79	44.95	47.78	49.79	52.54	55.36	57.77	60.47	62.99	65.29	66.86	69.23	71.38	73.83	76.05	78.01	80.29	81.73	83.77	85.83	87.62	89.73
55.92	10.97	17.04	22.43	27.21	31.54	35.62	39.34	42.20	45.60	48.89	52.08	55.36	57.28	60.23	62.99	65.81	68.43	71.11	73.83	75.49	78.01	80.29	82.89	85.24	87.62	90.03	91.25	93.40	95.58	97.78
61.52	11.84	18.53	24.13	29.42	34.11	38.54	42.62	45.60	49.34	52.77	56.32	59.73	62.99	65.04	68.17	71.11	74.11	76.89	80.01	82.60	84.36	87.02	89.43	92.17	94.65	97.15	99.69	102.27	103.56	105.86
67.11	12.73	19.79	26.05	31.54	36.58	41.38	45.81	48.89	53.00	56.80	60.47	64.26	67.64	71.11	73.28	76.33	79.72	82.60	85.83	88.82	91.56	93.40	96.21	99.05	101.62	104.54	107.18	109.84	112.20	114.93
72.70	13.54	21.24	27.71	33.74	39.14	44.10	48.89	53.47	56.56	60.72	64.78	68.43	72.19	76.05	79.43	81.73	84.95	88.22	91.56	94.65	97.78	100.97	102.59	105.53	108.51	111.53	114.25	117.00	119.79	122.60
78.29	14.50	22.43	29.42	35.81	41.58	46.90	51.85	56.80	59.98	64.52	68.70	72.74	76.89	80.58	84.36	86.72	90.34	93.71	97.47	100.65	103.89	107.18	110.52	112.20	115.28	118.39	121.54	124.38	127.25	130.16

Table 5. Wave Power Look-Up Table

Wave Power (J/s)

Wind Speed (m/s) \ Fetch (m)	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000	17000	18000	19000	20000	21000	22000	23000	24000	25000	26000	27000	28000	29000	30000
2.5	0.86	1.98	3.65	4.85	6.24	7.82	9.57	11.6	12.8	15.1	16.5	18.0	19.6	22.3	24.2	25.9	27.8	28.2	31.6	33.8	35.9	38.3	40.5	40.9	43.3	45.8	48.1	50.8	53.5	54.0
5	6.36	16.1	25.9	37.0	47.8	60.3	74.6	84.9	98.9	114	127	141	159	170	186	202	214	227	246	260	274	295	310	319	341	358	375	378	396	420
7.5	20.5	52.1	87.4	120	163	208	239	289	338	370	420	473	504	562	615	669	697	756	809	871	902	958	1019	1076	1139	1176	1227	1291	1362	1418
10	46.5	116	202	296	368	472	576	650	765	885	1007	1073	1192	1319	1442	1517	1647	1784	1912	1981	2112	2249	2392	2535	2670	2736	2891	3031	3168	3316
12.5	87.4	224	380	563	701	900	1099	1309	1452	1665	1898	2129	2272	2506	2748	2985	3235	3363	3633	3884	4135	4408	4528	4806	5068	5338	5605	5894	6026	6283
15	158	374	644	946	1280	1515	1860	2207	2586	2829	3195	3591	4007	4418	4624	5047	5482	5911	6362	6562	6996	7447	7917	8352	8820	9011	9484	9972	10434	10888
17.5	248	585	997	1484	1988	2347	2874	3452	4034	4640	4983	5592	6218	6871	7535	7848	8515	9180	9898	10567	11308	11604	12275	13019	13742	14463	15237	16007	16240	16987
20	362	863	1473	2170	2925	3715	4229	5043	5909	6820	7732	8213	9125	10100	11074	12064	12492	13486	14531	15543	16579	17591	18679	19096	20144	21229	22352	23402	24599	25717
22.5	508	1200	2068	3050	4102	5219	5932	7111	8290	9553	10844	11533	12826	14163	15472	16892	18302	19748	20345	21768	23210	24760	26256	27760	29296	29789	31343	32867	34464	35998
25	691	1631	2790	4131	5544	7061	8657	9588	11240	12904	14690	16526	17345	19138	20945	22860	24772	26715	28755	29452	31491	33397	35525	37587	39635	41849	42415	44460	46569	48743
27.5	906	2147	3667	5431	7304	9305	11389	12591	14775	16961	19291	21656	24090	25145	27559	30065	32557	35117	37873	40445	41329	43957	46613	49352	52108	54964	57807	60746	61365	64080
30	1168	2751	4710	6965	9347	11912	14655	16175	18936	21777	24767	27873	30954	34170	35422	38532	41799	45085	48519	52032	55399	56504	59943	63398	66876	70587	74186	77903	81617	85430
32.5	1465	3459	5935	8773	11787	14983	18400	22017	23825	27437	31180	34948	38915	42985	47060	48522	52632	56746	61066	65370	69744	74177	75287	79690	84119	88851	93317	97928	102685	107429
35	1812	4264	7338	10815	14549	18548	22751	27206	29431	33934	38549	43296	48217	53096	58179	59987	65030	70227	75554	80883	86313	91830	97423	98620	104169	109757	115537	121168	126974	132777

Table 6. Wave Runup Look-Up Table

Wave Runup (m)

Levee Slope = 1.5:1 (horizontal:vertical)

Fetch (m)

Wind Speed (m/s)	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000	17000	18000	19000	20000	21000	22000	23000	24000	25000	26000	27000	28000	29000	30000
2.5	0.11	0.16	0.20	0.22	0.24	0.27	0.29	0.31	0.32	0.34	0.35	0.36	0.38	0.40	0.41	0.42	0.43	0.43	0.45	0.46	0.47	0.48	0.50	0.50	0.51	0.52	0.53	0.54	0.55	0.55
5	0.27	0.38	0.46	0.52	0.57	0.63	0.68	0.71	0.76	0.80	0.83	0.86	0.91	0.93	0.96	0.99	1.01	1.04	1.07	1.09	1.11	1.14	1.17	1.18	1.21	1.23	1.25	1.25	1.28	1.31
7.5	0.43	0.62	0.76	0.85	0.96	1.05	1.11	1.19	1.27	1.31	1.37	1.44	1.47	1.53	1.59	1.64	1.66	1.72	1.76	1.81	1.83	1.88	1.92	1.96	2.00	2.03	2.06	2.10	2.15	2.18
10	0.61	0.87	1.07	1.24	1.35	1.48	1.60	1.67	1.78	1.89	1.98	2.02	2.11	2.19	2.27	2.31	2.38	2.46	2.52	2.56	2.62	2.68	2.75	2.81	2.87	2.89	2.95	3.00	3.06	3.11
12.5	0.79	1.14	1.40	1.63	1.77	1.94	2.10	2.24	2.33	2.46	2.58	2.70	2.76	2.87	2.97	3.07	3.16	3.21	3.30	3.39	3.47	3.56	3.59	3.67	3.75	3.82	3.90	3.97	4.00	4.07
15	1.02	1.41	1.74	2.02	2.27	2.42	2.61	2.79	2.97	3.07	3.21	3.36	3.50	3.64	3.70	3.82	3.95	4.06	4.18	4.22	4.33	4.43	4.54	4.63	4.73	4.76	4.86	4.95	5.04	5.12
17.5	1.23	1.71	2.09	2.44	2.73	2.90	3.14	3.36	3.57	3.77	3.87	4.04	4.21	4.38	4.53	4.60	4.74	4.88	5.03	5.15	5.29	5.34	5.45	5.58	5.69	5.81	5.92	6.04	6.06	6.17
20	1.44	2.00	2.46	2.86	3.21	3.52	3.69	3.94	4.19	4.43	4.65	4.75	4.94	5.14	5.33	5.50	5.57	5.74	5.90	6.06	6.21	6.35	6.50	6.55	6.68	6.82	6.95	7.08	7.21	7.34
22.5	1.65	2.30	2.84	3.29	3.69	4.05	4.24	4.55	4.83	5.10	5.35	5.47	5.70	5.92	6.13	6.33	6.53	6.73	6.80	6.97	7.15	7.33	7.49	7.66	7.82	7.85	8.01	8.16	8.31	8.45
25	1.88	2.61	3.21	3.74	4.19	4.59	4.97	5.16	5.48	5.78	6.08	6.36	6.47	6.72	6.95	7.19	7.42	7.63	7.85	7.91	8.12	8.31	8.50	8.69	8.87	9.05	9.09	9.26	9.42	9.59
27.5	2.10	2.93	3.60	4.19	4.70	5.16	5.57	5.78	6.14	6.48	6.81	7.12	7.42	7.53	7.80	8.06	8.31	8.56	8.81	9.03	9.10	9.31	9.53	9.74	9.94	10.15	10.35	10.55	10.57	10.75
30	2.34	3.25	4.00	4.65	5.21	5.71	6.19	6.42	6.81	7.19	7.56	7.91	8.24	8.55	8.66	8.94	9.22	9.50	9.77	10.04	10.28	10.35	10.58	10.81	11.04	11.27	11.48	11.70	11.92	12.13
32.5	2.57	3.57	4.40	5.12	5.73	6.29	6.81	7.29	7.50	7.92	8.32	8.69	9.06	9.41	9.75	9.84	10.16	10.46	10.76	11.04	11.32	11.59	11.64	11.90	12.15	12.41	12.64	12.88	13.12	13.35
35	2.81	3.90	4.81	5.58	6.26	6.87	7.44	7.97	8.19	8.65	9.09	9.51	9.91	10.28	10.65	10.76	11.10	11.43	11.75	12.07	12.38	12.67	12.96	13.01	13.28	13.55	13.82	14.08	14.33	14.58

Wave Runup (m)

Levee Slope = 5:1 (horizontal:vertical)

Fetch (m)

Wind Speed (m/s)	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000	17000	18000	19000	20000	21000	22000	23000	24000	25000	26000	27000	28000	29000	30000
2.5	0.06	0.09	0.11	0.13	0.14	0.16	0.17	0.19	0.19	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.33	0.33	0.34	0.34	0.35	0.36	0.37	0.37
5	0.12	0.18	0.22	0.26	0.29	0.32	0.36	0.38	0.40	0.43	0.45	0.47	0.50	0.51	0.54	0.56	0.57	0.59	0.61	0.62	0.64	0.66	0.67	0.68	0.70	0.72	0.73	0.74	0.75	0.77
7.5	0.18	0.27	0.34	0.40	0.45	0.50	0.54	0.59	0.63	0.66	0.69	0.73	0.75	0.79	0.82	0.85	0.87	0.90	0.93	0.96	0.97	1.00	1.03	1.05	1.08	1.10	1.12	1.14	1.17	1.19
10	0.24	0.36	0.46	0.55	0.61	0.68	0.74	0.78	0.84	0.89	0.95	0.98	1.02	1.07	1.11	1.14	1.18	1.22	1.26	1.28	1.32	1.36	1.40	1.43	1.46	1.49	1.52	1.55	1.58	1.61
12.5	0.31	0.46	0.58	0.69	0.76	0.85	0.93	1.00	1.06	1.12	1.19	1.25	1.29	1.35	1.40	1.45	1.51	1.53	1.59	1.64	1.68	1.73	1.75	1.80	1.84	1.88	1.92	1.97	1.99	2.03
15	0.38	0.55	0.70	0.83	0.95	1.03	1.12	1.21	1.30	1.36	1.43	1.51	1.58	1.65	1.69	1.75	1.82	1.88	1.94	1.97	2.03	2.08	2.14	2.19	2.24	2.27	2.32	2.37	2.42	2.47
17.5	0.44	0.65	0.82	0.97	1.11	1.20	1.31	1.42	1.52	1.62	1.68	1.76	1.85	1.93	2.01	2.05	2.13	2.20	2.27	2.34	2.41	2.44	2.50	2.57	2.63	2.69	2.75	2.81	2.84	2.89
20	0.51	0.75	0.94	1.12	1.27	1.41	1.51	1.63	1.74	1.86	1.96	2.02	2.12	2.21	2.30	2.39	2.44	2.52	2.60	2.68	2.76	2.83	2.91	2.94	3.01	3.08	3.15	3.22	3.29	3.35
22.5	0.57	0.84	1.06	1.26	1.44	1.60	1.70	1.84	1.97	2.09	2.21	2.28	2.39	2.50	2.60	2.70	2.80	2.89	2.94	3.03	3.11	3.20	3.28	3.36	3.44	3.48	3.56	3.64	3.71	3.78
25	0.64	0.94	1.19	1.41	1.60	1.78	1.94	2.05	2.19	2.33	2.46	2.60	2.66	2.78	2.89	3.00	3.11	3.22	3.32	3.37	3.47	3.56	3.66	3.75	3.84	3.93	3.96	4.05	4.13	4.21
27.5	0.70	1.03	1.31	1.55	1.77	1.96	2.15	2.26	2.42	2.57	2.72	2.86	2.99	3.06	3.19	3.31	3.43	3.55	3.67	3.77	3.82	3.93	4.03	4.13	4.23	4.33	4.43	4.53	4.56	4.65
30	0.77	1.13	1.43	1.69	1.93	2.15	2.35	2.47	2.64	2.81	2.97	3.13	3.28	3.42	3.49	3.62	3.75	3.88	4.01	4.13	4.24	4.30	4.41	4.52	4.63	4.74	4.84	4.95	5.05	5.15
32.5	0.84	1.23	1.55	1.84	2.10	2.33	2.55	2.75	2.87	3.05	3.23	3.39	3.55	3.71	3.86	3.93	4.07	4.21	4.35	4.48	4.61	4.74	4.78	4.90	5.02	5.14	5.25	5.36	5.48	5.59
35	0.90	1.32	1.67	1.98	2.26	2.51	2.74	2.97	3.09	3.29	3.48	3.66	3.84	4.00	4.17	4.24	4.39	4.54	4.69	4.83	4.97	5.11	5.24	5.29	5.42	5.54	5.67	5.79	5.91	6.02

Figures

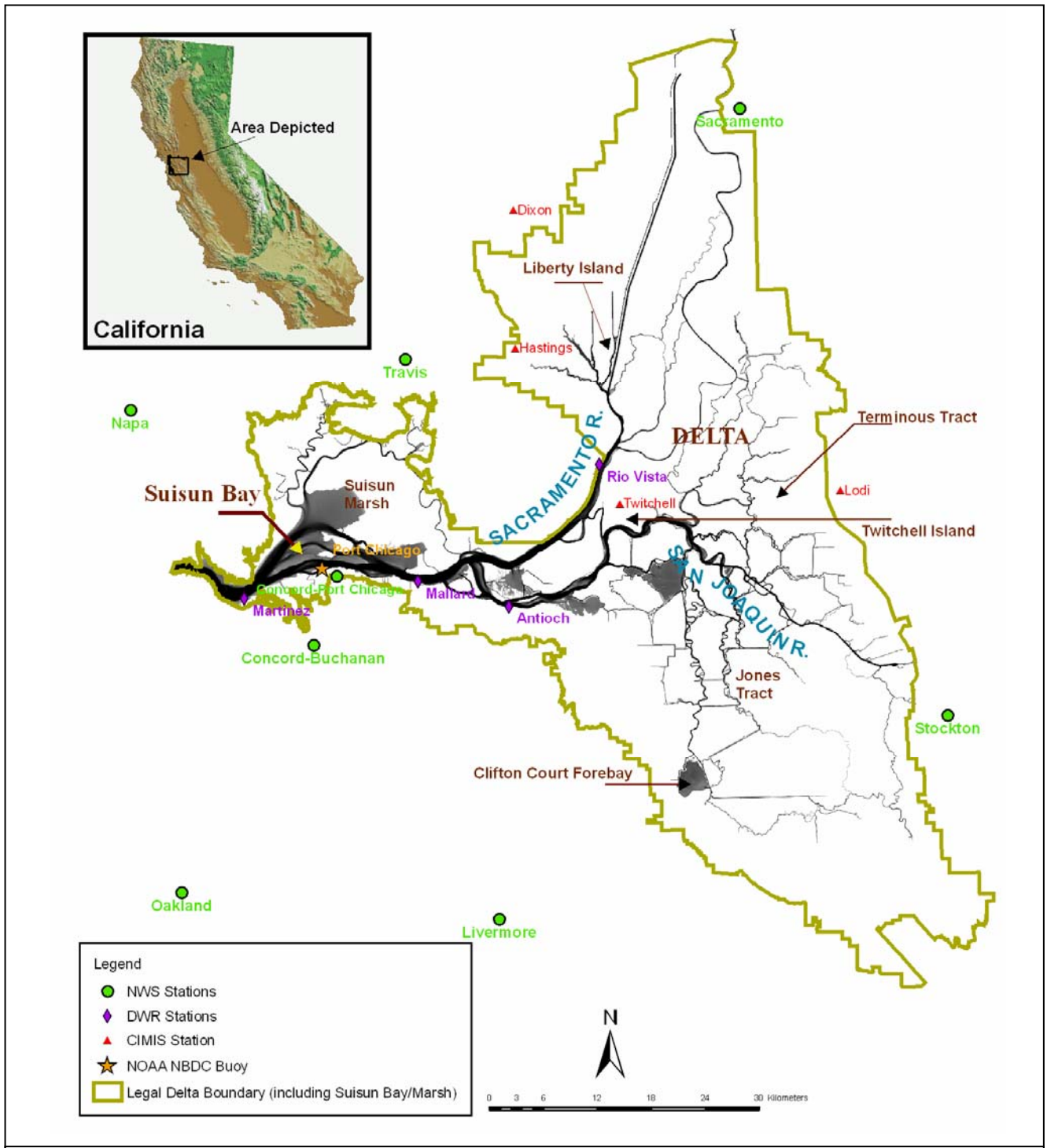


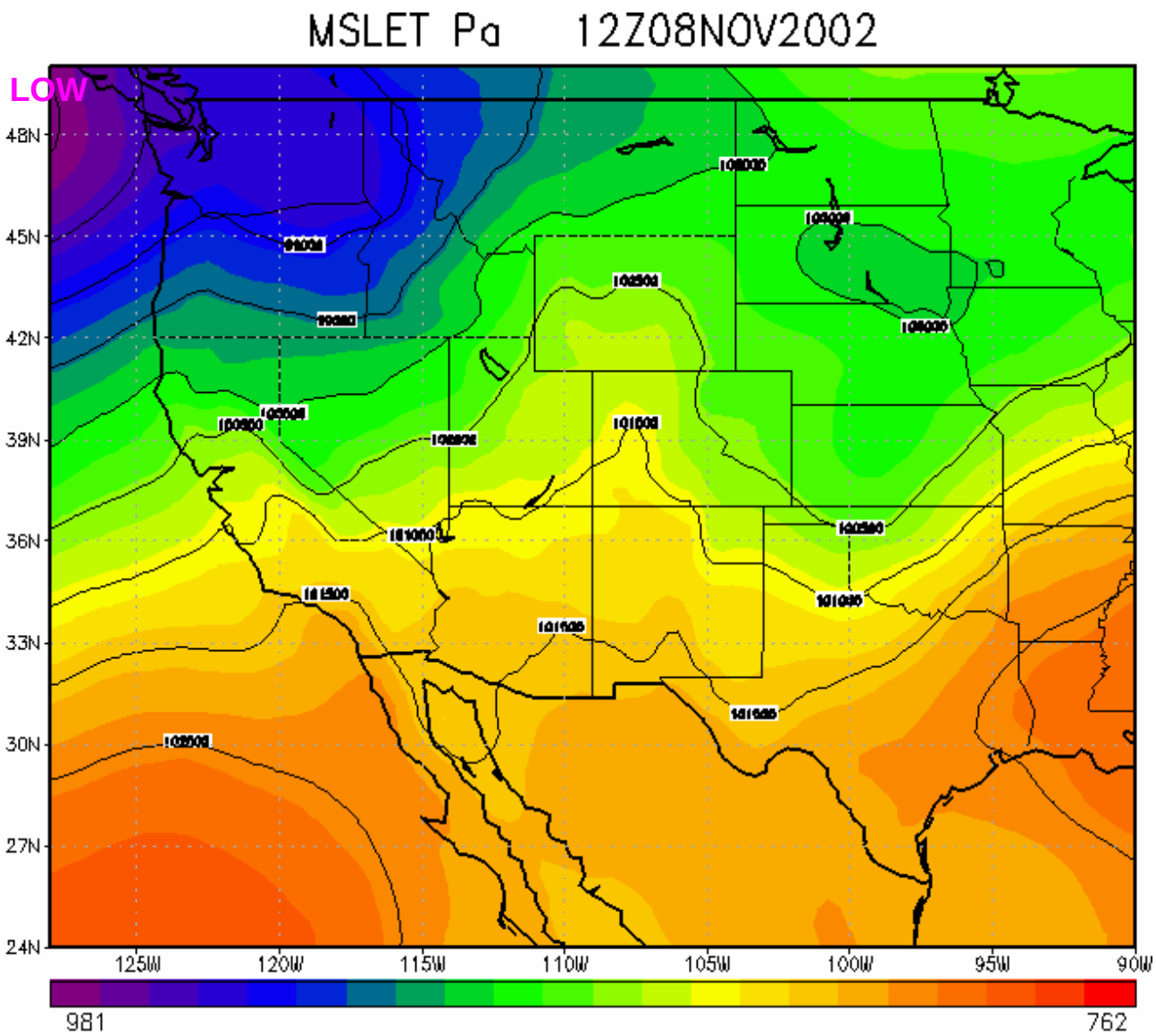
figure 1

DRMS Wind Wave Analysis

Site Map

PWA # 1836.02

PWA



Ex. Synoptic map of Pacific Low meteorology
8-Nov-02

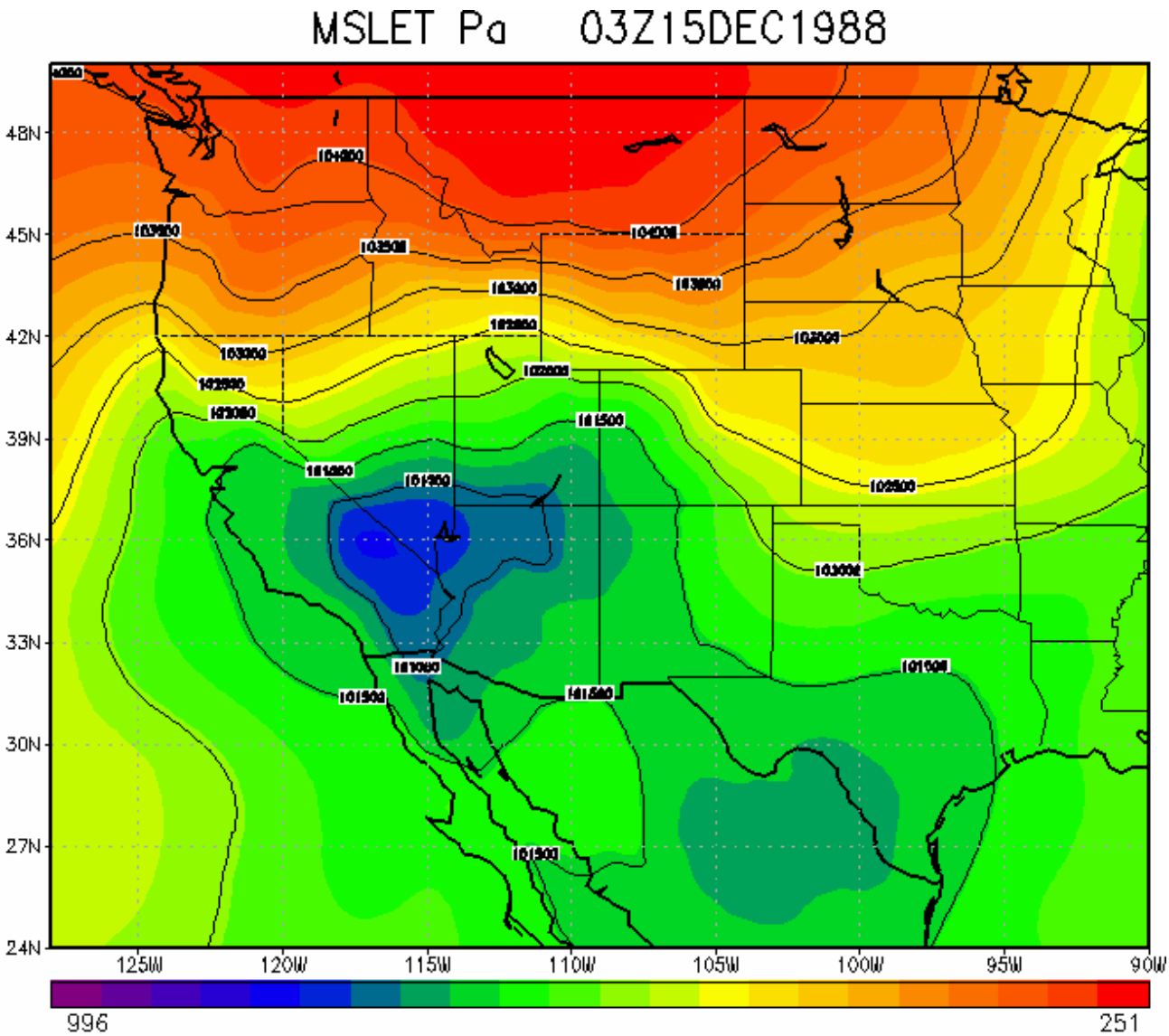
figure 2-a

DRMS Wind Wave Analysis

Extreme wind meteorologies, Pacific Low

PWA # 1836.02

PWA



Ex. Synoptic map of Polar Front meteorology
15-Dec-88

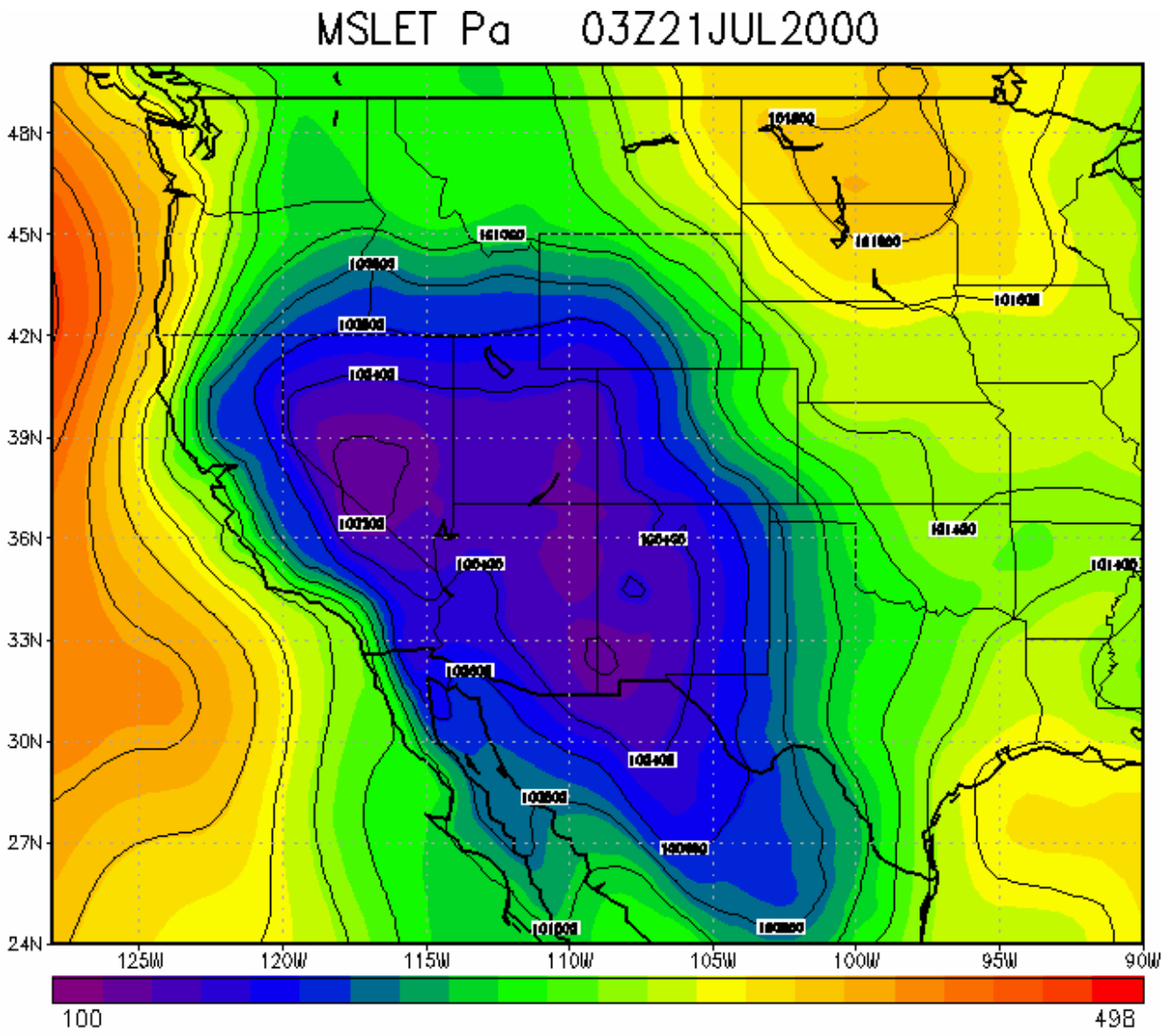
figure 2-b

DRMS Wind Wave Analysis

Extreme wind meteorologies, Polar Front

PWA # 1836.02

PWA



Ex. Synoptic map of Sea Breeze meteorology
18-Jun-53

figure 2-c

DRMS Wind Wave Analysis

Extreme wind meteorologies, Sea Breeze

PWA # 1836.02

PWA

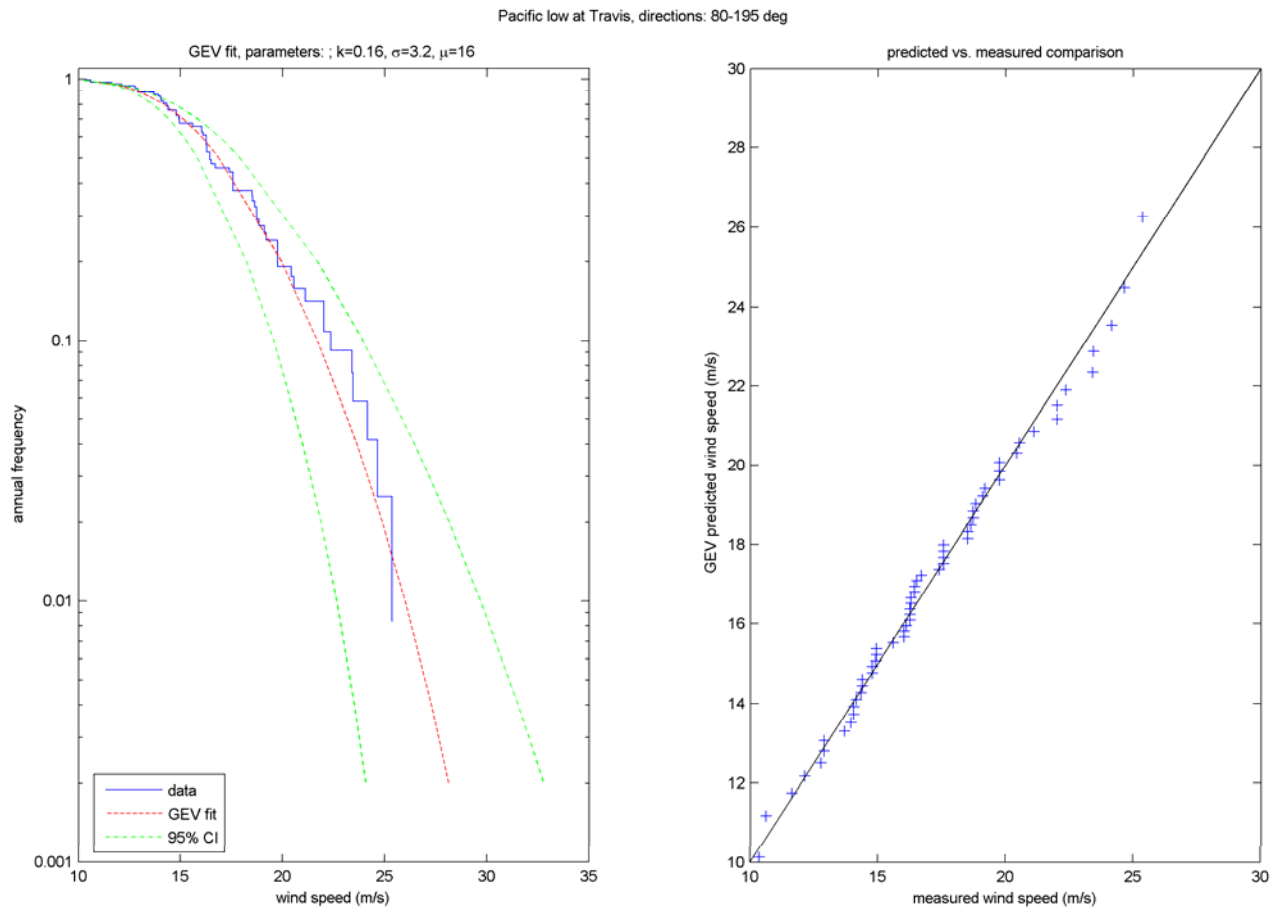


figure 3-a

DRMS Wind Wave Analysis

GEV Distributions of Reference Wind Speed, Pacific

PWA# 1836.02

PWA

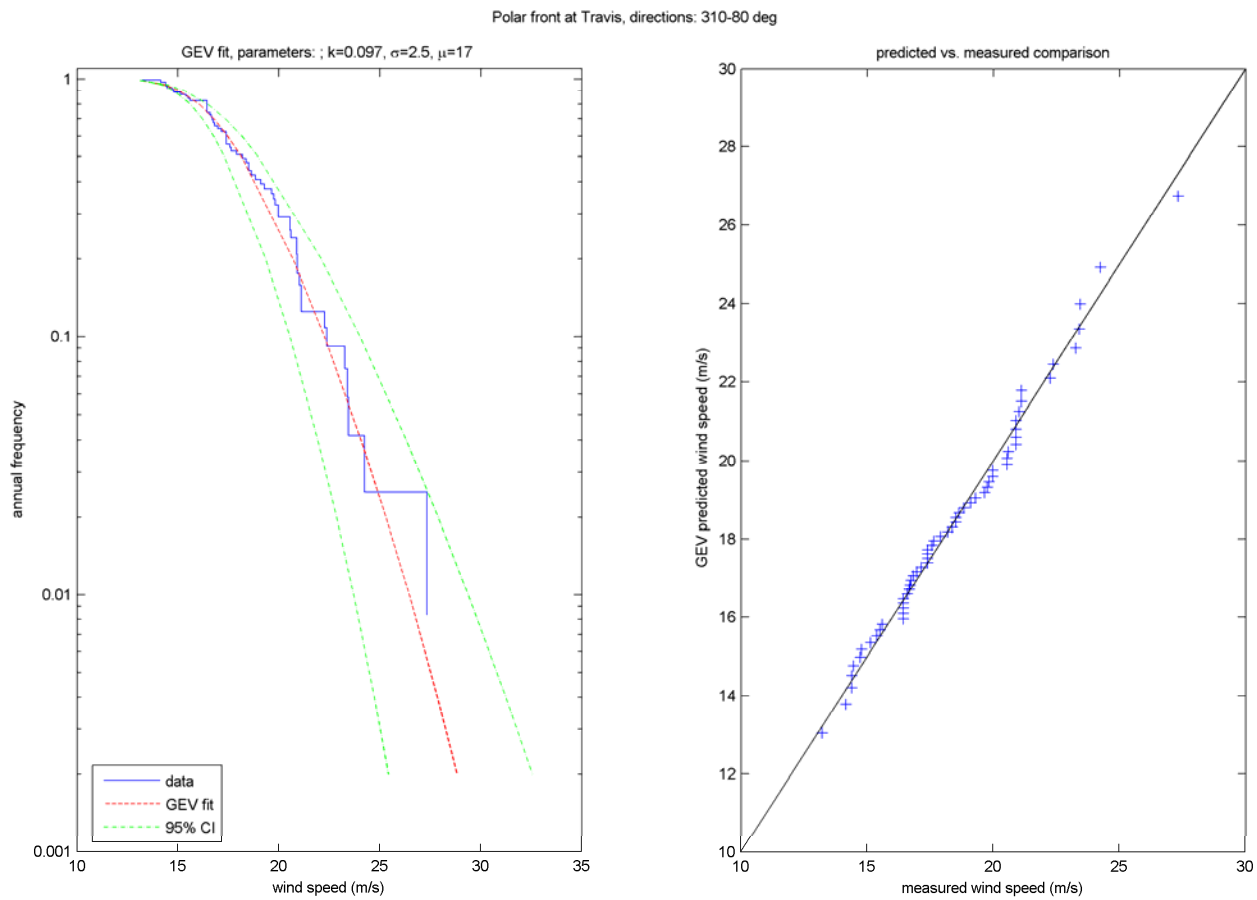


figure 3-b

DRMS Wind Wave Analysis

GEV Distributions of Reference Wind Speed, Polar

PWA# 1836.02

PWA

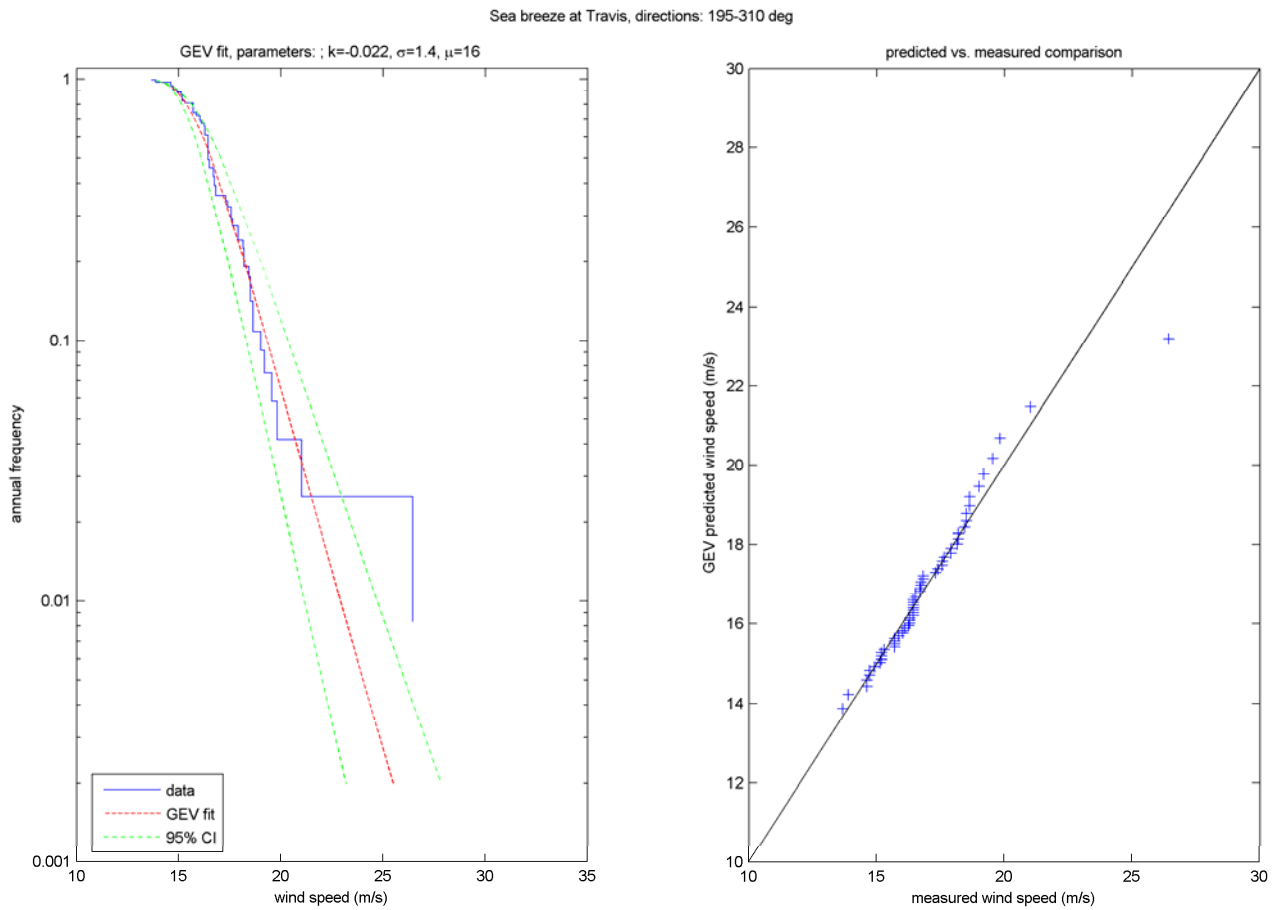


figure 3-c

DRMS Wind Wave Analysis

GEV Distributions of Reference Wind Speed, Sea

PWA# 1836.02

PWA

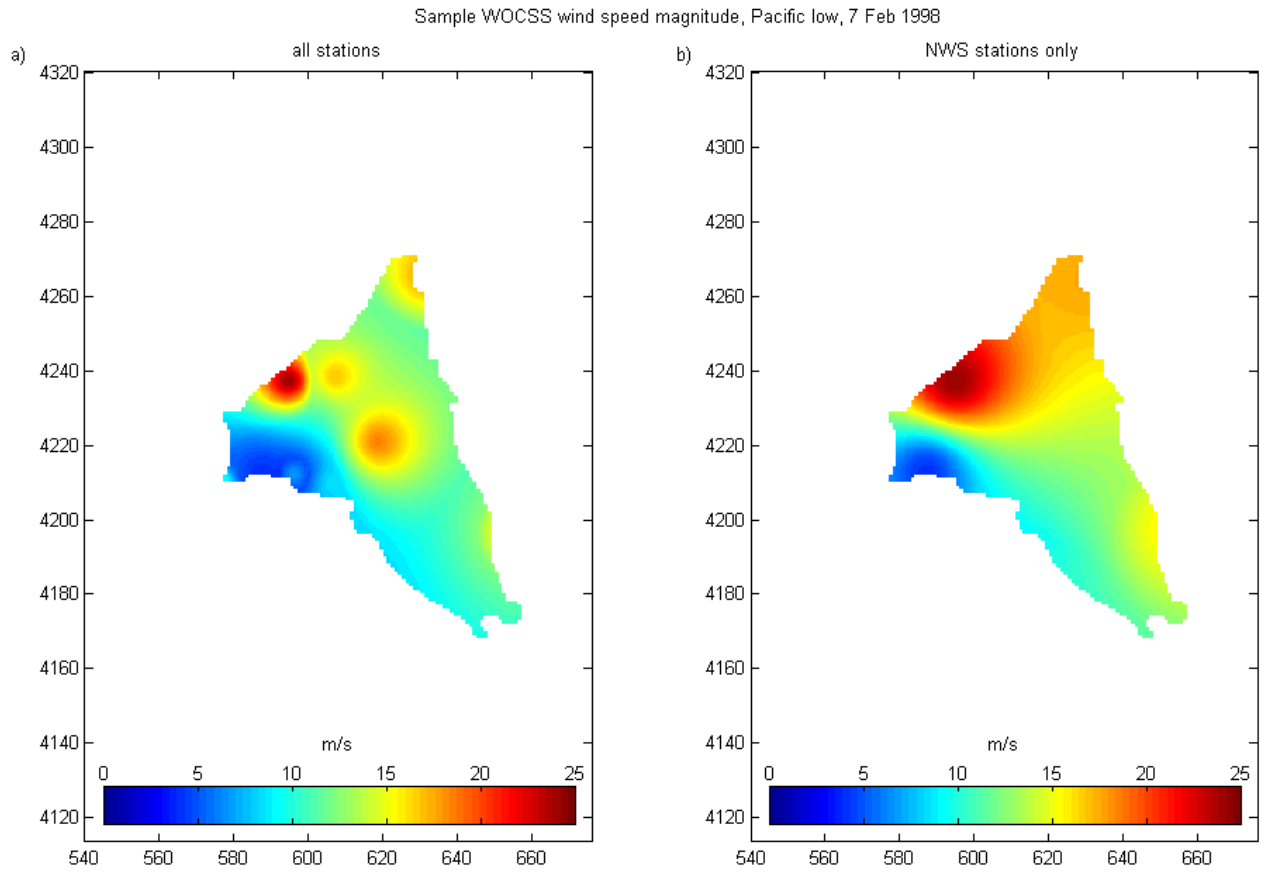


figure 4

DRMS Wind Wave Analysis

Selected WOCSS Results

PWA# 1836.02

PWA

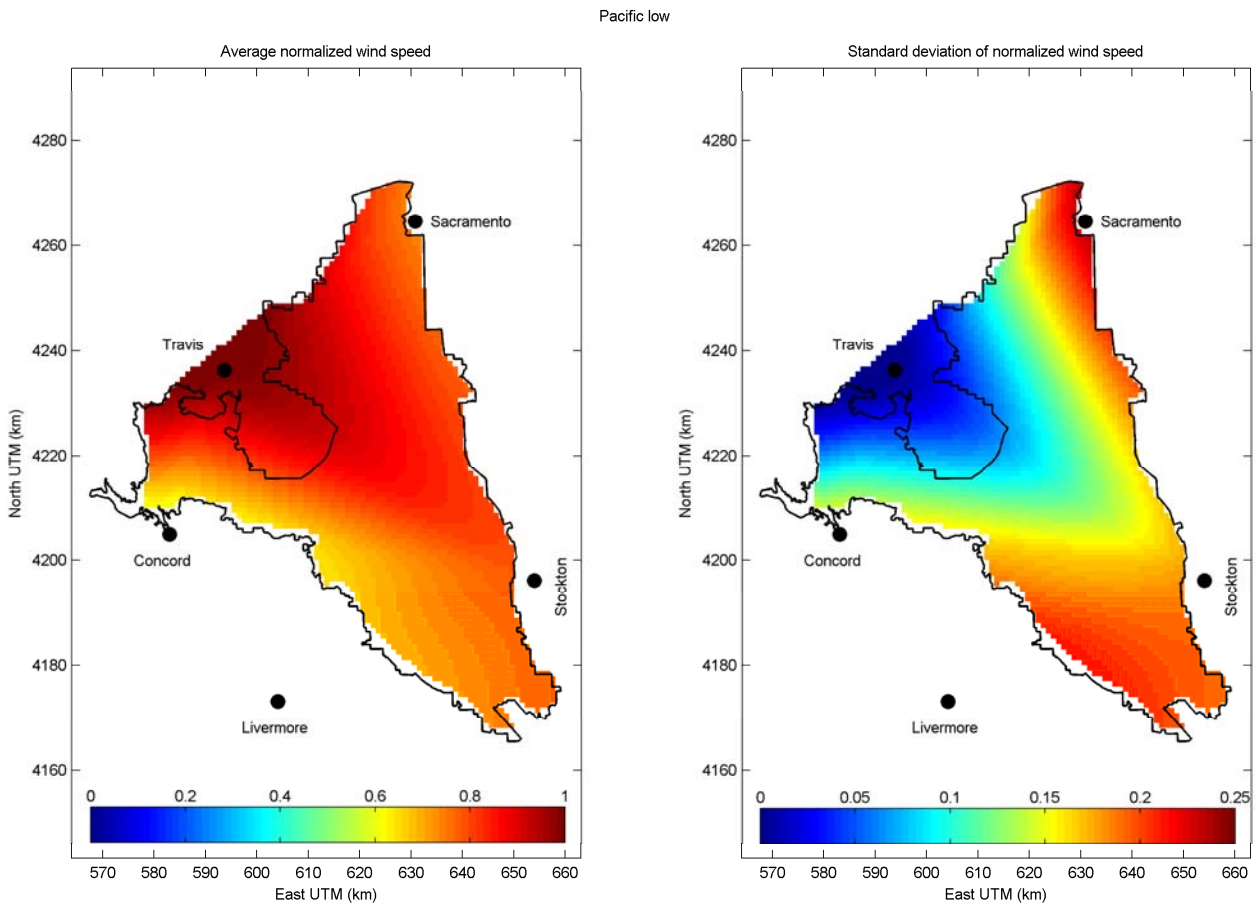


figure 5-ai

DRMS Wind Wave Analysis

Spatial Wind Scaling Pattern, Pacific Low

PWA# 1836.02

PWA

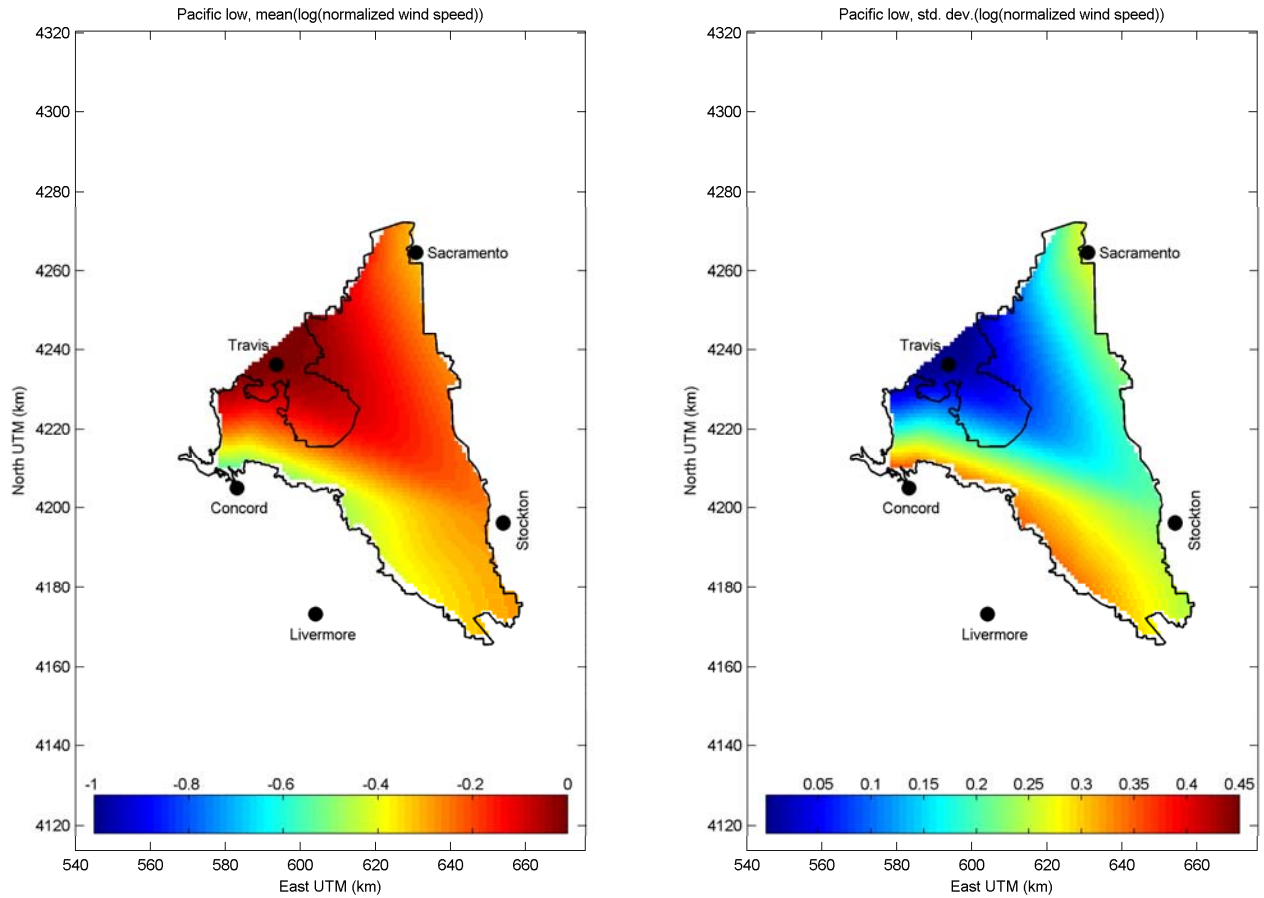


figure 5-aii

DRMS Wind Wave Analysis

Spatial Wind Scaling Pattern, Pacific Low

PWA# 1836.02

PWA

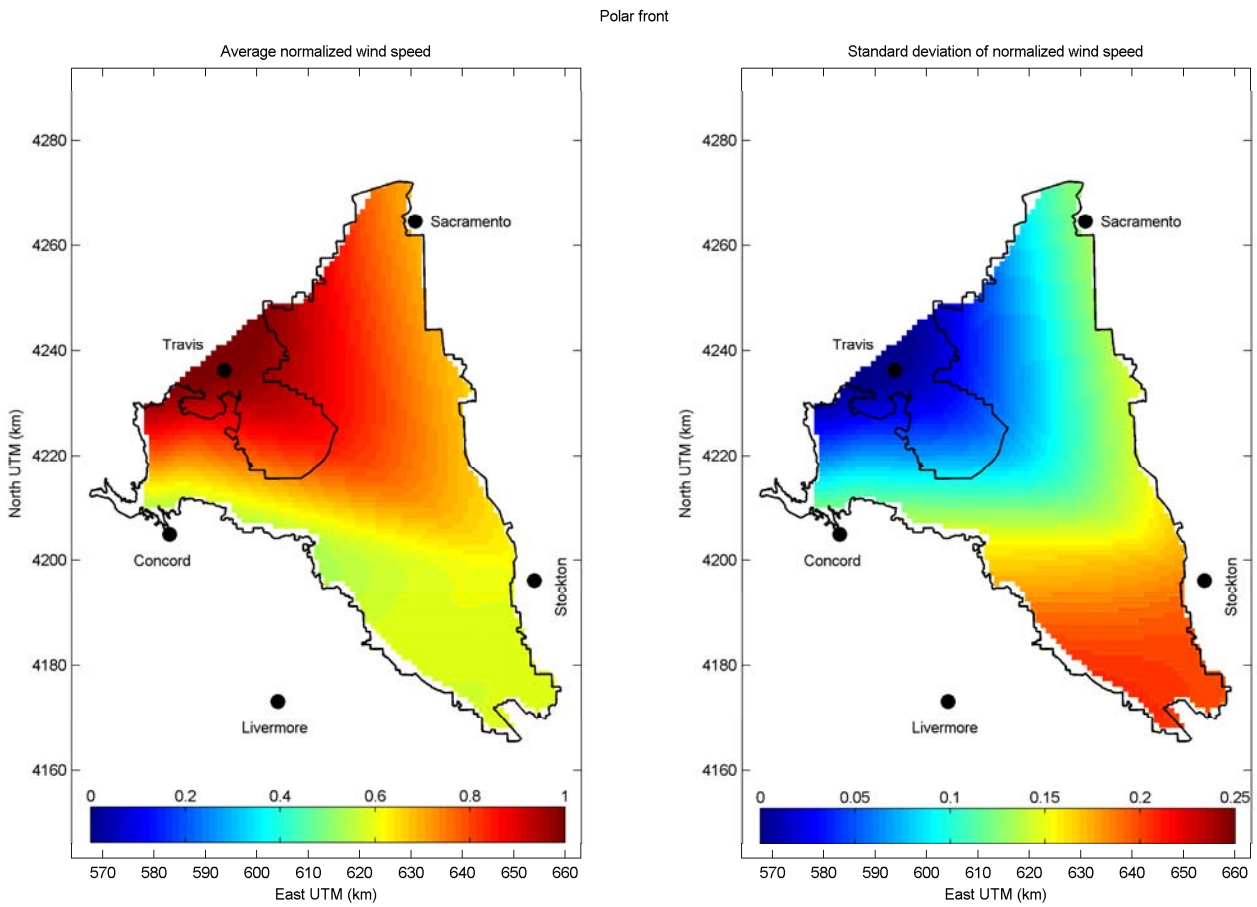


figure 5-bi

DRMS Wind Wave Analysis

Spatial Wind Scaling Pattern, Polar Front

PWA# 1836.02

PWA

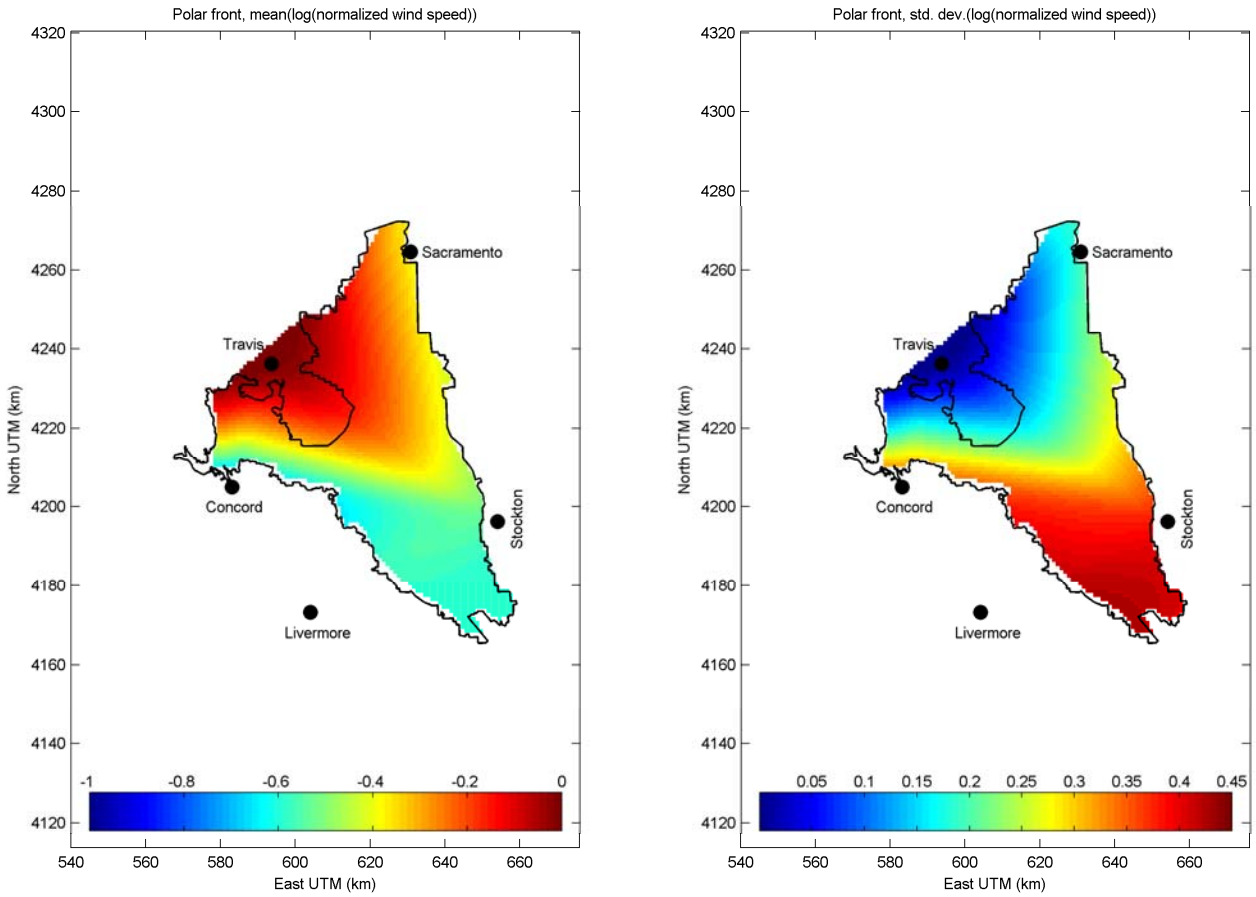


figure 5-bii

DRMS Wind Wave Analysis

Spatial Wind Scaling Pattern, Polar Front

PWA# 1836.02

PWA

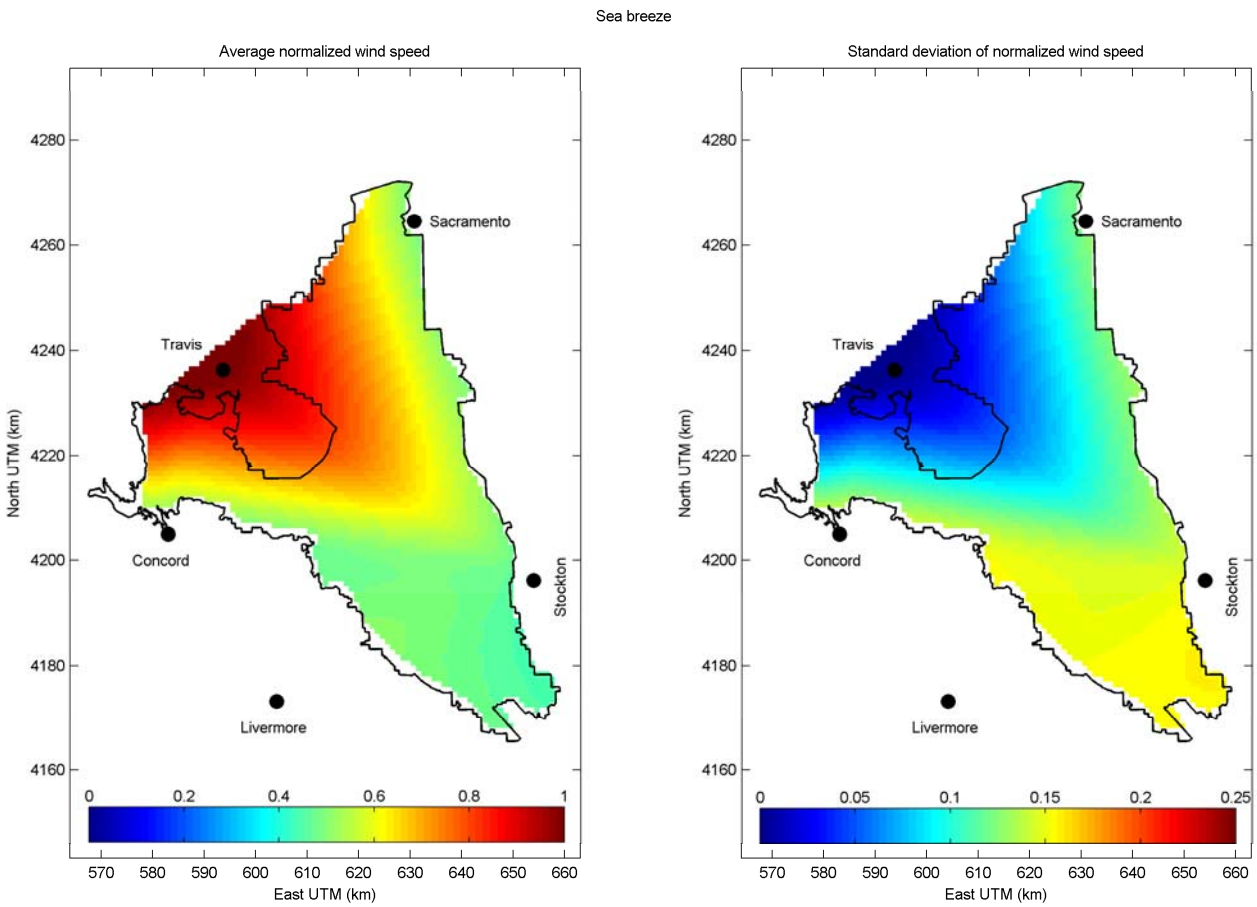


figure 5-ci

DRMS Wind Wave Analysis

Spatial Wind Scaling Pattern, Sea Breeze

PWA# 1836.02

PWA

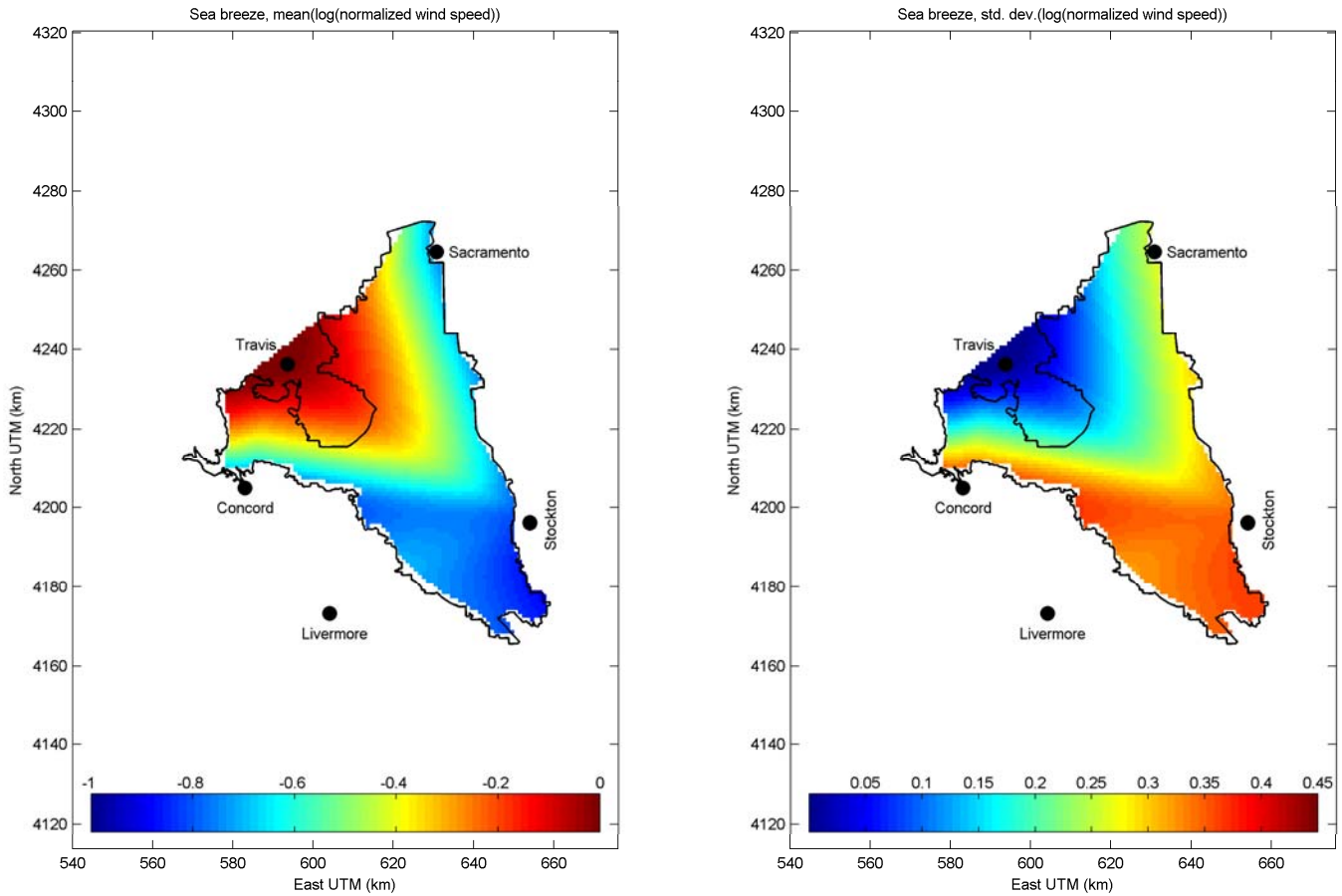


figure 5-cii

DRMS Wind Wave Analysis

Spatial Wind Scaling Pattern, Sea Breeze

PWA# 1836.02

PWA

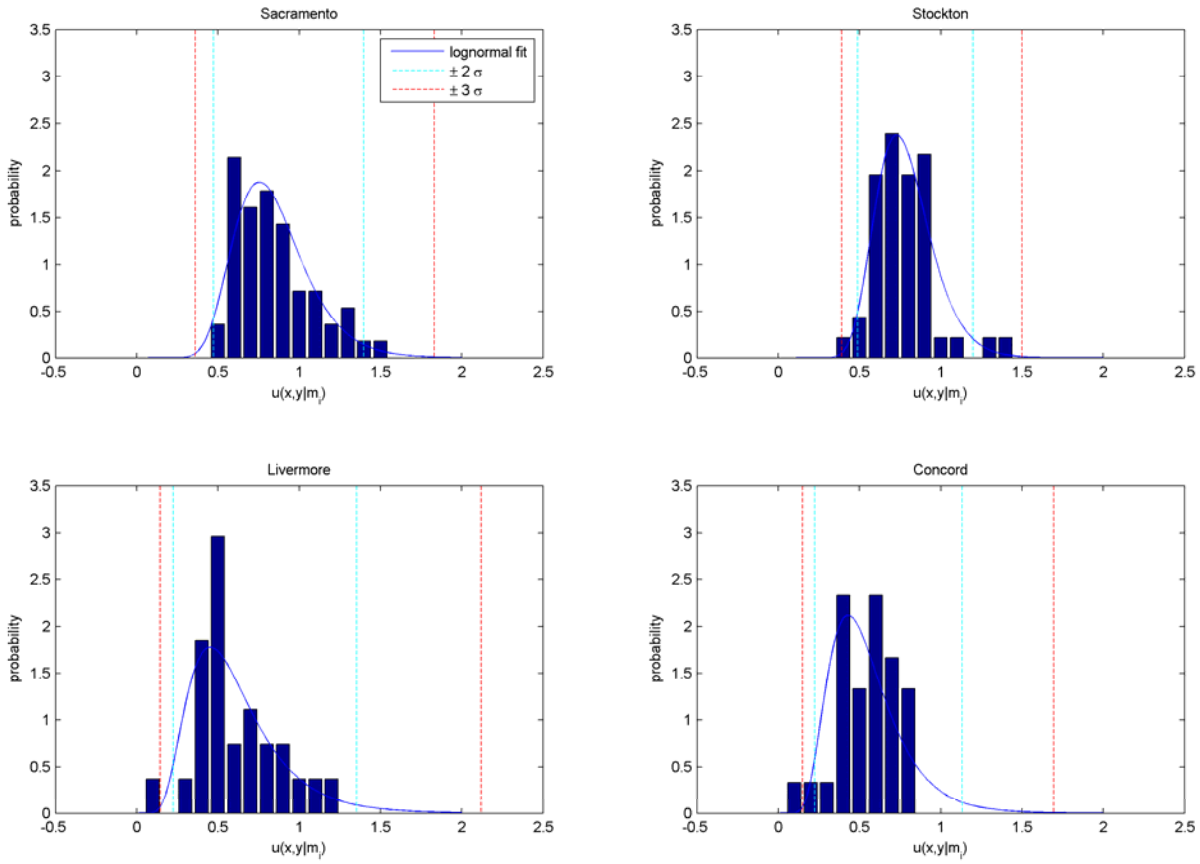


figure 6-a

DRMS Wind Wave Analysis

Wind speed scaling factor PMFs, Pacific Low

PWA# 1836.02

PWA

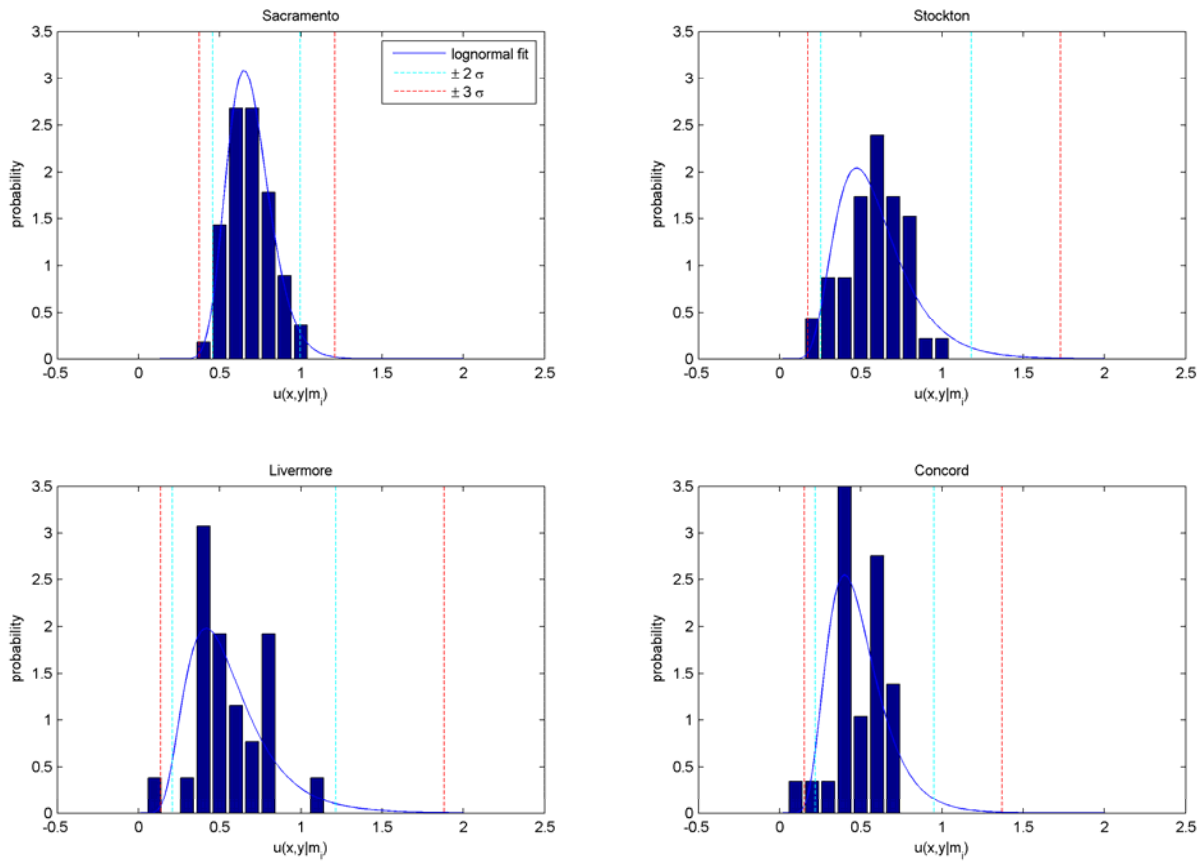


figure 6-b

DRMS Wind Wave Analysis

Wind speed scaling factor PMFs, Polar Front

PWA# 1836.02

PWA

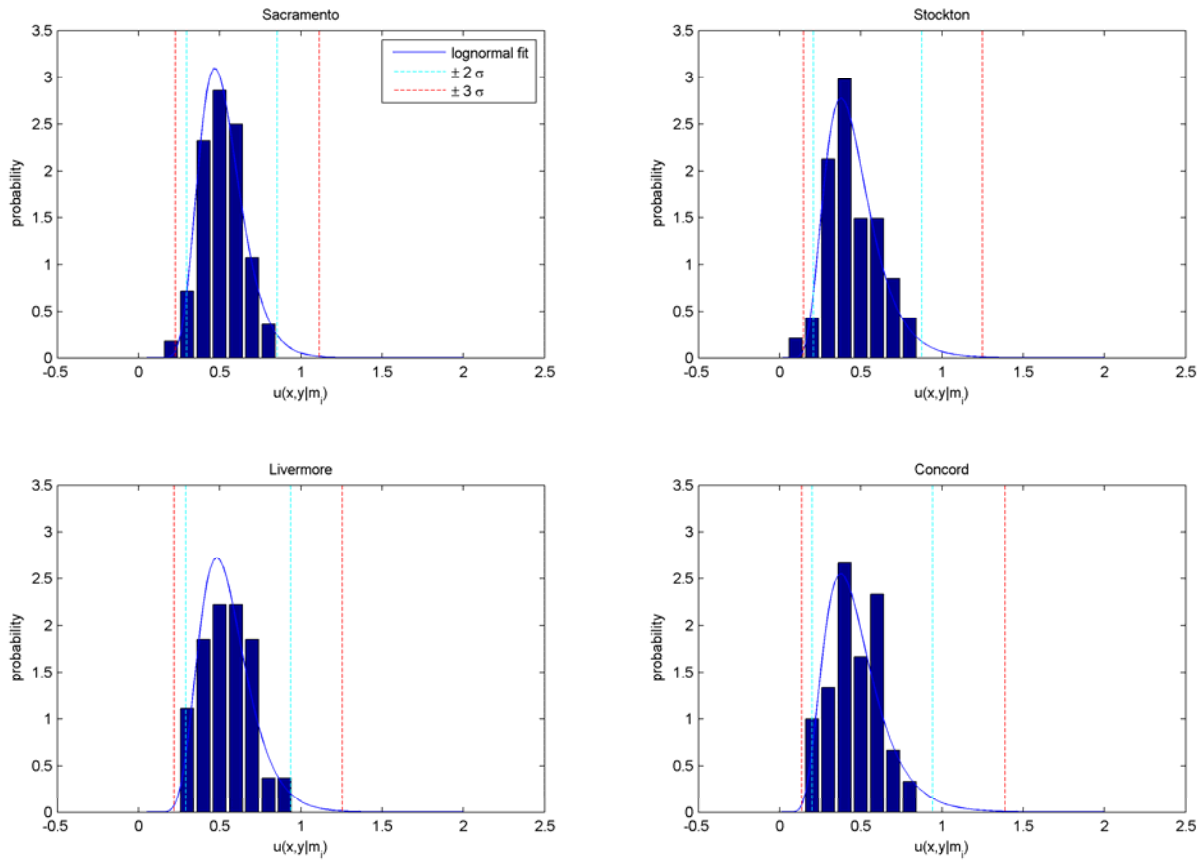


figure 6-c

DRMS Wind Wave Analysis

Wind speed scaling factor PMFs, Sea Breeze

PWA# 1836.02

PWA

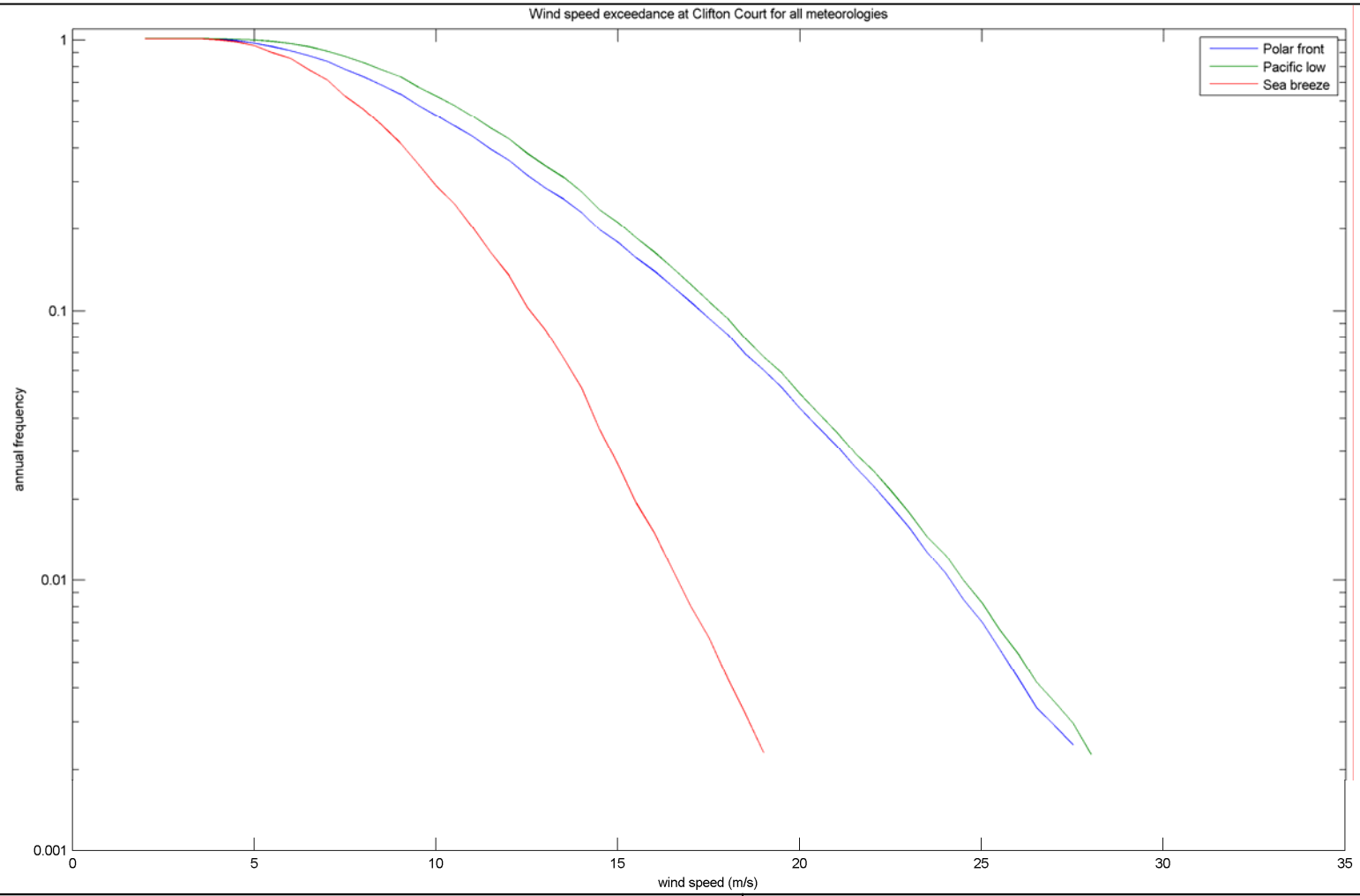


figure 7-a

DRMS Wind Wave Analysis

Wind speed exceedance probability distribution, Clifton Court

PWA# 1836.02

PWA

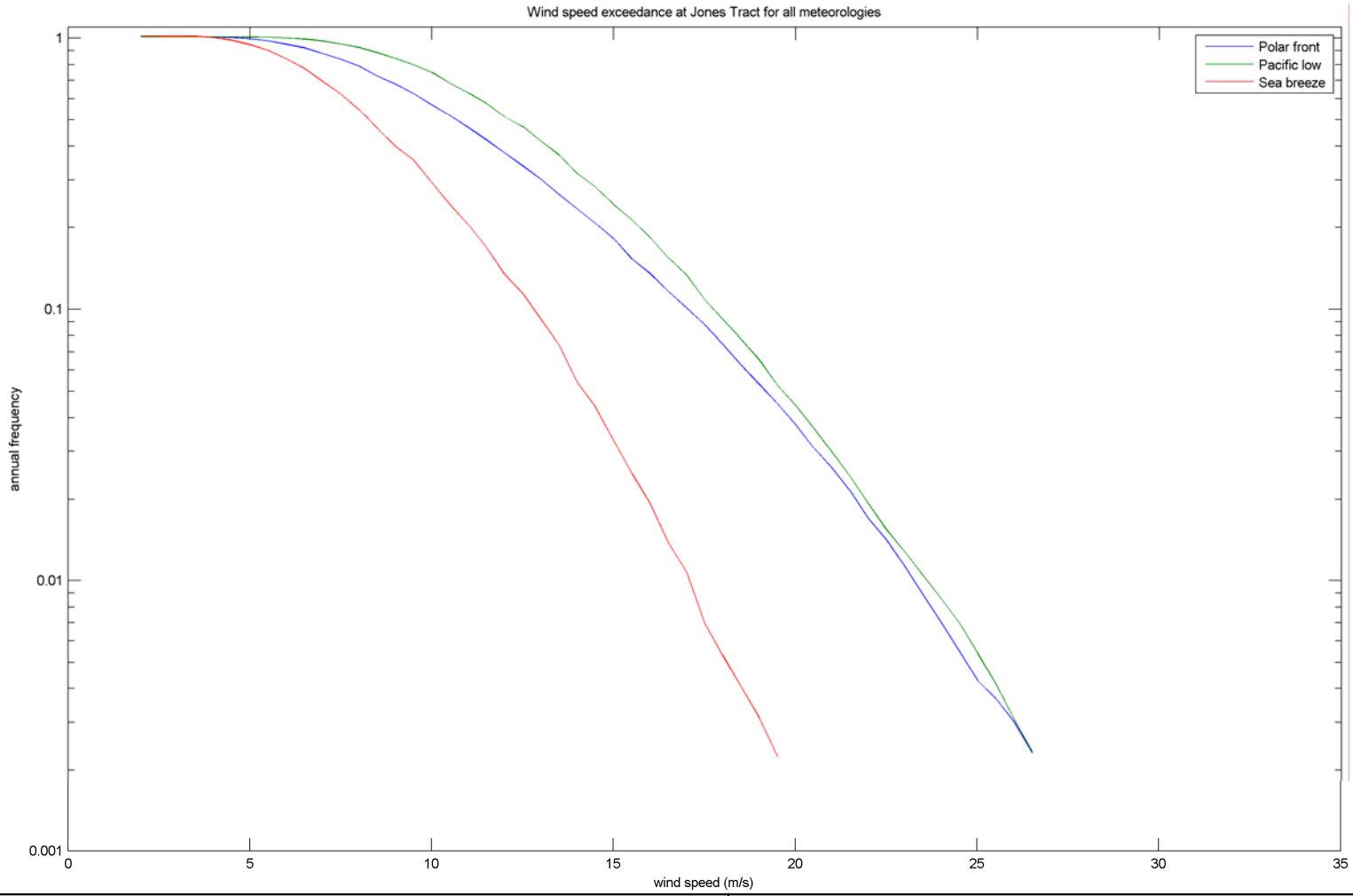


figure 7-b

DRMS Wind Wave Analysis

Wind speed exceedance probability distributions, Jones Tract

PWA# 1836.02

PWA

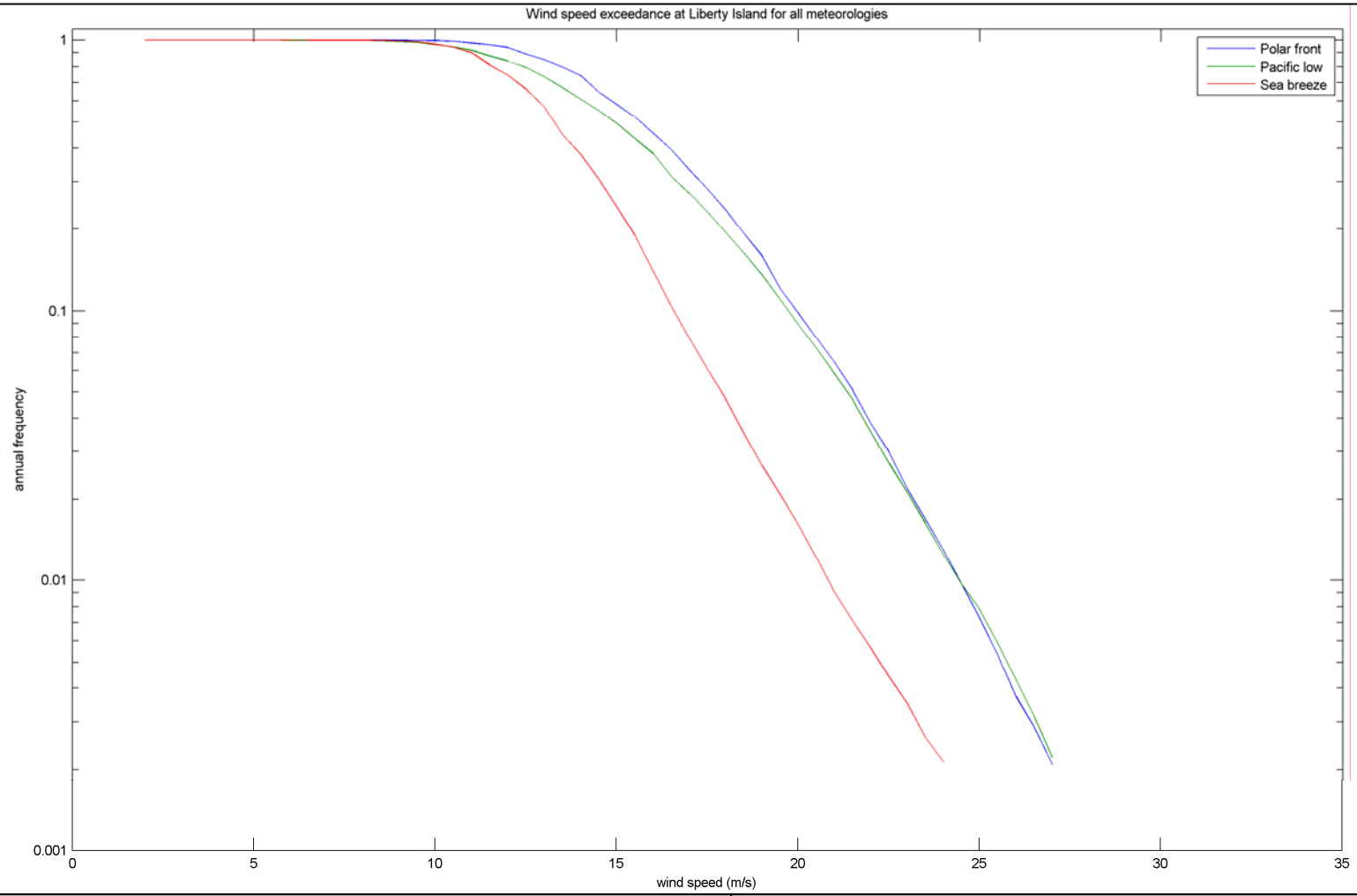


figure 7-c

DRMS Wind Wave Analysis

Wind speed exceedance probability distributions, Liberty Island

PWA# 1836.02

PWA

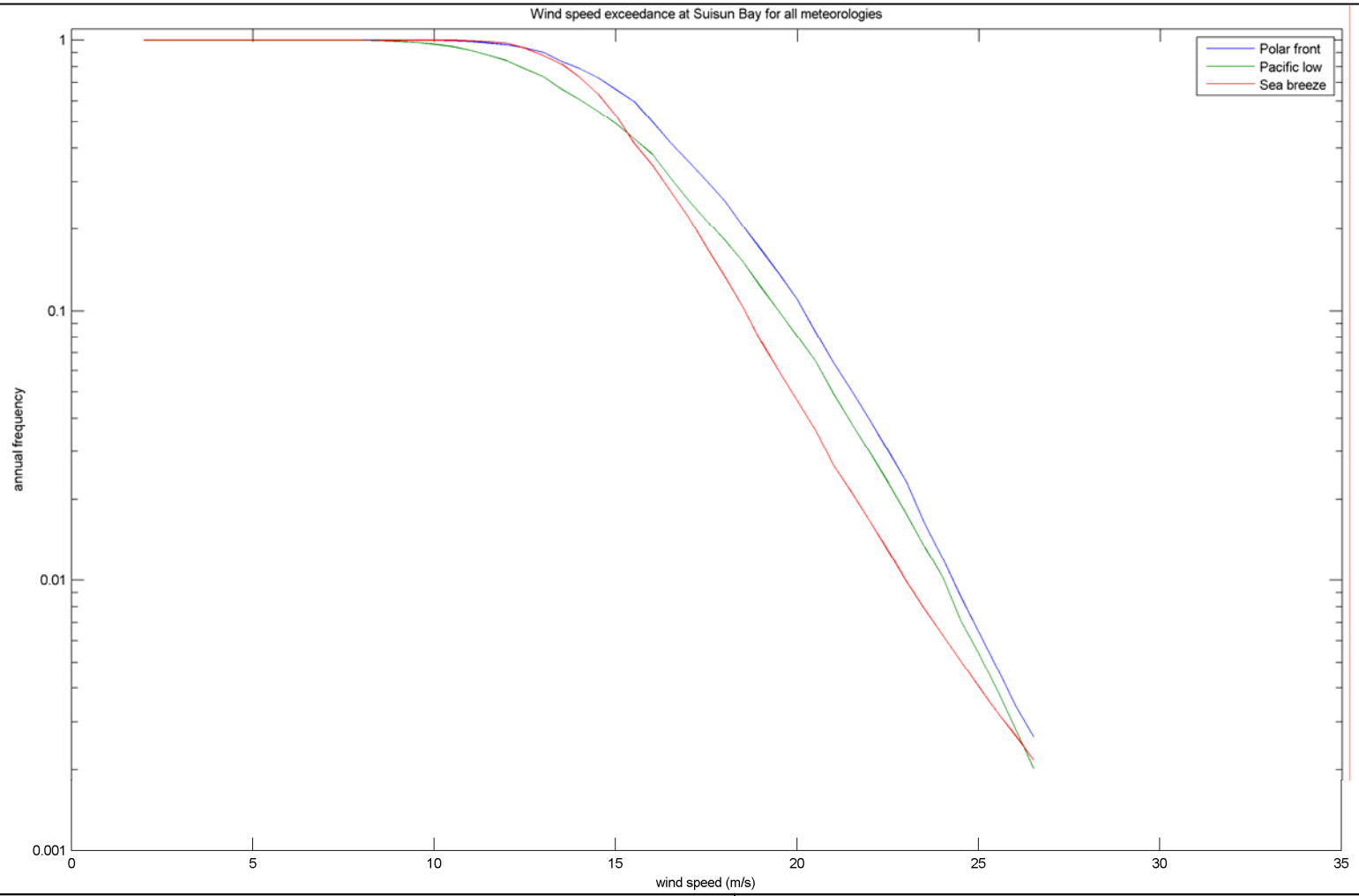


figure 7-d

DRMS Wind Wave Analysis

Wind speed exceedance probability distributions, Suisun Bay

PWA# 1836.02

PWA

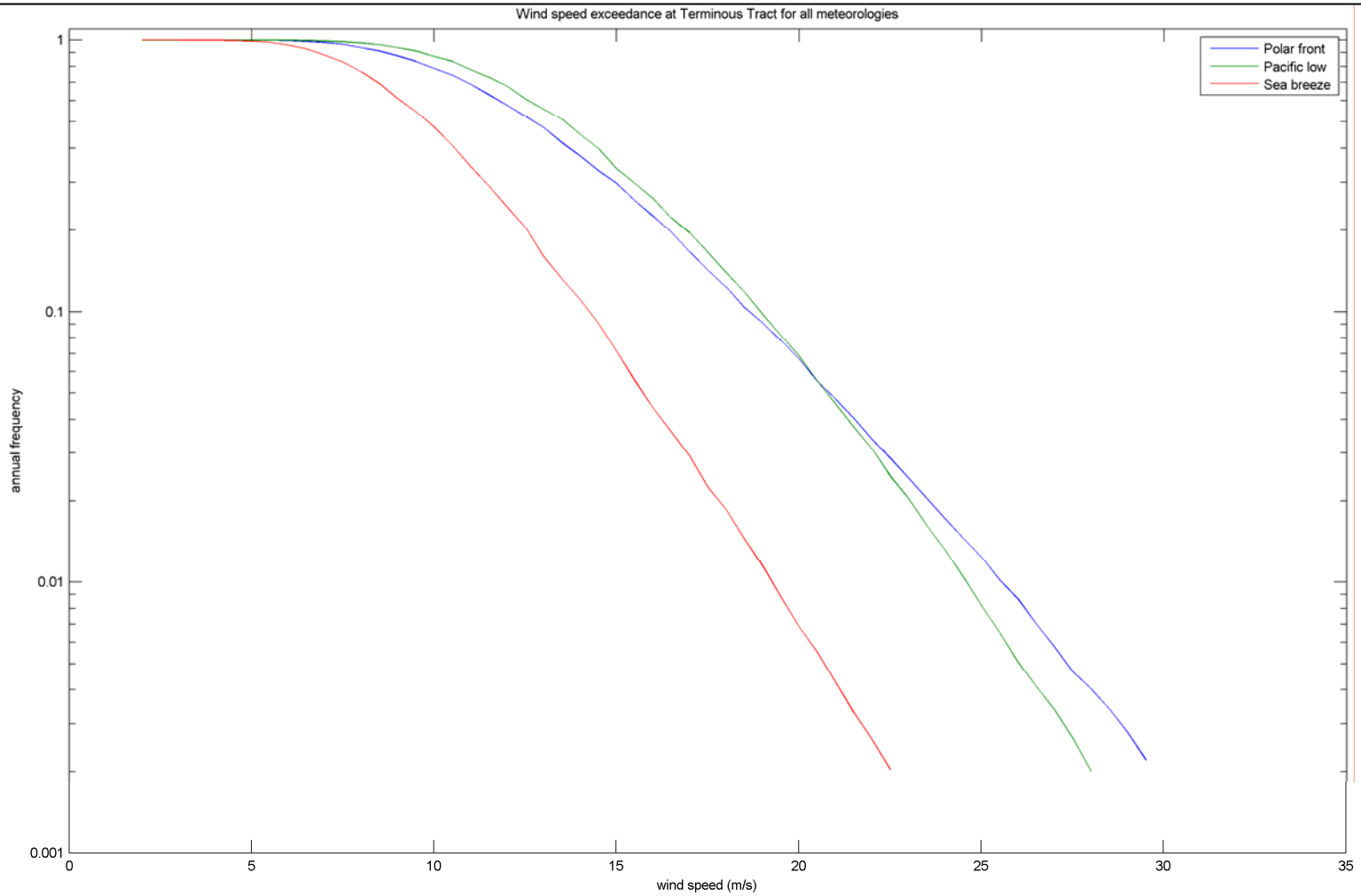


figure 7-e

DRMS Wind Wave Analysis

Wind speed exceedance probability distributions, Terminous Tract

PWA# 1836.02

PWA

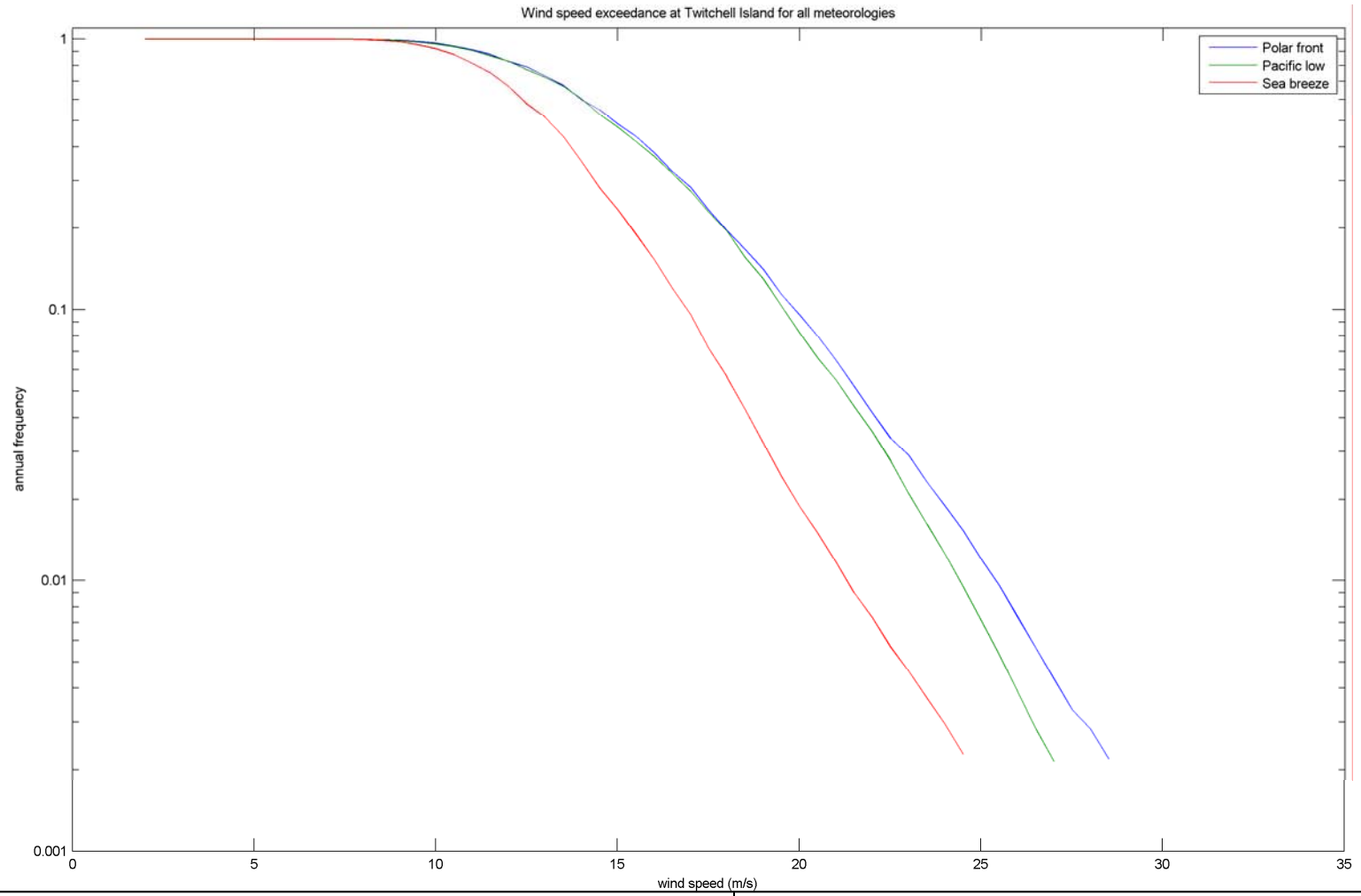


figure 7-f

DRMS Wind Wave Analysis

Wind speed exceedance probability distributions, Twitchell Island

PWA# 1836.02

PWA

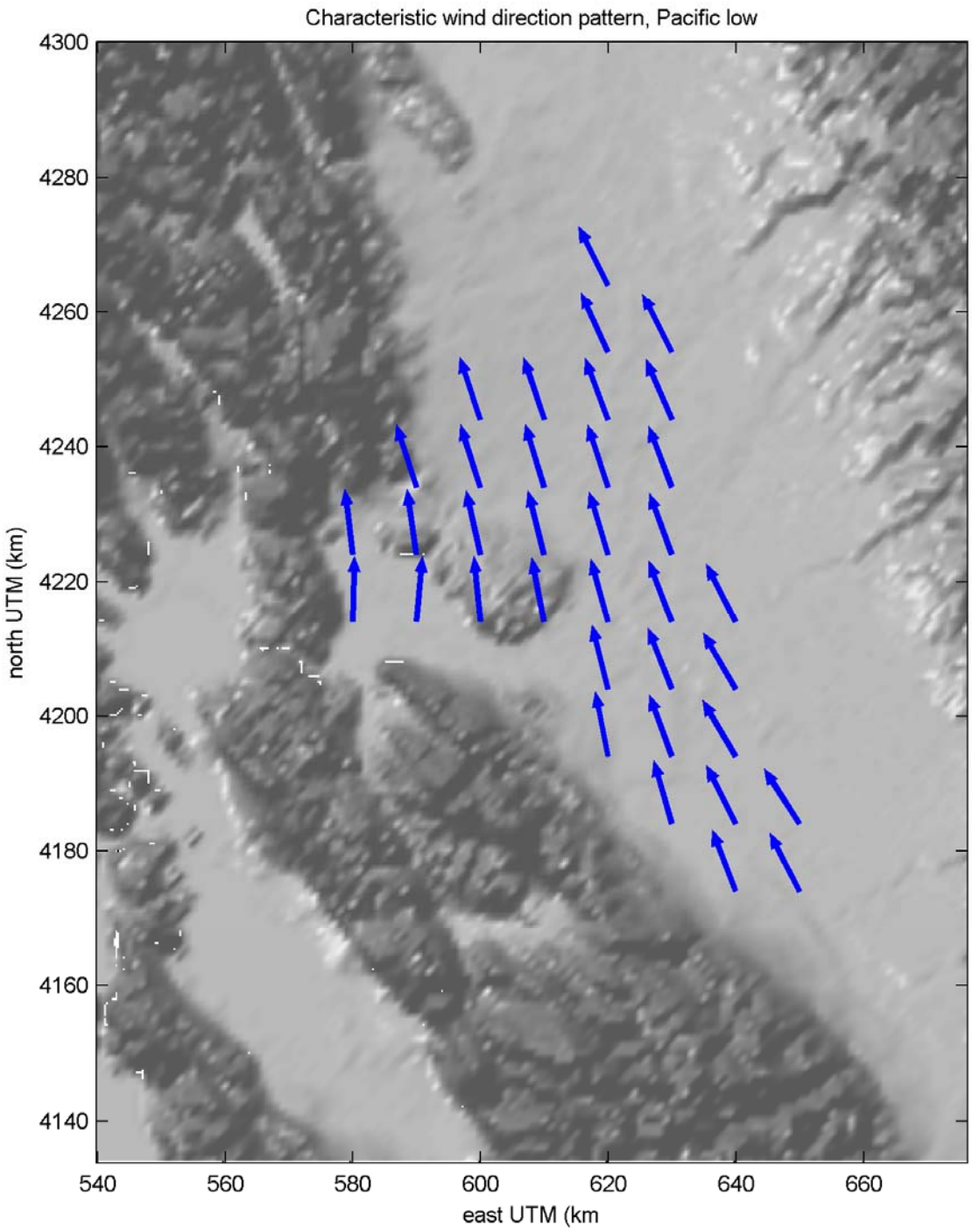


figure 8-a

DRMS Wind Wave Analysis

Spatial wind direction pattern, Pacific Low

PWA # 1836.02

PWA

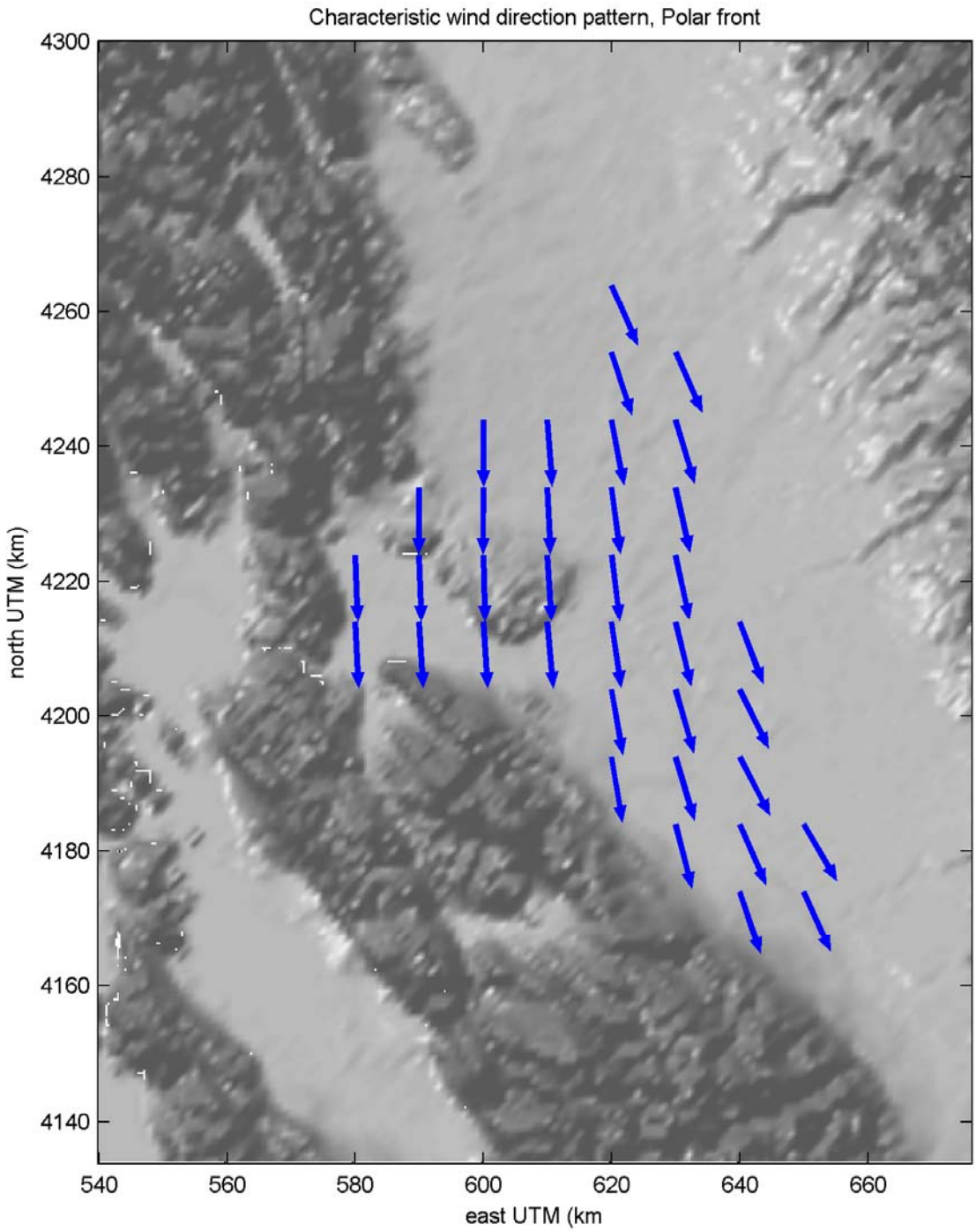


figure 8-b

DRMS Wind Wave Analysis

Spatial wind direction pattern, Polar Front

PWA # 1836.02

PWA

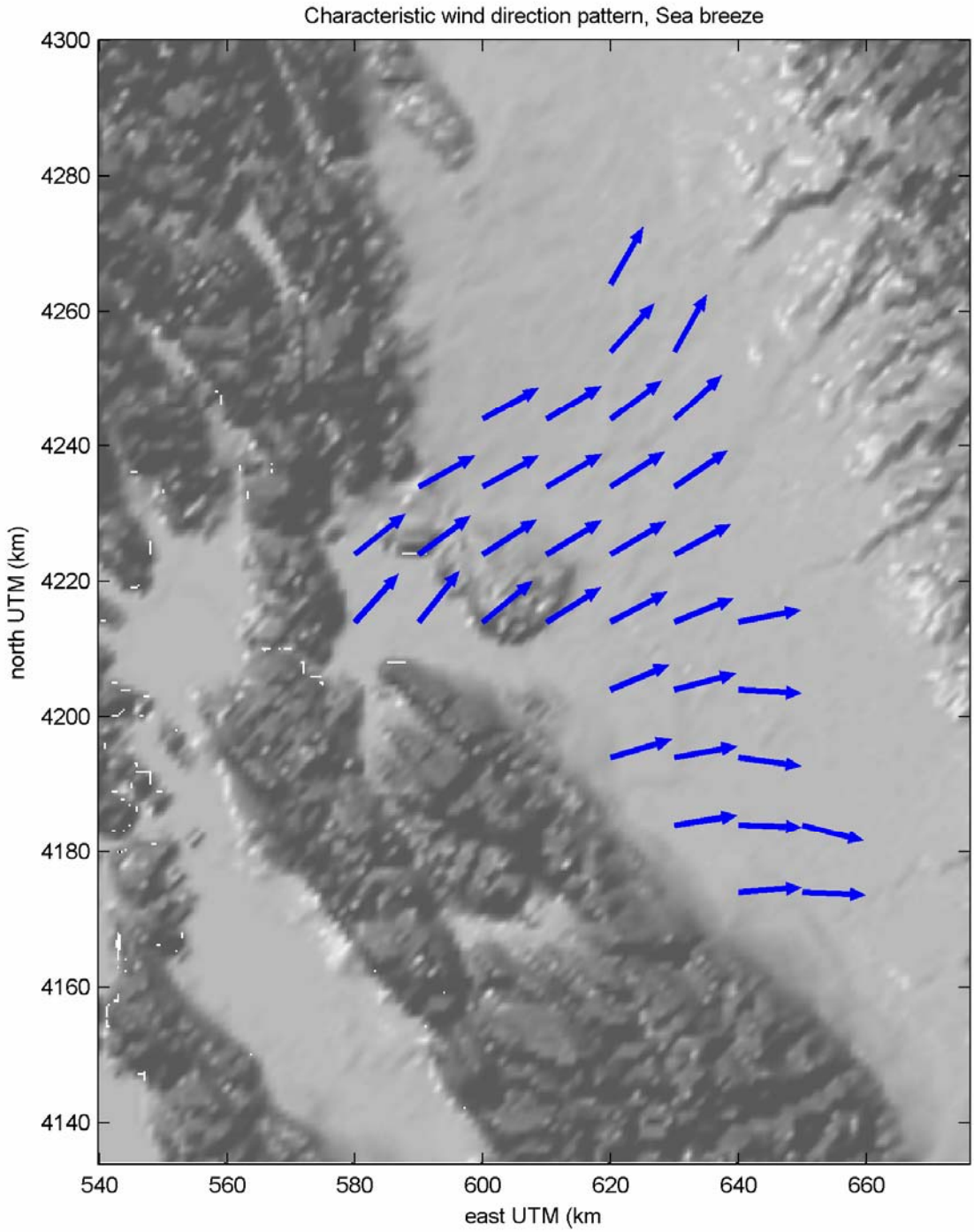


figure 8-c

DRMS Wind Wave Analysis

Spatial wind direction pattern, Sea Breeze

PWA # 1836.02

PWA

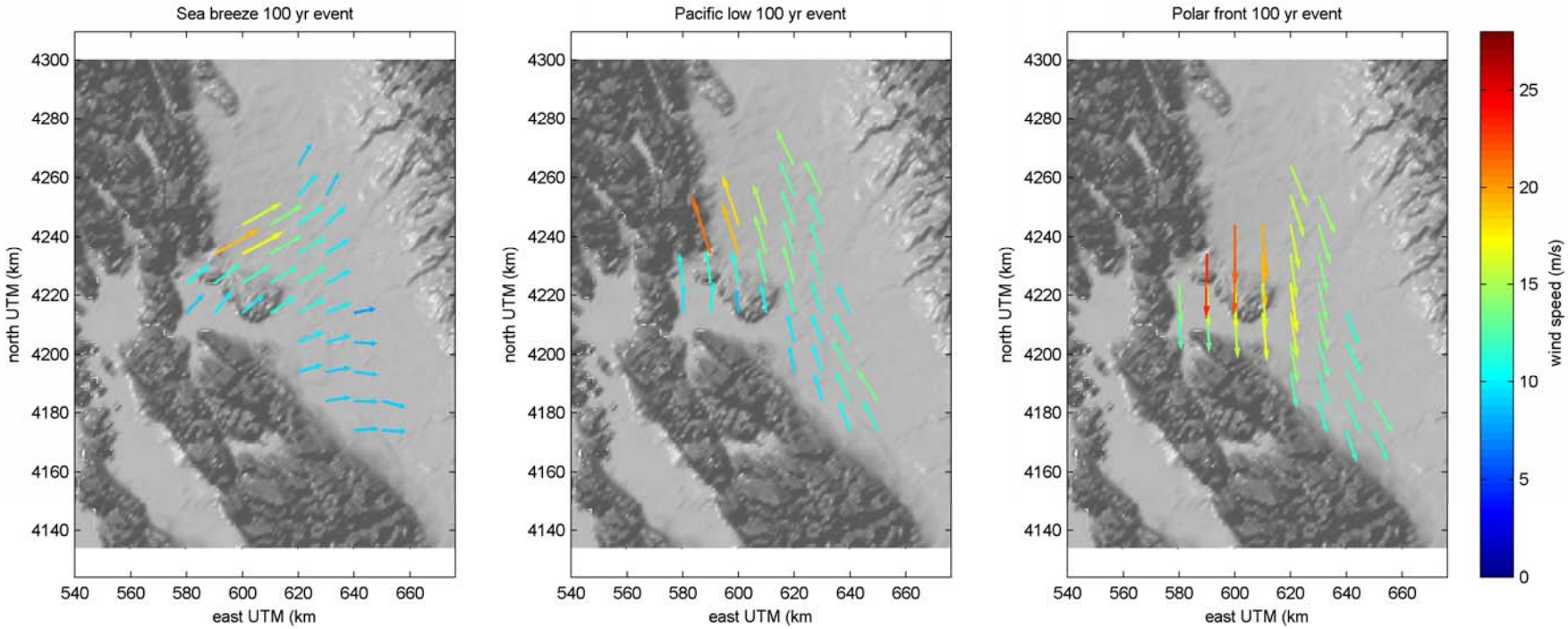


figure 9

DRMS Wind Wave Analysis

100-Year return period wind events

PWA# 1836.02

PWA

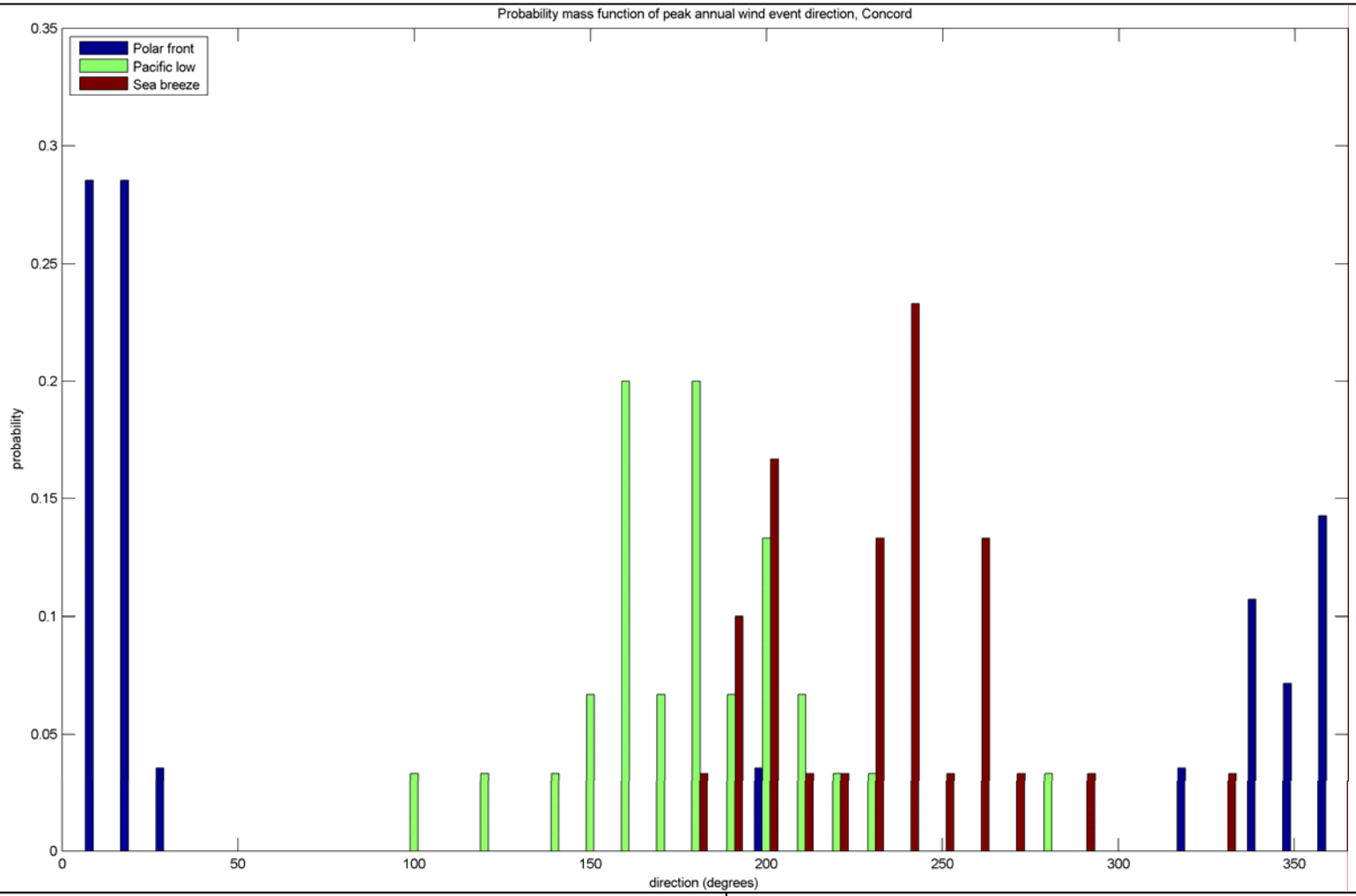


figure 10-a

DRMS Wind Wave Analysis

Wind direction PMF, Concord

PWA# 1836.02

PWA

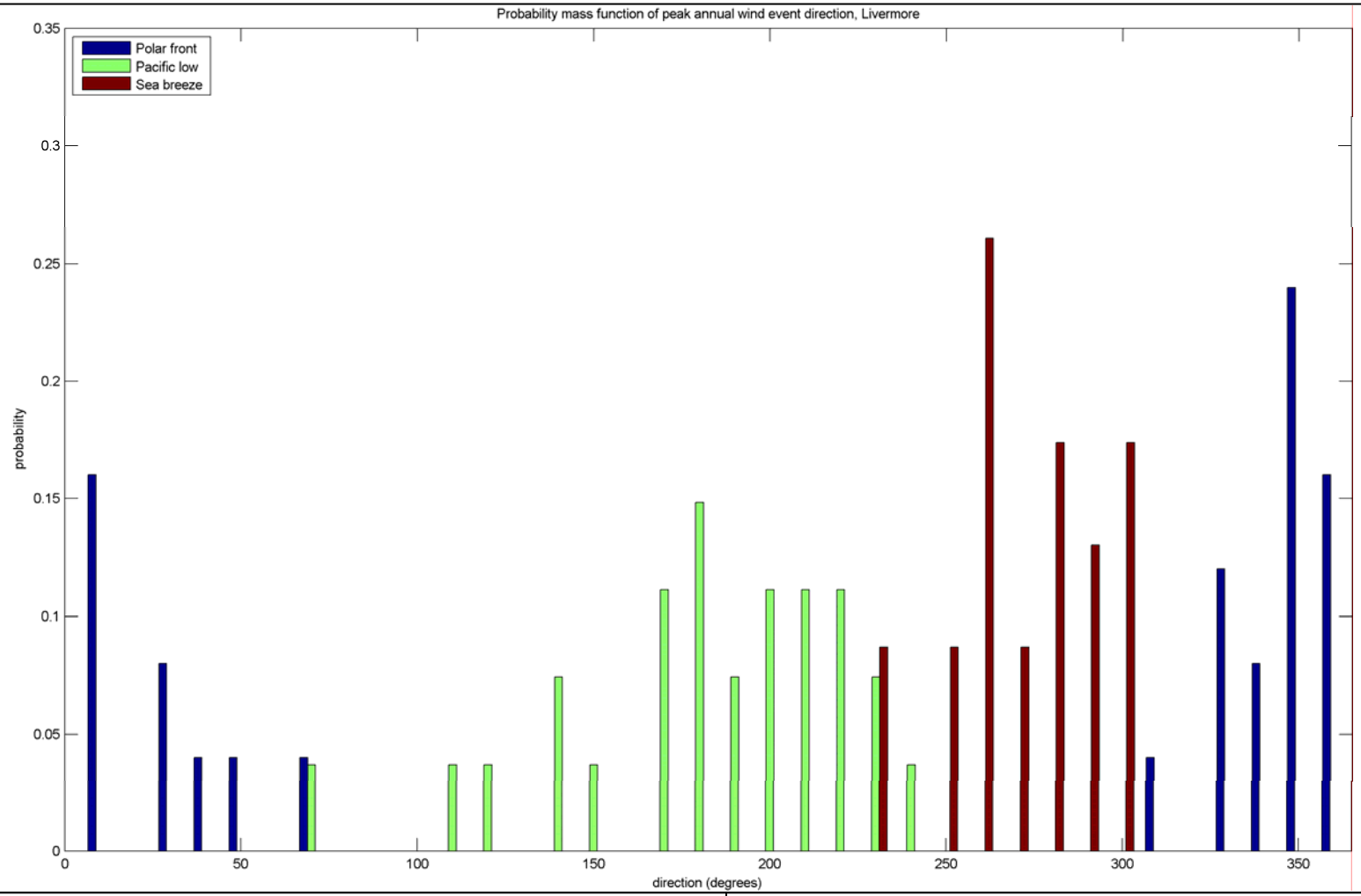


figure 10-b

DRMS Wind Wave Analysis

Wind direciton PMF, Livermore

PWA# 1836.02

PWA

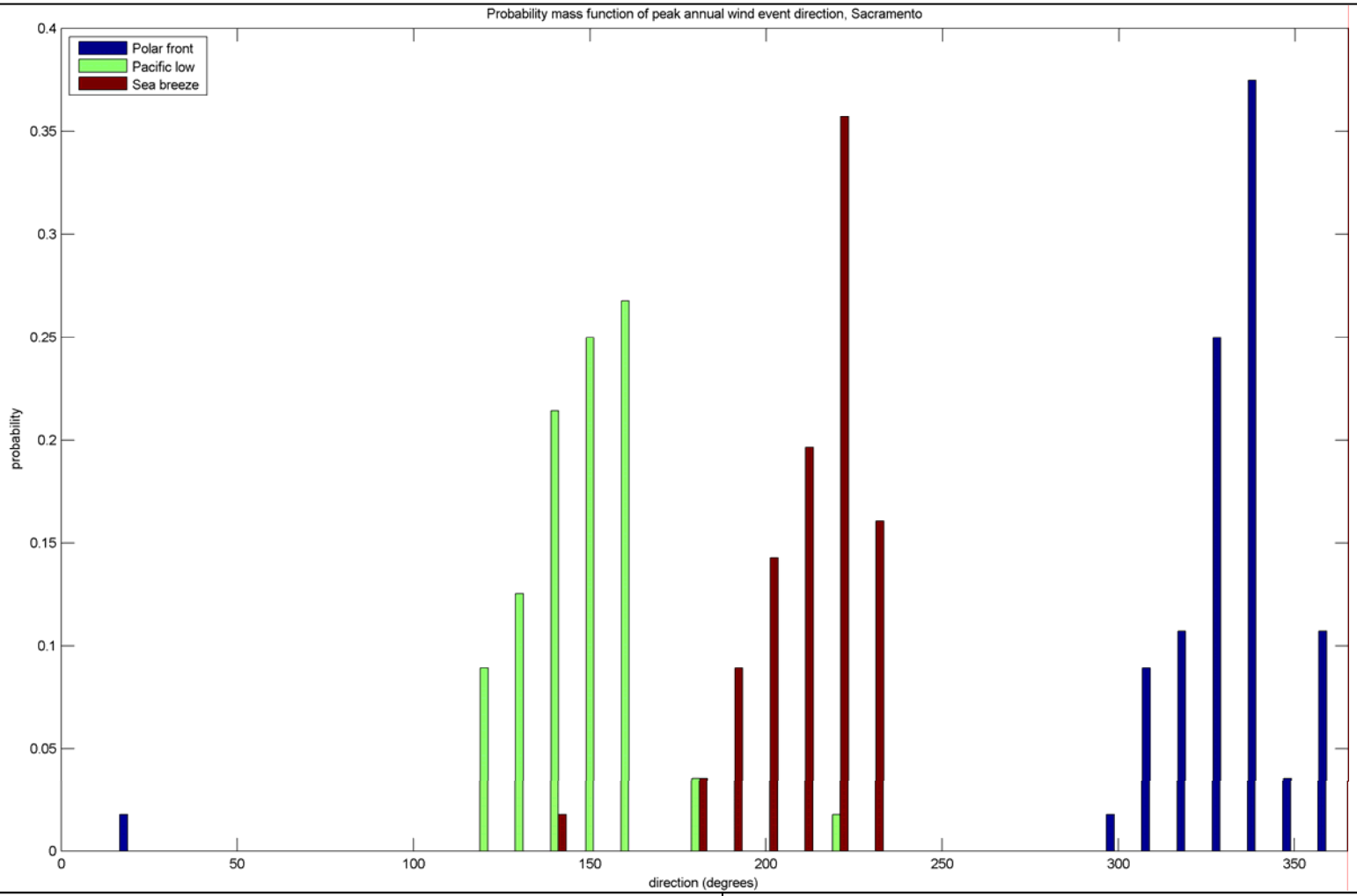


figure 10-c

DRMS Wind Wave Analysis

Wind direction PMF, Sacramento

PWA# 1836.02

PWA

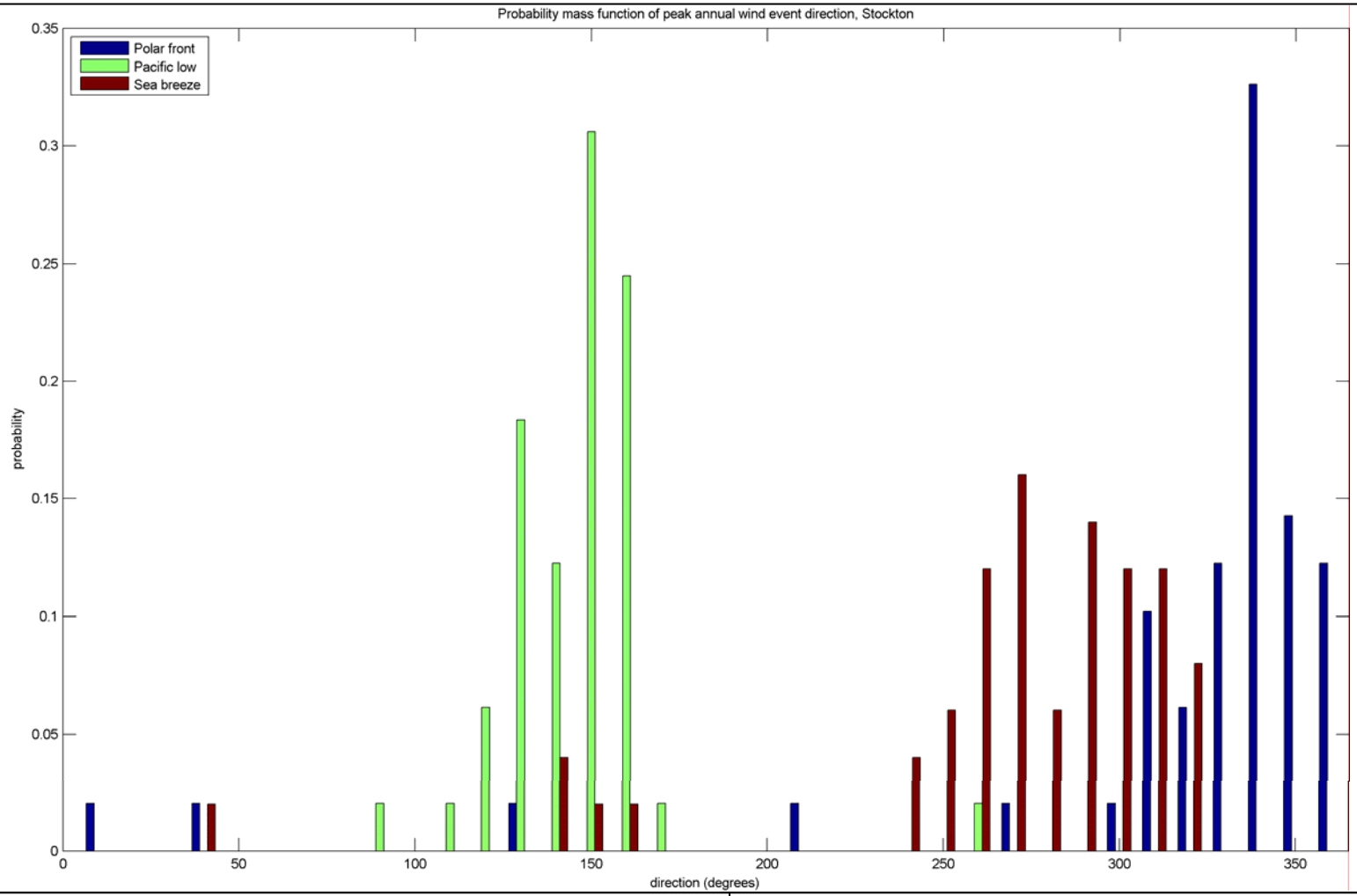


figure 10-d

DRMS Wind Wave Analysis

Wind direction PMF, Stockton

PWA# 1836.02

PWA

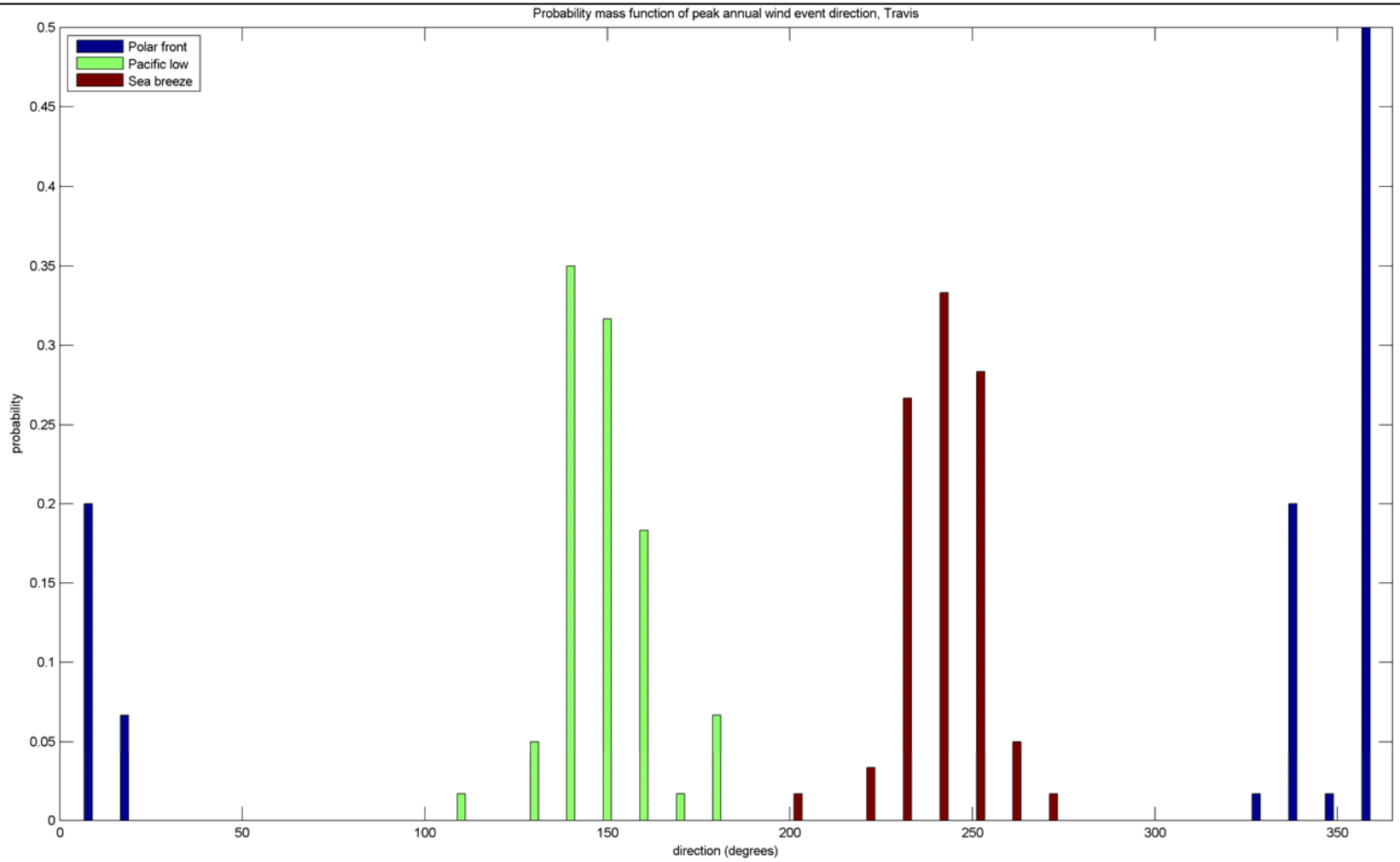


figure 10-e

DRMS Wind Wave Analysis

Wind direction PMF, Travis

PWA# 1836.02

PWA

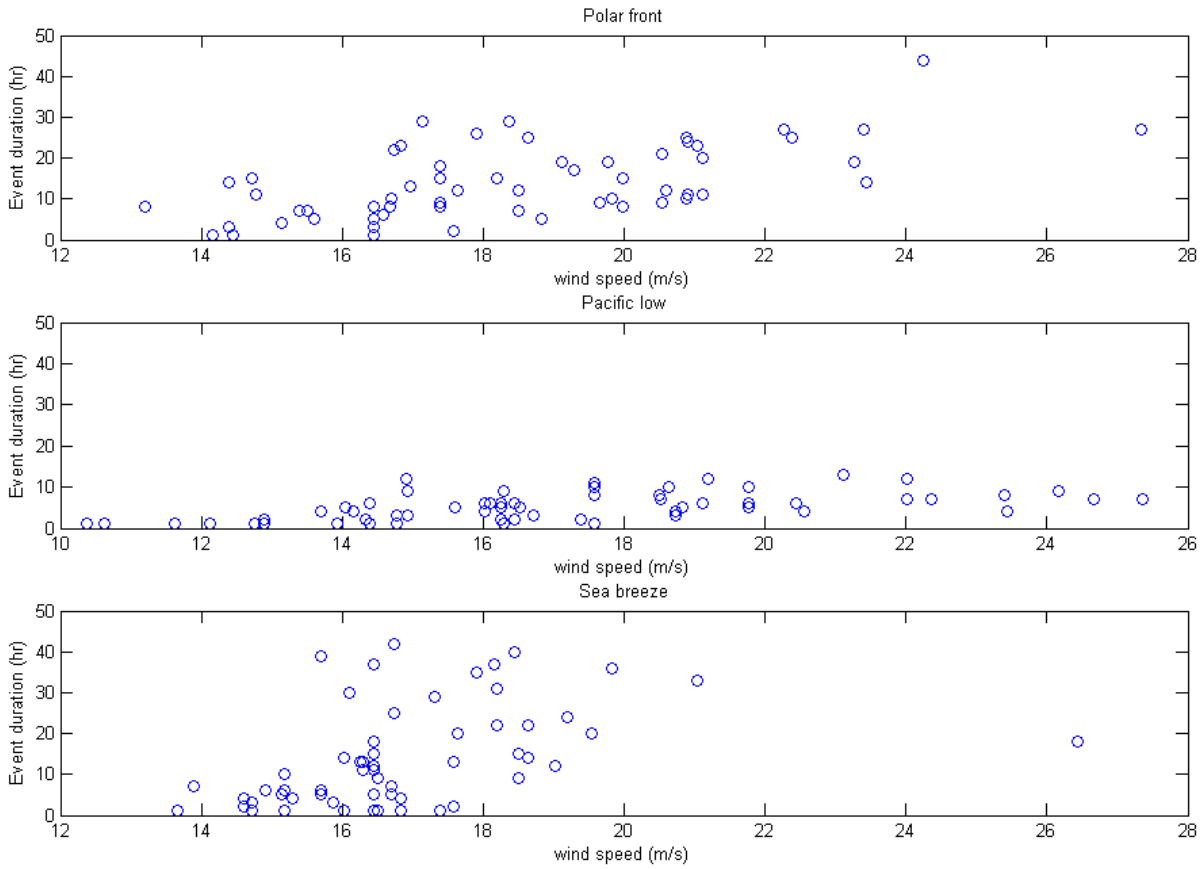


figure 11

DRMS Wind Wave Analysis

Relationship between wind event duration and wind

PWA# 1836.02

PWA

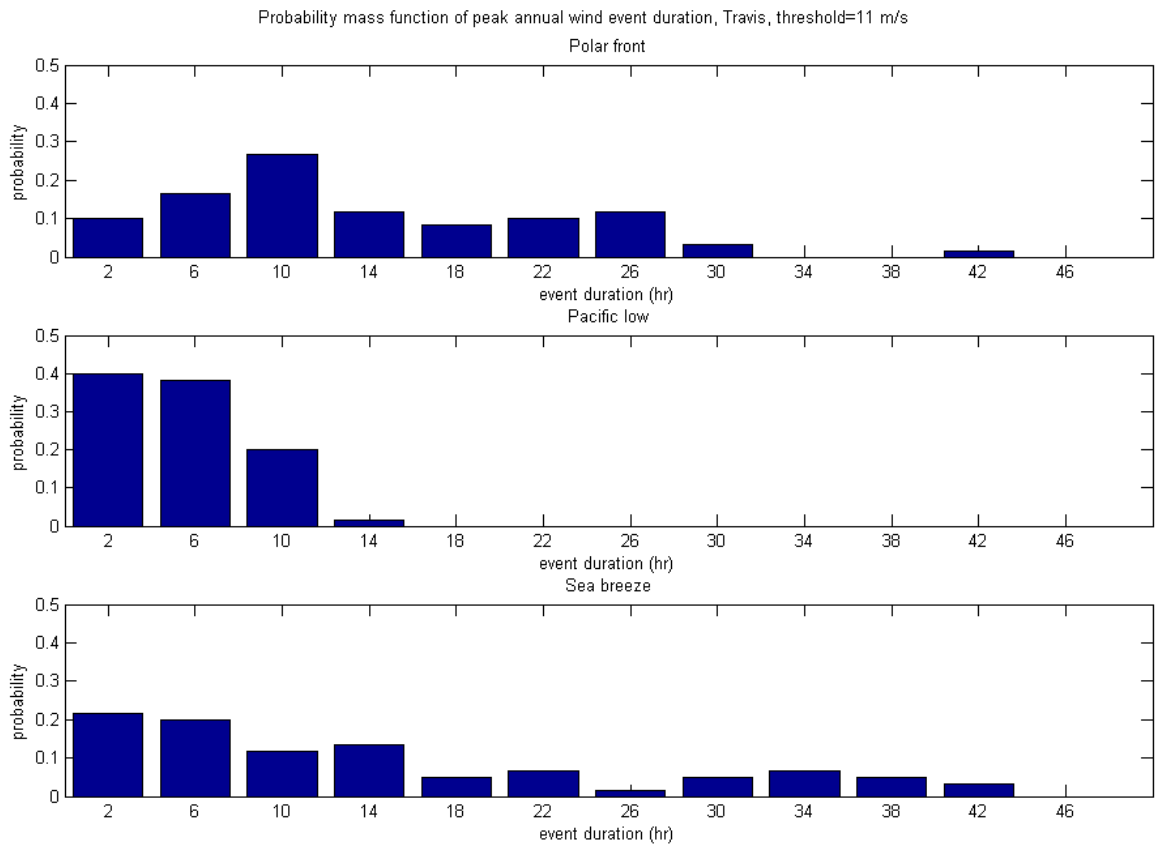


figure 12

DRMS Wind Wave Analysis

Wind event duration PMFs

PWA# 1836.02

PWA

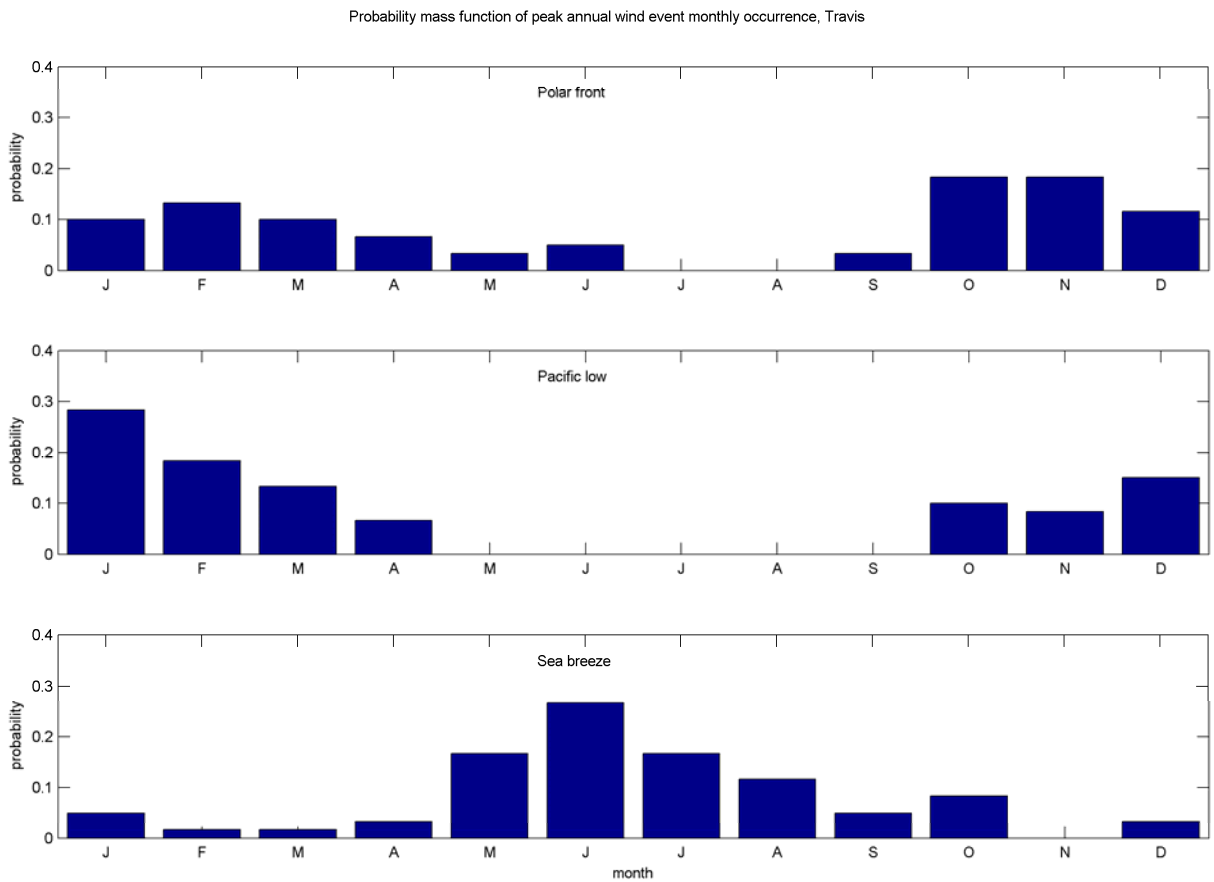


figure 13

DRMS Wind Wave Analysis

Month of wind event occurrence PMFs

PWA# 1836.02

PWA

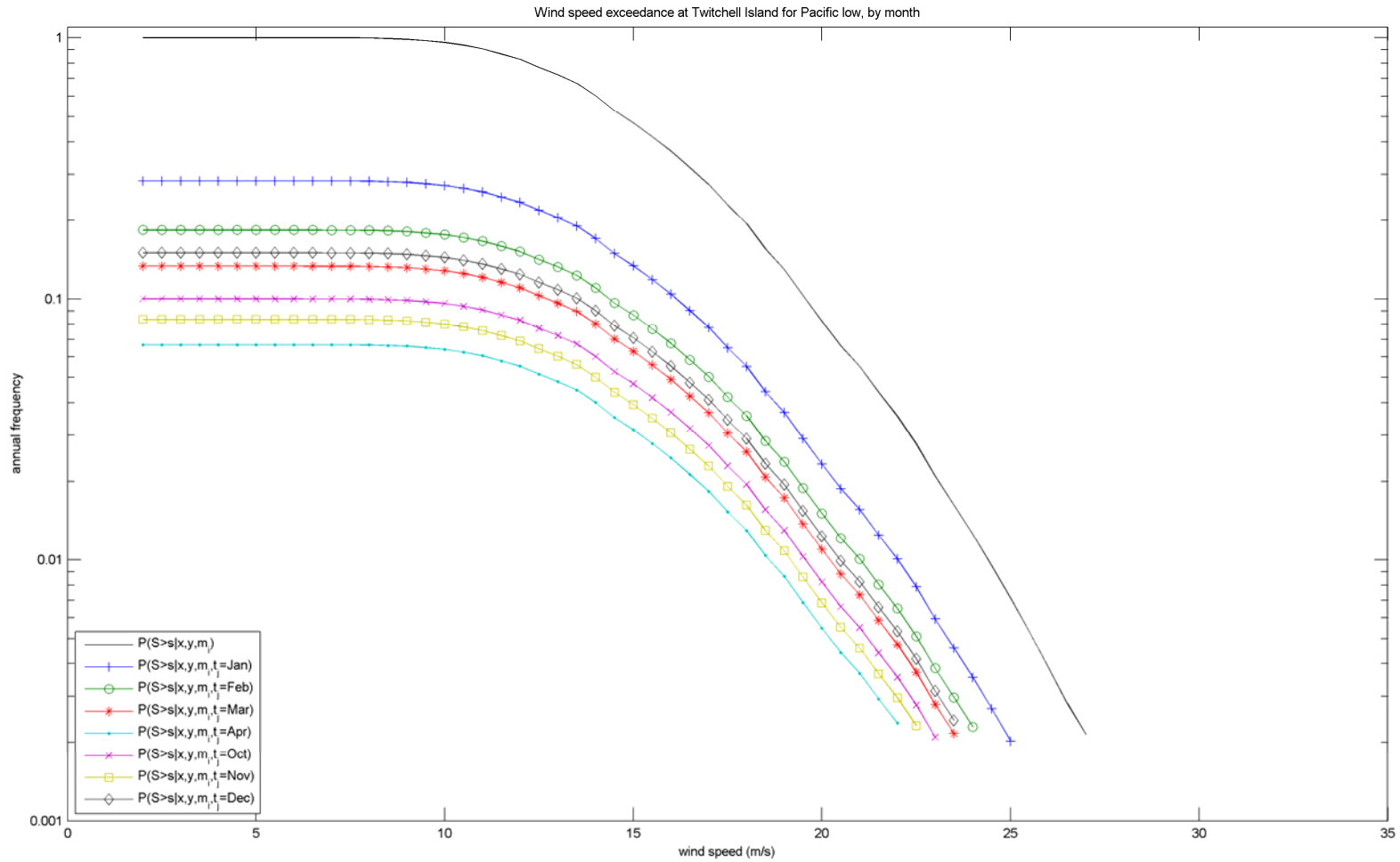


figure 14

DRMS Wind Wave Analysis

Distribution of Month of Wind Event Occurrence and Wind Speed Exceedance at Twitchell Island, Pacific Low

PWA# 1836.02

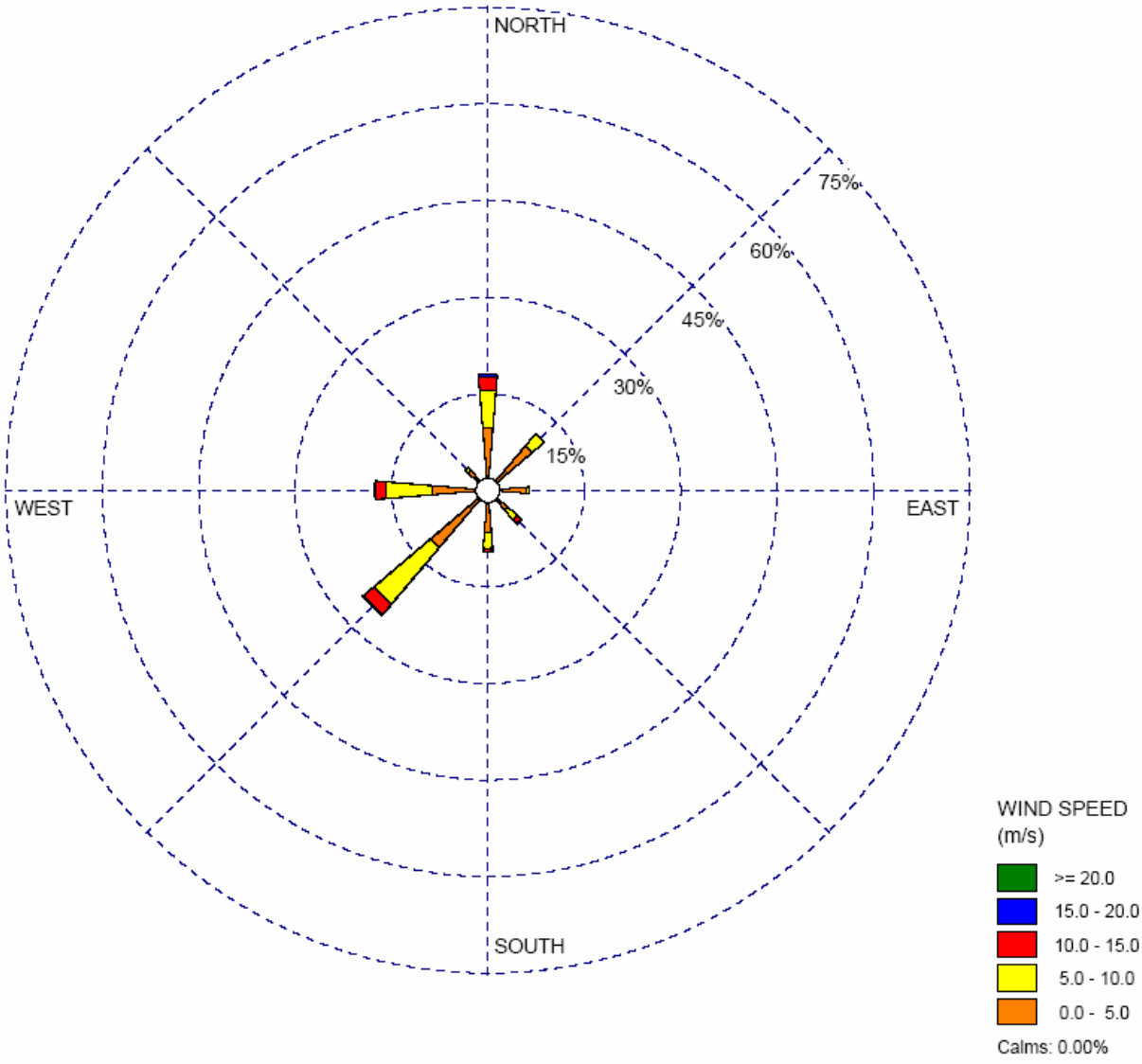
PWA

WIND ROSE PLOT:

Travis AFB, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
FALL-WINTER October 1 - March 31		**PWA**
		TOTAL COUNT: **32414 hrs.**
		DATE: **11/29/2006**

figure 15-ai

DRMS Wind Wave Analysis

Seasonal wind rose, Travis AFB

PWA # 1836.02

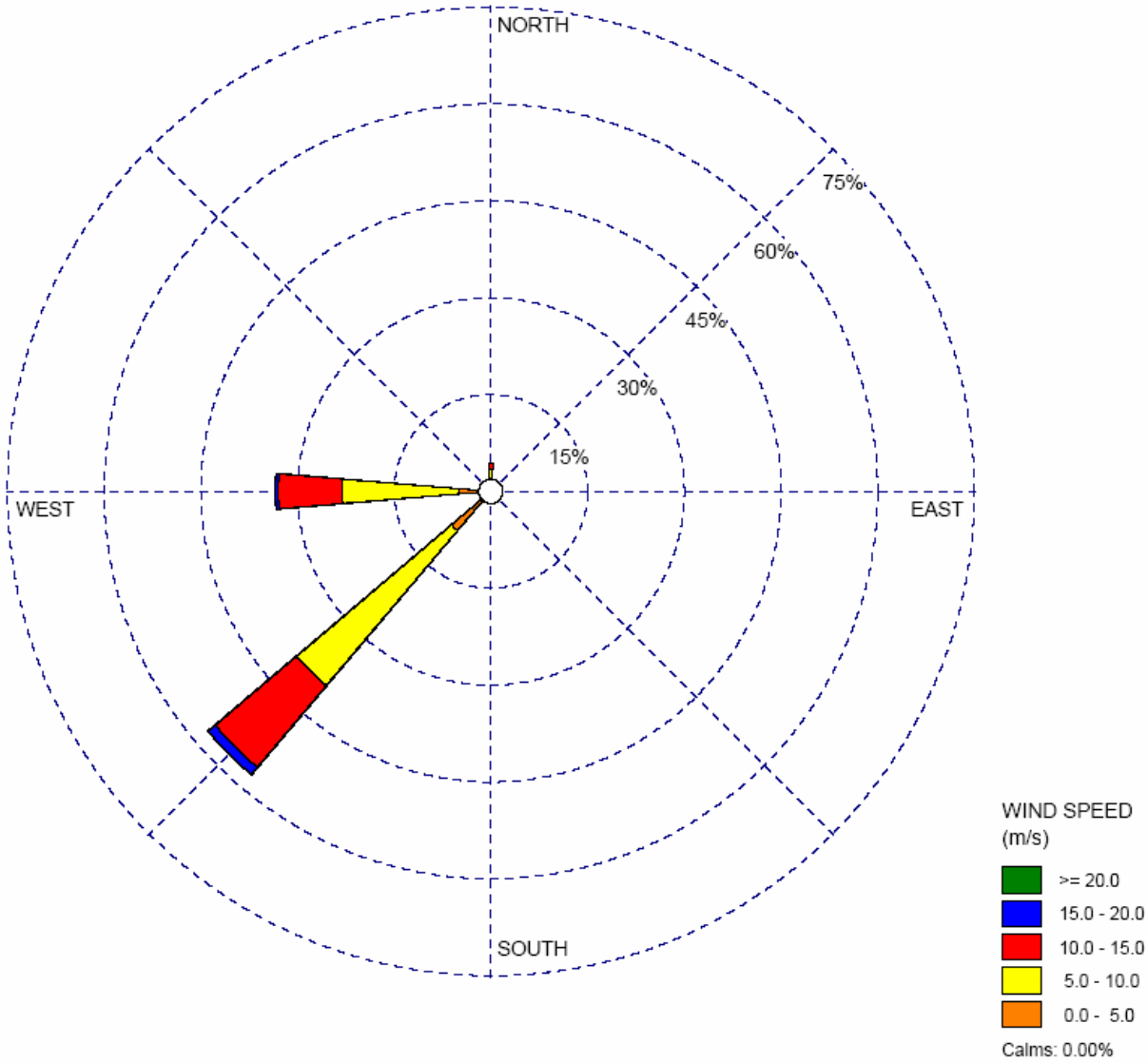
PWA

WIND ROSE PLOT:

Travis AFB, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
SPRING-SUMMER April 1 - September 30		PWA
		TOTAL COUNT: 36201 hrs.
		DATE: 11/29/2006

figure 15-aii

DRMS Wind Wave Analysis

Seasonal wind rose, Travis AFB

PWA # 1836.02

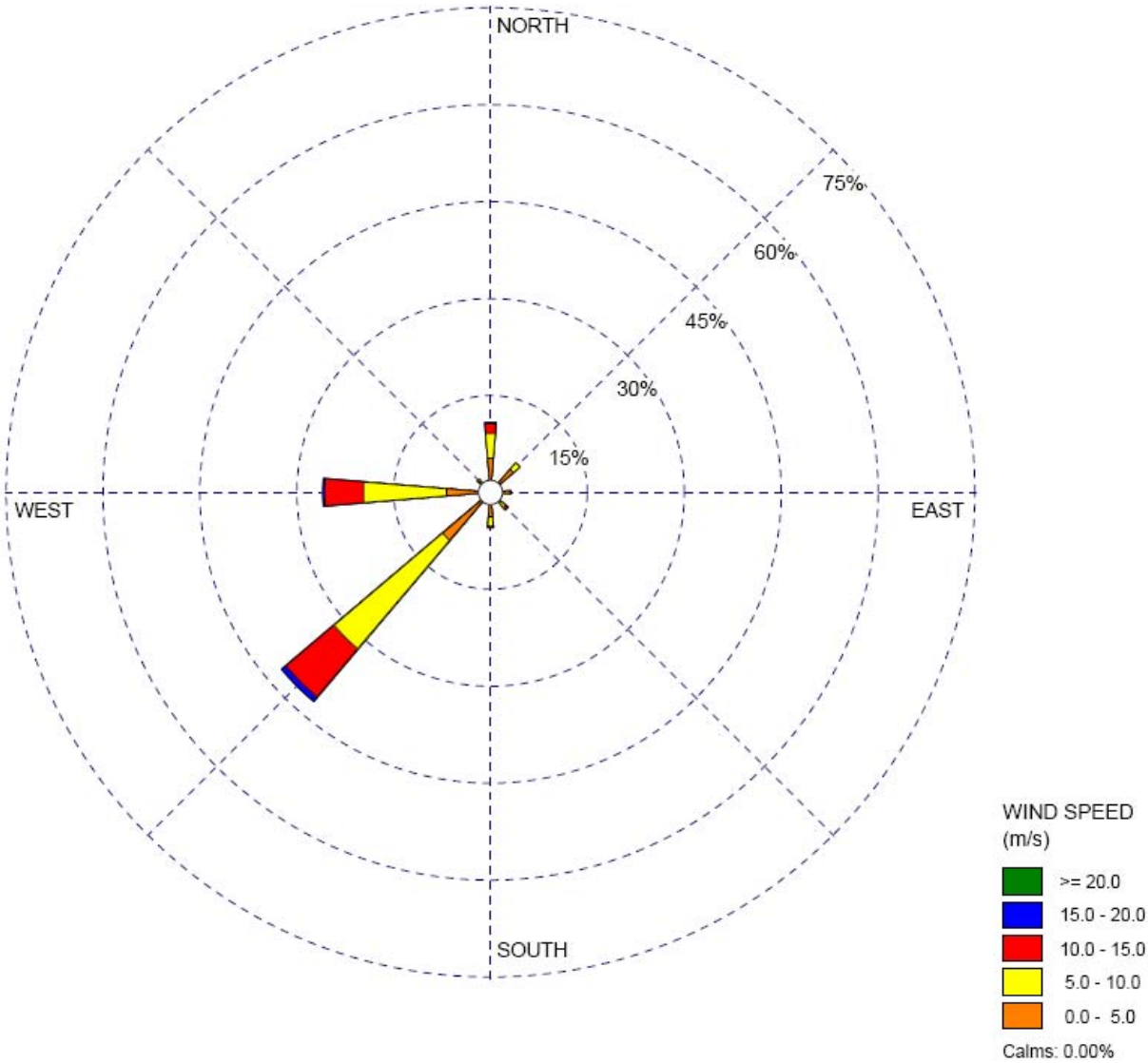
PWA

WIND ROSE PLOT:

Travis AFB, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
FULL YEAR January 1 - December 31		**PWA**
		TOTAL COUNT: **68615 hrs.**
		DATE: **11/29/2006**

figure 15-aiii

DRMS Wind Wave Analysis

Seasonal wind rose, Travis AFB

PWA # 1836.02

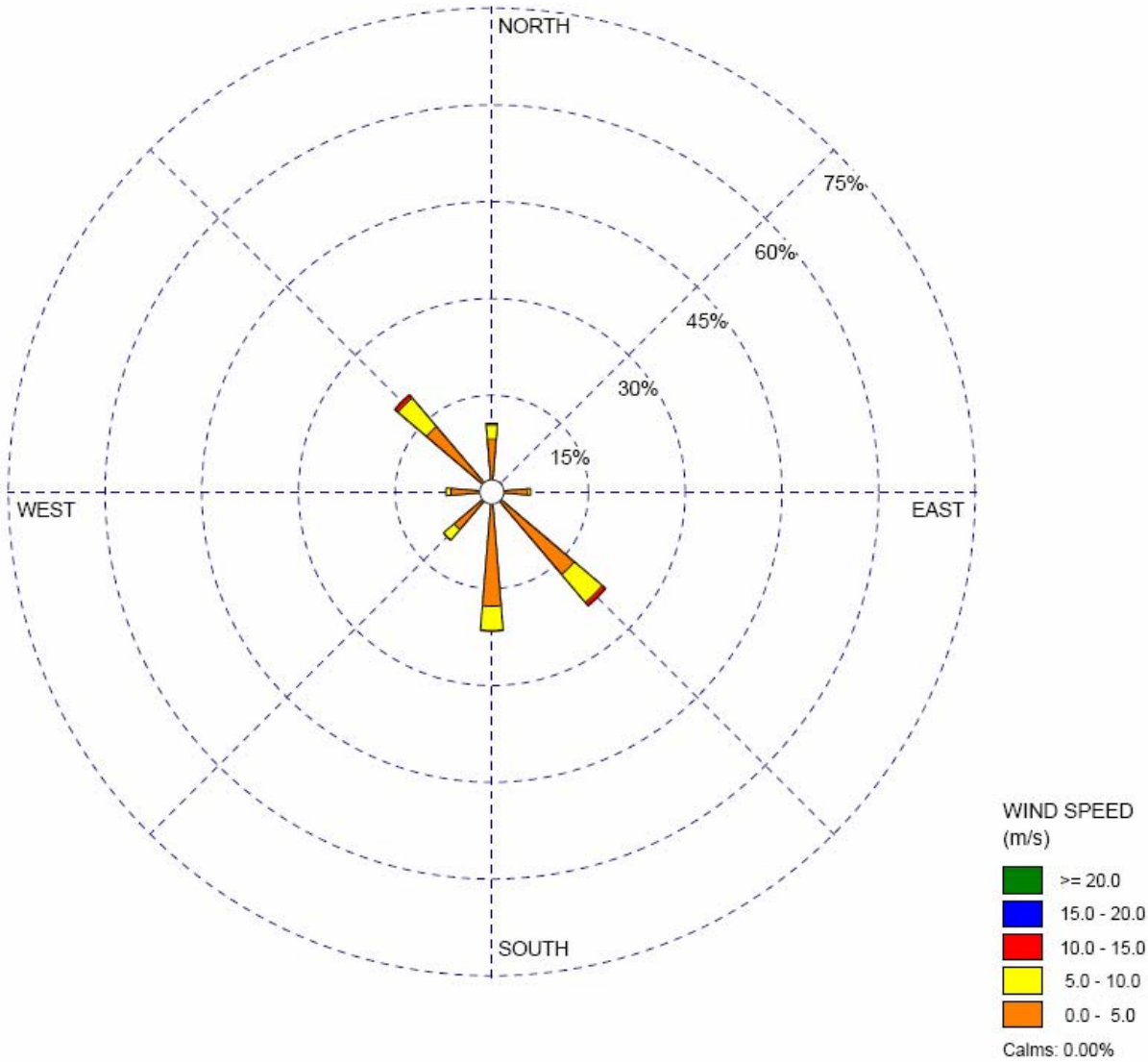
PWA

WIND ROSE PLOT:

Sacramento, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
FALL-WINTER October 1 - March 31		**PWA**
		TOTAL COUNT: **32637 hrs.**
		DATE: **11/29/2006**

figure 15-bi

DRMS Wind Wave Analysis

Seasonal wind rose, Sacramento

PWA # 1836.02

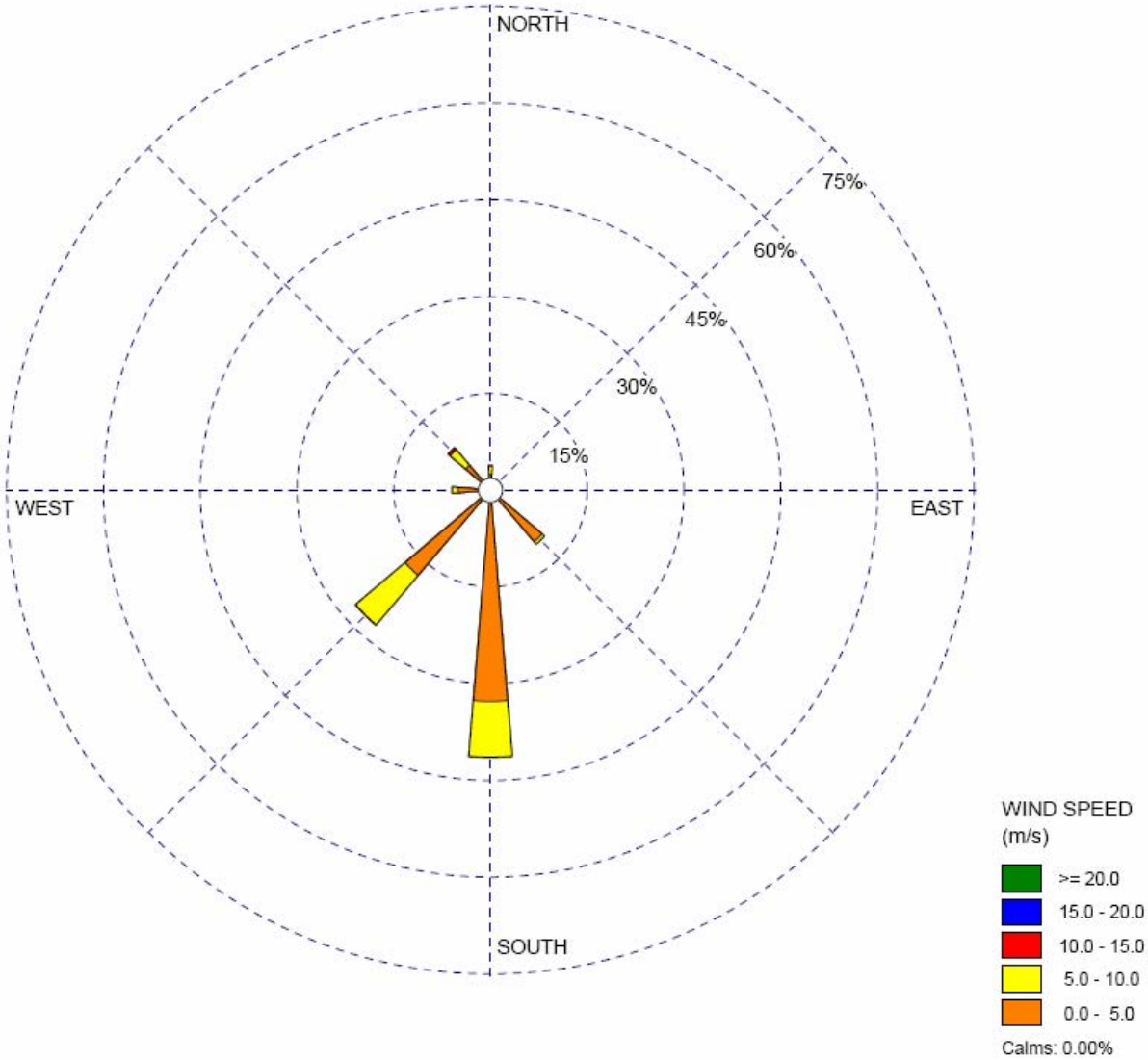
PWA

WIND ROSE PLOT:

Sacramento, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
SPRING-SUMMER April 1 - September 30		**PWA**
		TOTAL COUNT:
		36171 hrs.
		DATE:
		11/29/2006

figure 15-bii

DRMS Wind Wave Analysis

Seasonal wind rose, Sacramento

PWA # 1836.02

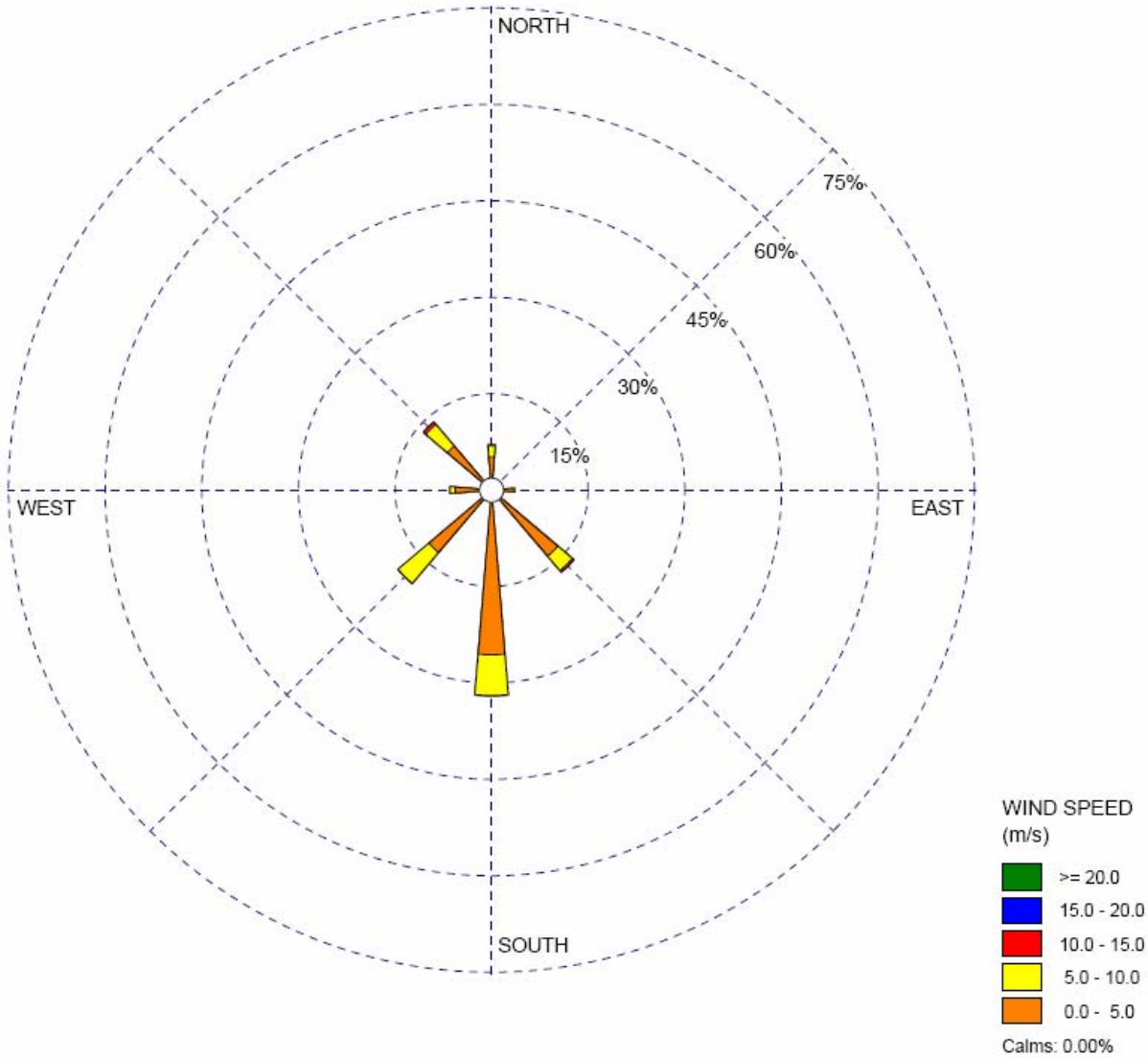
PWA

WIND ROSE PLOT:

Sacramento, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
FULL YEAR January 1 - December 31		**PWA**
		TOTAL COUNT: **68808 hrs.**
		DATE: **11/29/2006**

figure 15-biii

DRMS Wind Wave Analysis

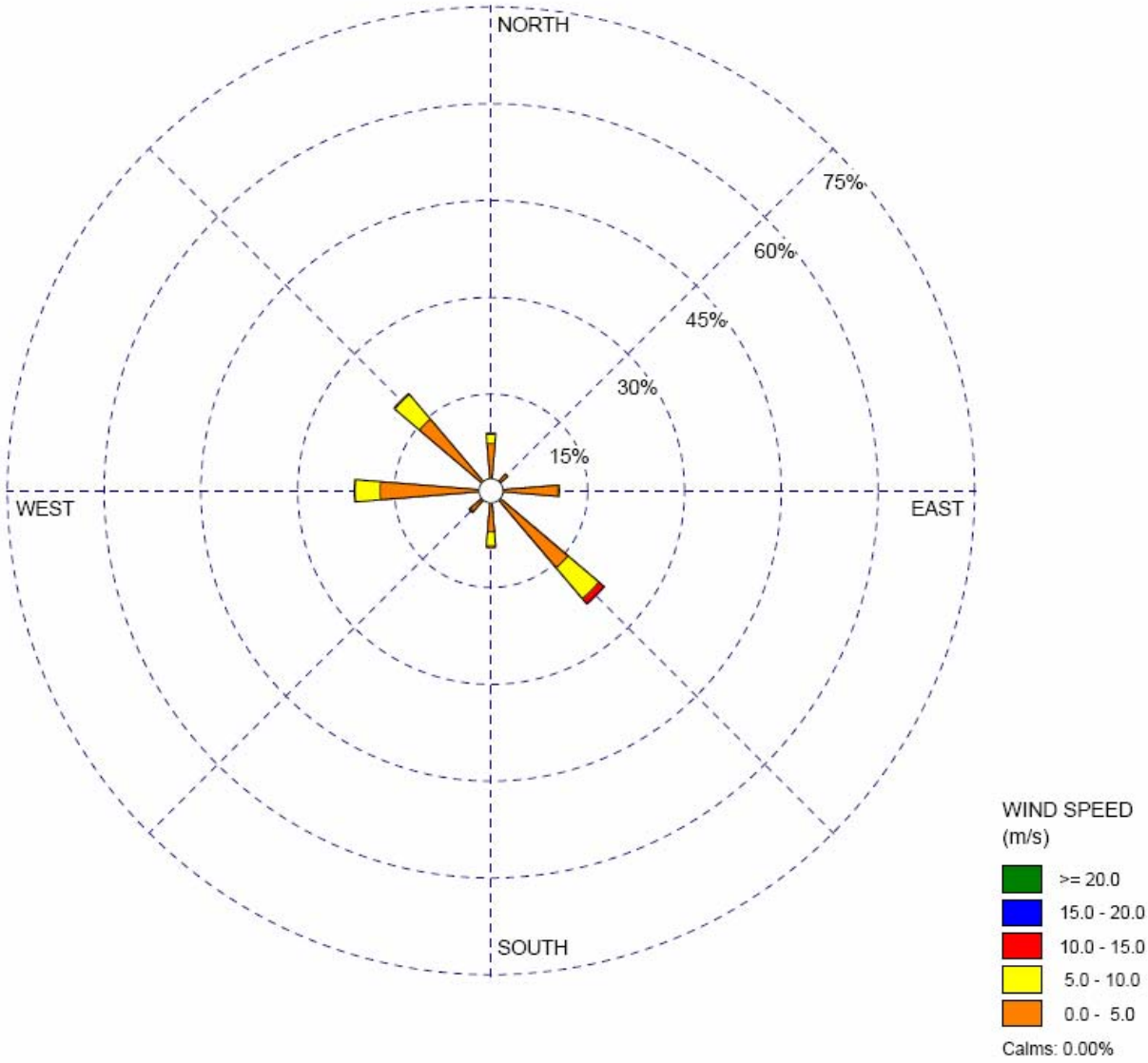
Seasonal wind rose, Sacramento

PWA # 1836.02

PWA

WIND ROSE PLOT:
Stockton, CA

DISPLAY:
Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
FALL-WINTER October 1 - March 31		**PWA**
		TOTAL COUNT: **36088 hrs.**
		DATE: **11/29/2006**

figure 15-ci

DRMS Wind Wave Analysis

Seasonal wind rose, Stockton

PWA # 1836.02

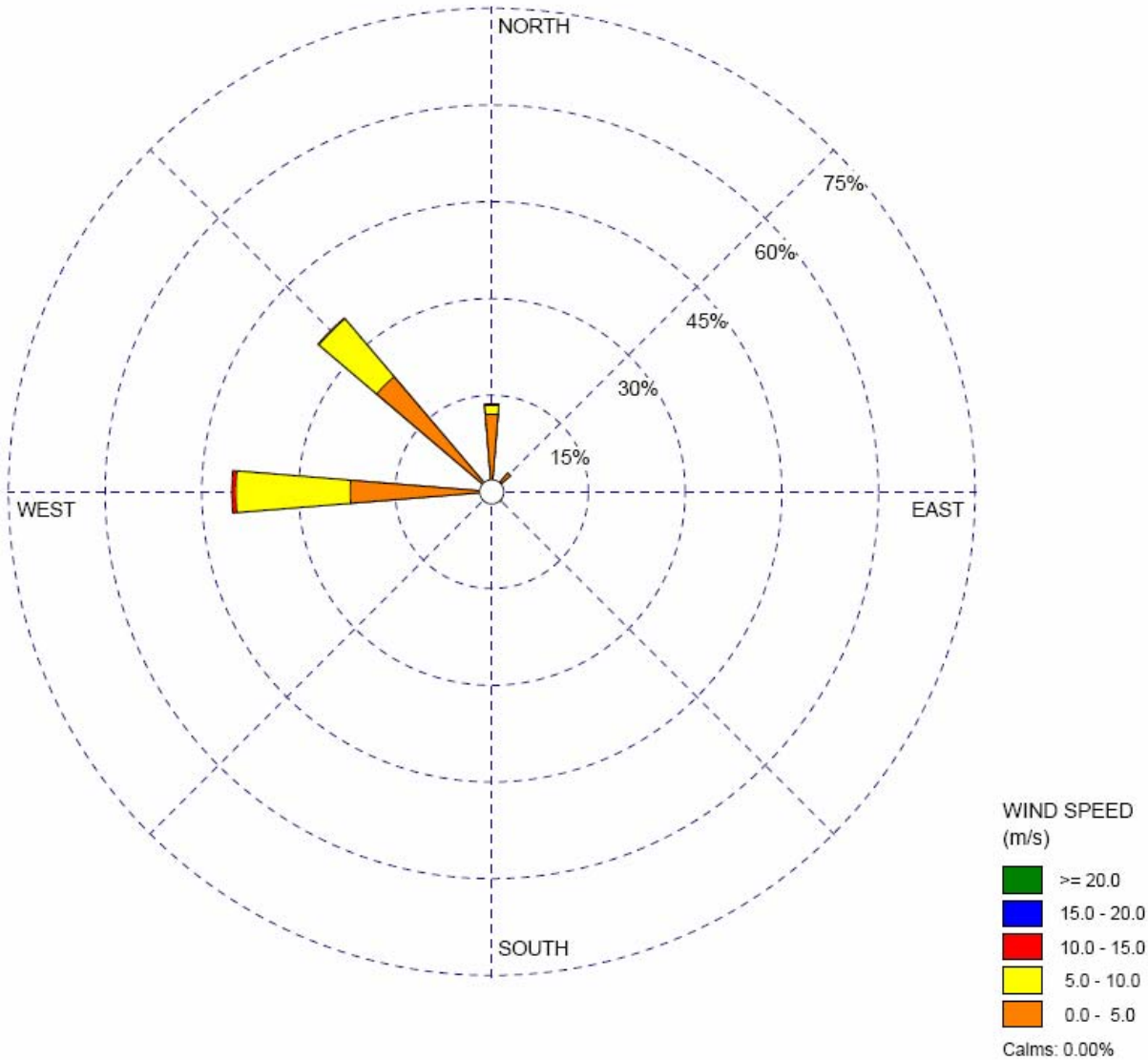
PWA

WIND ROSE PLOT:

Stockton, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
SPRING-SUMMER April 1 - September 30		**PWA**
		TOTAL COUNT: **38583 hrs.**
		DATE: **11/29/2006**

figure 15-cii

DRMS Wind Wave Analysis

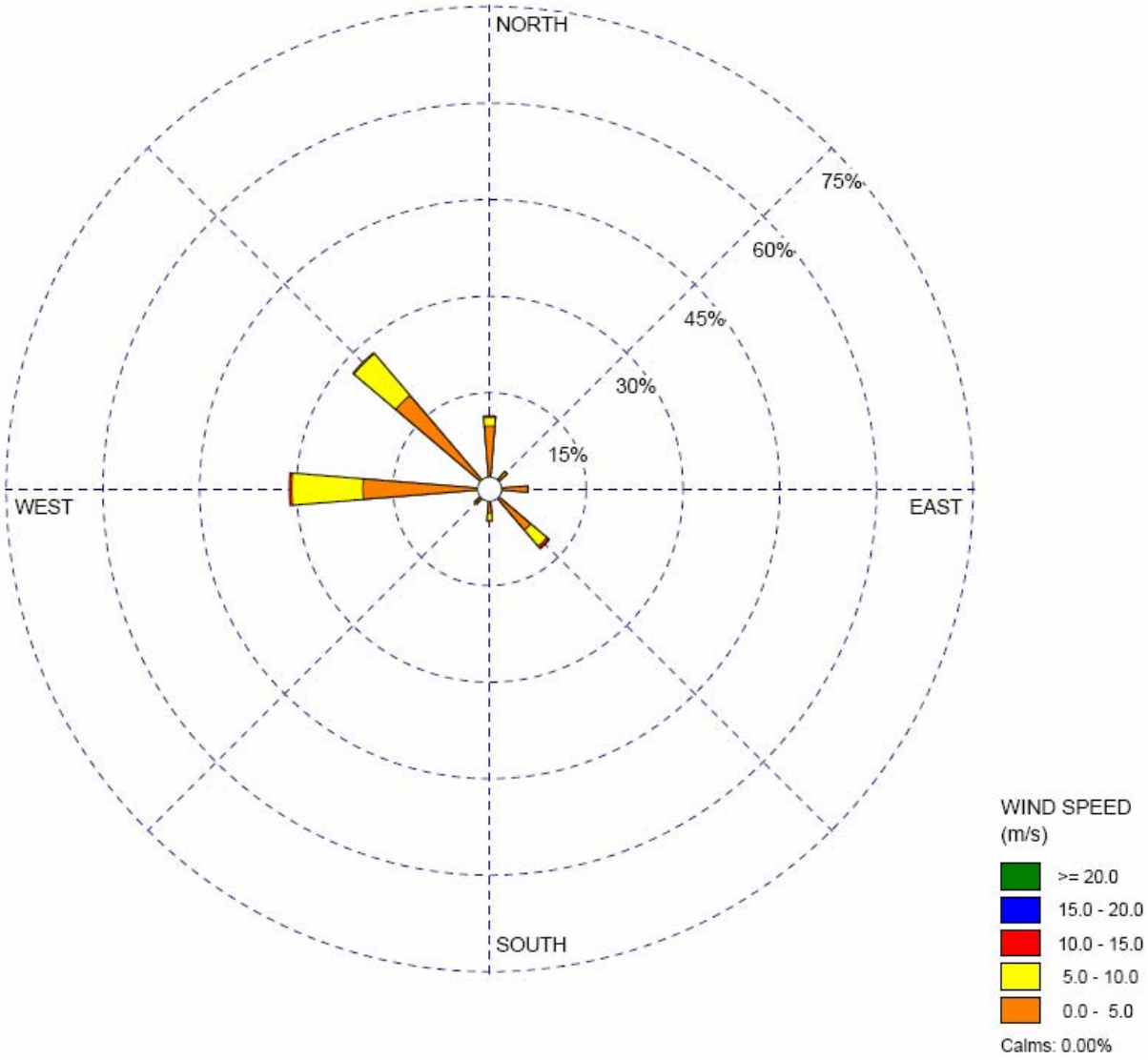
Seasonal wind rose, Stockton

PWA # 1836.02

PWA

WIND ROSE PLOT:
Stockton, CA

DISPLAY:
Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
FULL YEAR January 1 - December 31		**PWA**
		TOTAL COUNT: **74671 hrs.**
		DATE: **11/29/2006**

figure 15-ciii

DRMS Wind Wave Analysis

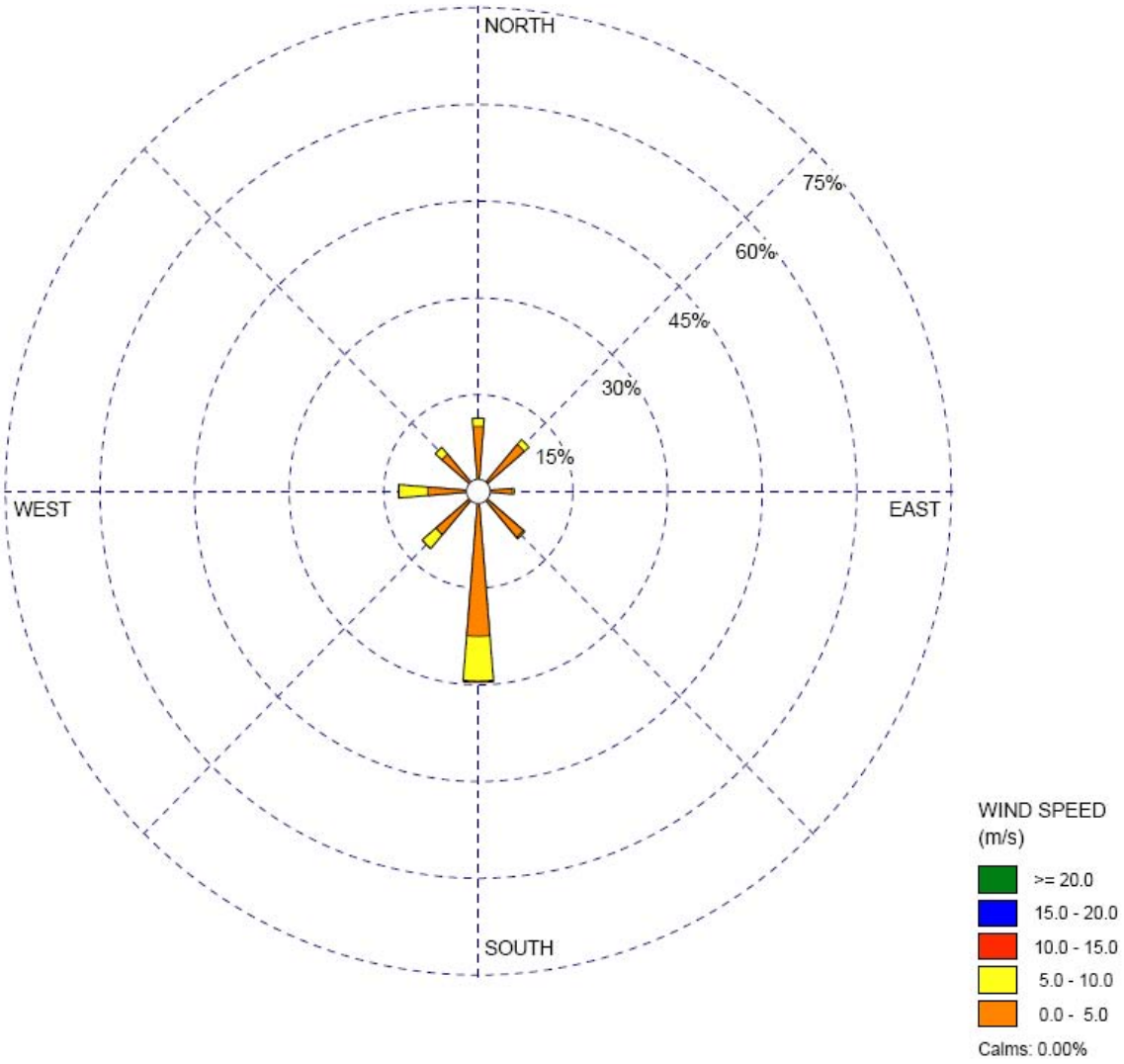
Seasonal wind rose, Stockton

PWA # 1836.02

PWA

WIND ROSE PLOT:
Concord, CA

DISPLAY:
Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
FALL-WINTER October 1 - March 31		**PWA**
		TOTAL COUNT: **22556 hrs.**
		DATE: **11/30/2006**

figure 15-di

DRMS Wind Wave Analysis

Seasonal wind rose, Concord Buchanan

PWA # 1836.02

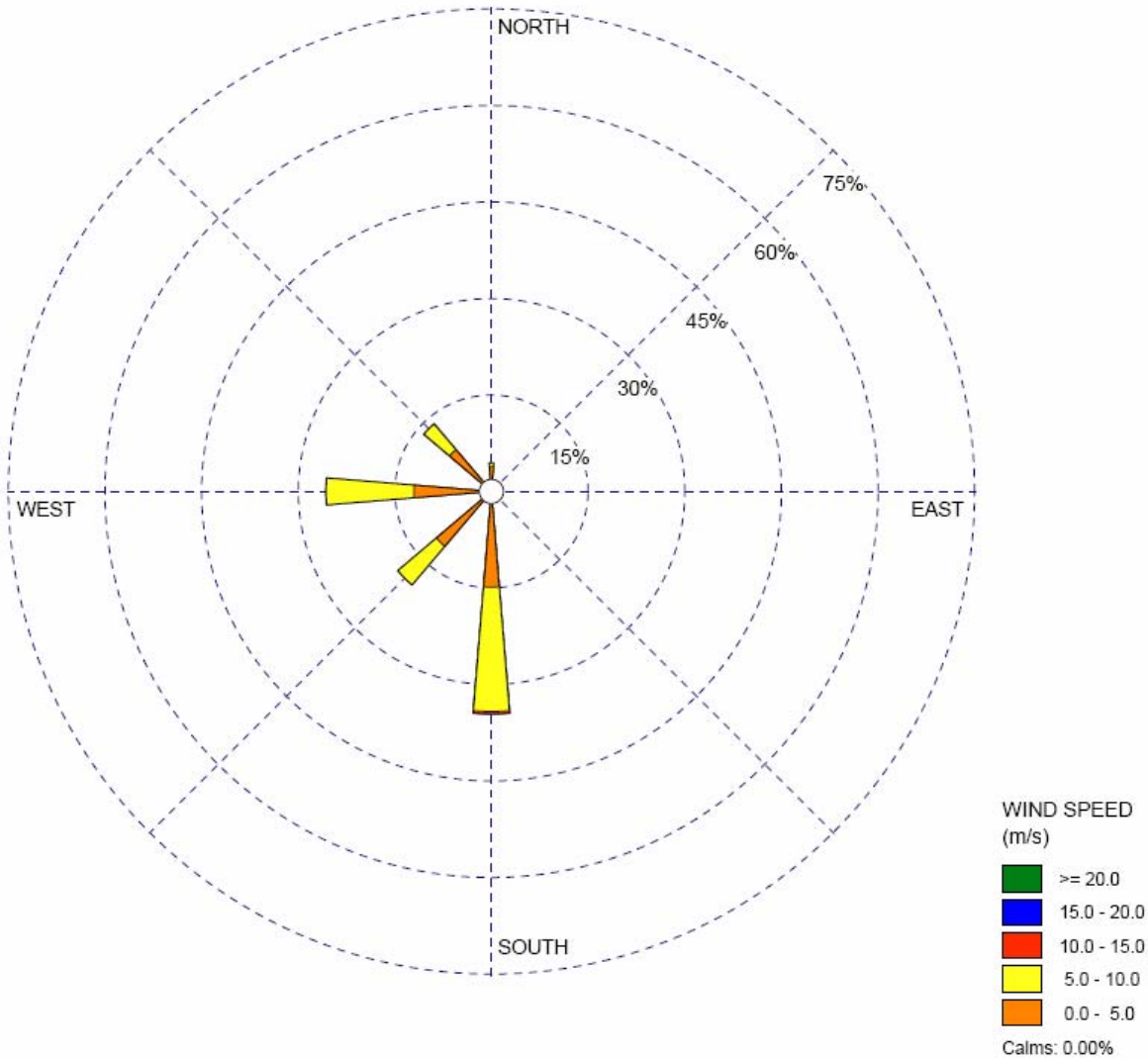
PWA

WIND ROSE PLOT:

Concord, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
SPRING-SUMMER April 1 - September 30		**PWA**
		TOTAL COUNT:
		27129 hrs.
		DATE:
		11/30/2006

figure 15-dii

DRMS Wind Wave Analysis

Seasonal wind rose, Concord Buchanan

PWA # 1836.02

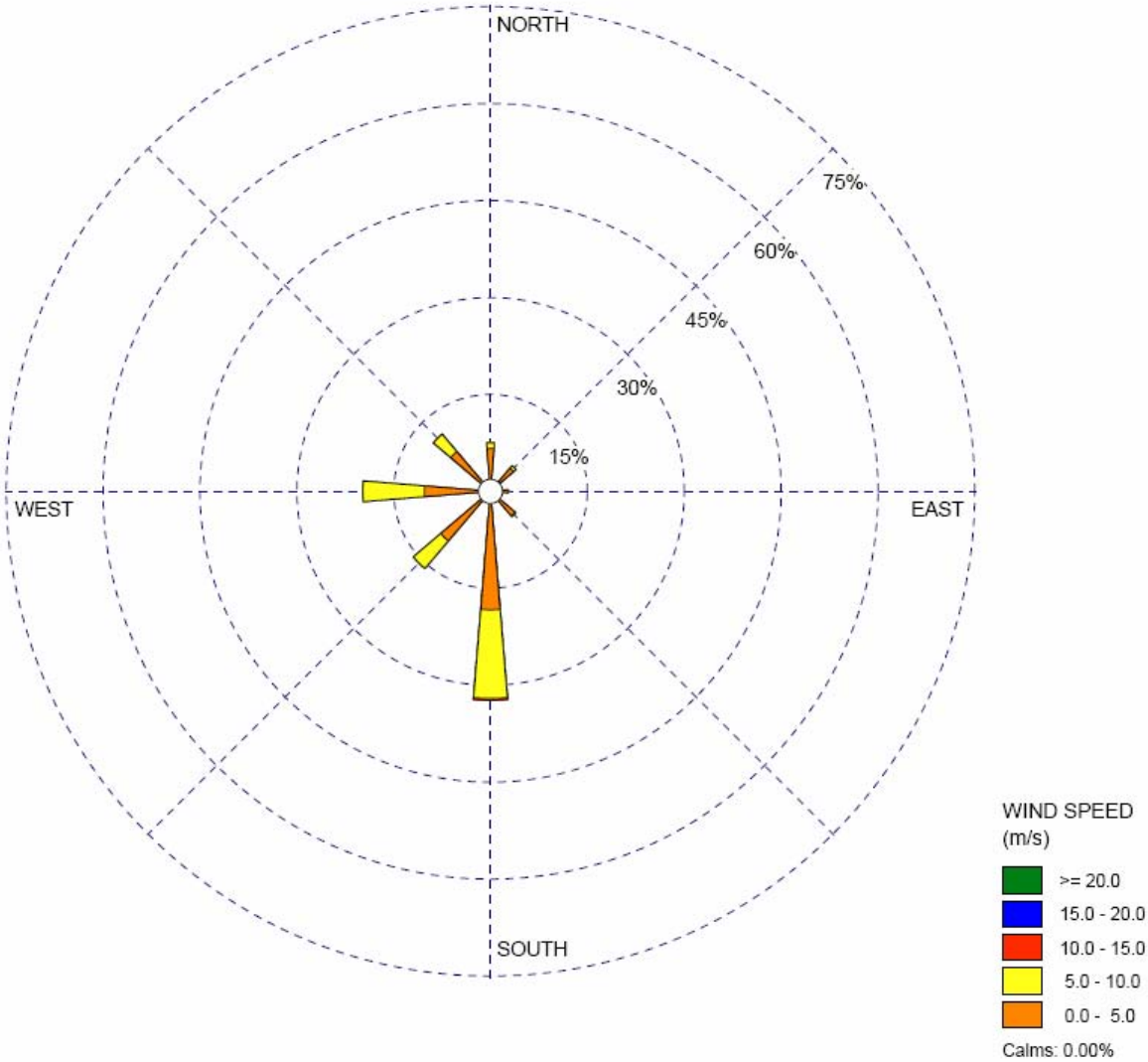
PWA

WIND ROSE PLOT:

Concord, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
FULL YEAR January 1 - December 31		**PWA**
		TOTAL COUNT: **49685 hrs.**
		DATE: **11/30/2006**

figure 15-diii

DRMS Wind Wave Analysis

Seasonal wind rose, Concord Buchanan

PWA # 1836.02

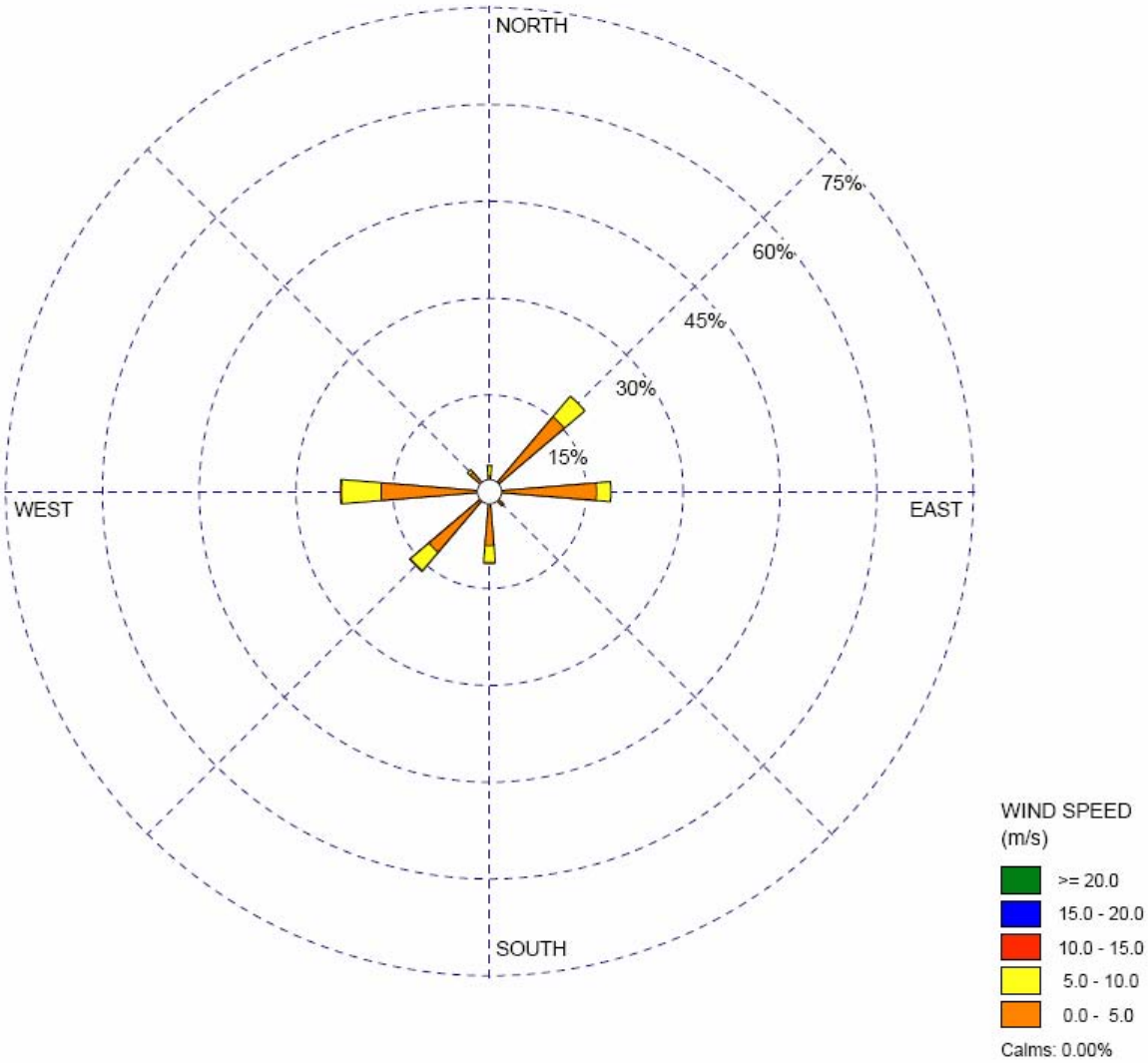
PWA

WIND ROSE PLOT:

Livermore, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
FALL-WINTER October 1 - March 31		**PWA**
		TOTAL COUNT: **21852 hrs.**
		DATE: **11/30/2006**

figure 15-ei

DRMS Wind Wave Analysis

Seasonal wind rose, Livermore

PWA # 1836.02

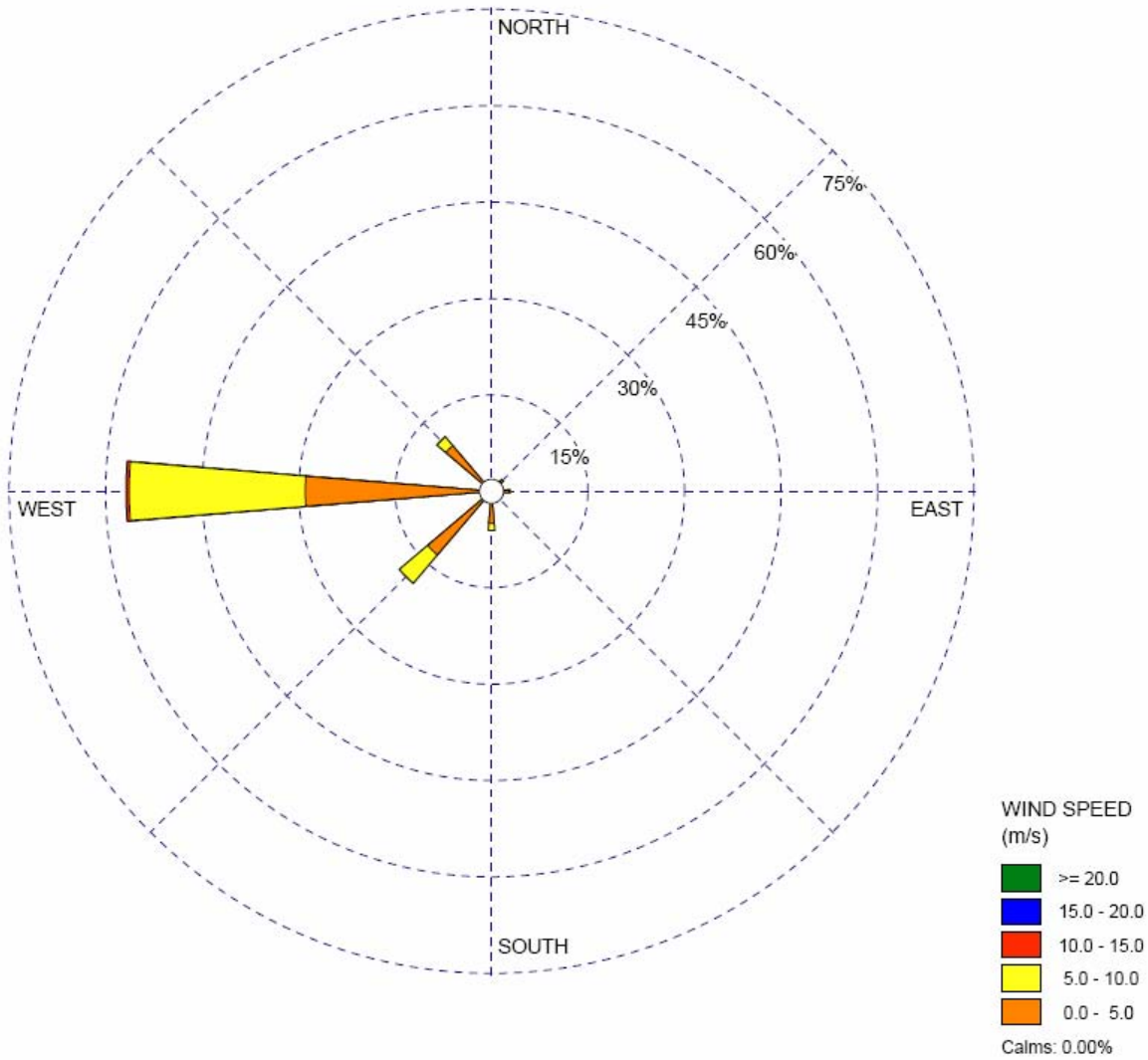
PWA

WIND ROSE PLOT:

Livermore, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
SPRING-SUMMER April 1 - September 30		**PWA**
		TOTAL COUNT:
		28212 hrs.
		DATE:
		11/30/2006

figure 15-eii

DRMS Wind Wave Analysis

Seasonal wind rose, Livermore

PWA # 1836.02

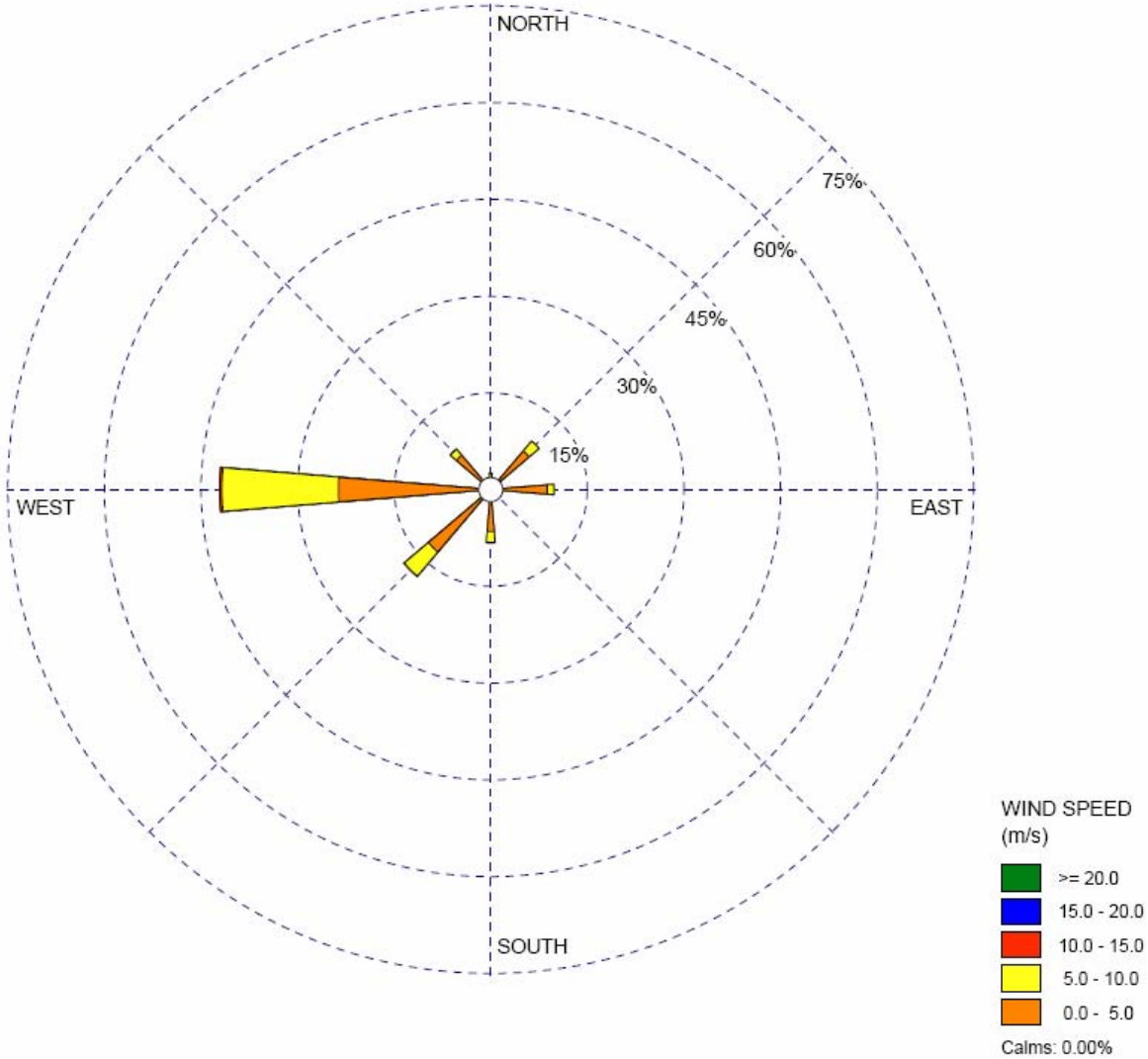
PWA

WIND ROSE PLOT:

Livermore, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:
FULL YEAR January 1 - December 31		**PWA**
		TOTAL COUNT: **50064 hrs.**
		DATE: **11/30/2006**

figure 15-eiii

DRMS Wind Wave Analysis

Seasonal wind rose, Livermore

PWA # 1836.02

PWA

Travis AFB

Date Range: Jan 1 - Dec 31

Frequency Distribution (Count)

Wind Direction	Speed m/s 0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	3610	2643	1037	127	3	7420
22.50 - 67.50	3190	921	25	0	0	4136
67.50 - 112.50	2062	129	2	0	0	2193
112.50 - 157.50	1465	672	265	48	3	2453
157.50 - 202.50	2593	976	160	18	1	3748
202.50 - 247.50	6661	15085	6673	575	15	29009
247.50 - 292.50	4654	8804	4111	201	9	17779
292.50 - 337.50	1606	242	29	0	0	1877
Sub-Total:	25841	29472	12302	969	31	68615
Calms:						0
Missing/Incomplete:						0
Total:						68615

Frequency Distribution (Normalized)

Wind Direction	Speed m/s 0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.052612	0.038519	0.015113	0.001851	0.000044	0.10814
22.50 - 67.50	0.046491	0.013423	0.000364	0	0	0.060278
67.50 - 112.50	0.030052	0.00188	0.000029	0	0	0.031961
112.50 - 157.50	0.021351	0.009794	0.003862	0.0007	0.000044	0.03575
157.50 - 202.50	0.037791	0.014224	0.002332	0.000262	0.000015	0.054624
202.50 - 247.50	0.097078	0.21985	0.097253	0.00838	0.000219	0.422779
247.50 - 292.50	0.067828	0.12831	0.059914	0.002929	0.000131	0.259112
292.50 - 337.50	0.023406	0.003527	0.000423	0	0	0.027356
Sub-Total:	0.376609	0.429527	0.17929	0.014122	0.000452	1
Calms:						0
Missing/Incomplete:						0
Total:						1

Frequency of Calm Winds: 0.00%

Average Wind Speed: 6.94 m/s

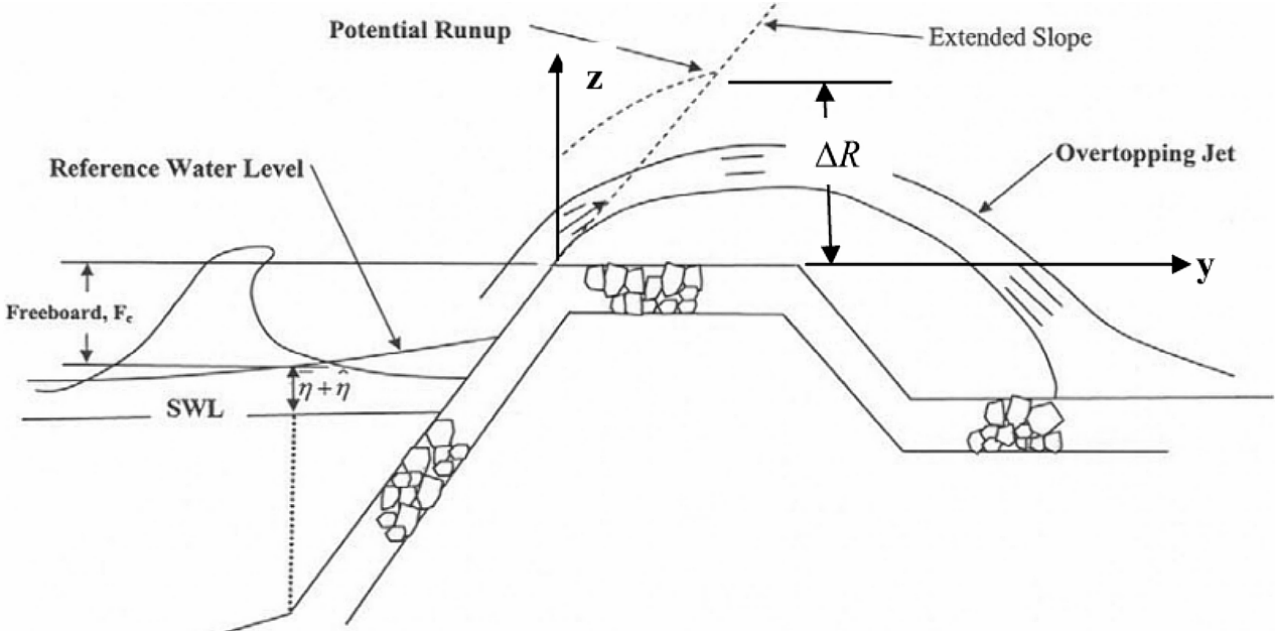
figure 16

DRMS Wind Wave Analysis

Example wind percent occurrence table

PWA # 1836.02

PWA



FEMA. 2004. Final Draft Guidelines for Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States

figure 17

DRMS Wind Wave Analysis

Wave runup schematic

PWA# 1836.02

PWA

Logic Tree for Extreme Probability Wind Model Uncertainties

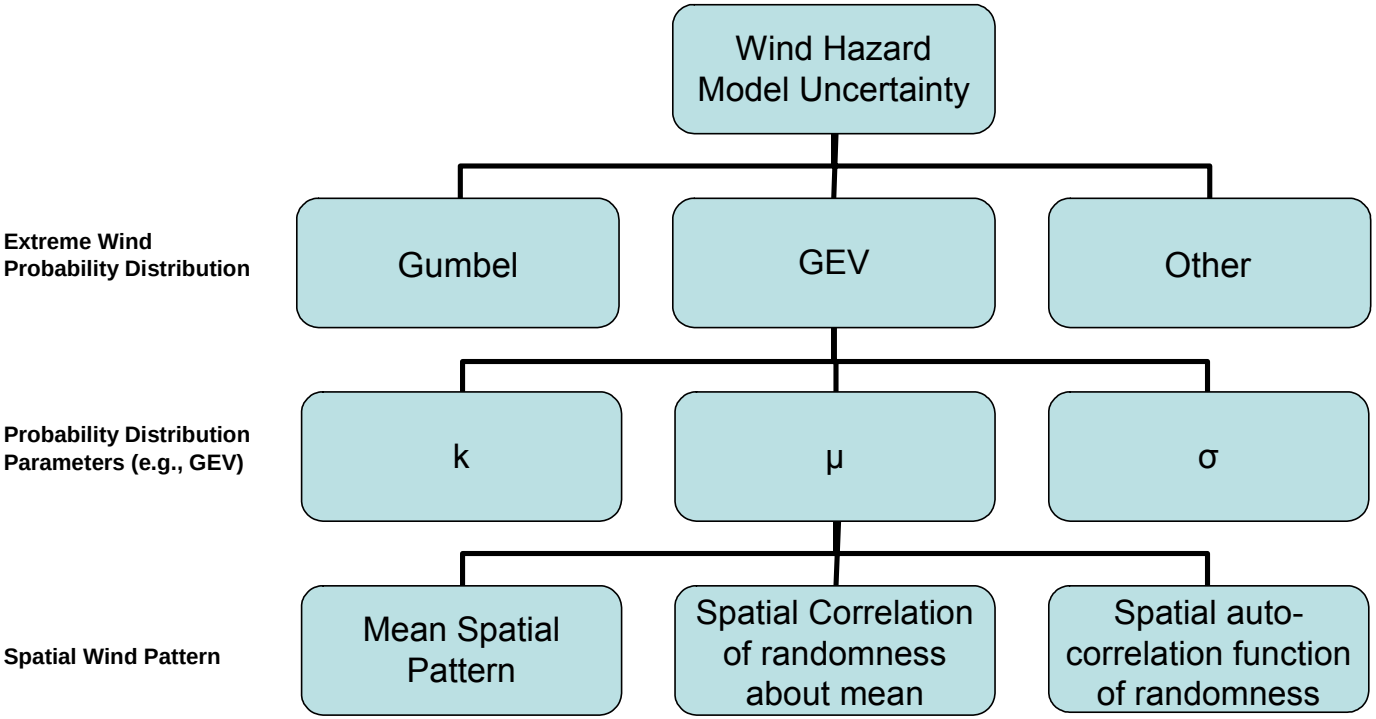


figure 18

DRMS Wind Wave Analysis

Epistemic uncertainty logic tree

PWA# 1836.02

PWA

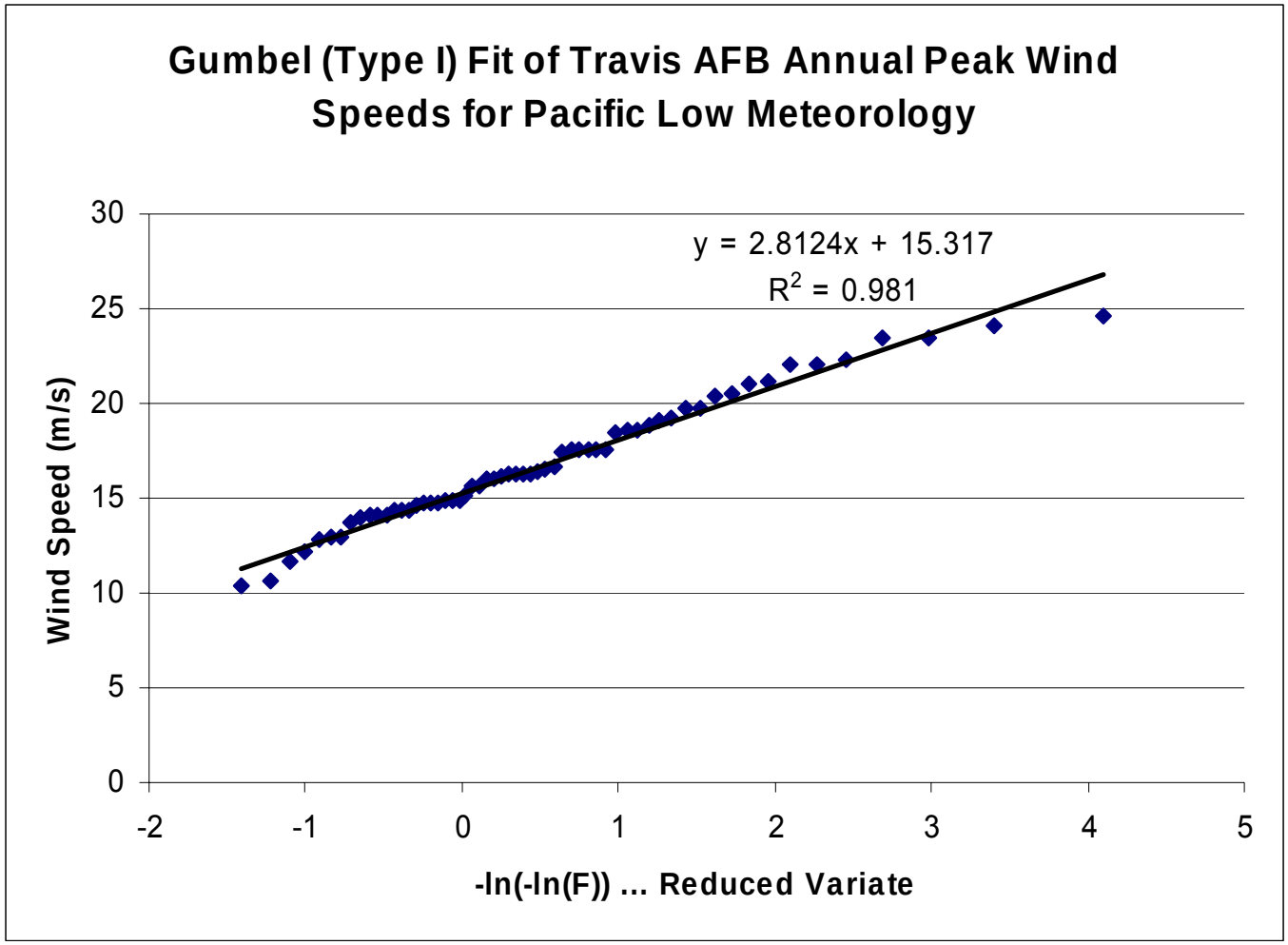


figure 19-a

DRMS Wind Wave Analysis

Gumbel distributions of reference wind speed, Pacific Low

PWA# 1836.02

PWA

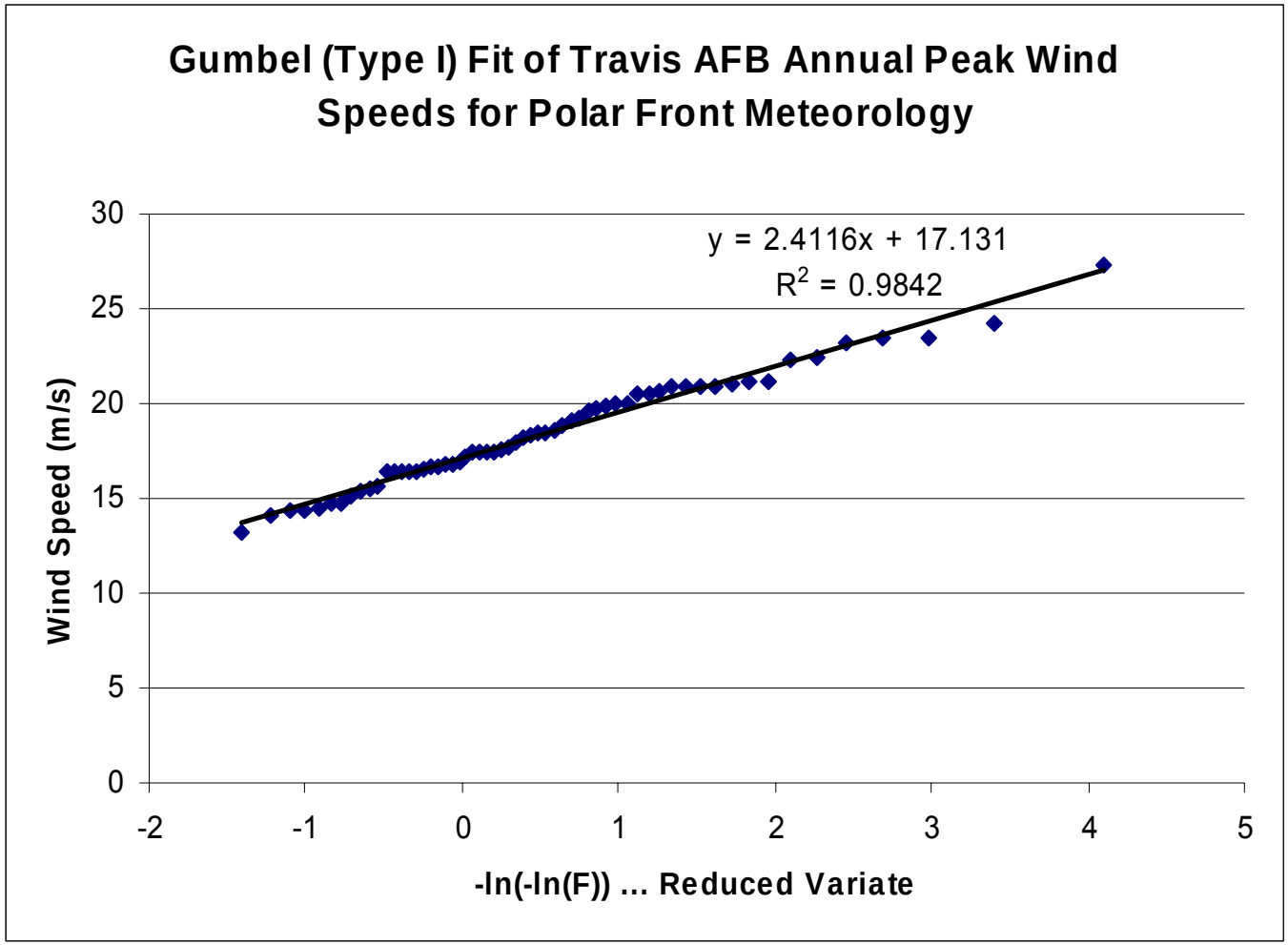


figure 19-b

DRMS Wind Wave Analysis

Gumbel distributions of reference wind speed, Polar Front

PWA# 1836.02

PWA

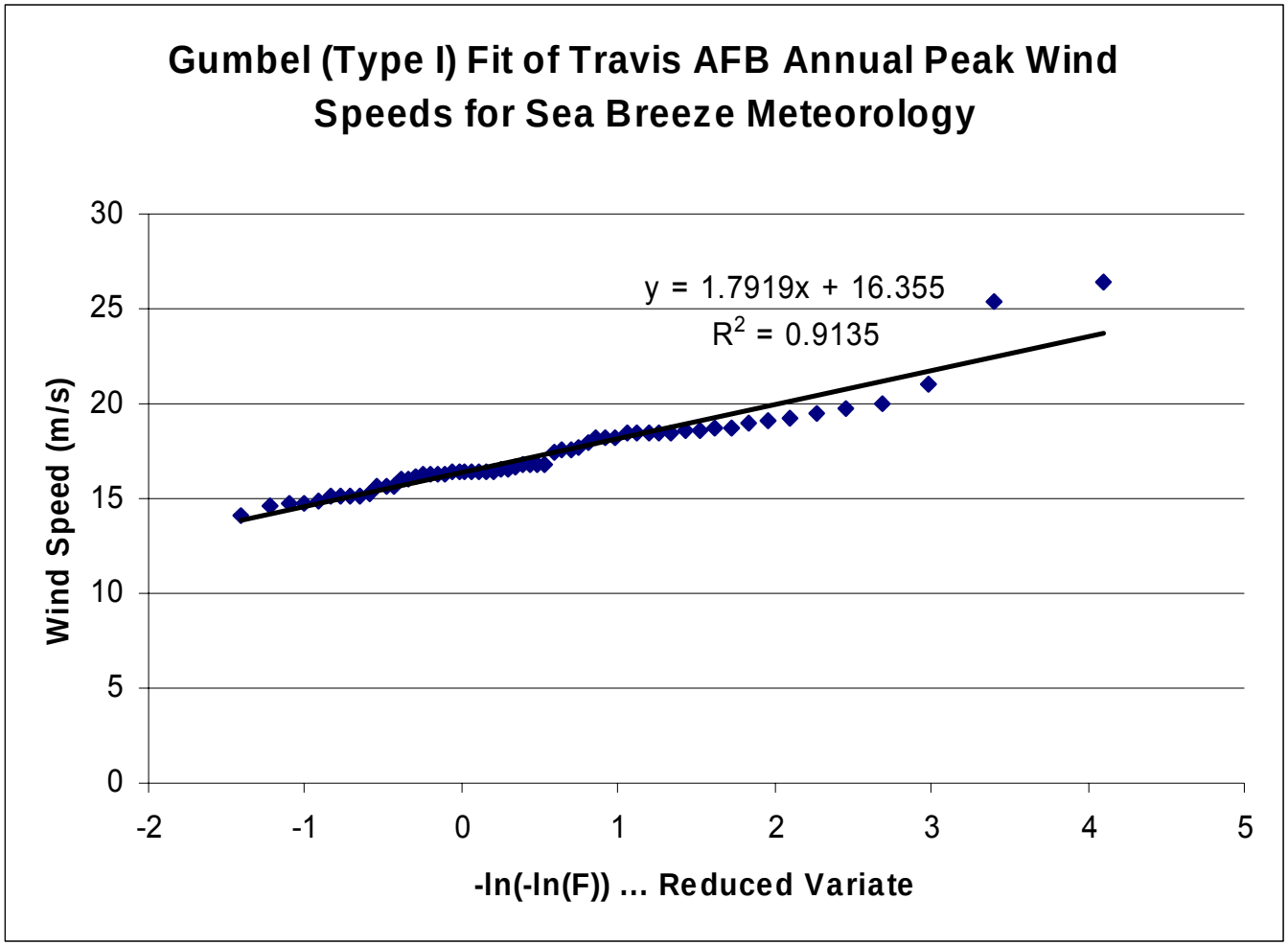


figure 19-c

DRMS Wind Wave Analysis

Gumbel distributions of reference wind speed, Sea Breeze

PWA# 1836.02

PWA

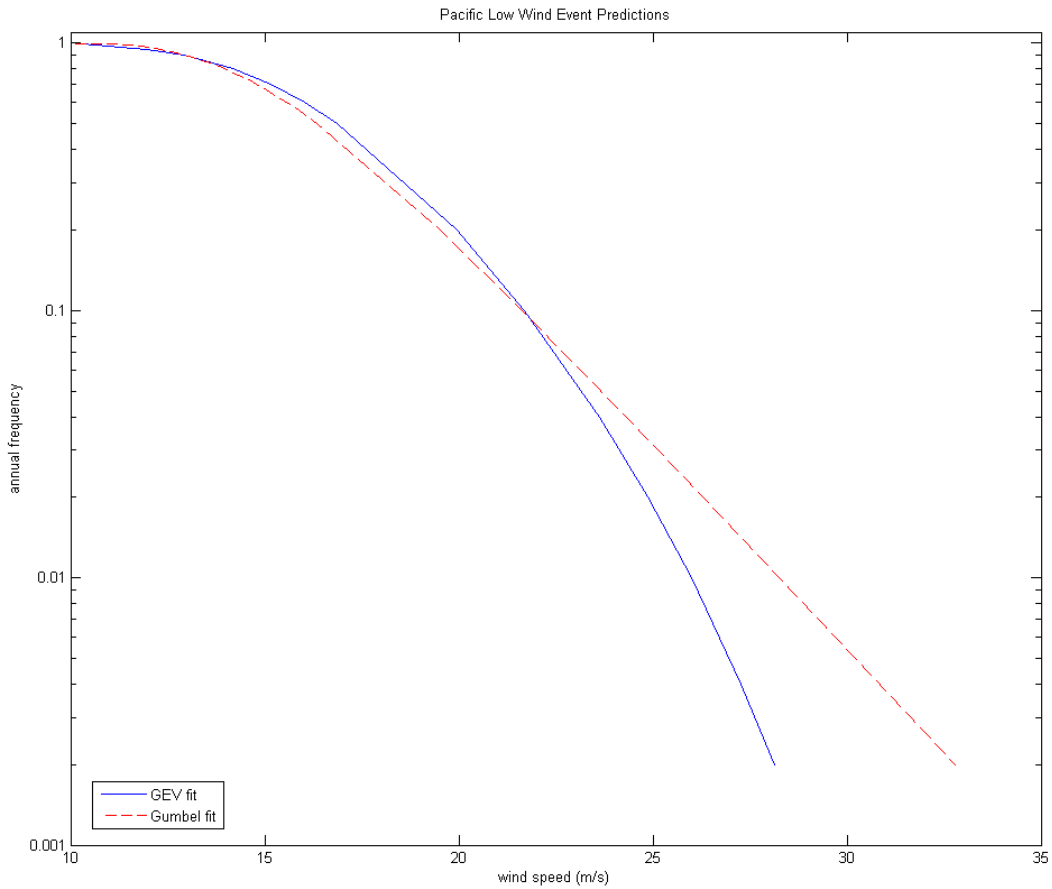


figure 20-a

DRMS Wind Wave Analysis

Comparison of wind speed exceedance distributions, Pacific Low

PWA# 1836.02

PWA

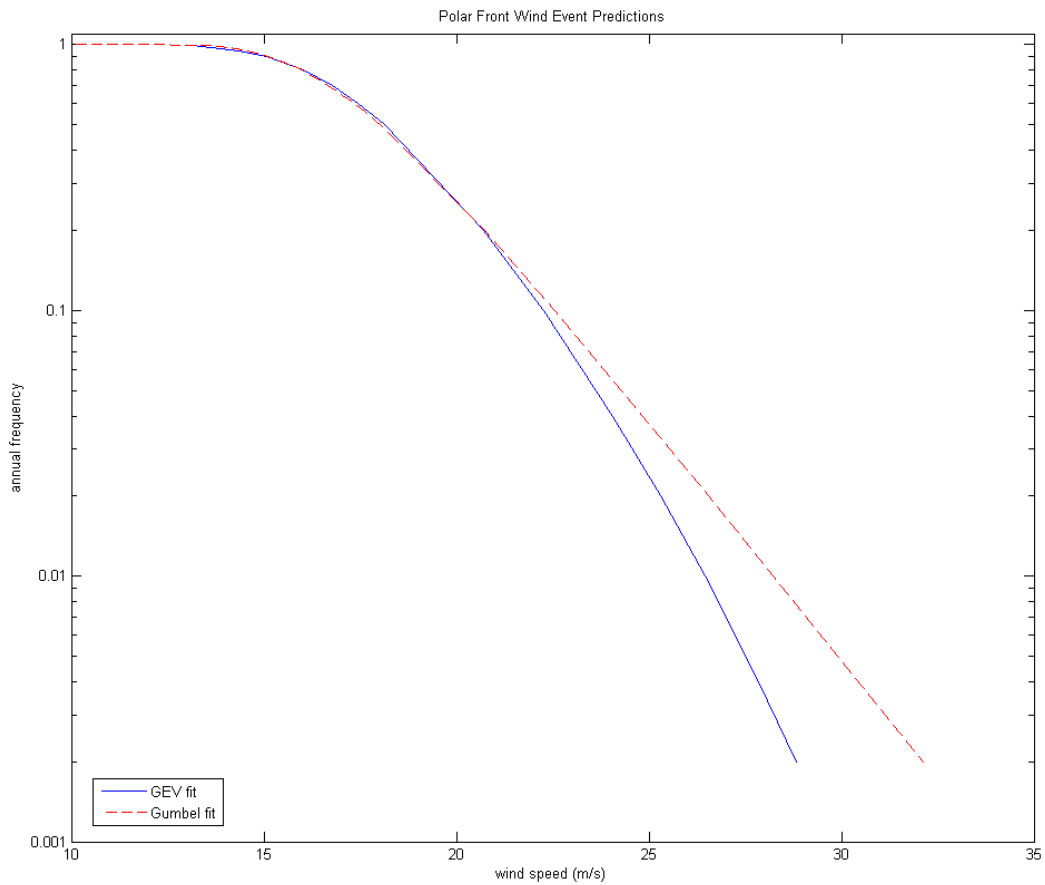


figure 20-b

DRMS Wind Wave Analysis

Comparison of wind speed exceedance distributions, Polar Front

PWA# 1836.02

PWA

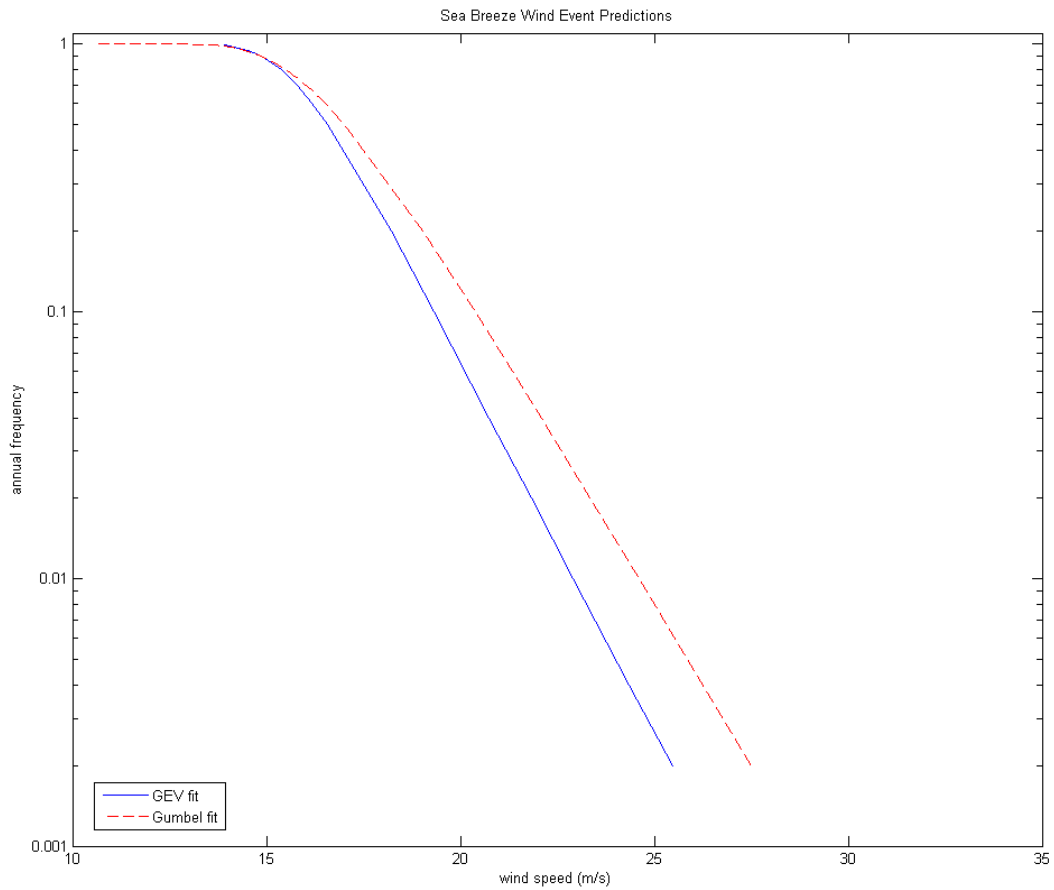


figure 20-c

DRMS Wind Wave Analysis

Comparison of wind speed exceedance distributions, Sea Breeze

PWA# 1836.02

PWA

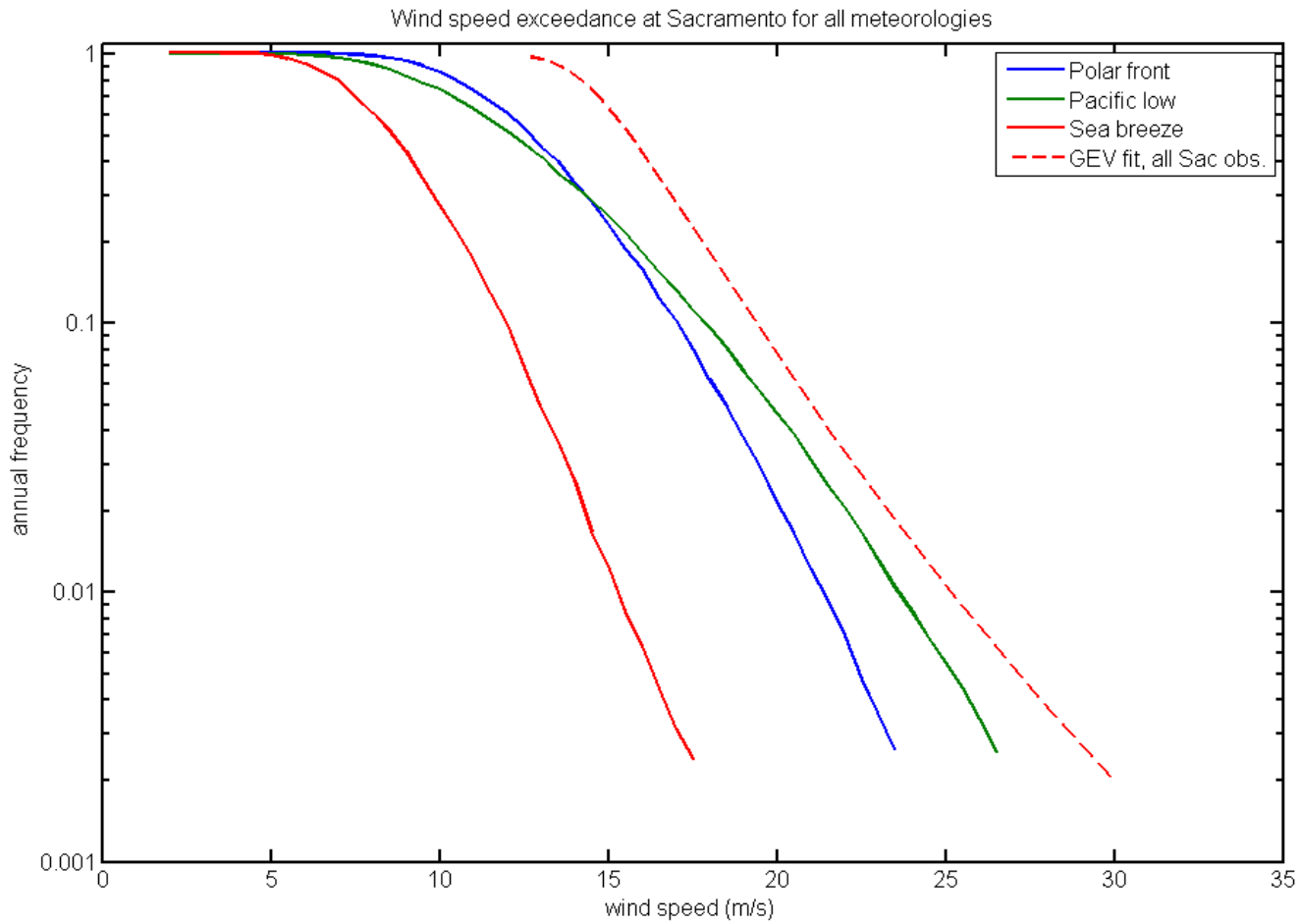


figure 21-a

DRMS Wind Wave Analysis

Comparison of Spatial and NWS Station Wind Speed Exceedance Distributions, Sacramento

PWA# 1836.02

PWA

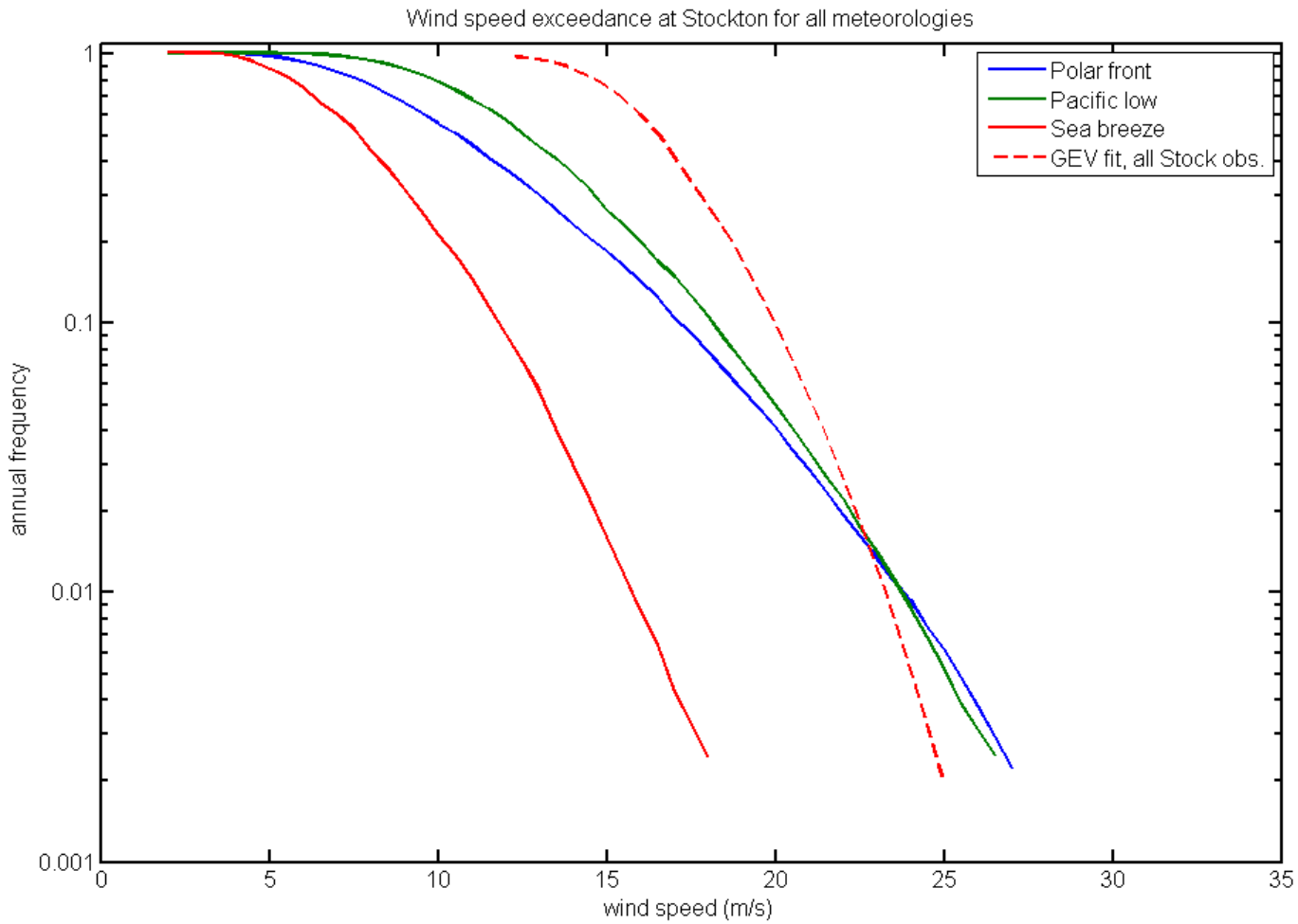


figure 21-b

DRMS Wind Wave Analysis

Comparison of Spatial and NWS Station Wind Speed Exceedance Distributions, Stockton

PWA# 1836.02

PWA

Appendix A
Seasonal Wind Percent Occurrence Tables for NWS Stations

Station ID: 23242 Run ID: Concord
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	2260	284	13	0	0	2557
22.50 - 67.50	2154	221	0	0	0	2375
67.50 - 112.50	1219	70	0	0	0	1289
112.50 - 157.50	2113	56	4	0	0	2173
157.50 - 202.50	5059	1556	49	0	0	6664
202.50 - 247.50	1984	633	12	0	0	2629
247.50 - 292.50	1812	1031	14	0	0	2857
292.50 - 337.50	1699	312	1	0	0	2012
Sub-Total:	18300	4163	93	0	0	22556
Calms:						0
Missing/Incomplete:						0
Total:						22556

Frequency of Calm Winds: 0.00%
Average Wind Speed: 3.47 m/s

Station ID: 23242 Run ID: Concord
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.100195	0.012591	0.000576	0.000000	0.000000	0.113362
22.50 - 67.50	0.095496	0.009798	0.000000	0.000000	0.000000	0.105293
67.50 - 112.50	0.054043	0.003103	0.000000	0.000000	0.000000	0.057147
112.50 - 157.50	0.093678	0.002483	0.000177	0.000000	0.000000	0.096338
157.50 - 202.50	0.224286	0.068984	0.002172	0.000000	0.000000	0.295442
202.50 - 247.50	0.087959	0.028063	0.000532	0.000000	0.000000	0.116554
247.50 - 292.50	0.080333	0.045708	0.000621	0.000000	0.000000	0.126663
292.50 - 337.50	0.075324	0.013832	0.000044	0.000000	0.000000	0.089200
Sub-Total:	0.811314	0.184563	0.004123	0.000000	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 3.47 m/s

Station ID: 23242 Run ID: Concord
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	1041	155	11	0	0	1207
22.50 - 67.50	173	38	1	0	0	212
67.50 - 112.50	105	9	0	0	0	114
112.50 - 157.50	375	11	0	0	0	386
157.50 - 202.50	4022	5232	103	6	0	9363
202.50 - 247.50	3032	2120	9	0	0	5161
247.50 - 292.50	3262	3683	15	0	0	6960
292.50 - 337.50	2311	1409	5	1	0	3726
Sub-Total:	14321	12657	144	7	0	27129
Calms:						0
Missing/Incomplete:						0
Total:						27129

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.78 m/s

Station ID: 23242 Run ID: Concord
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.038372	0.005713	0.000405	0.000000	0.000000	0.044491
22.50 - 67.50	0.006377	0.001401	0.000037	0.000000	0.000000	0.007815
67.50 - 112.50	0.003870	0.000332	0.000000	0.000000	0.000000	0.004202
112.50 - 157.50	0.013823	0.000405	0.000000	0.000000	0.000000	0.014228
157.50 - 202.50	0.148255	0.192856	0.003797	0.000221	0.000000	0.345129
202.50 - 247.50	0.111762	0.078145	0.000332	0.000000	0.000000	0.190239
247.50 - 292.50	0.120240	0.135759	0.000553	0.000000	0.000000	0.256552
292.50 - 337.50	0.085186	0.051937	0.000184	0.000037	0.000000	0.137344
Sub-Total:	0.527885	0.466549	0.005308	0.000258	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.78 m/s

Station ID: 23242 Run ID: Concord
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	3301	439	24	0	0	3764
22.50 - 67.50	2327	259	1	0	0	2587
67.50 - 112.50	1324	79	0	0	0	1403
112.50 - 157.50	2488	67	4	0	0	2559
157.50 - 202.50	9081	6788	152	6	0	16027
202.50 - 247.50	5016	2753	21	0	0	7790
247.50 - 292.50	5074	4714	29	0	0	9817
292.50 - 337.50	4010	1721	6	1	0	5738
Sub-Total:	32621	16820	237	7	0	49685
Calms:						0
Missing/Incomplete:						0
Total:						49685

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.19 m/s

Station ID: 23242 Run ID: Concord
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.066439	0.008836	0.000483	0.000000	0.000000	0.075757
22.50 - 67.50	0.046835	0.005213	0.000020	0.000000	0.000000	0.052068
67.50 - 112.50	0.026648	0.001590	0.000000	0.000000	0.000000	0.028238
112.50 - 157.50	0.050075	0.001348	0.000081	0.000000	0.000000	0.051504
157.50 - 202.50	0.182771	0.136621	0.003059	0.000121	0.000000	0.322572
202.50 - 247.50	0.100956	0.055409	0.000423	0.000000	0.000000	0.156788
247.50 - 292.50	0.102123	0.094878	0.000584	0.000000	0.000000	0.197585
292.50 - 337.50	0.080708	0.034638	0.000121	0.000020	0.000000	0.115488
Sub-Total:	0.656556	0.338533	0.004770	0.000141	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.19 m/s

Station ID: 23241 Run ID: Livermore
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	533	342	25	0	0	900
22.50 - 67.50	3317	902	9	0	0	4228
67.50 - 112.50	3616	480	7	0	0	4103
112.50 - 157.50	598	44	0	0	0	642
157.50 - 202.50	1824	562	44	0	0	2430
202.50 - 247.50	2684	816	28	1	0	3529
247.50 - 292.50	3662	1338	39	0	0	5039
292.50 - 337.50	861	115	5	0	0	981
Sub-Total:	17095	4599	157	1	0	21852
Calms:						0
Missing/Incomplete:						0
Total:						21852

Frequency of Calm Winds: 0.00%
Average Wind Speed: 3.63 m/s

Station ID: 23241 Run ID: Livermore
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.024391	0.015651	0.001144	0.000000	0.000000	0.041186
22.50 - 67.50	0.151794	0.041278	0.000412	0.000000	0.000000	0.193483
67.50 - 112.50	0.165477	0.021966	0.000320	0.000000	0.000000	0.187763
112.50 - 157.50	0.027366	0.002014	0.000000	0.000000	0.000000	0.029379
157.50 - 202.50	0.083471	0.025718	0.002014	0.000000	0.000000	0.111203
202.50 - 247.50	0.122826	0.037342	0.001281	0.000046	0.000000	0.161496
247.50 - 292.50	0.167582	0.061230	0.001785	0.000000	0.000000	0.230597
292.50 - 337.50	0.039401	0.005263	0.000229	0.000000	0.000000	0.044893
Sub-Total:	0.782308	0.210461	0.007185	0.000046	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 3.63 m/s

Station ID: 23241 Run ID: Livermore
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	211	159	26	0	0	396
22.50 - 67.50	594	100	1	0	0	695
67.50 - 112.50	770	48	2	0	0	820
112.50 - 157.50	132	10	0	0	0	142
157.50 - 202.50	1410	309	4	0	0	1723
202.50 - 247.50	3658	1626	14	0	0	5298
247.50 - 292.50	8154	7698	135	2	0	15989
292.50 - 337.50	2625	498	26	0	0	3149
Sub-Total:	17554	10448	208	2	0	28212
Calms:						0
Missing/Incomplete:						0
Total:						28212

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.56 m/s

Station ID: 23241 Run ID: Livermore
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.007479	0.005636	0.000922	0.000000	0.000000	0.014037
22.50 - 67.50	0.021055	0.003545	0.000035	0.000000	0.000000	0.024635
67.50 - 112.50	0.027293	0.001701	0.000071	0.000000	0.000000	0.029066
112.50 - 157.50	0.004679	0.000354	0.000000	0.000000	0.000000	0.005033
157.50 - 202.50	0.049979	0.010953	0.000142	0.000000	0.000000	0.061073
202.50 - 247.50	0.129661	0.057635	0.000496	0.000000	0.000000	0.187792
247.50 - 292.50	0.289026	0.272863	0.004785	0.000071	0.000000	0.566745
292.50 - 337.50	0.093046	0.017652	0.000922	0.000000	0.000000	0.111619
Sub-Total:	0.622217	0.370339	0.007373	0.000071	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.56 m/s

Station ID: 23241 Run ID: Livermore
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	744	501	51	0	0	1296
22.50 - 67.50	3911	1002	10	0	0	4923
67.50 - 112.50	4386	528	9	0	0	4923
112.50 - 157.50	730	54	0	0	0	784
157.50 - 202.50	3234	871	48	0	0	4153
202.50 - 247.50	6342	2442	42	1	0	8827
247.50 - 292.50	11816	9036	174	2	0	21028
292.50 - 337.50	3486	613	31	0	0	4130
Sub-Total:	34649	15047	365	3	0	50064
Calms:						0
Missing/Incomplete:						0
Total:						50064

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.15 m/s

Station ID: 23241 Run ID: Livermore
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.014861	0.010007	0.001019	0.000000	0.000000	0.025887
22.50 - 67.50	0.078120	0.020014	0.000200	0.000000	0.000000	0.098334
67.50 - 112.50	0.087608	0.010547	0.000180	0.000000	0.000000	0.098334
112.50 - 157.50	0.014581	0.001079	0.000000	0.000000	0.000000	0.015660
157.50 - 202.50	0.064597	0.017398	0.000959	0.000000	0.000000	0.082954
202.50 - 247.50	0.126678	0.048778	0.000839	0.000020	0.000000	0.176314
247.50 - 292.50	0.236018	0.180489	0.003476	0.000040	0.000000	0.420022
292.50 - 337.50	0.069631	0.012244	0.000619	0.000000	0.000000	0.082494
Sub-Total:	0.692094	0.300555	0.007291	0.000060	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.15 m/s

Station ID: 23232 Run ID: SACRAMENTO/EXECUTIVE ARPT
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	2664	705	99	1	0	3469
22.50 - 67.50	624	13	0	0	0	637
67.50 - 112.50	1822	143	13	0	0	1978
112.50 - 157.50	5467	1848	224	2	0	7541
157.50 - 202.50	5772	1223	44	0	0	7039
202.50 - 247.50	2489	705	22	0	0	3216
247.50 - 292.50	2067	253	3	0	0	2323
292.50 - 337.50	4335	1882	212	5	0	6434
Sub-Total:	25240	6772	617	8	0	32637
Calms:						0
Missing/Incomplete:						0
Total:						32637

Frequency of Calm Winds: 0.00%
Average Wind Speed: 3.97 m/s

Station ID: 23232 Run ID: SACRAMENTO/EXECUTIVE ARPT
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.081625	0.021601	0.003033	0.000031	0.000000	0.106290
22.50 - 67.50	0.019119	0.000398	0.000000	0.000000	0.000000	0.019518
67.50 - 112.50	0.055826	0.004382	0.000398	0.000000	0.000000	0.060606
112.50 - 157.50	0.167509	0.056623	0.006863	0.000061	0.000000	0.231057
157.50 - 202.50	0.176854	0.037473	0.001348	0.000000	0.000000	0.215675
202.50 - 247.50	0.076263	0.021601	0.000674	0.000000	0.000000	0.098538
247.50 - 292.50	0.063333	0.007752	0.000092	0.000000	0.000000	0.071177
292.50 - 337.50	0.132825	0.057665	0.006496	0.000153	0.000000	0.197138
Sub-Total:	0.773355	0.207495	0.018905	0.000245	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 3.97 m/s

Station ID: 23232 Run ID: SACRAMENTO/EXECUTIVE ARPT
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	881	461	49	0	0	1391
22.50 - 67.50	155	9	0	0	0	164
67.50 - 112.50	482	24	0	0	0	506
112.50 - 157.50	3790	186	1	0	0	3977
157.50 - 202.50	11813	3114	30	0	0	14957
202.50 - 247.50	6268	3619	37	0	0	9924
247.50 - 292.50	1821	320	7	0	1	2149
292.50 - 337.50	1833	1132	137	1	0	3103
Sub-Total:	27043	8865	261	1	1	36171
Calms:						0
Missing/Incomplete:						0
Total:						36171

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.14 m/s

Station ID: 23232 Run ID: SACRAMENTO/EXECUTIVE ARPT
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.024357	0.012745	0.001355	0.000000	0.000000	0.038456
22.50 - 67.50	0.004285	0.000249	0.000000	0.000000	0.000000	0.004534
67.50 - 112.50	0.013326	0.000664	0.000000	0.000000	0.000000	0.013989
112.50 - 157.50	0.104780	0.005142	0.000028	0.000000	0.000000	0.109950
157.50 - 202.50	0.326588	0.086091	0.000829	0.000000	0.000000	0.413508
202.50 - 247.50	0.173288	0.100053	0.001023	0.000000	0.000000	0.274363
247.50 - 292.50	0.050344	0.008847	0.000194	0.000000	0.000028	0.059412
292.50 - 337.50	0.050676	0.031296	0.003788	0.000028	0.000000	0.085787
Sub-Total:	0.747643	0.245086	0.007216	0.000028	0.000028	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.14 m/s

Station ID: 23232 Run ID: SACRAMENTO/EXECUTIVE ARPT
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	3545	1166	148	1	0	4860
22.50 - 67.50	779	22	0	0	0	801
67.50 - 112.50	2304	167	13	0	0	2484
112.50 - 157.50	9257	2034	225	2	0	11518
157.50 - 202.50	17585	4337	74	0	0	21996
202.50 - 247.50	8757	4324	59	0	0	13140
247.50 - 292.50	3888	573	10	0	1	4472
292.50 - 337.50	6168	3014	349	6	0	9537
Sub-Total:	52283	15637	878	9	1	68808
Calms:						0
Missing/Incomplete:						0
Total:						68808

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.06 m/s

Station ID: 23232 Run ID: SACRAMENTO/EXECUTIVE ARPT
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.051520	0.016946	0.002151	0.000015	0.000000	0.070631
22.50 - 67.50	0.011321	0.000320	0.000000	0.000000	0.000000	0.011641
67.50 - 112.50	0.033484	0.002427	0.000189	0.000000	0.000000	0.036100
112.50 - 157.50	0.134534	0.029561	0.003270	0.000029	0.000000	0.167393
157.50 - 202.50	0.255566	0.063030	0.001075	0.000000	0.000000	0.319672
202.50 - 247.50	0.127267	0.062842	0.000857	0.000000	0.000000	0.190966
247.50 - 292.50	0.056505	0.008328	0.000145	0.000000	0.000015	0.064992
292.50 - 337.50	0.089641	0.043803	0.005072	0.000087	0.000000	0.138603
Sub-Total:	0.759839	0.227256	0.012760	0.000131	0.000015	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.06 m/s

Station ID: 23237 Run ID: Stockton
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	2648	507	66	0	0	3221
22.50 - 67.50	1225	10	0	0	0	1235
67.50 - 112.50	3725	90	1	0	0	3816
112.50 - 157.50	5633	2257	377	30	0	8297
157.50 - 202.50	2295	782	89	6	0	3172
202.50 - 247.50	1476	109	11	1	0	1597
247.50 - 292.50	6194	1395	45	0	0	7634
292.50 - 337.50	5234	1807	75	0	0	7116
Sub-Total:	28430	6957	664	37	0	36088
Calms:						0
Missing/Incomplete:						0
Total:						36088

Frequency of Calm Winds: 0.00%
Average Wind Speed: 3.89 m/s

Station ID: 23237 Run ID: Stockton
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.073376	0.014049	0.001829	0.000000	0.000000	0.089254
22.50 - 67.50	0.033945	0.000277	0.000000	0.000000	0.000000	0.034222
67.50 - 112.50	0.103220	0.002494	0.000028	0.000000	0.000000	0.105742
112.50 - 157.50	0.156091	0.062542	0.010447	0.000831	0.000000	0.229910
157.50 - 202.50	0.063595	0.021669	0.002466	0.000166	0.000000	0.087896
202.50 - 247.50	0.040900	0.003020	0.000305	0.000028	0.000000	0.044253
247.50 - 292.50	0.171636	0.038656	0.001247	0.000000	0.000000	0.211538
292.50 - 337.50	0.145034	0.050072	0.002078	0.000000	0.000000	0.197185
Sub-Total:	0.787796	0.192779	0.018399	0.001025	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 3.89 m/s

Station ID: 23237 Run ID: Stockton
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	4640	538	66	8	0	5252
22.50 - 67.50	1474	6	0	0	0	1480
67.50 - 112.50	649	19	0	0	0	668
112.50 - 157.50	597	176	6	0	0	779
157.50 - 202.50	472	81	6	0	0	559
202.50 - 247.50	590	115	2	0	0	707
247.50 - 292.50	8458	6809	256	0	0	15523
292.50 - 337.50	9016	4518	81	0	0	13615
Sub-Total:	25896	12262	417	8	0	38583
Calms:						0
Missing/Incomplete:						0
Total:						38583

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.56 m/s

Station ID: 23237 Run ID: Stockton
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.120260	0.013944	0.001711	0.000207	0.000000	0.136122
22.50 - 67.50	0.038203	0.000156	0.000000	0.000000	0.000000	0.038359
67.50 - 112.50	0.016821	0.000492	0.000000	0.000000	0.000000	0.017313
112.50 - 157.50	0.015473	0.004562	0.000156	0.000000	0.000000	0.020190
157.50 - 202.50	0.012233	0.002099	0.000156	0.000000	0.000000	0.014488
202.50 - 247.50	0.015292	0.002981	0.000052	0.000000	0.000000	0.018324
247.50 - 292.50	0.219216	0.176477	0.006635	0.000000	0.000000	0.402327
292.50 - 337.50	0.233678	0.117098	0.002099	0.000000	0.000000	0.352876
Sub-Total:	0.671176	0.317808	0.010808	0.000207	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.56 m/s

Station ID: 23237 Run ID: Stockton
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	7288	1045	132	8	0	8473
22.50 - 67.50	2699	16	0	0	0	2715
67.50 - 112.50	4374	109	1	0	0	4484
112.50 - 157.50	6230	2433	383	30	0	9076
157.50 - 202.50	2767	863	95	6	0	3731
202.50 - 247.50	2066	224	13	1	0	2304
247.50 - 292.50	14652	8204	301	0	0	23157
292.50 - 337.50	14250	6325	156	0	0	20731
Sub-Total:	54326	19219	1081	45	0	74671
Calms:						0
Missing/Incomplete:						0
Total:						74671

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.23 m/s

Station ID: 23237 Run ID: Stockton
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.097601	0.013995	0.001768	0.000107	0.000000	0.113471
22.50 - 67.50	0.036145	0.000214	0.000000	0.000000	0.000000	0.036359
67.50 - 112.50	0.058577	0.001460	0.000013	0.000000	0.000000	0.060050
112.50 - 157.50	0.083433	0.032583	0.005129	0.000402	0.000000	0.121547
157.50 - 202.50	0.037056	0.011557	0.001272	0.000080	0.000000	0.049966
202.50 - 247.50	0.027668	0.003000	0.000174	0.000013	0.000000	0.030855
247.50 - 292.50	0.196221	0.109869	0.004031	0.000000	0.000000	0.310120
292.50 - 337.50	0.190837	0.084705	0.002089	0.000000	0.000000	0.277631
Sub-Total:	0.727538	0.257382	0.014477	0.000603	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.23 m/s

Station ID: 23202 Run ID: Travis
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed Knots

Wind Direction	0 - 9	10 - 19	19 - 29	29 - 38	>= 39	Total
337.50 - 22.50	488	748	329	37	0	1602
22.50 - 67.50	266	136	2	0	0	404
67.50 - 112.50	117	11	0	0	0	128
112.50 - 157.50	130	67	5	0	0	202
157.50 - 202.50	475	170	13	2	0	660
202.50 - 247.50	2888	11356	5987	523	14	20768
247.50 - 292.50	1830	6480	3592	170	8	12080
292.50 - 337.50	273	70	14	0	0	357
Sub-Total:	6467	19038	9942	732	22	36201
Calms:						0
Missing/Incomplete:						0
Total:						36201

Frequency of Calm Winds: 0.00%
Average Wind Speed: 16.42 Knots

Station ID: 23202 Run ID: Travis
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed Knots

Wind Direction	0 - 9	10 - 19	19 - 29	29 - 38	>= 39	Total
337.50 - 22.50	0.013480	0.020662	0.009088	0.001022	0.000000	0.044253
22.50 - 67.50	0.007348	0.003757	0.000055	0.000000	0.000000	0.011160
67.50 - 112.50	0.003232	0.000304	0.000000	0.000000	0.000000	0.003536
112.50 - 157.50	0.003591	0.001851	0.000138	0.000000	0.000000	0.005580
157.50 - 202.50	0.013121	0.004696	0.000359	0.000055	0.000000	0.018232
202.50 - 247.50	0.079777	0.313693	0.165382	0.014447	0.000387	0.573686
247.50 - 292.50	0.050551	0.179001	0.099224	0.004696	0.000221	0.333692
292.50 - 337.50	0.007541	0.001934	0.000387	0.000000	0.000000	0.009862
Sub-Total:	0.178641	0.525897	0.274633	0.020220	0.000608	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 16.42 Knots

Station ID: 23202 Run ID: Travis
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed Knots

Wind Direction	0 - 9	10 - 19	19 - 29	29 - 38	>= 39	Total
337.50 - 22.50	3122	1895	708	90	3	5818
22.50 - 67.50	2924	785	23	0	0	3732
67.50 - 112.50	1945	118	2	0	0	2065
112.50 - 157.50	1335	605	260	48	3	2251
157.50 - 202.50	2118	806	147	16	1	3088
202.50 - 247.50	3773	3729	686	52	1	8241
247.50 - 292.50	2824	2324	519	31	1	5699
292.50 - 337.50	1333	172	15	0	0	1520
Sub-Total:	19374	10434	2360	237	9	32414
Calms:						0
Missing/Incomplete:						0
Total:						32414

Frequency of Calm Winds: 0.00%
Average Wind Speed: 10.20 Knots

Station ID: 23202 Run ID: Travis
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed Knots

Wind Direction	0 - 9	10 - 19	19 - 29	29 - 38	>= 39	Total
337.50 - 22.50	0.096316	0.058462	0.021842	0.002777	0.000093	0.179490
22.50 - 67.50	0.090208	0.024218	0.000710	0.000000	0.000000	0.115135
67.50 - 112.50	0.060005	0.003640	0.000062	0.000000	0.000000	0.063707
112.50 - 157.50	0.041186	0.018665	0.008021	0.001481	0.000093	0.069445
157.50 - 202.50	0.065342	0.024866	0.004535	0.000494	0.000031	0.095267
202.50 - 247.50	0.116400	0.115043	0.021164	0.001604	0.000031	0.254242
247.50 - 292.50	0.087123	0.071697	0.016012	0.000956	0.000031	0.175819
292.50 - 337.50	0.041124	0.005306	0.000463	0.000000	0.000000	0.046893
Sub-Total:	0.597705	0.321898	0.072808	0.007312	0.000278	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 10.20 Knots

Station ID: 23202 Run ID: Travis
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed Knots

Wind Direction	0 - 9	10 - 19	19 - 29	29 - 38	>= 39	Total
337.50 - 22.50	3610	2643	1037	127	3	7420
22.50 - 67.50	3190	921	25	0	0	4136
67.50 - 112.50	2062	129	2	0	0	2193
112.50 - 157.50	1465	672	265	48	3	2453
157.50 - 202.50	2593	976	160	18	1	3748
202.50 - 247.50	6661	15085	6673	575	15	29009
247.50 - 292.50	4654	8804	4111	201	9	17779
292.50 - 337.50	1606	242	29	0	0	1877
Sub-Total:	25841	29472	12302	969	31	68615
Calms:						0
Missing/Incomplete:						0
Total:						68615

Frequency of Calm Winds: 0.00%
Average Wind Speed: 13.48 Knots

Station ID: 23202 Run ID: Travis
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed Knots

Wind Direction	0 - 9	10 - 19	19 - 29	29 - 38	>= 39	Total
337.50 - 22.50	0.052612	0.038519	0.015113	0.001851	0.000044	0.108140
22.50 - 67.50	0.046491	0.013423	0.000364	0.000000	0.000000	0.060278
67.50 - 112.50	0.030052	0.001880	0.000029	0.000000	0.000000	0.031961
112.50 - 157.50	0.021351	0.009794	0.003862	0.000700	0.000044	0.035750
157.50 - 202.50	0.037791	0.014224	0.002332	0.000262	0.000015	0.054624
202.50 - 247.50	0.097078	0.219850	0.097253	0.008380	0.000219	0.422779
247.50 - 292.50	0.067828	0.128310	0.059914	0.002929	0.000131	0.259112
292.50 - 337.50	0.023406	0.003527	0.000423	0.000000	0.000000	0.027356
Sub-Total:	0.376609	0.429527	0.179290	0.014122	0.000452	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 13.48 Knots

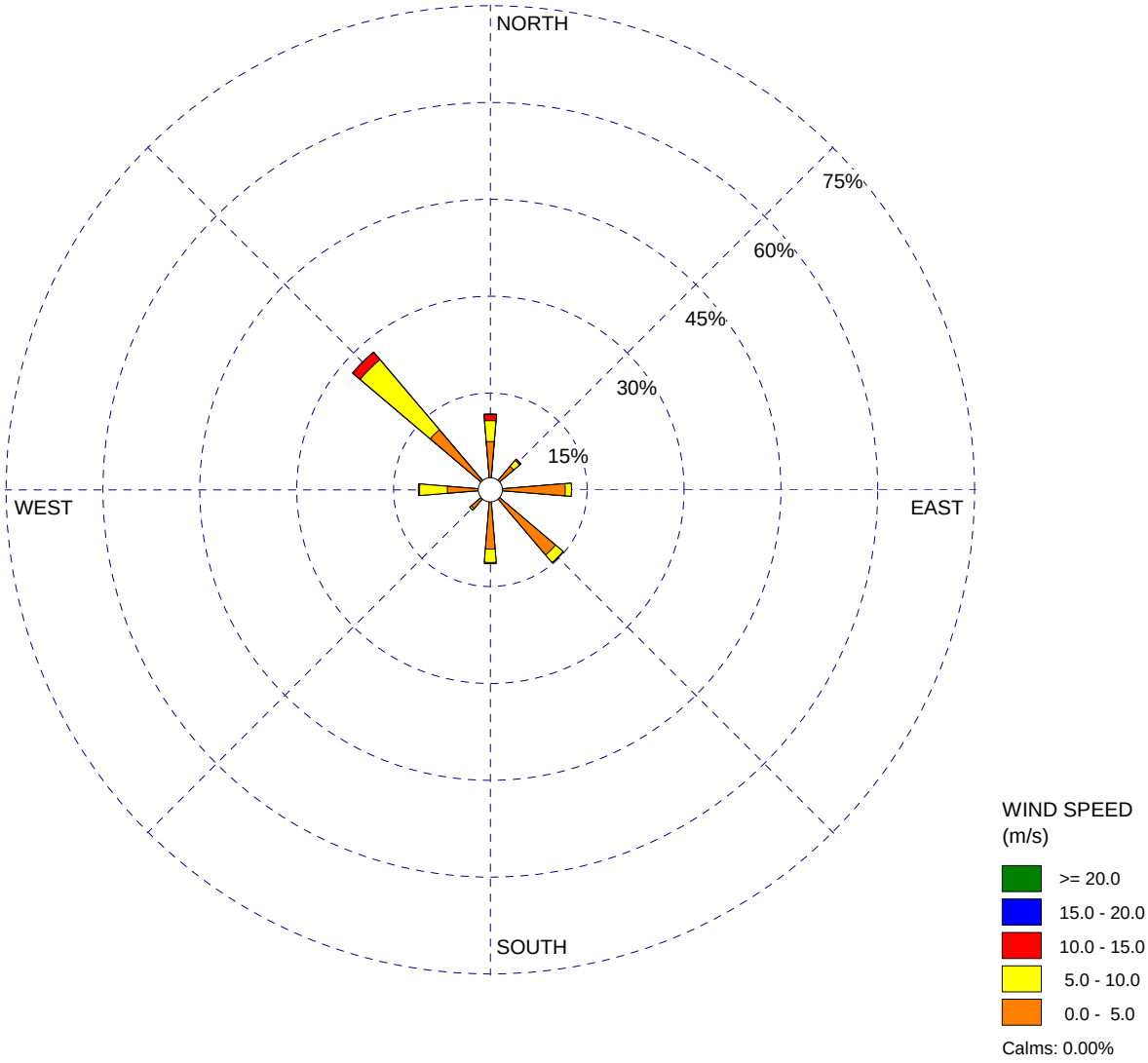
Appendix B
Seasonal Wind Analysis for DWR and CIMIS Stations

WIND ROSE PLOT:

Antioch, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 30 DEC. 2005	COMPANY NAME:	
FALL-WINTER October 1 - March 31		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **37107 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

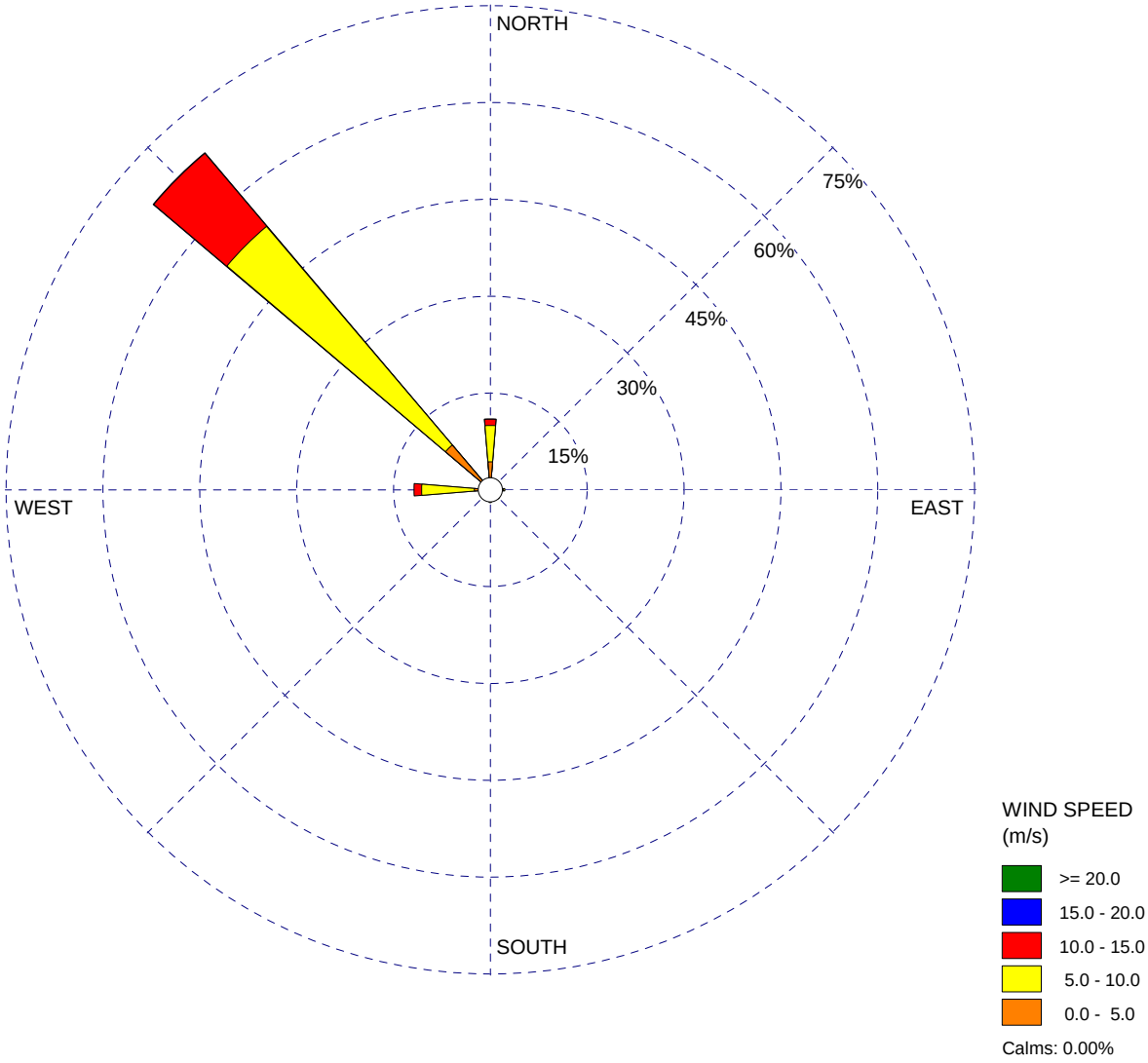
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Antioch, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 30 DEC. 2005	COMPANY NAME:	
SPRING-SUMMER April 1 - September 30		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **35655 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

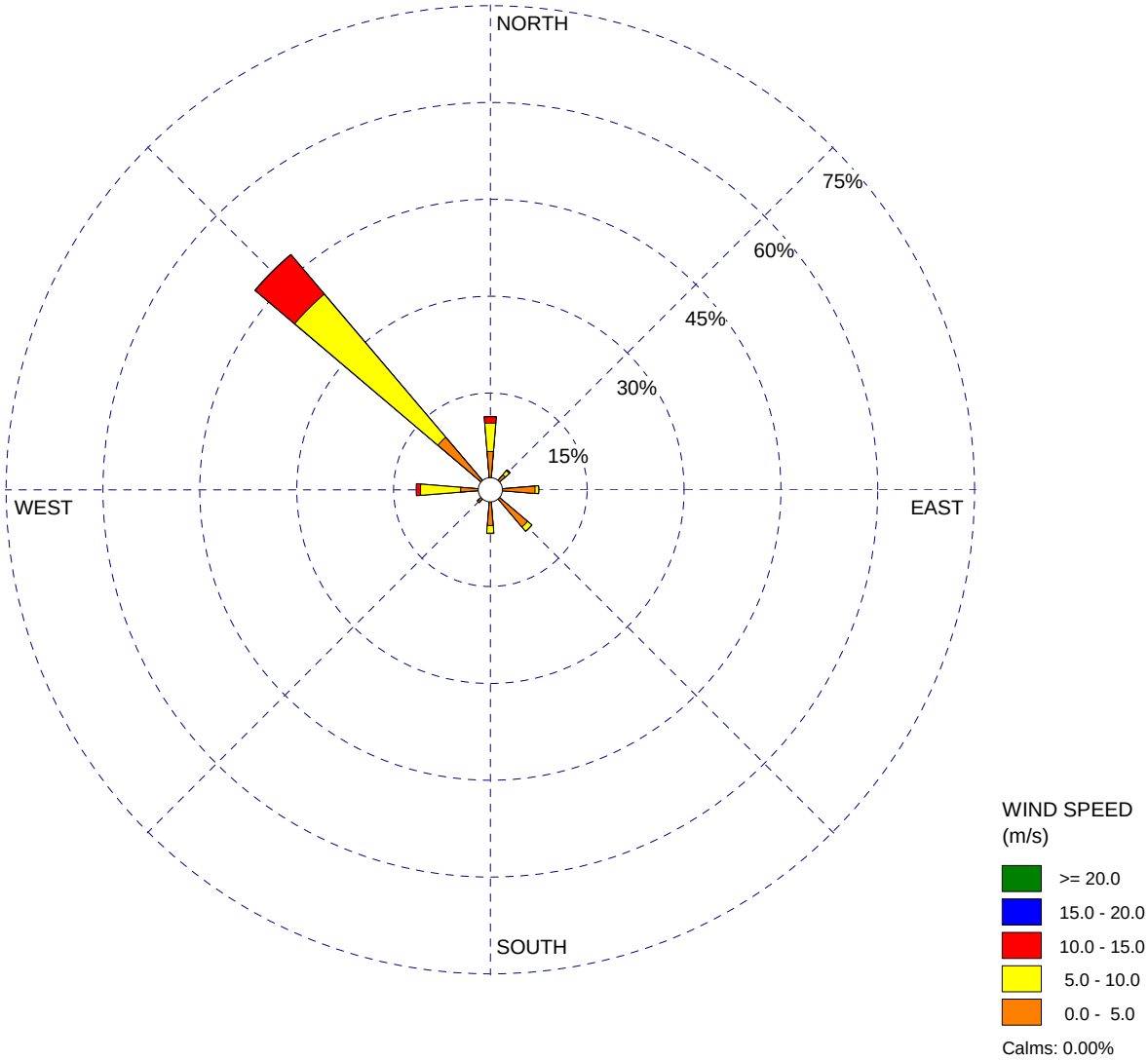
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Antioch, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 30 DEC. 2005	COMPANY NAME:	
FULL YEAR January 1 - December 31		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **72762 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

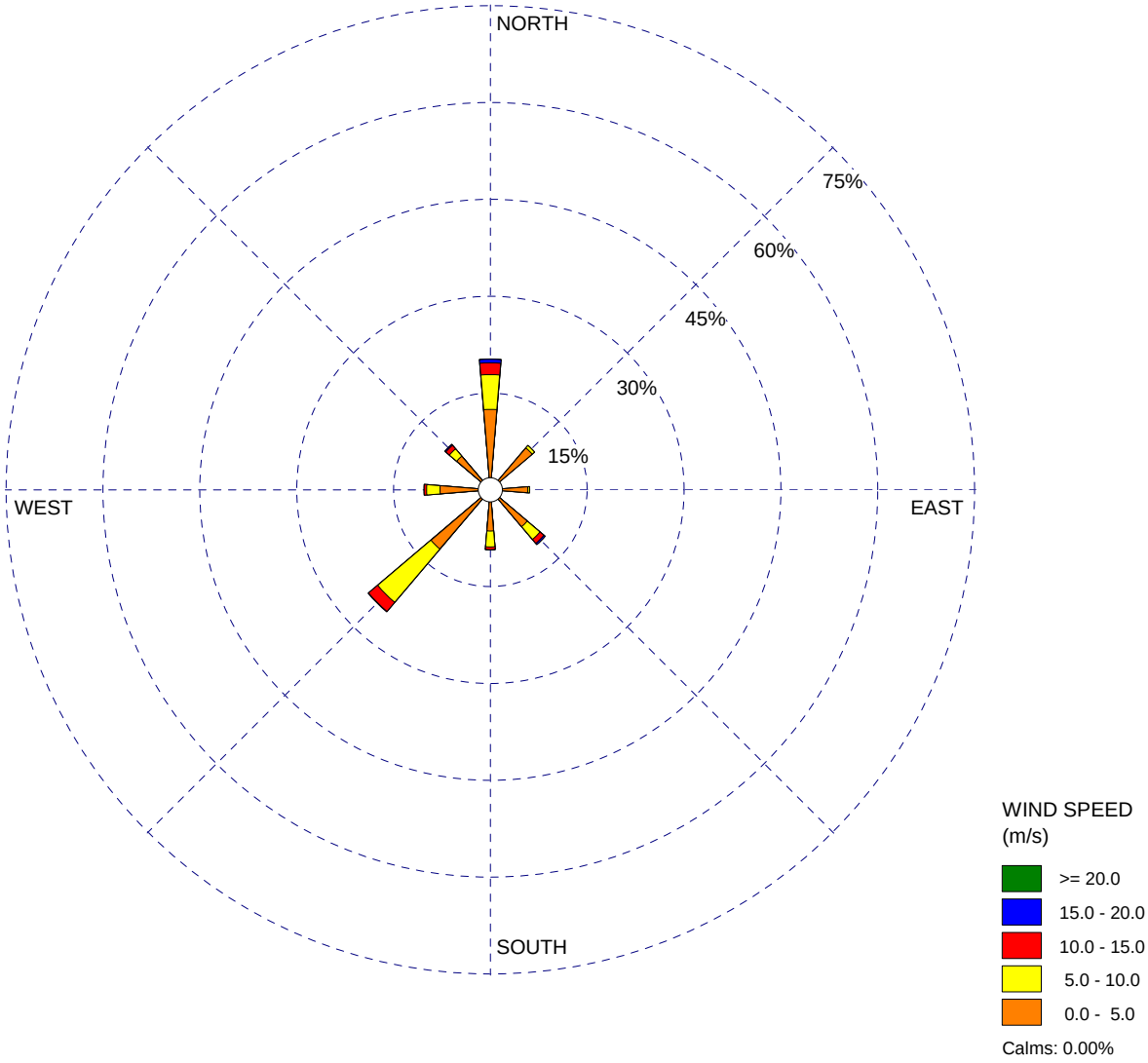
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Hastings, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:	
FALL-WINTER October 1 - March 31		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **39358 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

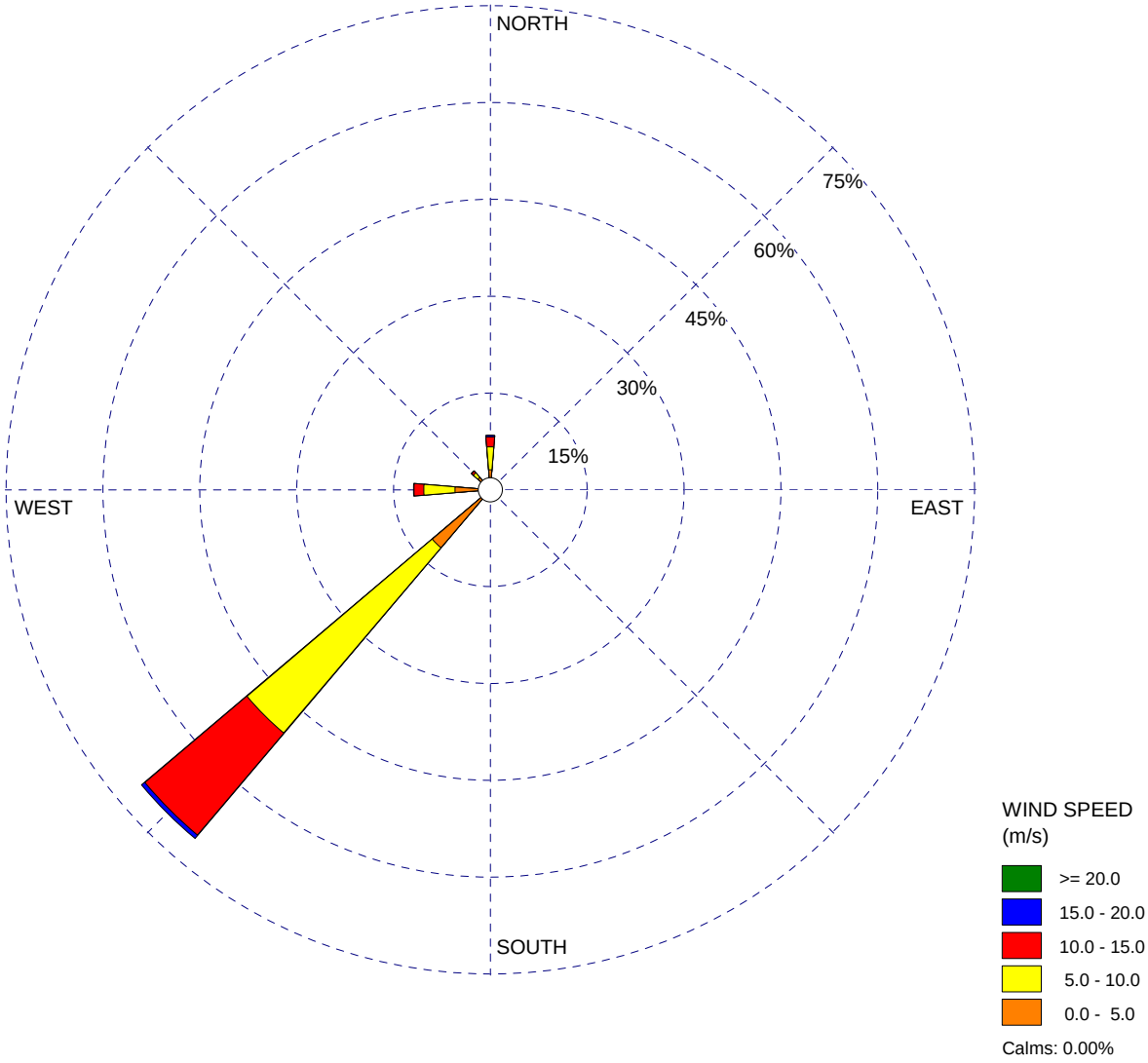
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Hastings, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:	
SPRING-SUMMER April 1 - September 30		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **39525 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

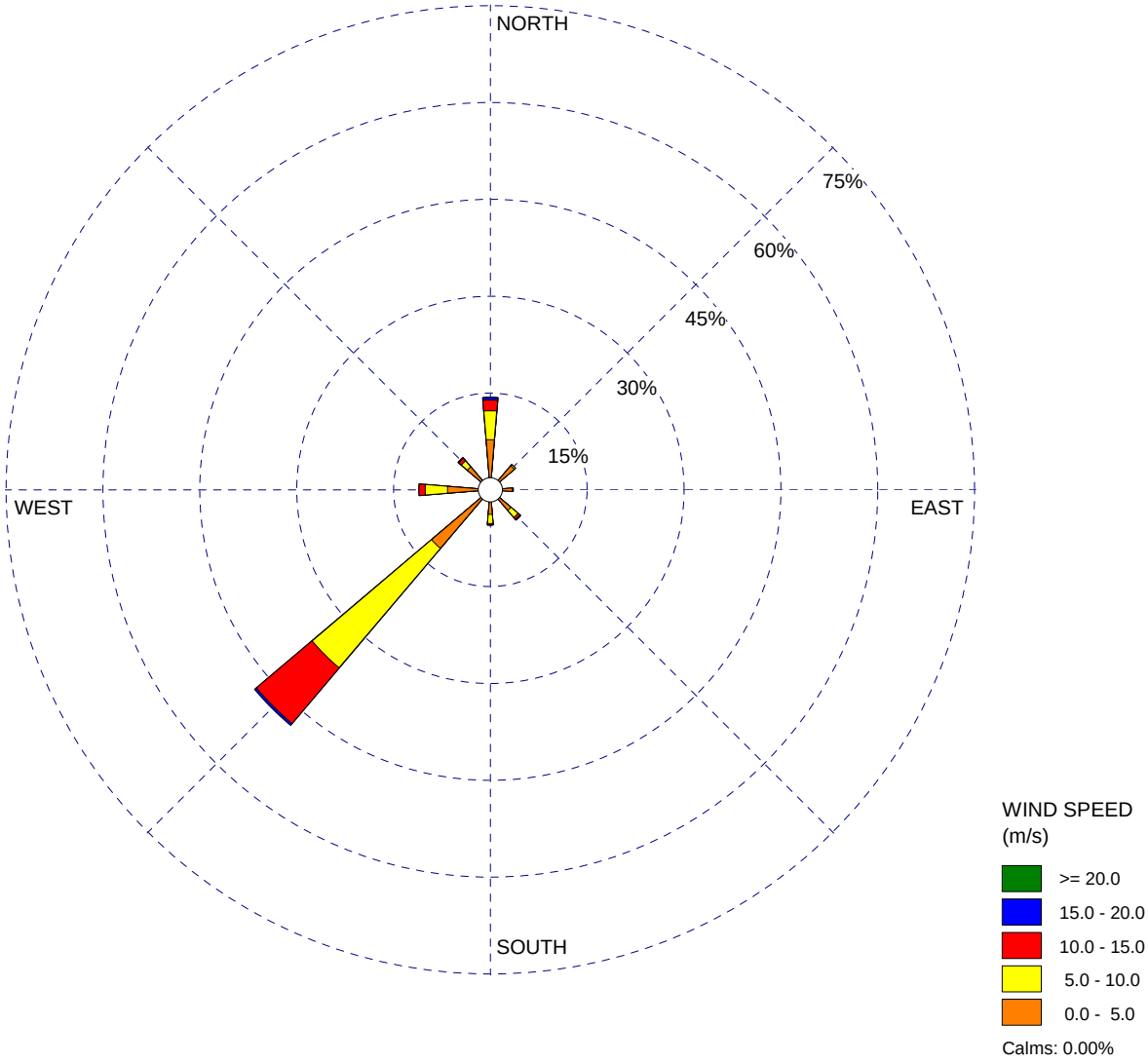
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Hastings, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:	
FULL YEAR January 1 - December 31		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **78883 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

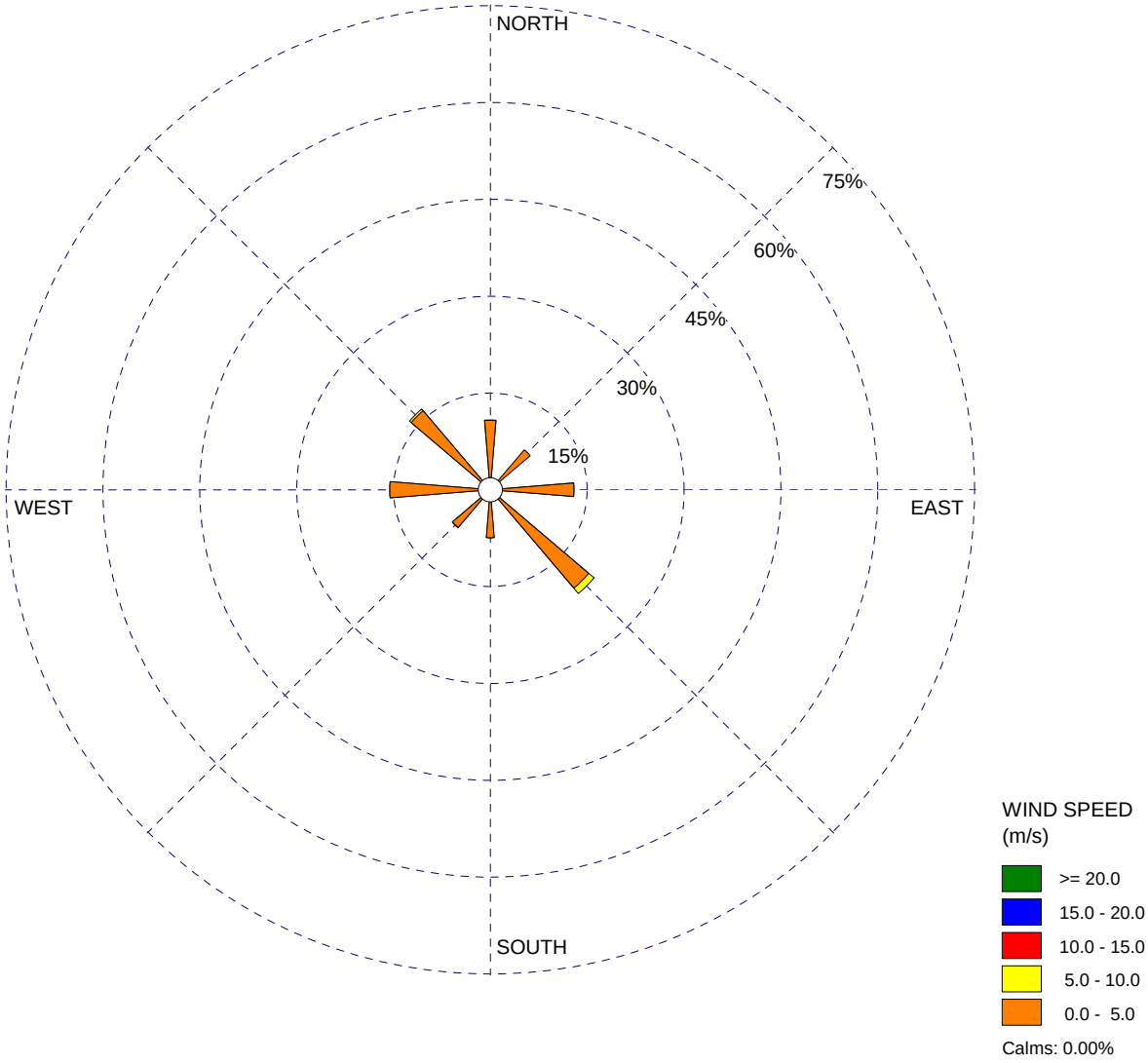
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Lodi, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 11 SEP 2000 - 31 DEC. 2005	COMPANY NAME:	
FALL-WINTER October 1 - March 31		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **22817 hrs.**	
		DATE: **12/13/2006**	PROJECT NO.: **1836.02**

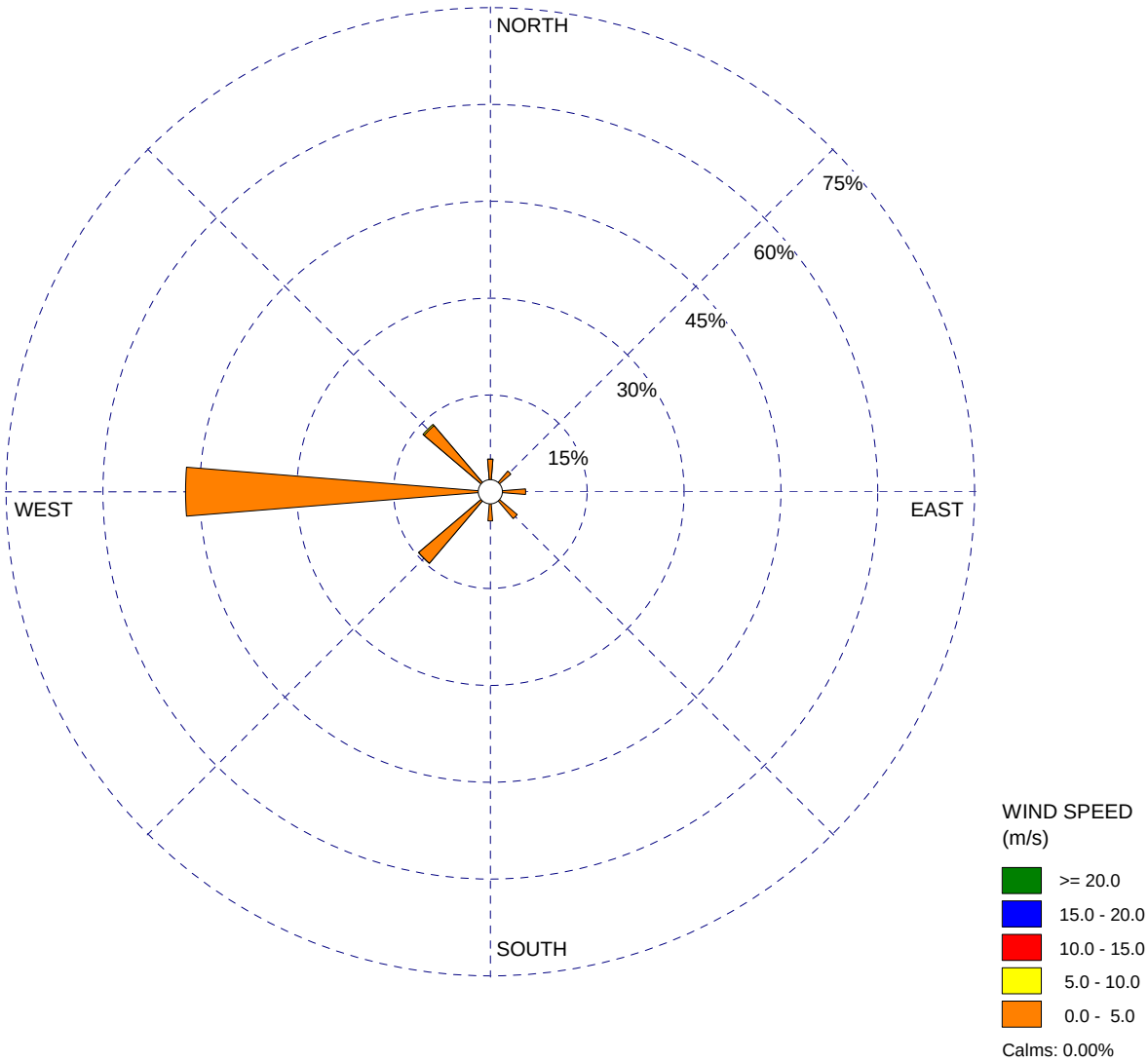
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Lodi, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 11 SEP 2000 - 31 DEC. 2005	COMPANY NAME:	
SPRING-SUMMER April 1 - September 30		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **22389 hrs.**	
		DATE: **12/13/2006**	PROJECT NO.: **1836.02**

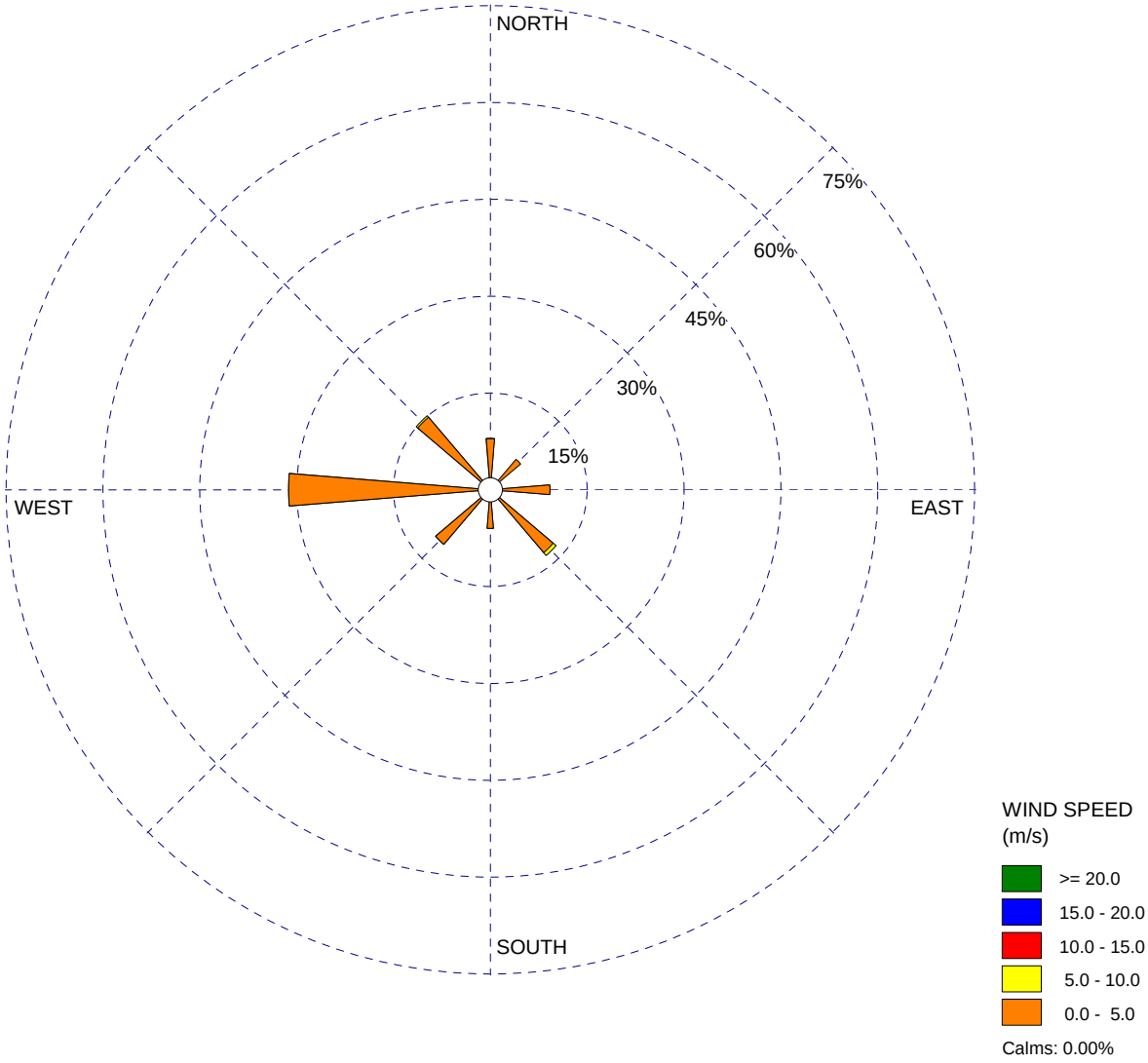
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Lodi, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 11 SEP 2000 - 31 DEC. 2005	COMPANY NAME:	
FULL YEAR January 1 - December 31		**PWA**	
		TOTAL COUNT: **45206 hrs.**	
		DATE: **12/13/2006**	PROJECT NO.: **1836.02**

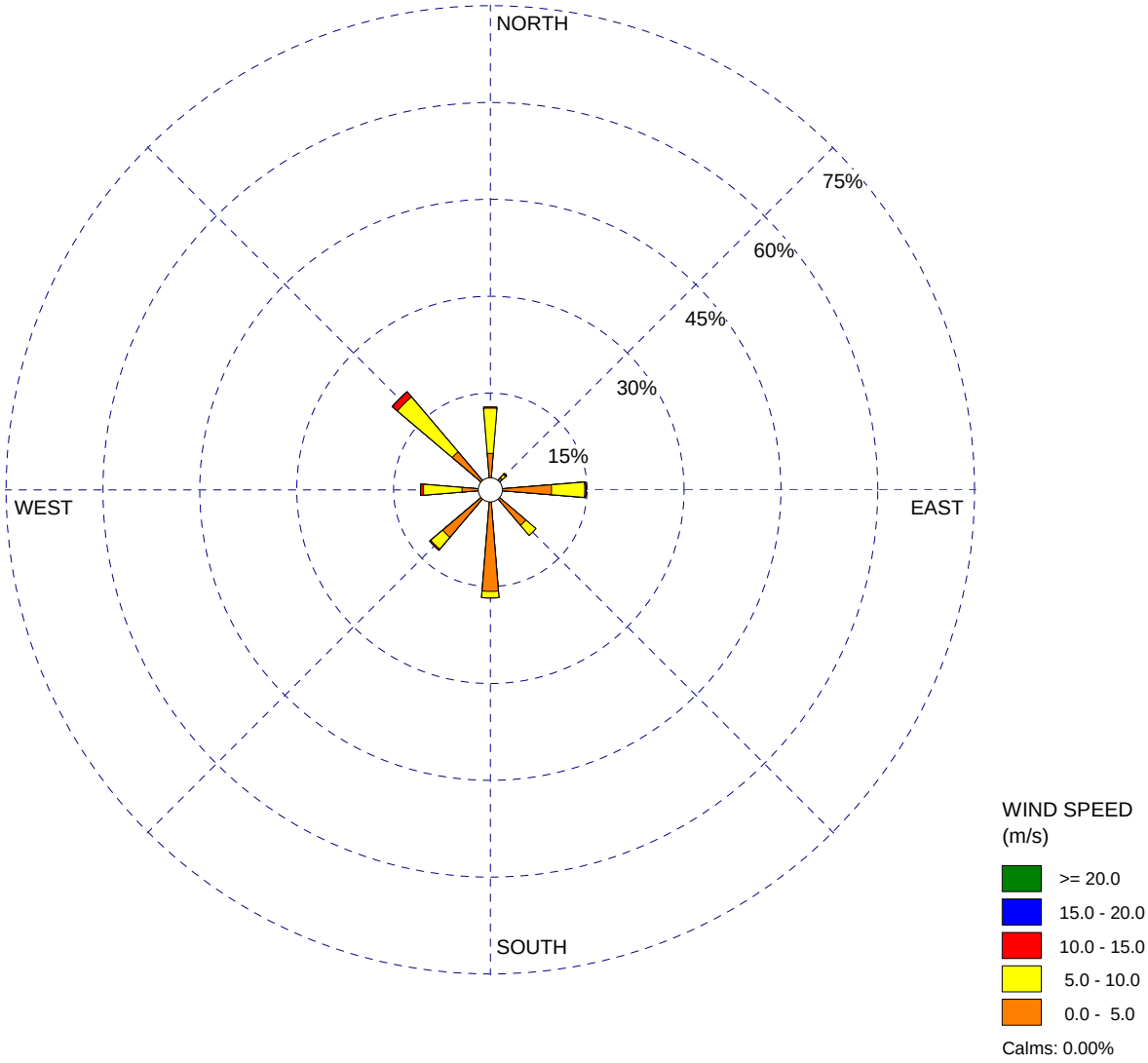
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Martinez, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:	
FALL-WINTER October 1 - March 31		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **37331 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

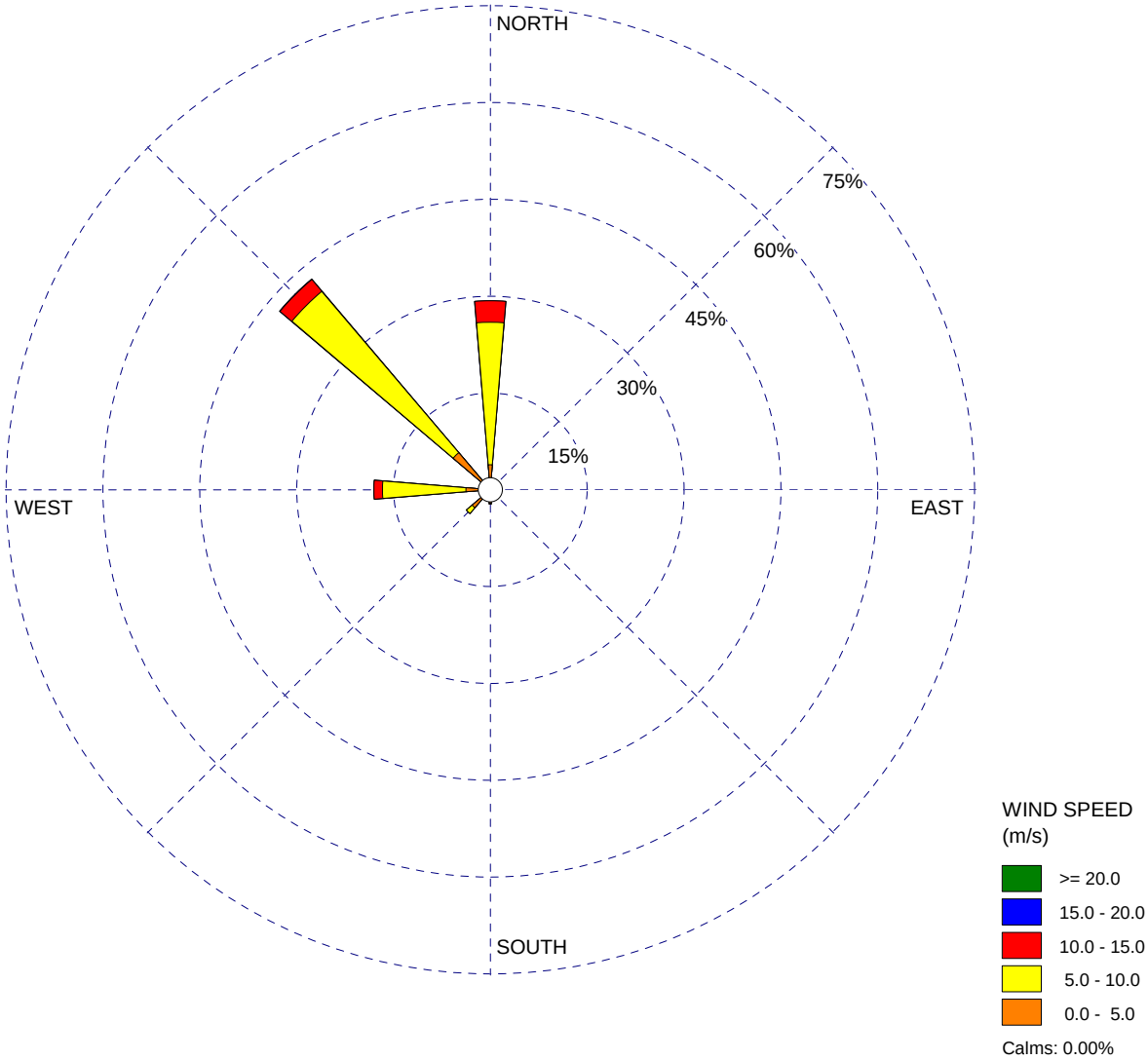
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Martinez, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:	
SPRING-SUMMER April 1 - September 30		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **37641 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

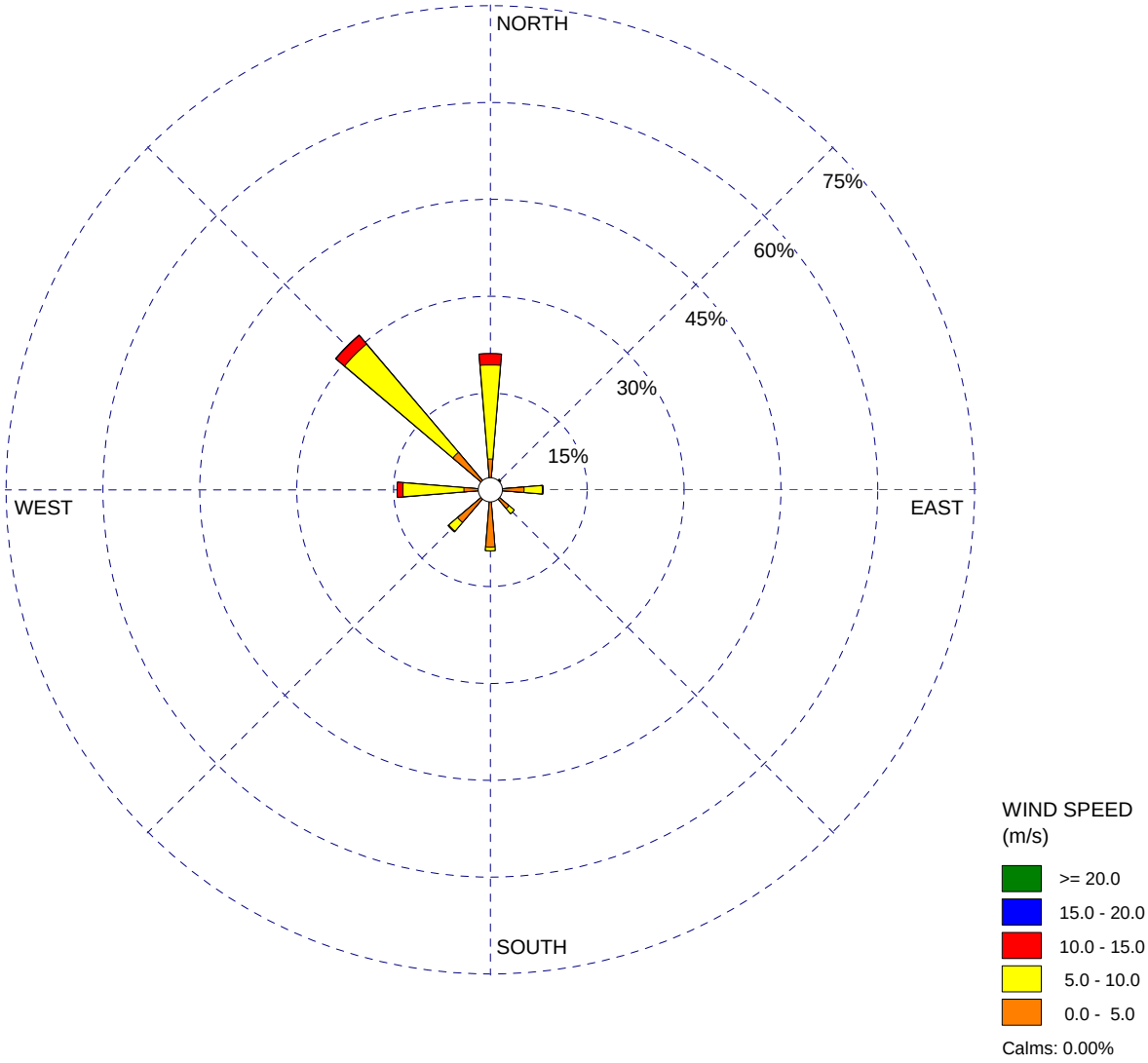
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Martinez, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:	
FULL YEAR January 1 - December 31		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **74972 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

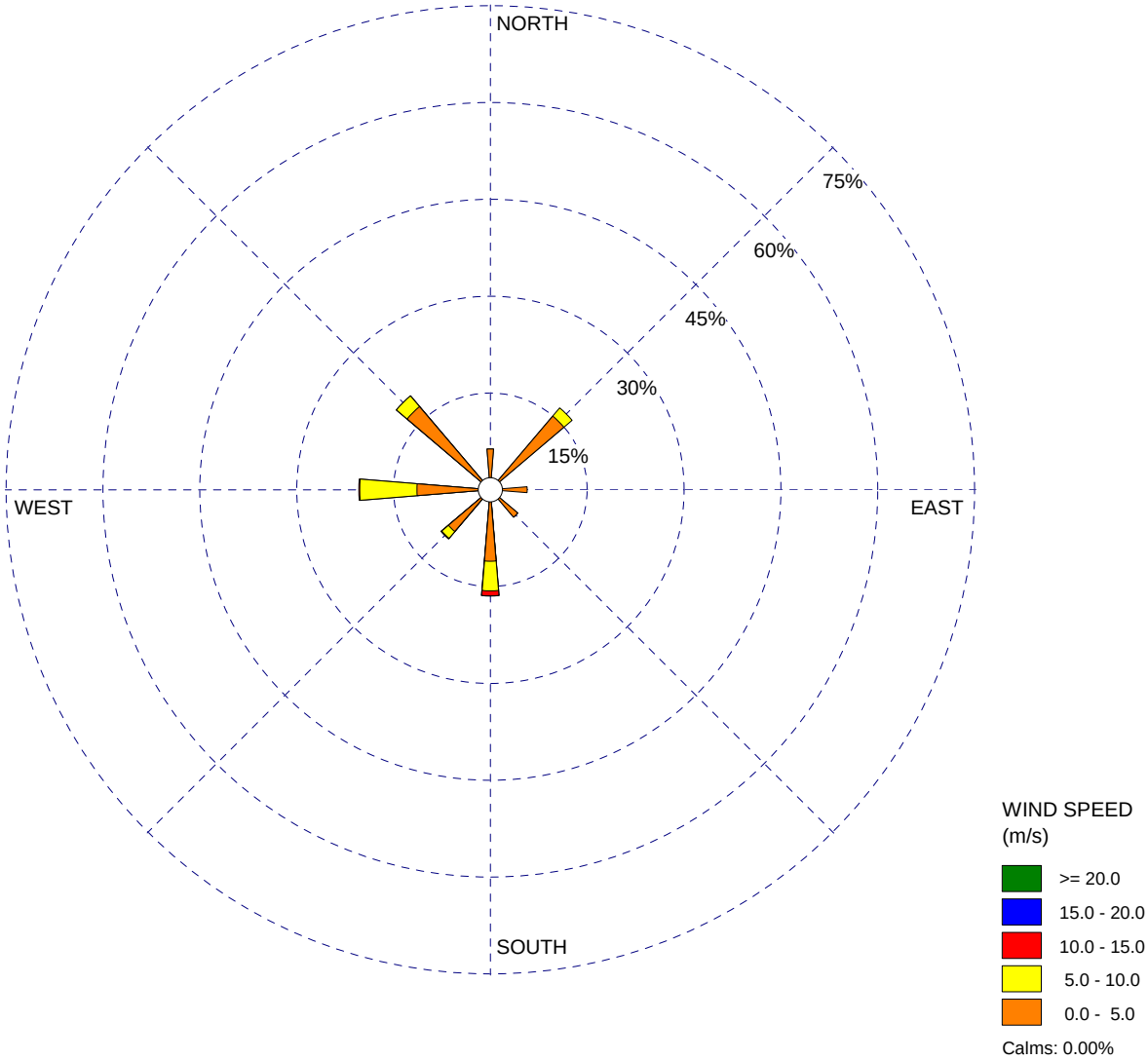
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Rio Vista, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:	
FALL-WINTER October 1 - March 31		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **37923 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

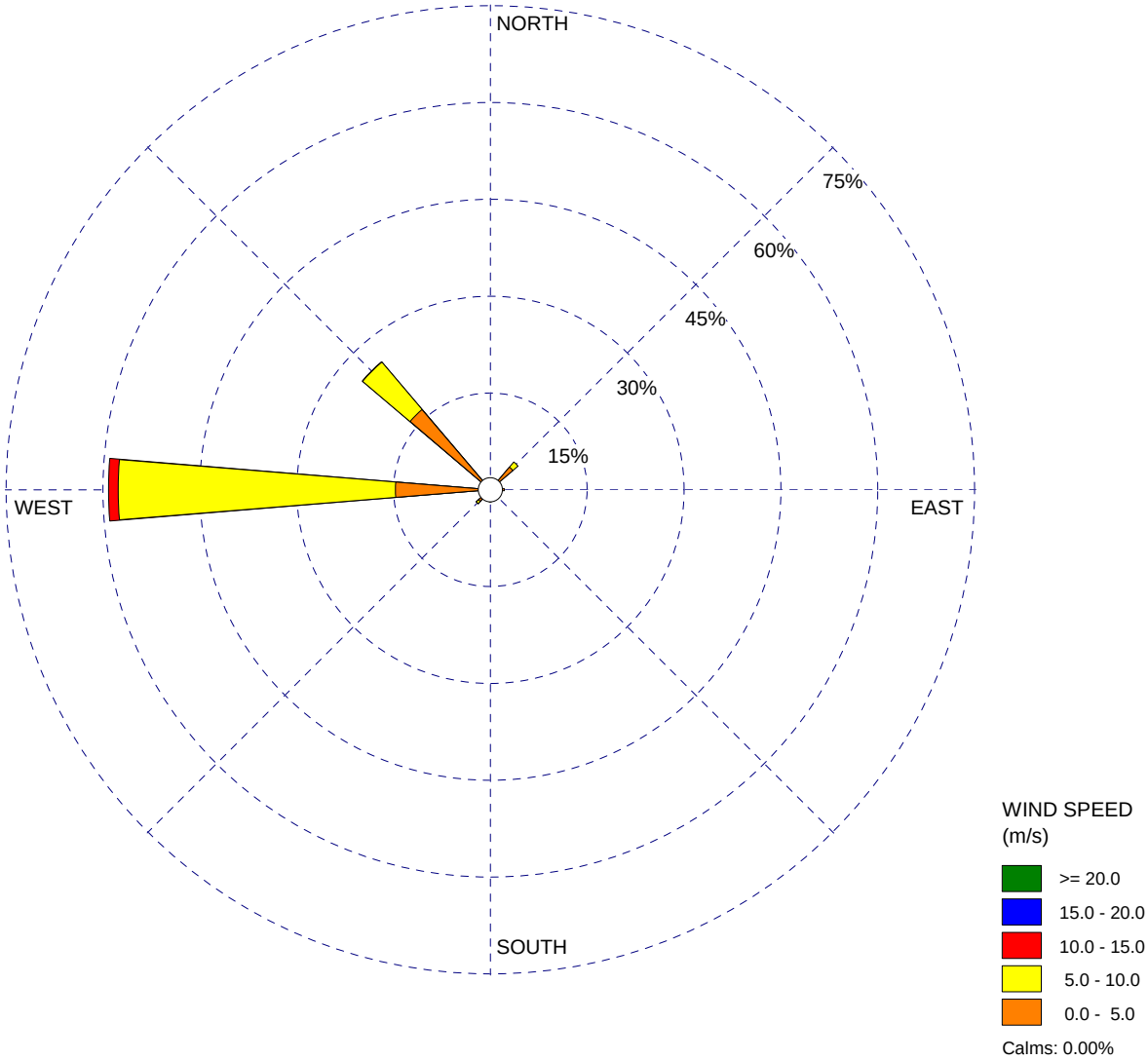
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Rio Vista, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:	
SPRING-SUMMER April 1 - September 30		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **37357 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

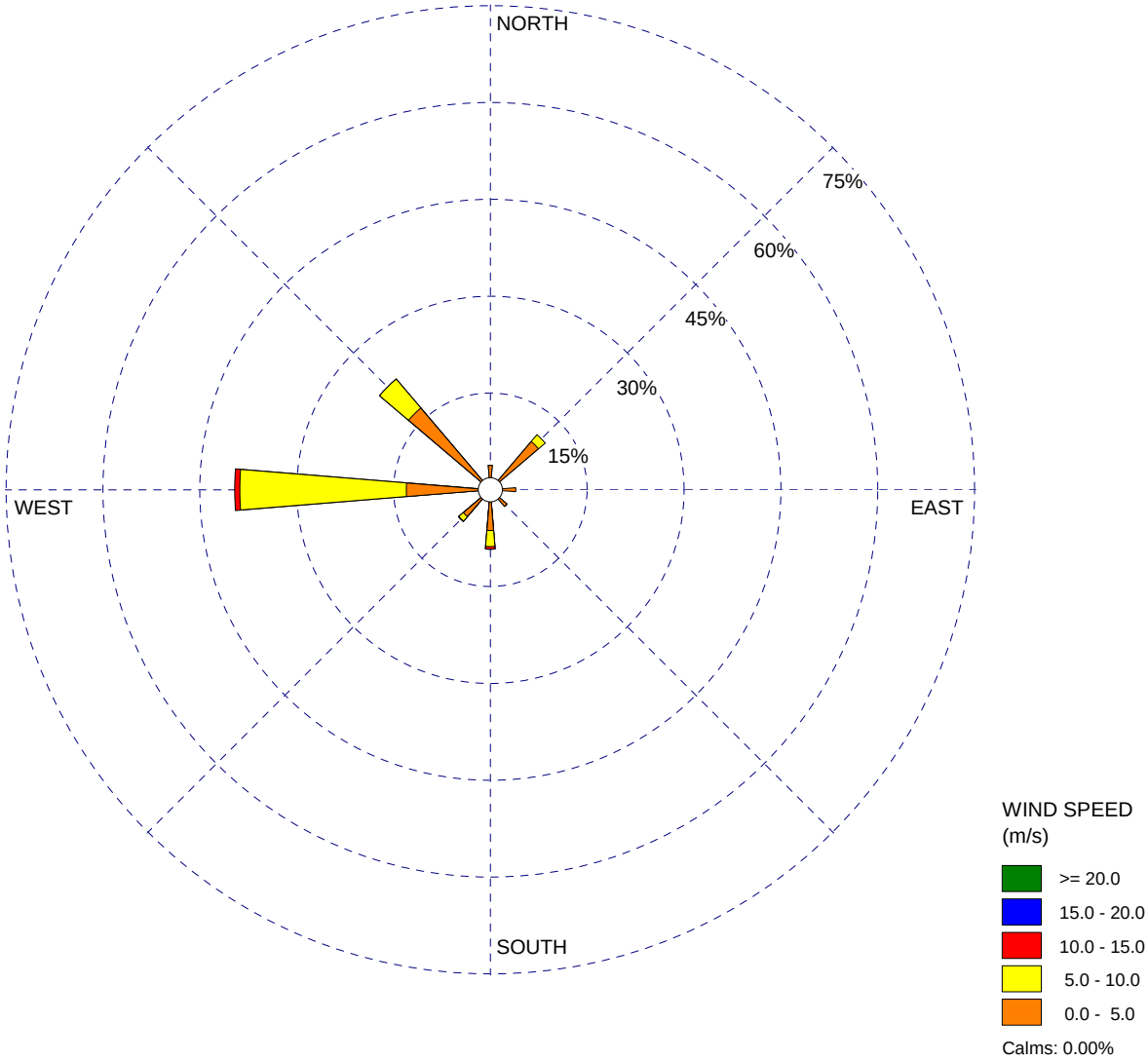
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Rio Vista, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 JAN. 1997 - 31 DEC. 2005	COMPANY NAME:	
FULL YEAR January 1 - December 31		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **75280 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

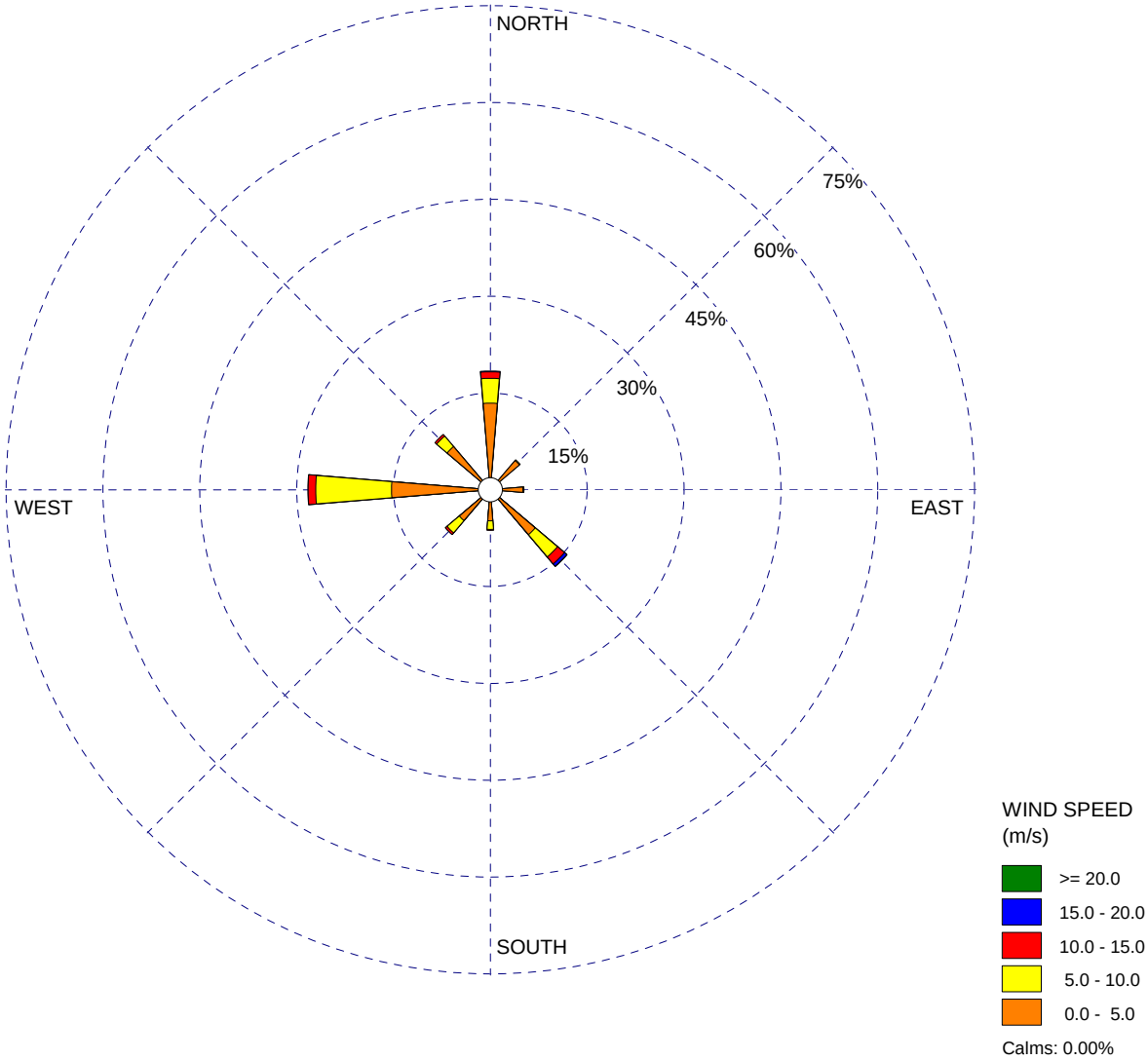
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Twitchell, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 NOV. 1997 - 24 DEC. 2005	COMPANY NAME:	
FALL-WINTER October 1 - March 31		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **35317 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

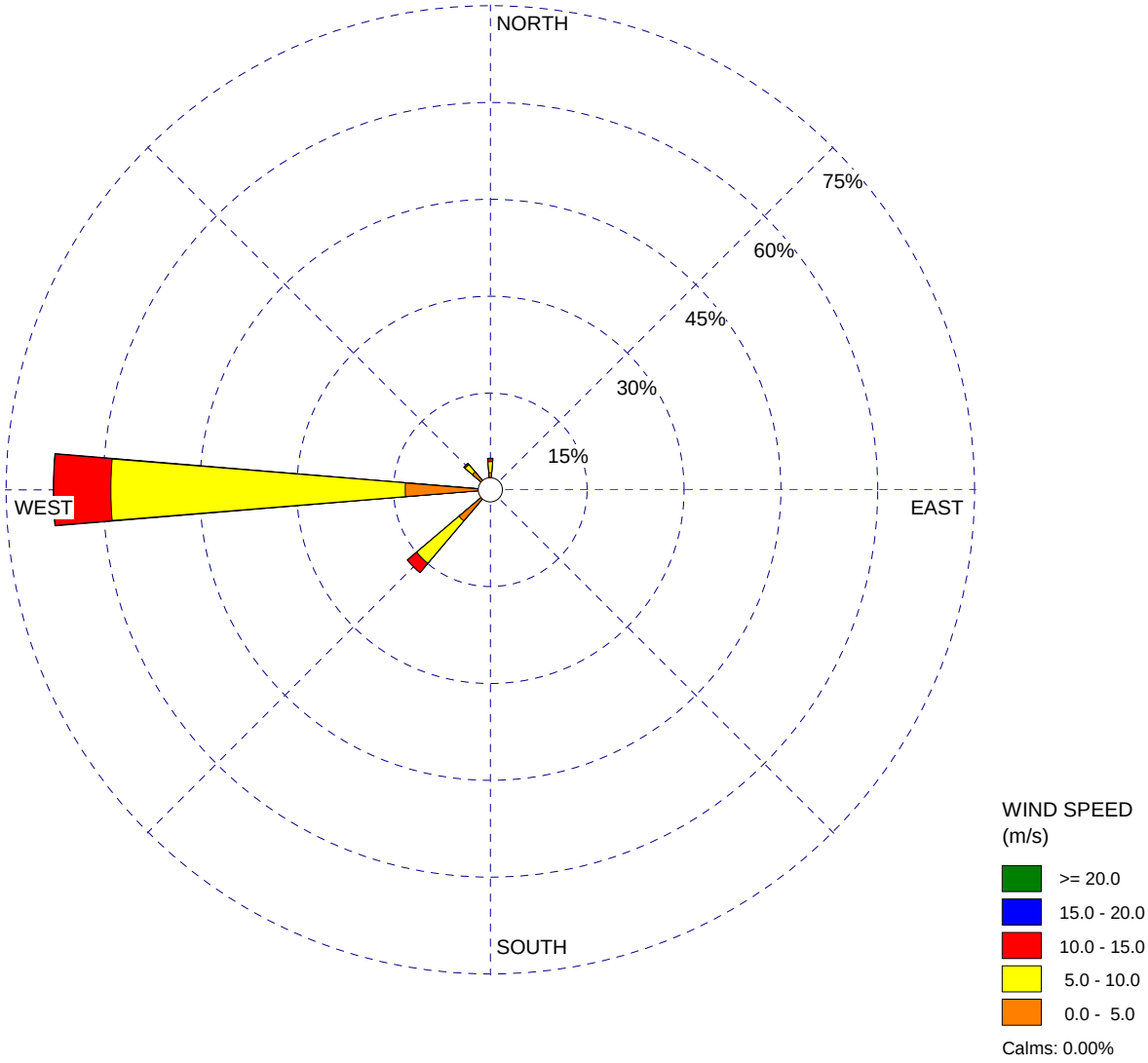
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Twitchell, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 NOV. 1997 - 24 DEC. 2005	COMPANY NAME:	
SPRING-SUMMER April 1 - September 30		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **35073 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

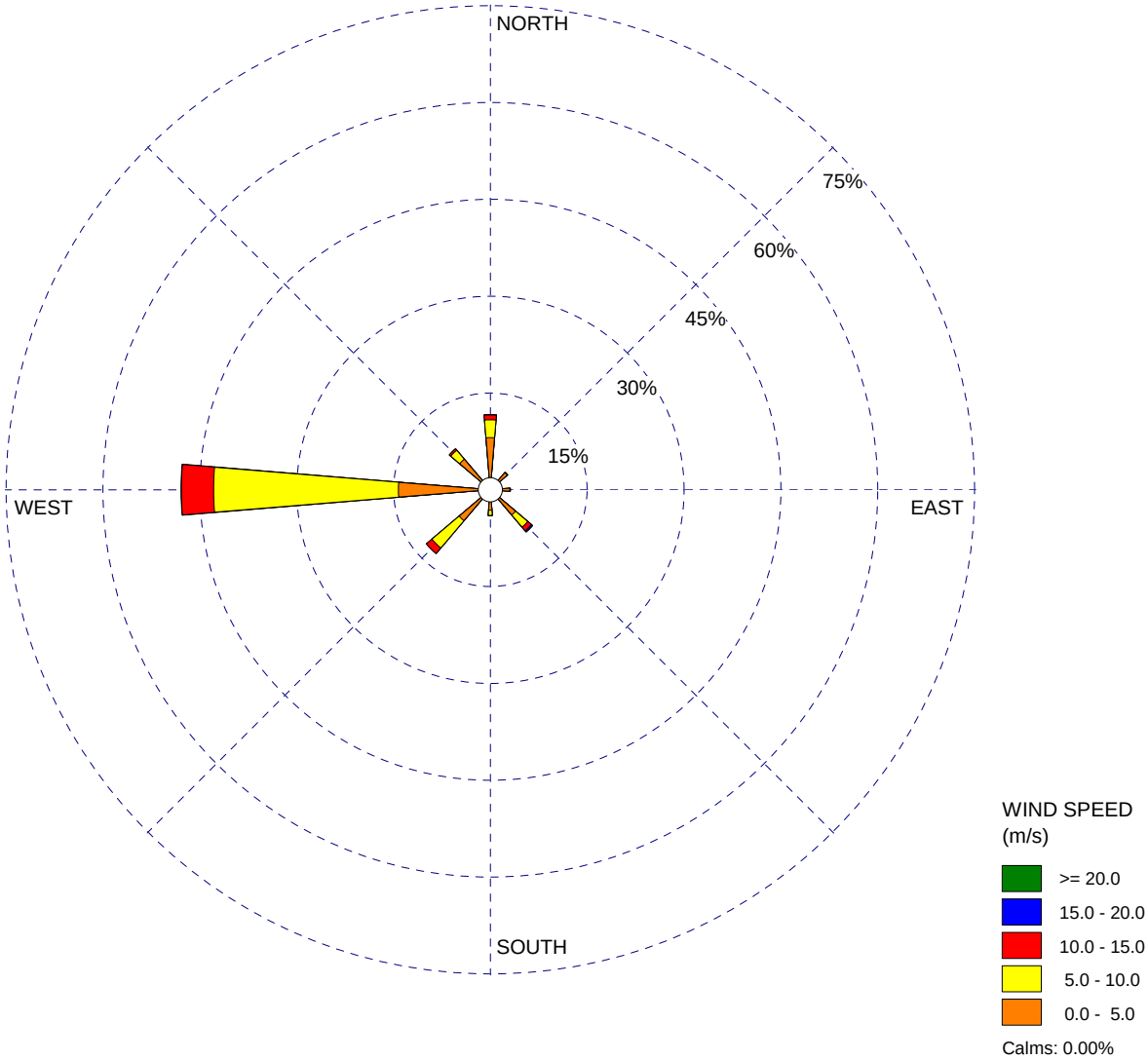
WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:

Twitchell, CA

DISPLAY:

Wind Speed
Direction (blowing from)



SEASON REPRESENTED:	PERIOD: 1 NOV. 1997 - 24 DEC. 2005	COMPANY NAME:	
FULL YEAR January 1 - December 31		**PWA**	PWA PHILIP WILLIAMS & ASSOCIATES, LTD ENVIRONMENTAL HYDROLOGY 720 California St., Suite 600 San Francisco, California 94108-2404 TEL 415.262.2300 FAX 415.262.2303 www.pwa-ltd.com
		TOTAL COUNT: **70390 hrs.**	
		DATE: **11/29/2006**	PROJECT NO.: **1836.02**

WRPLOT View - Lakes Environmental Software

Station ID: 23244 Run ID: Antioch
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	2767	1202	356	29	0	4354
22.50 - 67.50	1760	449	90	7	0	2306
67.50 - 112.50	4298	358	1	0	0	4657
112.50 - 157.50	4902	573	35	0	0	5510
157.50 - 202.50	3400	778	65	0	0	4243
202.50 - 247.50	1429	119	2	0	0	1550
247.50 - 292.50	2464	1595	68	0	0	4127
292.50 - 337.50	4517	5271	563	9	0	10360
Sub-Total:	25537	10345	1180	45	0	37107
Calms:						0
Missing/Incomplete:						0
Total:						37107

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.11 m/s

Station ID: 23244 Run ID: Antioch
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.074568	0.032393	0.009594	0.000782	0.000000	0.117336
22.50 - 67.50	0.047430	0.012100	0.002425	0.000189	0.000000	0.062145
67.50 - 112.50	0.115827	0.009648	0.000027	0.000000	0.000000	0.125502
112.50 - 157.50	0.132104	0.015442	0.000943	0.000000	0.000000	0.148490
157.50 - 202.50	0.091627	0.020966	0.001752	0.000000	0.000000	0.114345
202.50 - 247.50	0.038510	0.003207	0.000054	0.000000	0.000000	0.041771
247.50 - 292.50	0.066403	0.042984	0.001833	0.000000	0.000000	0.111219
292.50 - 337.50	0.121729	0.142049	0.015172	0.000243	0.000000	0.279193
Sub-Total:	0.688199	0.278788	0.031800	0.001213	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.11 m/s

Station ID: 23244 Run ID: Antioch
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	1544	1996	352	14	0	3906
22.50 - 67.50	456	151	34	2	0	643
67.50 - 112.50	727	80	0	0	0	807
112.50 - 157.50	602	57	2	0	0	661
157.50 - 202.50	643	57	1	0	0	701
202.50 - 247.50	323	68	0	0	0	391
247.50 - 292.50	885	2907	419	0	0	4211
292.50 - 337.50	3233	15816	5258	28	0	24335
Sub-Total:	8413	21132	6066	44	0	35655
Calms:						0
Missing/Incomplete:						0
Total:						35655

Frequency of Calm Winds: 0.00%
Average Wind Speed: 7.07 m/s

Station ID: 23244 Run ID: Antioch
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.043304	0.055981	0.009872	0.000393	0.000000	0.109550
22.50 - 67.50	0.012789	0.004235	0.000954	0.000056	0.000000	0.018034
67.50 - 112.50	0.020390	0.002244	0.000000	0.000000	0.000000	0.022634
112.50 - 157.50	0.016884	0.001599	0.000056	0.000000	0.000000	0.018539
157.50 - 202.50	0.018034	0.001599	0.000028	0.000000	0.000000	0.019661
202.50 - 247.50	0.009059	0.001907	0.000000	0.000000	0.000000	0.010966
247.50 - 292.50	0.024821	0.081531	0.011752	0.000000	0.000000	0.118104
292.50 - 337.50	0.090675	0.443584	0.147469	0.000785	0.000000	0.682513
Sub-Total:	0.235956	0.592680	0.170130	0.001234	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 7.07 m/s

Station ID: 23244 Run ID: Antioch
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	4311	3198	708	43	0	8260
22.50 - 67.50	2216	600	124	9	0	2949
67.50 - 112.50	5025	438	1	0	0	5464
112.50 - 157.50	5504	630	37	0	0	6171
157.50 - 202.50	4043	835	66	0	0	4944
202.50 - 247.50	1752	187	2	0	0	1941
247.50 - 292.50	3349	4502	487	0	0	8338
292.50 - 337.50	7750	21087	5821	37	0	34695
Sub-Total:	33950	31477	7246	89	0	72762
Calms:						0
Missing/Incomplete:						0
Total:						72762

Frequency of Calm Winds: 0.00%
Average Wind Speed: 5.56 m/s

Station ID: 23244 Run ID: Antioch
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.059248	0.043952	0.009730	0.000591	0.000000	0.113521
22.50 - 67.50	0.030455	0.008246	0.001704	0.000124	0.000000	0.040529
67.50 - 112.50	0.069061	0.006020	0.000014	0.000000	0.000000	0.075094
112.50 - 157.50	0.075644	0.008658	0.000509	0.000000	0.000000	0.084811
157.50 - 202.50	0.055565	0.011476	0.000907	0.000000	0.000000	0.067948
202.50 - 247.50	0.024079	0.002570	0.000027	0.000000	0.000000	0.026676
247.50 - 292.50	0.046027	0.061873	0.006693	0.000000	0.000000	0.114593
292.50 - 337.50	0.106512	0.289808	0.080001	0.000509	0.000000	0.476829
Sub-Total:	0.466590	0.432602	0.099585	0.001223	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 5.56 m/s

Station ID: 23240 Run ID: Hastings
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	4894	2106	724	224	11	7959
22.50 - 67.50	3349	188	7	0	0	3544
67.50 - 112.50	2287	107	1	0	0	2395
112.50 - 157.50	2946	1026	319	86	5	4382
157.50 - 202.50	2516	958	162	21	1	3658
202.50 - 247.50	4741	4247	730	33	0	9751
247.50 - 292.50	3063	822	147	7	0	4039
292.50 - 337.50	2676	583	293	73	5	3630
Sub-Total:	26472	10037	2383	444	22	39358
Calms:						0
Missing/Incomplete:						0
Total:						39358

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.42 m/s

Station ID: 23240 Run ID: Hastings
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.124346	0.053509	0.018395	0.005691	0.000279	0.202221
22.50 - 67.50	0.085091	0.004777	0.000178	0.000000	0.000000	0.090045
67.50 - 112.50	0.058108	0.002719	0.000025	0.000000	0.000000	0.060852
112.50 - 157.50	0.074851	0.026068	0.008105	0.002185	0.000127	0.111337
157.50 - 202.50	0.063926	0.024341	0.004116	0.000534	0.000025	0.092942
202.50 - 247.50	0.120458	0.107907	0.018548	0.000838	0.000000	0.247751
247.50 - 292.50	0.077824	0.020885	0.003735	0.000178	0.000000	0.102622
292.50 - 337.50	0.067991	0.014813	0.007444	0.001855	0.000127	0.092230
Sub-Total:	0.672595	0.255018	0.060547	0.011281	0.000559	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.42 m/s

Station ID: 23240 Run ID: Hastings
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	1231	1396	595	99	3	3324
22.50 - 67.50	486	20	3	4	0	513
67.50 - 112.50	383	26	0	0	0	409
112.50 - 157.50	374	101	13	0	0	488
157.50 - 202.50	490	164	5	0	0	659
202.50 - 247.50	4653	14848	8155	255	0	27911
247.50 - 292.50	2153	1907	610	18	0	4688
292.50 - 337.50	992	373	142	26	0	1533
Sub-Total:	10762	18835	9523	402	3	39525
Calms:						0
Missing/Incomplete:						0
Total:						39525

Frequency of Calm Winds: 0.00%
Average Wind Speed: 7.44 m/s

Station ID: 23240 Run ID: Hastings
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.031145	0.035319	0.015054	0.002505	0.000076	0.084099
22.50 - 67.50	0.012296	0.000506	0.000076	0.000101	0.000000	0.012979
67.50 - 112.50	0.009690	0.000658	0.000000	0.000000	0.000000	0.010348
112.50 - 157.50	0.009462	0.002555	0.000329	0.000000	0.000000	0.012347
157.50 - 202.50	0.012397	0.004149	0.000127	0.000000	0.000000	0.016673
202.50 - 247.50	0.117723	0.375661	0.206325	0.006452	0.000000	0.706161
247.50 - 292.50	0.054472	0.048248	0.015433	0.000455	0.000000	0.118608
292.50 - 337.50	0.025098	0.009437	0.003593	0.000658	0.000000	0.038786
Sub-Total:	0.272283	0.476534	0.240936	0.010171	0.000076	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 7.44 m/s

Station ID: 23240 Run ID: Hastings
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	6125	3502	1319	323	14	11283
22.50 - 67.50	3835	208	10	4	0	4057
67.50 - 112.50	2670	133	1	0	0	2804
112.50 - 157.50	3320	1127	332	86	5	4870
157.50 - 202.50	3006	1122	167	21	1	4317
202.50 - 247.50	9394	19095	8885	288	0	37662
247.50 - 292.50	5216	2729	757	25	0	8727
292.50 - 337.50	3668	956	435	99	5	5163
Sub-Total:	37234	28872	11906	846	25	78883
Calms:						0
Missing/Incomplete:						0
Total:						78883

Frequency of Calm Winds: 0.00%
Average Wind Speed: 5.93 m/s

Station ID: 23240 Run ID: Hastings
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.077647	0.044395	0.016721	0.004095	0.000177	0.143035
22.50 - 67.50	0.048616	0.002637	0.000127	0.000051	0.000000	0.051431
67.50 - 112.50	0.033848	0.001686	0.000013	0.000000	0.000000	0.035546
112.50 - 157.50	0.042088	0.014287	0.004209	0.001090	0.000063	0.061737
157.50 - 202.50	0.038107	0.014224	0.002117	0.000266	0.000013	0.054727
202.50 - 247.50	0.119088	0.242067	0.112635	0.003651	0.000000	0.477441
247.50 - 292.50	0.066123	0.034596	0.009596	0.000317	0.000000	0.110632
292.50 - 337.50	0.046499	0.012119	0.005514	0.001255	0.000063	0.065451
Sub-Total:	0.472016	0.366010	0.150932	0.010725	0.000317	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 5.93 m/s

Station ID: 23239 Run ID: Lodi
Year: 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	2452	12	0	0	0	2464
22.50 - 67.50	1852	0	0	0	0	1852
67.50 - 112.50	2949	3	0	0	0	2952
112.50 - 157.50	4555	247	0	0	0	4802
157.50 - 202.50	1694	5	0	0	0	1699
202.50 - 247.50	1751	10	0	0	0	1761
247.50 - 292.50	3546	2	0	0	0	3548
292.50 - 337.50	3660	79	0	0	0	3739
Sub-Total:	22459	358	0	0	0	22817
Calms:						0
Missing/Incomplete:						0
Total:						22817

Frequency of Calm Winds: 0.00%
Average Wind Speed: 1.59 m/s

Station ID: 23239 Run ID: Lodi
Year: 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.107464	0.000526	0.000000	0.000000	0.000000	0.107990
22.50 - 67.50	0.081168	0.000000	0.000000	0.000000	0.000000	0.081168
67.50 - 112.50	0.129246	0.000131	0.000000	0.000000	0.000000	0.129377
112.50 - 157.50	0.199632	0.010825	0.000000	0.000000	0.000000	0.210457
157.50 - 202.50	0.074243	0.000219	0.000000	0.000000	0.000000	0.074462
202.50 - 247.50	0.076741	0.000438	0.000000	0.000000	0.000000	0.077179
247.50 - 292.50	0.155410	0.000088	0.000000	0.000000	0.000000	0.155498
292.50 - 337.50	0.160407	0.003462	0.000000	0.000000	0.000000	0.163869
Sub-Total:	0.984310	0.015690	0.000000	0.000000	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 1.59 m/s

Station ID: 23239 Run ID: Lodi
Year: 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	1126	9	0	0	0	1135
22.50 - 67.50	940	0	0	0	0	940
67.50 - 112.50	1221	0	0	0	0	1221
112.50 - 157.50	1221	0	0	0	0	1221
157.50 - 202.50	1014	0	0	0	0	1014
202.50 - 247.50	3255	3	0	0	0	3258
247.50 - 292.50	10543	0	0	0	0	10543
292.50 - 337.50	3005	52	0	0	0	3057
Sub-Total:	22325	64	0	0	0	22389
Calms:						0
Missing/Incomplete:						0
Total:						22389

Frequency of Calm Winds: 0.00%
Average Wind Speed: 1.82 m/s

Station ID: 23239 Run ID: Lodi
Year: 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.050293	0.000402	0.000000	0.000000	0.000000	0.050695
22.50 - 67.50	0.041985	0.000000	0.000000	0.000000	0.000000	0.041985
67.50 - 112.50	0.054536	0.000000	0.000000	0.000000	0.000000	0.054536
112.50 - 157.50	0.054536	0.000000	0.000000	0.000000	0.000000	0.054536
157.50 - 202.50	0.045290	0.000000	0.000000	0.000000	0.000000	0.045290
202.50 - 247.50	0.145384	0.000134	0.000000	0.000000	0.000000	0.145518
247.50 - 292.50	0.470901	0.000000	0.000000	0.000000	0.000000	0.470901
292.50 - 337.50	0.134218	0.002323	0.000000	0.000000	0.000000	0.136540
Sub-Total:	0.997141	0.002859	0.000000	0.000000	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 1.82 m/s

Station ID: 23239 Run ID: Lodi
Year: 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed Knots

Wind Direction	0 - 9	10 - 19	19 - 29	29 - 38	>= 39	Total
348.75 - 11.25	1914	5	0	0	0	1919
11.25 - 33.75	1500	0	0	0	0	1500
33.75 - 56.25	1390	0	0	0	0	1390
56.25 - 78.75	1518	0	0	0	0	1518
78.75 - 101.25	2055	0	0	0	0	2055
101.25 - 123.75	3011	38	0	0	0	3049
123.75 - 146.25	3162	196	0	0	0	3358
146.25 - 168.75	1673	20	0	0	0	1693
168.75 - 191.25	1295	0	0	0	0	1295
191.25 - 213.75	1275	3	0	0	0	1278
213.75 - 236.25	2095	8	0	0	0	2103
236.25 - 258.75	6569	3	0	0	0	6572
258.75 - 281.25	7234	1	0	0	0	7235
281.25 - 303.75	4406	1	0	0	0	4407
303.75 - 326.25	3581	87	0	0	0	3668
326.25 - 348.75	2106	60	0	0	0	2166
Sub-Total:	44784	422	0	0	0	45206
Calms:						0
Missing/Incomplete:						0
Total:						45206

Frequency of Calm Winds: 0.00%
Average Wind Speed: 3.31 Knots

Station ID: 23239 Run ID: Lodi
Year: 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed Knots

Wind Direction	0 - 9	10 - 19	19 - 29	29 - 38	>= 39	Total
348.75 - 11.25	0.042340	0.000111	0.000000	0.000000	0.000000	0.042450
11.25 - 33.75	0.033181	0.000000	0.000000	0.000000	0.000000	0.033181
33.75 - 56.25	0.030748	0.000000	0.000000	0.000000	0.000000	0.030748
56.25 - 78.75	0.033580	0.000000	0.000000	0.000000	0.000000	0.033580
78.75 - 101.25	0.045459	0.000000	0.000000	0.000000	0.000000	0.045459
101.25 - 123.75	0.066606	0.000841	0.000000	0.000000	0.000000	0.067447
123.75 - 146.25	0.069946	0.004336	0.000000	0.000000	0.000000	0.074282
146.25 - 168.75	0.037008	0.000442	0.000000	0.000000	0.000000	0.037451
168.75 - 191.25	0.028647	0.000000	0.000000	0.000000	0.000000	0.028647
191.25 - 213.75	0.028204	0.000066	0.000000	0.000000	0.000000	0.028271

213.75 - 236.25	0.046343	0.000177	0.000000	0.000000	0.000000	0.046520
236.25 - 258.75	0.145313	0.000066	0.000000	0.000000	0.000000	0.145379
258.75 - 281.25	0.160023	0.000022	0.000000	0.000000	0.000000	0.160045
281.25 - 303.75	0.097465	0.000022	0.000000	0.000000	0.000000	0.097487
303.75 - 326.25	0.079215	0.001925	0.000000	0.000000	0.000000	0.081140
326.25 - 348.75	0.046587	0.001327	0.000000	0.000000	0.000000	0.047914
Sub-Total:	0.990665	0.009335	0.000000	0.000000	0.000000	1.000000
Calms:					0.000000	
Missing/Incomplete:					0.000000	
Total:					1.000000	

Frequency of Calm Winds: 0.00%
Average Wind Speed: 3.31 Knots

Station ID: 23243 Run ID: Martinez
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	2102	2608	83	0	0	4793
22.50 - 67.50	899	265	78	7	0	1249
67.50 - 112.50	3533	1916	75	2	0	5526
112.50 - 157.50	2695	770	1	0	0	3466
157.50 - 202.50	5863	376	11	0	0	6250
202.50 - 247.50	3608	900	76	4	0	4588
247.50 - 292.50	1640	2217	172	3	0	4032
292.50 - 337.50	2875	4146	394	12	0	7427
Sub-Total:	23215	13198	890	28	0	37331
Calms:						0
Missing/Incomplete:						0
Total:						37331

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.45 m/s

Station ID: 23243 Run ID: Martinez
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.056307	0.069862	0.002223	0.000000	0.000000	0.128392
22.50 - 67.50	0.024082	0.007099	0.002089	0.000188	0.000000	0.033457
67.50 - 112.50	0.094640	0.051325	0.002009	0.000054	0.000000	0.148027
112.50 - 157.50	0.072192	0.020626	0.000027	0.000000	0.000000	0.092845
157.50 - 202.50	0.157054	0.010072	0.000295	0.000000	0.000000	0.167421
202.50 - 247.50	0.096649	0.024109	0.002036	0.000107	0.000000	0.122901
247.50 - 292.50	0.043931	0.059388	0.004607	0.000080	0.000000	0.108007
292.50 - 337.50	0.077014	0.111061	0.010554	0.000321	0.000000	0.198950
Sub-Total:	0.621869	0.353540	0.023841	0.000750	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.45 m/s

Station ID: 23243 Run ID: Martinez
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	1462	8286	1248	1	0	10997
22.50 - 67.50	203	93	57	2	0	355
67.50 - 112.50	391	190	18	0	0	599
112.50 - 157.50	162	18	1	0	0	181
157.50 - 202.50	787	47	6	0	0	840
202.50 - 247.50	1389	430	14	0	0	1833
247.50 - 292.50	1424	4851	490	1	0	6766
292.50 - 337.50	2834	12302	912	22	0	16070
Sub-Total:	8652	26217	2746	26	0	37641
Calms:						0
Missing/Incomplete:						0
Total:						37641

Frequency of Calm Winds: 0.00%
Average Wind Speed: 6.52 m/s

Station ID: 23243 Run ID: Martinez
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.038841	0.220132	0.033155	0.000027	0.000000	0.292155
22.50 - 67.50	0.005393	0.002471	0.001514	0.000053	0.000000	0.009431
67.50 - 112.50	0.010388	0.005048	0.000478	0.000000	0.000000	0.015913
112.50 - 157.50	0.004304	0.000478	0.000027	0.000000	0.000000	0.004809
157.50 - 202.50	0.020908	0.001249	0.000159	0.000000	0.000000	0.022316
202.50 - 247.50	0.036901	0.011424	0.000372	0.000000	0.000000	0.048697
247.50 - 292.50	0.037831	0.128875	0.013018	0.000027	0.000000	0.179751
292.50 - 337.50	0.075290	0.326824	0.024229	0.000584	0.000000	0.426928
Sub-Total:	0.229856	0.696501	0.072952	0.000691	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 6.52 m/s

Station ID: 23243 Run ID: Martinez
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	3564	10894	1331	1	0	15790
22.50 - 67.50	1102	358	135	9	0	1604
67.50 - 112.50	3924	2106	93	2	0	6125
112.50 - 157.50	2857	788	2	0	0	3647
157.50 - 202.50	6650	423	17	0	0	7090
202.50 - 247.50	4997	1330	90	4	0	6421
247.50 - 292.50	3064	7068	662	4	0	10798
292.50 - 337.50	5709	16448	1306	34	0	23497
Sub-Total:	31867	39415	3636	54	0	74972
Calms:						0
Missing/Incomplete:						0
Total:						74972

Frequency of Calm Winds: 0.00%
Average Wind Speed: 5.49 m/s

Station ID: 23243 Run ID: Martinez
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.047538	0.145308	0.017753	0.000013	0.000000	0.210612
22.50 - 67.50	0.014699	0.004775	0.001801	0.000120	0.000000	0.021395
67.50 - 112.50	0.052340	0.028090	0.001240	0.000027	0.000000	0.081697
112.50 - 157.50	0.038108	0.010511	0.000027	0.000000	0.000000	0.048645
157.50 - 202.50	0.088700	0.005642	0.000227	0.000000	0.000000	0.094569
202.50 - 247.50	0.066652	0.017740	0.001200	0.000053	0.000000	0.085645
247.50 - 292.50	0.040869	0.094275	0.008830	0.000053	0.000000	0.144027
292.50 - 337.50	0.076148	0.219389	0.017420	0.000454	0.000000	0.313410
Sub-Total:	0.425052	0.525730	0.048498	0.000720	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 5.49 m/s

Station ID: 23245 Run ID: RioVista
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	2395	4	0	0	0	2399
22.50 - 67.50	5658	637	0	0	0	6295
67.50 - 112.50	2164	0	0	0	0	2164
112.50 - 157.50	2111	16	0	0	0	2127
157.50 - 202.50	4192	1730	298	6	0	6226
202.50 - 247.50	3223	516	39	3	0	3781
247.50 - 292.50	4305	3353	49	0	0	7707
292.50 - 337.50	6398	823	3	0	0	7224
Sub-Total:	30446	7079	389	9	0	37923
Calms:						0
Missing/Incomplete:						0
Total:						37923

Frequency of Calm Winds: 0.00%
Average Wind Speed: 3.19 m/s

Station ID: 23245 Run ID: RioVista
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.063154	0.000105	0.000000	0.000000	0.000000	0.063260
22.50 - 67.50	0.149197	0.016797	0.000000	0.000000	0.000000	0.165994
67.50 - 112.50	0.057063	0.000000	0.000000	0.000000	0.000000	0.057063
112.50 - 157.50	0.055665	0.000422	0.000000	0.000000	0.000000	0.056087
157.50 - 202.50	0.110540	0.045619	0.007858	0.000158	0.000000	0.164175
202.50 - 247.50	0.084988	0.013607	0.001028	0.000079	0.000000	0.099702
247.50 - 292.50	0.113520	0.088416	0.001292	0.000000	0.000000	0.203228
292.50 - 337.50	0.168710	0.021702	0.000079	0.000000	0.000000	0.190491
Sub-Total:	0.802837	0.186668	0.010258	0.000237	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 3.19 m/s

Station ID: 23245 Run ID: RioVista
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	455	10	0	0	0	465
22.50 - 67.50	1713	391	0	0	0	2104
67.50 - 112.50	820	0	0	0	0	820
112.50 - 157.50	437	2	0	0	0	439
157.50 - 202.50	556	148	5	0	0	709
202.50 - 247.50	892	182	7	0	0	1081
247.50 - 292.50	5476	16003	560	0	0	22039
292.50 - 337.50	6087	3587	26	0	0	9700
Sub-Total:	16436	20323	598	0	0	37357
Calms:						0
Missing/Incomplete:						0
Total:						37357

Frequency of Calm Winds: 0.00%
Average Wind Speed: 5.21 m/s

Station ID: 23245 Run ID: RioVista
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.012180	0.000268	0.000000	0.000000	0.000000	0.012447
22.50 - 67.50	0.045855	0.010467	0.000000	0.000000	0.000000	0.056321
67.50 - 112.50	0.021950	0.000000	0.000000	0.000000	0.000000	0.021950
112.50 - 157.50	0.011698	0.000054	0.000000	0.000000	0.000000	0.011751
157.50 - 202.50	0.014883	0.003962	0.000134	0.000000	0.000000	0.018979
202.50 - 247.50	0.023878	0.004872	0.000187	0.000000	0.000000	0.028937
247.50 - 292.50	0.146586	0.428380	0.014990	0.000000	0.000000	0.589956
292.50 - 337.50	0.162941	0.096019	0.000696	0.000000	0.000000	0.259657
Sub-Total:	0.439971	0.544021	0.016008	0.000000	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 5.21 m/s

Station ID: 23245 Run ID: RioVista
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	2850	14	0	0	0	2864
22.50 - 67.50	7371	1028	0	0	0	8399
67.50 - 112.50	2984	0	0	0	0	2984
112.50 - 157.50	2548	18	0	0	0	2566
157.50 - 202.50	4748	1878	303	6	0	6935
202.50 - 247.50	4115	698	46	3	0	4862
247.50 - 292.50	9781	19356	609	0	0	29746
292.50 - 337.50	12485	4410	29	0	0	16924
Sub-Total:	46882	27402	987	9	0	75280
Calms:						0
Missing/Incomplete:						0
Total:						75280

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.19 m/s

Station ID: 23245 Run ID: RioVista
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.037859	0.000186	0.000000	0.000000	0.000000	0.038045
22.50 - 67.50	0.097914	0.013656	0.000000	0.000000	0.000000	0.111570
67.50 - 112.50	0.039639	0.000000	0.000000	0.000000	0.000000	0.039639
112.50 - 157.50	0.033847	0.000239	0.000000	0.000000	0.000000	0.034086
157.50 - 202.50	0.063071	0.024947	0.004025	0.000080	0.000000	0.092123
202.50 - 247.50	0.054663	0.009272	0.000611	0.000040	0.000000	0.064586
247.50 - 292.50	0.129928	0.257120	0.008090	0.000000	0.000000	0.395138
292.50 - 337.50	0.165848	0.058581	0.000385	0.000000	0.000000	0.224814
Sub-Total:	0.622768	0.364001	0.013111	0.000120	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.19 m/s

Station ID: 23238 Run ID: Twitchell
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	4730	1356	360	38	0	6484
22.50 - 67.50	2094	53	0	0	0	2147
67.50 - 112.50	1780	57	1	0	0	1838
112.50 - 157.50	3226	1589	495	168	15	5493
157.50 - 202.50	1701	474	37	1	0	2213
202.50 - 247.50	2216	874	127	2	0	3219
247.50 - 292.50	5387	4142	414	13	0	9956
292.50 - 337.50	3092	753	122	0	0	3967
Sub-Total:	24226	9298	1556	222	15	35317
Calms:						0
Missing/Incomplete:						0
Total:						35317

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.23 m/s

Station ID: 23238 Run ID: Twitchell
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Check Date Range Report
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.133930	0.038395	0.010193	0.001076	0.000000	0.183594
22.50 - 67.50	0.059292	0.001501	0.000000	0.000000	0.000000	0.060792
67.50 - 112.50	0.050401	0.001614	0.000028	0.000000	0.000000	0.052043
112.50 - 157.50	0.091344	0.044992	0.014016	0.004757	0.000425	0.155534
157.50 - 202.50	0.048164	0.013421	0.001048	0.000028	0.000000	0.062661
202.50 - 247.50	0.062746	0.024747	0.003596	0.000057	0.000000	0.091146
247.50 - 292.50	0.152533	0.117281	0.011722	0.000368	0.000000	0.281904
292.50 - 337.50	0.087550	0.021321	0.003454	0.000000	0.000000	0.112326
Sub-Total:	0.685959	0.263273	0.044058	0.006286	0.000425	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 4.23 m/s

Station ID: 23238 Run ID: Twitchell
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	942	587	167	20	0	1716
22.50 - 67.50	350	12	1	0	0	363
67.50 - 112.50	337	21	4	0	0	362
112.50 - 157.50	394	124	29	0	0	547
157.50 - 202.50	524	97	2	0	0	623
202.50 - 247.50	2223	3018	657	1	0	5899
247.50 - 292.50	4617	15940	3105	19	0	23681
292.50 - 337.50	1275	530	71	6	0	1882
Sub-Total:	10662	20329	4036	46	0	35073
Calms:						0
Missing/Incomplete:						0
Total:						35073

Frequency of Calm Winds: 0.00%
Average Wind Speed: 6.58 m/s

Station ID: 23238 Run ID: Twitchell
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Apr 1 - Sep 30
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.026858	0.016737	0.004761	0.000570	0.000000	0.048927
22.50 - 67.50	0.009979	0.000342	0.000029	0.000000	0.000000	0.010350
67.50 - 112.50	0.009609	0.000599	0.000114	0.000000	0.000000	0.010321
112.50 - 157.50	0.011234	0.003535	0.000827	0.000000	0.000000	0.015596
157.50 - 202.50	0.014940	0.002766	0.000057	0.000000	0.000000	0.017763
202.50 - 247.50	0.063382	0.086049	0.018732	0.000029	0.000000	0.168192
247.50 - 292.50	0.131640	0.454481	0.088530	0.000542	0.000000	0.675192
292.50 - 337.50	0.036353	0.015111	0.002024	0.000171	0.000000	0.053660
Sub-Total:	0.303995	0.579620	0.115074	0.001312	0.000000	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 6.58 m/s

Station ID: 23238 Run ID: Twitchell
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	5672	1943	527	58	0	8200
22.50 - 67.50	2444	65	1	0	0	2510
67.50 - 112.50	2117	78	5	0	0	2200
112.50 - 157.50	3620	1713	524	168	15	6040
157.50 - 202.50	2225	571	39	1	0	2836
202.50 - 247.50	4439	3892	784	3	0	9118
247.50 - 292.50	10004	20082	3519	32	0	33637
292.50 - 337.50	4367	1283	193	6	0	5849
Sub-Total:	34888	29627	5592	268	15	70390
Calms:						0
Missing/Incomplete:						0
Total:						70390

Frequency of Calm Winds: 0.00%
Average Wind Speed: 5.40 m/s

Station ID: 23238 Run ID: Twitchell
Year: 1957 1958 1959 1960 1961 1962 1963 1964 1965
Date Range: Jan 1 - Dec 31
Time Range: 00:00 - 23:00

Frequency Distribution
(Normalized)

Speed m/s

Wind Direction	0.0 - 5.0	5.0 - 10.0	10.0 - 15.0	15.0 - 20.0	>= 20.0	Total
337.50 - 22.50	0.080580	0.027603	0.007487	0.000824	0.000000	0.116494
22.50 - 67.50	0.034721	0.000923	0.000014	0.000000	0.000000	0.035658
67.50 - 112.50	0.030075	0.001108	0.000071	0.000000	0.000000	0.031254
112.50 - 157.50	0.051428	0.024336	0.007444	0.002387	0.000213	0.085808
157.50 - 202.50	0.031610	0.008112	0.000554	0.000014	0.000000	0.040290
202.50 - 247.50	0.063063	0.055292	0.011138	0.000043	0.000000	0.129535
247.50 - 292.50	0.142122	0.285296	0.049993	0.000455	0.000000	0.477866
292.50 - 337.50	0.062040	0.018227	0.002742	0.000085	0.000000	0.083094
Sub-Total:	0.495639	0.420898	0.079443	0.003807	0.000213	1.000000
Calms:						0.000000
Missing/Incomplete:						0.000000
Total:						1.000000

Frequency of Calm Winds: 0.00%
Average Wind Speed: 5.40 m/s