NUREG/CR-2754
PNL-4292

Critical Review of Studies on Atmospheric Dispersion in Coastal Regions

Prepared by D. L. Shearer, R. J. Kaleel/TRC

TRC Environmental Consultants, Inc.

Pacific Northwest Laboratory
Operated by
Battelle Memorial Institute

Prepared for
U.S. Nuclear Regulatory Commission

NOTICE

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 1717 H Street, N.W.
   Washington, DC 20555

2. The NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission,
   Washington, DC 20555

3. The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC Office of Inspection and Enforcement bulletins, circulars, information notices, inspection and investigation notices; Licensee Event Reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the NRC/GPO Sales Program: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, and NRC booklets and brochures. Also available are Regulatory Guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances*.

Documents available from the National Technical Information Service include NUREG series reports and technical reports prepared by other federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal and periodical articles, and transactions. *Federal Register* notices, federal and state legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, 7920 Norfolk Avenue, Bethesda, Maryland, and are available there for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

GPO Printed copy price: $4.75

NUREG/CR-2754
PNL-4292
RB

Critical Review of Studies on Atmospheric Dispersion in Coastal Regions

Manuscript Completed: June 1982
Date Published: September 1982

Prepared by
D. L. Shearer, R. J. Kaleel, TRC

TRC Environmental Consultants, Ir.c.
Englewood, CO 80111

Under Subcontract to
Pacific Northwest Laboratory
Richland, WA 99352

Prepared for
Division of Health, Siting and Waste Management
Office of Nuclear Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN B2384

EXECUTIVE SUMMARY

This study effort was required as a preliminary step prior to initiation of field measurements of atmospheric dispersion in coastal regions.

NRC is in the process of planning an extensive field measurement program to generate data which will serve as improved data bases for licensing decisions, confirmation of regulations, standards, and guides, and for site characterizations. The study being reported here is an effort directed to obtaining as much information as is possible from existing studies that is relevant toward NRC's objectives. This is being done in an attempt to minimize the need for new data, as well as to improve the measurement programs that may still be needed.

For this present study, reports covering research and meteorological measurements conducted for industrial purposes, utility needs, military objectives, and academic studies have been obtained and critically reviewed in light of NRC's current data needs. This present report provides an interpretation of the extent of existing usable information, an indication of the potential for tailoring existing research toward current NRC information needs, and recommendations for several follow-on studies which could provide valuable additional information through reanalysis of the data. Recommendations are also offered regarding new measurement programs.

Emphasis has been placed on the identification and acquisition of data from atmospheric tracer studies conducted in coastal regions. A total of 225 references were identified which deal with the coastal atmosphere, including meteorological and tracer measurement programs, theoretical descriptions of the relevant processes, and dispersion models. Most of the identified references have been obtained and are represented in this critical review.

CONTENTS

ACKNOWLEDGMENTS

The work reported herein was supported by Pacific Northwest Laboratory, operated by Battelle Memorial Institute, under subcontract B-C3061-A-N. The programmatic direction and technical guidance of Dr. Ronald K. Hadlock, Manager, Applied Meteorology & Emission Assessment, Geosciences and Engineering Department, PNL, contributed significantly to the quality of this report. The Earth Sciences Branch, Division of Health, Siting, and Waste Management, Office of Nuclear Regulatory Research, USNRC, funds PNL under FIN B2384 to conduct a program entitled "Atmospheric Dispersion Data Assessment," of which this report is a part. The useful and relevant perspective of Dr. Robert F. Abbey, Jr., the NRC technical contract monitor, served to focus the effort on NRC's particular needs in the area of atmospheric transport and diffusion in shoreline environments. The contributions of Drs. Hadlock and Abbey are gratefully acknowledged.

1.0 BACKGROUND

The study being reported here was conducted to identify any information that could be employed to satisfy or partially satisfy current NRC needs. Specifically, these NRC needs relate to field measurements of atmospheric dispersion in coastal regions.

This study involved identifying, obtaining, and reviewing past field studies and research efforts that were applicable to atmospheric dispersion in coastal regions. These endeavors could be used to yield information that is relevant to the objectives of NRC's Atmospheric Dispersion Research Program which is being carried out by the Office of Nuclear Regulatory Research. The studies have been reviewed according to NRC's specification for data which will improve the bases for licensing decisions and for improvement of the concentration prediction models being implemented for emergency planning and site characterization.

NRC, in their endeavors to meet the data requirements to improve the bases for licensing and emergency response planning process, have correctly determined that there is a need to generate new data upon which to base those improvements. Further, they have recognized that some past measurement and research efforts, although generally pursued for objectives different than NRC's current objectives, can contribute information that is relevant, if properly reanalyzed. This project then, is an important step in the efforts being conducted by NRC prior to full-scale initiation of new measurement programs.

The review of publications (termed "critical review"), along with the summaries of those reviews, comprise the "Findings" section of this report. The reviews will identify the status of knowledge about dispersion in coastal regions, identify needed new measurements, and indicate the potential to derive more information from the past studies through carefully designed reanalysis schemes. These reanalyses in turn will be employed to fill some existing information gaps, to broaden, and to generalize the findings expected to result from NRC's new measurement programs.

2.0 OBJECTIVE

The overall objective of the study is to identify, obtain, and review existing information about atmospheric dispersion and atmospheric trajectory studies conducted in coastal regions. The reason for reviewing this information is to determine the status of knowledge about atmospheric processes in coastal regions such that this knowledge can serve to identify current NRC field data needs. These data needs are those related to efforts in progress to upgrade models employed for prediction of emissions that may occur from nuclear plants located in coastal regions.

Primary emphasis is placed on information about atmospheric dispersion and particularly on data from atmospheric tracer field measurements. Secondly, data from atmospheric trajectory measurements is also of interest.

3.0 METHODS

3.1 PREVIOUS RELATED WORK

Initial effort is devoted to establishing the extent and nature of direct and related work that applies to transport and diffusion (dispersion) of airborne materials in coastal regions. This base of information is interpreted to determine the extent to which existing work can assist in describing the atmospheric processes which control transport of airborne materials and their diffusion properties in coastal regions. Methods already developed to describe and predict the dispersion of airborne materials are identified and reviewed so as to judge their value in light of current NRC needs.

Several significant programs have generated very useful information. Particularly noteworthy programs are those related to the electric producing utilities and military programs--several related to field behavior of chemical and biological warfare agents and others related to various aspects of missile programs.

A number of U.S. Army program data reports were obtained through negotiations with the Commander, U.S. Army Dugway Proving Ground, Utah. These data reports contain extensive analyses of numerous field tests conducted to evaluate, in some cases, the effectiveness of munitions, and in other cases, the behaviors of simulant agent materials in differing coastal field conditions. Other military field measurements were conducted specifically to determine atmospheric dispersion conditions where degrees of coastal terrain complexity were tested to determine their specific influences on the dispersion processes. These measurement programs span a time frame of nearly thirty years. The later programs were of course more sophisticated and employed more modern measurement and analytical technology. Essentially all these Army programs were originally either security classified or were security sensitive and thus were not released to the scientific public. Recent security classification downgrading has relaxed the original level of sensitivity and thus these data reports have become available. Since these data reports are now available and have been included in the data base for this present report, there is a significant body of dispersion data that is "new to the field." This new data, being of significant extent, is due in large part to the cooperative assistance of the Commander, Dugway Proving Ground and his staff.

Other military measurement programs were not originally restricted from the scientific public and thus are not necessarily new to the field. These program reports are also included here in order that this critical review will represent all the significant measurements available at this time. An example of this latter group of unrestricted military programs lies in those projects conducted by or for the U.S. Air Force to generate dispersion information applicable to the safety aspects of missile launch operations.

Last, the open literature itself has yielded numerous reference papers dealing with the meteorology, the dynamics, and the theories of atmospheric behavior in coastal regions.

3.2 ATMOSPHERIC PROCESSES

An area that is investigated for this present report is one dealing with the level of understanding of the atmospheric processes which control transport and diffusion in coastal region . The efforts pursued by way of field measurements and model developments have resulted in the development of a certain level of understanding of these processes. Particular attention to this level of understanding is given for this present analysis in order that specification of future needs will reflect the proper emphasis. It is also important to take account of this level of under tanding as it relates to the predictability of atmospheric processes which are needed for model inputs to enable use of the models to derive predictions of dispersion and concentrations.

3.3 DISPERSION MODELS

Mathematical model developments or adaptations have accompanied many of the field measurement efforts either as part of the original projects or as follow-on analysis endeavors. Modeling approaches have included both the fitting of models to field data and development of model input parameters from field data. These modeling efforts are reviewed for this present report and areas that are inadequately developed or are outmoded by recent advances are identified so that such information will help to specify requirements for new study areas.

3.4 DATA AND MODEL GAPS

The information that has been assembled and reviewed, is viewed in continuum so as to assess its completeness. Specific note is taken of the extent of field measurements, the thoroughness of the analyses, and the degree to which modern technology has been applied to describe transport and diffusion of airborne materials in coastal regions. From this view, specific shortcomings of field measurements, models (source configurations, short-term, long-term, concentration, dosage, etc.), and model evaluations are identified.

3.5 MEASUREMENT NEEDS

Having identified the degree of completeness of existing information about dispersion in coastal regions and its level of modernization, the new measurement requirements are identified in light of NRC program objectives.

4.0 FINDINGS

4.1 ORGANIZATION OF MATERIAL

The list of papers and reports collected for this study is considered to be a thorough, although hardly exhaustive, collection of materials dealing with atmospheric processes in coastal regions. It is seen that a broad spectrum of measurements, analytical studies, and theoretical treatments are included in this list. In order to evaluate the breadth of these many works, a categorizing scheme was developed to assist in the review of the collected material. The categorizing scheme was developed around a chronology of the processes involved, then the works within each group were reviewed so as to evaluate the status of knowledge about that particular aspect. The order was established as follows:

- o Overview or Summary Papers
- o Theoretical Studies
- o Meteorological Studies Including Trajectory Studies
- o Tracer Studies

The paragraphs of this section comprise a discussion and summary of each of these four categories.

4.2 OVERVIEW PAPERS

From an initial screening of the many papers collected, it became evident that there existed a category of articles which did not involve detailed measurements or theoretical solutions to observed atmospheric phenomena, but were primarily narrative discussions of atmospheric processes in coastal zones. These generic descriptions of coastal meteorology were grouped together as "overview" papers and were considered to be relevant to the objectives of the NRC as they demonstrate the current level of understanding of the processes involved in dispersion of effluents in coastal regions. Recognizing that this topic has received a great deal of attention in recent years, it is not the intent of the present discussion to develop a primer on coastal meteorology, but rather to compile a list of works that have been prepared to date.

Atmospheric transport and diffusion processes in coastal zones have generated considerable interest in the years following World War II, judging by the number of reports published since that time. Possibly the best of the early overview papers was written by Prophet (1961) who reviewed the papers from the 1940's and 1950's and prepared a treatise on the "state of knowledge." He obtained information from a variety of sources, described the basic processes involved in dispersing effluents in coastal zones, described trajectories under both onshore and offshore flows, and computed vertical eddy diffusivities under varying lapse conditions, at different coastal locations.

Other works published in the 1960's include those by Van der Hoven (1967) and Schroeder, et al, (1967).

Lyons (1975) presented a very detailed treatise on transport and diffusion in coastal regimes at the AMS Workshop on Meteorology and Environmental Assessment. He discussed the general processes involved, including the development of mesoscale subsidence inversions and the turbulent internal boundary layer (TIBL), reviewed some of the various tracer and meteorological measurement programs conducted in shoreline environments, and presented a model to account for fumigation processes of smoke plumes intersecting the TIBL. The model was applied to a power plant plume on the western shore of Lake Michigan and calibrated against measurements of SO_2 under lakeshore fumigation conditions.

Another important overview paper was presented by S. A. Hsu (1975) at the Third International Ocean Development Conference in Tokyo. Some basic concepts of atmospheric dispersion were discussed in conjunction with the coastal transition zone. The effects of internal boundary layers, caused by discontinuities of surface heating and roughness elements, on effluents released into the atmosphere were presented. Other considerations, such as complex terrain common along many coastlines, were discussed. Hsu concluded his report with a series of recommendations on the proper siting of emission sources in coastal environments.

Hsu (1977) extended his basic arguments presented in this 1975 paper to a specific application--the Louisiana coastal zone. Climatological summaries of relevant meteorological parameters including frequencies of wind and inversion depth were compiled from historical records gathered at several Gulf stations.

Brookhaven National Laboratories have been conducting detailed meteorological research programs for a number of years. Their research has involved the collection and analysis of meteorological data, including some tracer experiments, primarily in the coastal region of Long Island, New York. The tracer experiments and meteorological measurements will be discussed later in this report, but some of the findings of this research effort have been summarized by Raynor and collaborators (1978, 1979). The characteristics of the meteorological regime in coastal zones were discussed, with emphasis on diffusion characteristics. Representative turbulence profiles and the development of internal boundary layers were presented from measurements performed on Long Island. The 1979 paper also included an overview of "state-of-the-art" modeling approaches for estimation of ground-level effluent concentrations, including algorithms for coastal fumigation conditions.

4.3 THEORETICAL STUDIES

A second basic category of reports that became evident from the initial screening process were studies that described meteorological events in coastal regions from a theoretical standpoint. Papers identified for this category involved the development of an equation or set of equations, models, or objective schemes for describing the characteristics of the coastal regime. As can be expected, some reports do not neatly fit into a particular category. Some reports that have been categorized as "theoretical" deal with objective schemes based on actual measurements. Similarly, papers categorized as being "meteorological" studies or "tracer" studies were designed such that the data collected would be used for the development or evaluation of a model. Keeping this in mind, three basic groups of reports were identified which fit the theoretical classification: those whose primary objective was to describe the purely dynamical aspects of coastal circulations; those that were concerned with interpreting the unique synoptic situation; and finally, studies which dealt with dispersion of particles and gases in the coastal environment.

The unique aspects of coastal meteorology, in particular the abrupt discontinuity in surface heating and roughness, has evidently provided considerable challenge to theoretical and dynamic meteorologists. Several important works were published in the years following World War II, which attempted to describe circulations in coastal zones (especially the sea breeze circulation) through integration and numerical solutions to the basic equations of motion. The principal efforts conducted during that time, and upon which more recent efforts have been based, include the works of Schmidt (1947), Haurwitz (1947), De Fant (1951), Stern (1954), Pearce (1955), Fisher (1961), and Estoque (1961, 1962). In general the models developed by these researchers attempted to describe the circulations resulting from the differential heating of the surface in the coastal zone. The models, being simplified solutions to the basic equations of motion, were generally linear (i.e., they did not account for advection of heat, with the exception of Fisher) and two-dimensional (i.e., assumed straight or idealized shorelines). It should also be noted that these models were generally applied to just the daytime sea-breeze circulation and not the full diurnal cycle. This was probably due to limitations in speed and storage capacity of computers in that time period.

The model which has probably received the most attention since the early 1960's is the one presented by Estoque (1961) and further refined in 1962. His efforts were probably the first to describe the sea breeze as a mesoscale phenomena embedded in a synoptic scale circulation. He applied his model to assumed initial conditions of zero gradient flow, gradient winds parallel to the shoreline, and both onshore and offshore gradient flows.

Numerical modeling of the sea breeze conducted after 1962 were generally improvements or expansions of Estoque's formulations. McPherson (1970) expanded the basic equations to three dimensions to simulate the effects on the sea-breeze circulation caused by an irregular shoreline (represented by an idealized indentation or bay in the shoreline). Pielke (1974) presented an eight-level, three-dimensional model to explain the convergence zone created by converging sea breezes in southern Florida. Neumann and Mahrer (1971) applied Estoque's equations through a full diurnal cycle and discovered a computational instability due to a violation of the mass conservation law and an overly-simplified simulation of vertical accelerations. The same authors applied their corrected formulations to the special application of circular islands of various radii (1974). Neumann (1977) also attempted to explain the interrelationships of the Coriolis force, the mesoscale pressure gradient resulting from differential heating, and the synoptic-scale pressure gradient as they relate to the observed clockwise turning of the sea/land-breeze circulation with time. Mak and Walsh (1976) noted that land and sea breezes do not display equal intensities, even when temperature gradients are of an equal magnitude. They applied a simplified model to test the hypothesis that the difference in intensities are due to changes in stability and eddy diffusivity from night to day. Finally, researchers at the University of Virginia have developed a computer algorithm, the University of Virginia Mesoscale Model, based on the set of Primitive and Hydrostatic Equations (Lyons, et al, 1979). When viewed chronologically, the increasing sophistication of numerical models of the sea breeze closely parallels the increasing capabilites of electronic computers. This fact is certainly not coincidental, so further advances in numerical techniques can be expected.

Other modeling approaches have been attempted by various authors in recent years. Most of these approaches have been developed through statistical analysis of detailed meteorological measurements. O'Brien and Pillsbury (1974) have applied an oceanographic analysis technique, the rotary spectrum analysis, to measurements performed during the Coastal Upwelling Experiments (CUE) in Oregon. Rao and Samson (1976) performed a similar analysis of data collected over Long Island. Keen, Lyons, and Schuh (1979) reported on a kinematic diagnostic analysis model which computes vertical velocities using a divergence equation, from measurements of the horizontal components of the wind, and then interpolates the results over a larger grid.

The sea/land-breeze circulation system poses a unique problem to the weather forecaster. Objective schemes have been developed to forecast the occurrence of a sea (or lake) breeze based on various synoptic situations which are known at the time the forecast is prepared. Hall (1954) realized that the onset of a lake breeze could cause a reduction of visibility at Chicago's Midway Airport because of accumulated smoke associated with the sea-breeze front. He developed an objective scheme based on a categorization of synoptic map types and knowledge of expected pressure gradients, surface winds, and sky cover. Biggs and Graves (1962) developed a sea-breeze "index" based on the ratio of inertial forces (as represented by gradient wind speed) to buoyancy forces (as measured by the difference between the air and water surface temperatures). A critical or threshold value of the index, indicating either an occurrence or nonoccurrence of a lake breeze, was developed from data measurements performed at the Enrico Fermi Nuclear Station on Lake Erie. Burda (1976) developed a critical value of the same index for predicting the sea breeze in Boston, as did Lyons (1972) for Chicago's lake breeze.

The final grouping of theoretical papers were those incorporating knowledge of coastal meteorology to the specific problem of diffusion of effluents in such an environment. The dispersion models applied to the coastal regime used varying techniques for describing the characteristics of the sea-breeze circulation, but can be described in terms of the usual Gaussian vs. numerical approaches. McCallister (1974) tested the sensitivity of both Gaussian and numerical models to various meteorological inputs through simulation of a hypothetical power plant located on the coast.

A detailed model development program was conducted by Brookhaven National Laboratories as described by Tingle and Dieterle (1976). That development expanded on earlier work by Tingle (1973). A mesoscale model defining coastal circulations occurring under various synoptic orientations was run in a "leap-frog" fashion with a "particle-in-cell" model which describes pollutant distributions using a Lagrangian technique.

Keen, Lyons, and Schuh (1979) utilized the kinematic diagnostic analysis described earlier in this section to determine trajectories of particles with different settling velocities through an entire diurnal cycle. The effects of differing release heights on downwind concentration profiles was also discussed.

Lyons, et al, (1981) presented a coastal fumigation model which is capable of predicting the characteristics of the TIBL as a function of synoptic conditions and distance from the coastline. Pollutant dispersion is handled in a Gaussian framework until the plume intersects the TIBL, where Turner's fumigation equations are applied. An interesting feature incorporated into this model (Lyons calls it "GLUMP II" for Great Lakes University of Wisconsin Mesometeorology Project) is a "split-sigma" approach whereby different sigma curves are applied for plumes that are either above or below the TIBL.

In regards to theoretical predictions of the characteristics of the TIBL, several articles are worthy of note. However, not all of those listed here deal specifically with the problem of coastal fumigation. In addition to the scheme presented by Lyons, et al, are methods described by Elliott (1958), Raynor (1975), Venkatram (1977), and Anthes (1978).

4.4 METEOROLOGICAL MEASUREMENT PROGRAMS

In contrast to the efforts described previously, whereby investigators have described the characteristics of the atmosphere in terms of dynamic theory, several efforts to actually measure those characteristics have been conducted in recent decades. These measurement programs have played an integral role in the definition of the problems involved in coastal meteorology, as well as providing the necessary data bases for evaluating the solutions of the theorists.

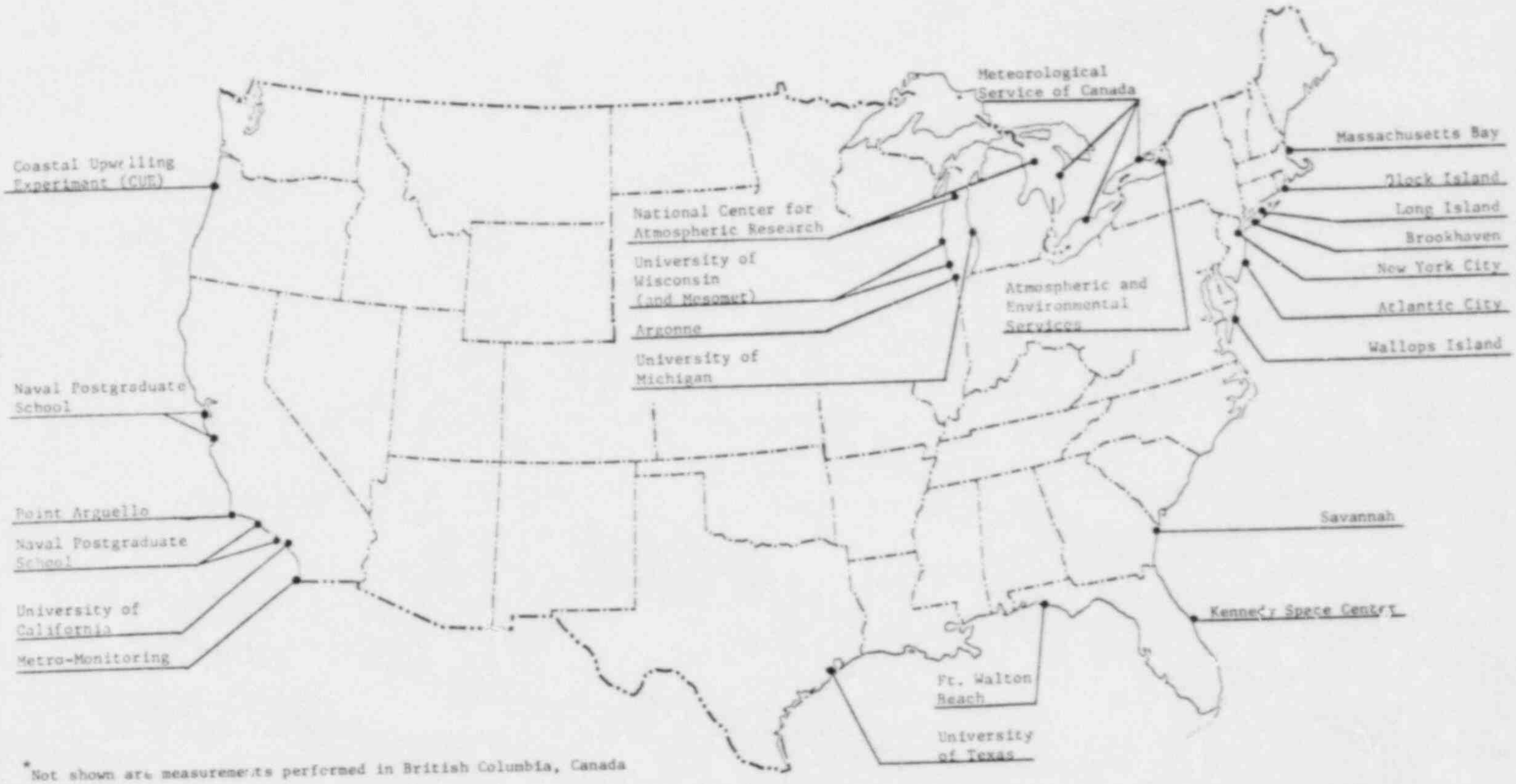
The sea/land-breeze circulation system has been the subject of considerable meteorological investigations. Several authors have performed excellent analyses using existing records from the National Weather Service and other sources. Others have developed detailed measurement programs that have been tailored to the specific objectives of the investigators. It is the latter group of experiments that are the focus of this survey. In other words, the purpose of this investigation is to identify and review those measurement programs that are supplemental to the existing National Weather Service data base or those that add information to that which is available from the National Climatic Center. However, an analysis using National Weather Service records that is worthy of mention is the diffusion climatology of the Atlantic and Gulf coasts prepared by the Brookhaven National Laboratories. The studies, which were reported by Raynor and Hayes (1976, 1980), utilized statistical analysis of two years of meteorological measurements from 30 NWS stations to characterize the dispersion potential of the Atlantic and Gulf coasts.

The meteorological measurement programs that have been reviewed for the current investigation are summarized in Table 1, and depicted graphically in Figure 1. The programs have been grouped by the geographic area in which the measurements were performed (i.e., West Coast, Gulf Coast, etc.) to account for the unique problems that each area poses to the NRC. It is evident from both the table and the figure that a good overall meteorological representation of each type of coastline is available.

Several studies have been conducted to define the structure of the sea/land-breeze circulation system. Profiles of winds, temperature, and humidity were taken over the land, over water, and in some cases both, by aircraft, boat, surface stations, and balloons. The following measurement programs all had similar objectives--the description of the structure of the sea-breeze regime: Craig (1945, 1949)--Massachusetts Bay; Edinger (1957, 1961)--California; Fisher (1960)--Block Island, Rhode Island; Moroz (1966, 1967)--Lake Michigan; Hsu (1970)--Florida Gulf Coast; Phillips (1972)--Lake Ontario; Lenschow (1973)--Lakes Michigan and Huron; and Schacher (1980)--California.

Other reports concentrated on specific aspects of the structure of the sea-breeze system such as wind flows or TIBL measurements. Trajectories determined from pibal tetroon or neutral balloon releases were reported by Frizzola (1963)--New York City; Pack (1963)--Los Angeles; Angell (1965)--Atlantic City; and Sheih (1979)--Lake Michigan and Long Island. Studies which concentrated on the measurement of the turbulent internal boundary layer (TIBL) include those by Edinger

FIGURE 1: Location of Meteorological Measurement Programs Conducted in Coastal Regions



*Not shown are measurements performed in British Columbia, Canada

TABLE 1: LISTING OF METEOROLOGICAL MEASUREMENT PROGRAMS CONDUCTED IN COASTAL REGIONS

GROUP	IDENTIFIER/ LOCATION	INVESTIGATOR(S)	DATE OF MEASUREMENT	MEASUREMENTS PERFORMED
WEST COAST	NAVAL POSTGRADUATE SCHOOL - [CEWCOM-76] - Monterey to San Diego - [CARB] - Los Angeles Basin - [CEWCOM-78] - San Nicholas Island - [MABLES] - San Francisco Bay - [CTQ] - Monterey Bay	Schacher, Davidson, and Fairall	- October 1976 - July 1977 - May 1978 - July 1978 - June 1979	From Boat: (T_a, T_w, WD_s, IH, H)
	UNIVERSITY OF CALIFORNIA - Los Angeles Basin - San Fernando Valley - Santa Clara Valley	Edinger	- Summer 1957 - Summer 1957 - July 1961	From Aircraft: (T_u, P, H, IH) (WD_u, WS_u) From PIBALS- (San Fernando only)
	POINT ARGUELLO, CA	Cramer, Dumbauld, Record, and Swanson	Continuous 1962 - 1965	From 300' Tower: (T_a, T_u, WD_s, WS_s, WD_u, WS_u) IH [Method Unknown]
	METRO-MONITORING	Kauper	Summers of 1975 - 1976	From Aircraft: (T_u, IH) Also: (WD_u, WS_u) From PIBALS
	BRITISH COLUMBIA	Miyake, Stewart, Pond, and Others	Summers of 1962 - 1968	From Vertical Mast Over Water (Height Unknown): (T_a, T_u, WD_s, WS_s, WD_u, WS_u, H)
	COASTAL UPWELLING EXPERIMENTS (CUE) - Oregon	O'Brien	Summers of 1972 - 1973	(WD_s, WS_s) Method Unknown Note: Other measurements performed but are not identified in report.

TABLE 1: LISTING OF METEOROLOGICAL MEASUREMENT PROGRAMS CONDUCTED IN COASTAL REGIONS (Continued)

GROUP	IDENTIFIER/ LOCATION	INVESTIGATOR(S)	DATE OF MEASUREMENTS	MEASUREMENTS PERFORMED
GULF COAST	UNIVERSITY OF TEXAS - Upper Texas Coast	Echols, Wagner, Yu	- June 1968	From 8 Inland and 1 Offshore (Drilling Platform): (T_a, WD_s, WS_s, H)
	FORT WALTON BEACH, FL	Hsu	- May 1970	From 2 Towers (1-10m, 1-100m) (T_a, T_u, WD_s, WS_s, WD_u, WS_u)
ATLANTIC COAST	BROOKHAVEN, NY	Raynor and Others	Intermittent 1972 - 1977	From Coastal Site and 1 Offshore Site (Buoy): (T_a, T_w, WD_s, WS_s) Note: Measurements performed on land at other sites, from aircraft, and boat in support of diffusion studies. See "Tracer Studies".
	LONG ISLAND, NY	Di Vecchio and Others	May - July 1974	From 2 Coastal 120 meter Towers: (T_a, T_u, T_s, WD_s, WS_s, WD_u, WS_u)**
	MASSACHUSETTS BAY, MA	Craig and Others	Summer - Autumn 1944	From Boat and Aircraft: (T_a, T_u, T_w, WD_s, WS_s, H, IH)* Also: (WD_u, WS_u) from PIBALS
	NEW YORK CITY, NY	Frizzola and Fisher	- June 1960	(WD_u, WS_u) from PIBALS**
	BLOCK ISLAND, RI	Fisher	- August 1958	From Aircraft: (T_u, IH) Also: (WD_u, WS_u) from PIBALS (T_w) - Method Unknown
	ATLANTIC CITY, NJ	Angell and Pack	- July 1964	(WD_u, WS_u) from Tetroons*

TABLE 1: LISTING OF METEOROLOGICAL MEASUREMENT PROGRAMS CONDUCTED IN COASTAL REGIONS (Continued)

GROUP	IDENTIFIER/ LOCATION	INVESTIGATOR(S)	DATE OF MEASUREMENTS	MEASUREMENTS PERFORMED
ATLANTIC COAST (CONT'D)	WALLOPS ISLAND, VA (NASA)	Parsons and Williams	Summers of 1977 - 1978	Note: Parameters measured on Wallops Island not specified in report.
	SAVANNAH, GA	Blanton and Others	February - September 1977	From Offshore Tower (Navigational Light Tower 27 meters high) (T_a, T_w, WD_s, WS_s, P)
	KENNEDY SPACE CENTER, FL	Record and Others	Summers of 1966 - 1967	From 150 meter Tower: (T_a, T_w, WD_s, WS_s, WD_u, WS_u) From Radiosondes: (T_u, IH, WD_u, WS_u, H, P) Note: Tetroons also used on selected days.
GREAT LAKES	UNIVERSITY OF WISCONSIN - Lake Michigan	Lyons and Others	Summers of 1967, 1970, 1974	From Aircraft: (T_u, IH, WD_s, WS_s, H, P)** From Boat: (T_a, T_w) Also: (WD_u, WS_u) From PIBALS and Tetroons
	METEOROLOGICAL SERVICE OF CANADA - Lake Huron - Lake Erie - Lake Ontario	Munn, Richards and Others	Summers of 1960 - 1967 (Intermittent)	From Surface Stations (Some using tethered balloons): (T_a, T_u, WD_s, WS_s) Also: (WD_u, WS_u) from PIBALS From Boats: (Using tethered balloons): (T_a, T_u, T_w, WS_s)
	ARGONNE - Lake Michigan	Sheih and Others	(Reported 1979)	(WD_u, WS_u) from neutral balloons

TABLE 1: LISTING OF METEOROLOGICAL MEASUREMENT PROGRAMS CONDUCTED IN COASTAL REGIONS (Continued)

GROUP	IDENTIFIER/ LOCATION	INVESTIGATOR(S)	DATE OF MEASUREMENTS	MEASUREMENTS PERFORMED
GREAT LAKES (Cont'd)	NCAR - Lake Michigan - Lake Huron	Lenschow	November 1970	From Aircraft: (T_u, IH, T_w, WS_u, H)
	AES - Lake Ontario	Phillips	Winters of 1965 - 1969	From Ships: (T_a, T_w, WD_s, WS_s)*
	UNIVERSITY OF MICHIGAN	Moroz	Summer of 1964	From Surface Stations: (T_a, H) From Ships: (T_w) From Aircraft: (T_u, IH, H) Also: (WD_u, WS_u) from PIBALS

FOOTNOTES:

*Data base supplimented with surface observations from the National Weather Service.

**Data base supplemented with both surface and upper air (radiosonde) observations from the National Weather Service.

LEGEND FOR TABLE 1

T_a	Air Temperature At Surface	WD_u	Upper Level Wind Direction
T_u	Upper Level Air Temperatures	WS_u	Upper Level Wind Speed
T_w	Water Surface Temperature	IH	Inversion Height
WD_s	Surface Wind Direction	H	Humidity
WS_s	Surface Wind Speed	P	Pressure

(1959)--Los Angeles; Di Vecchio (1976)--Long Island; and Rizzo (1977)--Milwaukee.

The characterization of turbulent diffusion in coastal zones has been the topic of several measurement programs. Munn (1967) collected meteorological data for several summers on the eastern shore of Lake Huron to provide a data base for future diffusion studies. Cramer (1970) collected information from meteorological stations at Vandenberg Air Force Base (Point Arguello) in California to provide the basis for the development of concentration estimates of toxic combustion by-products from Titan-III missile launches. Record (1970) had similar objectives for the collection of data at the Kennedy Space Center in Florida.

Two other measurement programs are worthy of special comment. Lyons, Olsson, Keen and others have performed extensive measurements of the structure of the lake/land breeze system on the western shore of Lake Michigan. The analysis of these measurements are the subject of a series of reports by the above listed authors (1972, 1973A, 1973B, and 1978) and have formed the basis for the development and evaluation of several meteorological and dispersion models (mentioned in Section 4.3 above were the Kinematic Diagnostic Model, the University of Virginia Mesoscale Model, and GLUMP-II).

Another detailed coastal meteorology program has been conducted by the Brookhaven National Laboratories. Meteorological measurements in the vicinity of Long Island began in 1972 and continued for several years. These measurement programs were the basis for several papers published by Raynor, SethuRaman, Brown, and others (1975, 1976A, 1976B, 1978, 1979, 1979A, 1979B, and 1980) and will be discussed more fully in the next section.

It should be recognized that most of the tracer programs discussed in the next section were accompanied by detailed meteorological measurements which greatly expands the amount of data which is available for further analysis.

Meteorological measurements in coastal zones have been performed by researchers whose objectives did not relate to the sea-breeze circulation system. Some researchers were concerned with coastal discontinuity because of changes in surface roughness and heating. Echols (1972) and Yu (1970) performed measurements on the upper coast of Texas to quantify the change in wind speed from water to land because of increased surface roughness. Similarly, Richards (1966) measured the increase of wind speed from land to water over Lakes Erie and Ontario. Munn (1969) examined the effects of the urban heat island of Toronto on the development of the lake breeze.

Other researchers required the collection of data in coastal zones for various study objectives. Kauper (1979) performed aircraft measurements of the marine boundary layer off the coast of southern

California to define the transport of ozone from Los Angeles. Parsons (1979) studied the effects of the sea breeze on variations in local ozone levels at Wallops Island, Virginia. Lowry (1959) in Oregon and Fosberg (1966) in California were both concerned with the effect of marine air penetration on the potential for forest fires.

Several oceanographic investigations have required the collection of meteorological data. Blanton (1978) collected data at a lighthouse off the coast of Georgia in support of his efforts to describe ocean currents over the continental shelf. Pond (1966) and Miyake (1970) performed air-sea interface experiments off the coast of Spanish Banks in British Columbia, which included measurements of the transfer of heat, moisture, and momentum from the ocean's surface. With similar objectives, the Coastal Upwelling Experiments (CUE) were conducted off the coast of Oregon in 1972 and 1973, as reported by O'Brien (1974).

Finally, a limited number of measurement programs have been identified that were conducted in locations other than the continental United States and Canada. Leopold (1949) utilized pibals, time-lapse photography, and several instrument shelters to define the interactions of the trade winds with sea and land breezes on the island of Lanai in Hawaii. Sivertson (1973) studied the effects of fjords, valleys, and mountains on the climatology of Troms, Norway using a number of surface stations at various distances from the coast. Finally, Gamo and others (1977) performed several measurements of the TIBL using light aircraft at both onshore and offshore locations near the Kashima Industrial Zone in Japan. The authors used the data to evaluate theoretical predictions of inversion height.

In summary, the measurement programs conducted in coastal zones have been primarily concerned with the structure of the sea/land-breeze circulation system, and in particular the sea-breeze cell. With this objective, it is not surprising that most of these programs were of short duration, from several days to a month or two, were conducted in the spring and summer months when gradient winds are light and air-water temperature differences are at a maximum, and were performed during daylight hours. Because the structure of the sea breeze has been the major topic of concern, other aspects of the coastal regime have not received much attention. The land-breeze portion of the diurnal cycle has not received as much attention as its day-time counterpart. This is due to the fact that population densities are low over water, and also owing to the obvious difficulties in making accurate measurements over water. In light of the conclusions of various researchers that the reversal of the land breeze to a sea breeze can cause pollutants emitted at night to be transported back over land, the full diurnal cycle is undoubtedly of interest to the NRC and should be studied further. Similarly, summertime measurements allow the collection of data during periods when the land is warmer than the water. However, during the winter months, especially in the Great Lakes region, the water temperatures are higher than over land. This results in very unstable atmospheres over water, and can set up a persistent land breeze when gradient winds are light. With the exception of Phillips (1972) and Lenschow (1973), this area of coastal meteorology has received very little investigation.

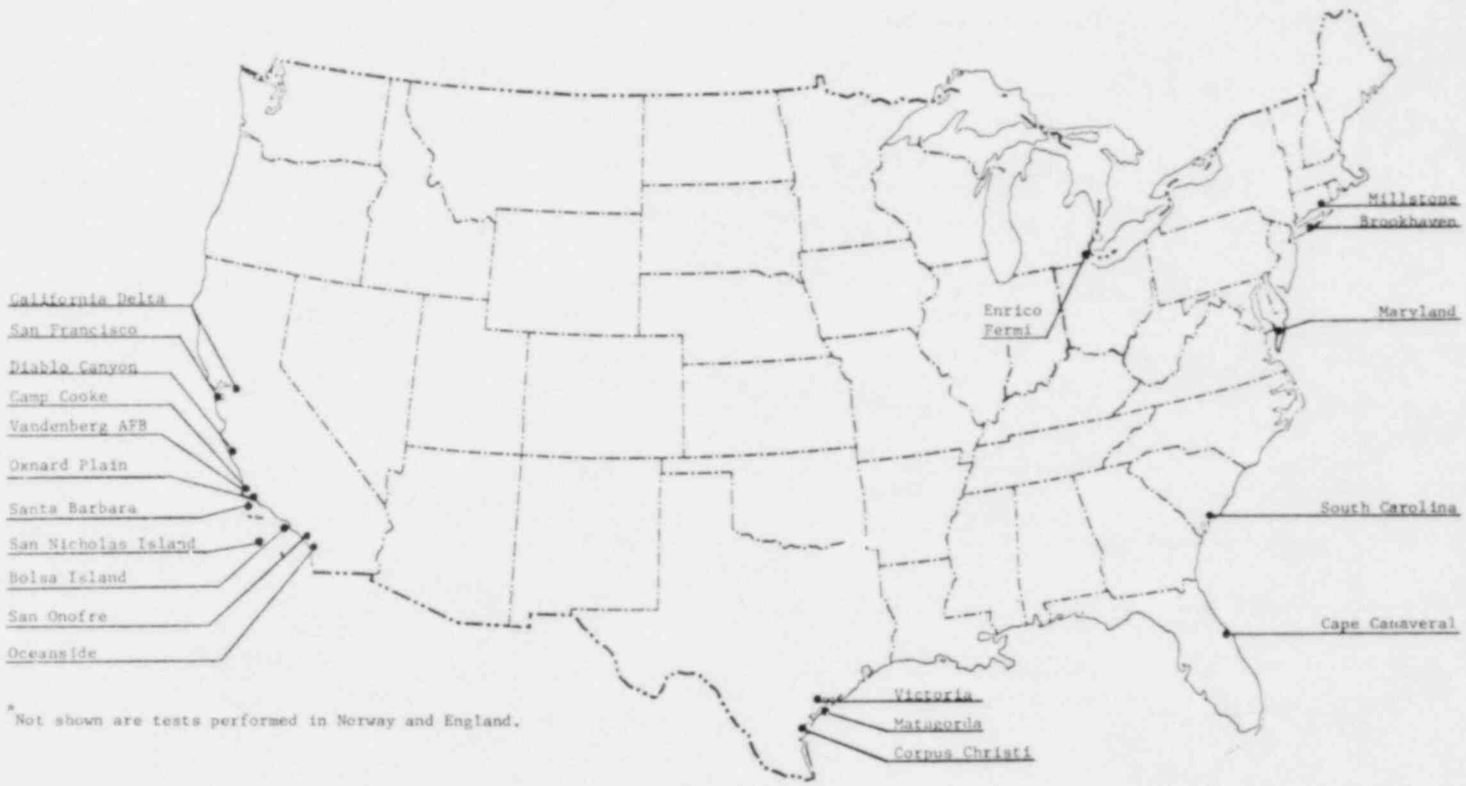
4.5 ATMOSPHERIC TRACER STUDIES

The final, and probably most important, category of research into the characteristics of the coastal atmosphere is "tracer" studies. The investigations that fit into this category include actual field programs where the transport and diffusion capabilities of the atmosphere were tested directly with gaseous or particle tracers. A considerable number of such programs have been identified, and can be classified into three basic groupings: programs conducted by or for specific industrial project or utilities; studies conducted by or sponsored by various government organizations (nonmilitary); and work conducted by or for the military services. A summary of the tracer studies is listed in Table 2, with the geographical locations of these investigations depicted graphically in Figure 2. Several authors who were not necessarily connected with the tracer programs have performed additional analysis of the data bases established in the tests. These reanalyses have been included in Table 2 as a fourth category.

The tracer studies that have been performed to date were conducted with very different objectives. For example, the Millstone, Enrico Fermi, San Onofre, and Diablo Canyon trials were all conducted to characterize dispersion in regions where nuclear powered generating facilities would be or have been located. The military services performed the Mountain Iron, the Ocean Breeze and Dry Gulch, the San Nicolas Island, and the Point Arguello tests because of concern about the transport of exhaust from rocket and missile launches which use toxic propellants. The military also used simulants for biological agents to determine the dispersion characteristics of biological warfare agents. It should be recognized however, that even though the programs had varying objectives, the measurements performed are relevant to NRC's current concerns regarding turbulent diffusion and transport in coastal zones.

The methods used in each of the diffusion programs, as well as the basic conditions during which the tests were performed, are summarized in Table 3. In general, tracer releases (from Table 2, fluorescent particles were the most frequently used tracers) were in the form of continuous plumes from point sources at or near the ground. Five of the programs used "line" source releases; usually from aircraft, and three programs disseminated the tracers from instantaneous puffs (bomblets). As mentioned, most of the tracers were released within 10 meters of the ground, although six of the programs utilized point releases at heights of at least 30 meters.

FIGURE 2: Locations of Tracer Studies Conducted in Coastal Regions



*Not shown are tests performed in Norway and England.

TABLE 2 - LISTING OF TRACER EXPERIMENTAL PROGRAMS CONDUCTED IN COASTAL REGIONS

GROUP	IDENTIFIER/LOCATION	INVESTIGATOR(S)	TIME OF MEASUREMENTS	TRACER TYPE*
INDUSTRIAL/ UTILITY	San Onofre, CA	Septoff and Others	1976 (Winter)	SF_6
	Diablo Canyon, CA	Cramer, Record	1969	FP
	Bolsa Island, CA	Smith	1967 (Summer)	FP
	Enrico Fermi Reactor, MI	Bierly, Hewson	1959 - 1960	FP
	Millstone, CT	Johnson and Others	1974 (Autumn)	SF_6 F-12B-2
	Southhampton, England	Emberlin	1973 (Spring)	SF_6
GOVERNMENT (Non-Military)	Oxnard Coastal Plain, CA	Lamb, Lorenzen, Shair	1975 (Summer)	SF_6
	California Delta Region	Lamb, Shair, Smith	1976 (Summer)	SF_6 $CBrF_3$
	Brookhaven, NY (Great Gull Island and Tiana Beach)	Raynor and Others	1972 - 1975 (Intermittent)	SF_6 Smoke
	Ventura County, CA (Santa Barbara Channel)	Aeroviroment and Naval Postgraduate School (Schacher and Others)	1980 - 1981 (Autumn/Winter)	SF_6
MILITARY	Mountain Iron/ Vandenberg AFB, CA	Hinds, Nickola, Daubek, and Others	1965 - 1966	FP

TABLE 2: LISTING OF TRACER EXPERIMENTAL PROGRAMS CONDUCTED IN COASTAL REGIONS (Continued)

GROUP	IDENTIFIER/LOCATION	INVESTIGATOR(S)	TIME OF MEASUREMENTS	TRACER TYPE*
MILITARY (Cont'd)	Ocean Breeze and Dry Gulch/Cape Canaveral, FL and Vandenberg AFB, CA	Haugen, Fuquay, Taylor	1961 - 1962	FP
	San Francisco	Grinnel, Perkins, Leighton and Others	1950 - 1952	BG, FP
	Camp Cooke, CA (Now Vandenberg AFB)	Wolfe, Cox Palmer, Dorrel	1955 - 1956 (Summers)	BG, SM, FP
	San Nicolas Island, CA	Cramer, Hamilton DeSanto	1964 (Autumn/Winter)	FP Smoke Tetroons
	Victoria, TX	Miller, Smith	1965 (Summer)	FP LP
	Matagorda Island, TX	Ettenheim, Crum	1967 (Summer)	FP LP
	Corpus Christi, TX	Smith, Wolf	1962 (Summer)	FP
	Oceanside, CA	Smith, Niemann	1967 (Summer)	FP
	South Carolina	Morton, Shinn	1967 (Summer)	FP
	Maryland (East Shore)	Allison, Morton and Others	1969 (Autumn)	FP
	North Norway	Gotaas, Eidsviks	1968 (Summer)	FP

TABLE 2: LISTING OF TRACER EXPERIMENTAL PROGRAMS CONDUCTED IN COASTAL REGIONS (Continued)

GROUP	IDENTIFIER/LOCATION	INVESTIGATOR(S)	TIME OF MEASUREMENTS	TRACER TYPE*
RE-ANALYSIS OF EXISTING MEASUREMENTS	Oceanside, CA	Minott, Shearer	(Report: 1977)	--
	North Norway	Minott, Shearer	(Report: 1977)	--
	Santa Barbara Channel, CA	Rappolt	(Report: 1981)	--
	Victoria, TX	Vaughan	(Report: 1966)	--
	Matagorda, TX	Vaughan	(Report: 1967)	--

*KEY TO TRACER TYPES:

FP Fluorescent Particles (Yellow or Green) - Zinc Sulfide or Zinc Cadmium Sulfide.

LP "Large" Particles with Appreciable Settling Velocities - Usually Glass Beads or Fluorescent-Stained Cork.

SF_6 Sulfur Hexafluoride Gas.

F-12B-2 Freon Gas

$CBrF_3$ Freon Gas

BG Bacillus Subtilis Var. Niger (Spore Simulant)

SM Serratia Marcescens (Vegetative Simulant)

Smoke Oil-Fog Smoke

TABLE 3

TRACER STUDY METHODS AND TEST CONDITIONS

STUDY	NUMBER OF TRACER TESTS	TYPE RELEASE				RELEASE HEIGHT (meters)			RELEASE LOCATION			WIND FLOW	
		POINT	LINE	CONTIN.	INST.	0 - 10	10 - 30	> 30	Off-Shore	Coastal	On-Shore	On-Shore	Off-Shore
Mountain Iron	113	X		X		X				X		X	
Ocean Breeze/ Dry Gulch	76 109	X		X		X				X	X	X	
San Onofre	20	X		X		X		X		X			X
Diablo Canyon	27	X		X		X		X		X		X	
Oxnard Plain	2	X		X				X		X		X	
California Delta	8	X		X		X					X	X	
Brookhaven	32*	X		X		X			X	X		X	
Bolsa Island	13	X		X			X		X			X	
Enrico Fermi	13	X		X			X			X		X	X
Southhampton	1	X		X				X		X		X	
Millstone	59	X		X			X	X		X	X	X	
San Francisco	4	X		X		X			X			X	
Camp Cooke	61	X	X	X	X	X					X	X	
San Nicolas Island	16*	X		X		X					X		X
Victoria	17		X		X			X	X			X	
Matagorda	16		X		X			X	X			X	
Corpus Christi	9		X		X			X	X			X	
Oceanside	55	X	X	X	X	X		X	X	X	X	X	
North Norway	11	X		X		X			X			X	
South Carolina	13	X			X	X					X	X	
Maryland	115	X			X	X	X				X	X	
Santa Barbara Channel	8	X		X		X			X			X	

*Some of these tests involved the use of oil-fog smoke as a tracer.

In terms of the location with respect to the coastline, a good representation of onshore, coastal, and offshore tracer releases can be obtained from the existing programs. For the purposes of this study measurement programs conducted within one kilometer of the coastline were considered to be "coastal" tests, while those experiments conducted further than one kilometer from the coastline were considered to be "onshore" tests. The offshore releases, either from boats or aircraft, vary in distance from the coast but are generally within 20 kilometers. A full range of terrain types are represented by existing programs. It is also interesting to note that almost all of the tests were conducted during onshore wind conditions.

A summary of the basic measurements that have been performed during the tracer programs is shown in Table 4. In general, the measurement arrays consisted of samplers spaced at regular (often logarithmic) distances in both the crosswind and downwind distances. Certain compromises had to be made by investigators due to the usual access problems, especially offshore and in areas of complex terrain. Virtually all of the programs utilized horizontal (or crosswind) sampling arrays, and a surprising number utilized some form of vertical measurement. This allows the investigators to compute both horizontal and vertical dispersion parameters. As would be expected, the sampling arrays were onshore at distances from a few hundred meters to 15-20 kilometers from the coast. Only two of the measurement programs (the Victoria and Matagorda programs) sampled at distances greater than 60 kilometers from the emission source, so long-range transport of atmospheric effluents are poorly defined in existing programs. Another regime that has received little attention is the offshore regime. As shown in the table, only four programs performed offshore measurements. This is most certainly due to the difficulties involved in accurately measuring tracer dosages and related meteorological parameters over water, coupled with the simple fact that possible exposure of humans to pollutants offshore is practically nonexistent. Regardless of the reasons, the absence of tracer studies and meteorological measurements (see previous section) in the offshore regime represents an area of coastal dispersion that has not been adequately defined.

The dispersion and meteorological measurements performed to date have provided researchers a large data base for analyses and interpretations that should be of interest to the NRC. The Mountain Iron and the Ocean Breeze and Dry Gulch Diffusion Programs were all conducted to provide information for the development of site-specific empirical equations which compute expected dosages of rocket propellant exhaust. These equations were incorporated into a computerized system called the Weather Information Network Display (WIND), which uses real-time meteorological data from remote sites in conjunction with the above-mentioned equations to determine if conditions are appropriate for missile or rocket launches.

TABLE 4

MEASUREMENTS PERFORMED DURING THE TRACER PROGRAMS

STUDY	MEASUREMENT ARRAYS					
	HORIZONTAL	VERTICAL	OVER WATER	INLAND 0-5 km	INLAND 5-10 km	INLAND > 10 km
Mountain Iron	X			X	X	X
Ocean Breeze/Dry Gulch	X			X		
San Onofre	X	X		X		
Diablo Canyon	X	X		X	X	
Oxnard Plain	X			X	X	X
California Delta	X			X	X	X
Brookhaven	X	X	X	X		
Bolsa Island	X			X		
Enrico Fermi	X	X		X		
Southhampton	X			X	X	X
Millstone	X	X		X	X	
San Francisco	X			X	X	X
Camp Cooke	X			X		
San Nicolas Island	X	X	X	X		
Victoria	X	X		X	X	X
Matagorda	X	X		X	X	X
Corpus Christi	X	X		X	X	X
Oceanside	X	X		X	X	X
North Norway	X		X	X	X	X
South Carolina	X	X		X		
Maryland	X	X		X		
Santa Barbara Channel	X	X	X	X	X	X

The experiments conducted at the Millstone Nuclear Reactor site were used both in the development of a new dispersion model and the evaluation of existing NRC models. The tests included measurements of downwind concentrations during downwash conditions, which were applied to a "Split-H" model. This approach assumes that under certain conditions an effluent plume is split into two segments, a portion that is entrained to ground level in the building wake, and another portion which remains buoyant. Other tracer programs that were used in either the development or evaluation of Gaussian dispersion models are the Brookhaven, the San Nicolas Island, the Ventura County, and the California Delta experiments.

Horizontal and vertical dispersion parameters have been computed from several of the tracer experiments. Crosswind integrated concentrations (CWIC) were calculated by the authors or subsequent researchers from the Millstone, Enrico Fermi, Camp Cooke, and Brookhaven measurement programs. These computations would be useful to future investigators in determining dispersion coefficients. Actual sigma values (either sigma-y or sigma-z, or both) have already been computed from the Oxnard, California Delta, Bolsa Island, Oceanside, Brookhaven, and Maryland tracer tests.

It is evident from the previous discussions that a considerable number of dispersion measurements have been made in coastal zones. Indeed a total of 798 tracer tests have been performed during the various programs reported here. Of these tests, 615 were conducted by the military services, making it the most important category of measurement programs identified. This is also true because many of the experiments conducted by the military have only recently been declassified, and have therefore received little attention from nonmilitary investigators.

A great potential exists for further analysis of existing data, and this may alleviate the need for establishing additional measurement programs. However, techniques for measuring the behavior of the atmosphere in recent years, not to mention pollutants carried by it, may make some of the existing data base "old." Further studies which may be conducted from those tracer experiments should carefully consider the methodologies and the equipment employed during these programs.

5.0 SUMMARY OF INFORMATION AVAILABLE

Probably the most significant aspect of this study lies in the amount of data that have been revealed during the course of review. After conducting as thorough a review of this body of data as time would allow, several points emerge that should be presented in summary fashion. Those points deal mainly with the potential to satisfy or to partially satisfy current NRC information needs through the reanalysis of existing data rather than the generation of all new data. It goes without saying that the fulfillment of information gaps through analysis of existing data will enable NRC to achieve program objectives at a substantial saving of both time and money. The main points regarding information available are as follows:

- Numerous tests exist where data have been collected to document onshore wind flow and plume behavior during those onshore wind conditions.

- Numerous tests were conducted where data have documented lateral dispersion and limited tests included documentation of vertical dispersion to several distances from the sources.

- A large body of test data was generated by military interests. These data span a long time period and are, for the most part, new to the field. Due to the nature of the military data collection and reporting system, these data are very well documented and thoroughly reported, all of which indicates these data will be very useful in spite of some being old.

- Numerous dispersion tests have been collected along the California coast making it the most studied of the U.S. coasts.

- Studies have also been conducted along the East Coast, and to a limited extent along the Gulf Coast and in the Great Lakes. This distribution of experimental efforts provides at least some information about all of the coastal regions of the country.

- Although it was not an objective of this present study to establish coastal terrain types, it does appear that the broad range of tests does span the different coastal terrain types quite well.

- The emission source type which is best represented by the existing test data is the continuous emitting (1-2 hour) point located at ground level.

- The situation best represented by the existing test data is the steady-state, short-term, short distance (i.e., times from few minutes to 2 hours and distances from few meters tc 1-2 km).

6.0 SUMMARY OF INFORMATION NOT AVAILABLE OR NOT COMPLETELY REPRESENTED

As has been discussed in the preceding sections, many experimental test programs have been conducted to generate data for a very broad range of objectives. It is indeed fortunate that these data can serve other purposes than were originally intended. However broad those original objectives were, they do not fully represent all the areas that need to be addressed for NRC's current needs. The main areas not represented or not fully represented are listed below:

- Trajectories of emissions have generally been limited to the simple form. That is, by design, tests were conducted during consistent and persistent flow conditions and thus the common meandering flow has not been studied.

- For the same reasons, dispersion and trajectories have not been studied during transition periods.

- Dispersion and trajectories have not been studied through a diurnal cycle, especially a diurnal cycle where flow reversal or return flow might be experienced.

- Existing tests, with few exceptions, have not employed continuous emissions beyond 1-2 hours duration. Further, long range transport of effluents in the coastal atmosphere has not been addressed by existing programs.

- Instantaneous or puff emissions have been studied mostly by the military and those data have not yet been interpreted in light of NRC's concerns.

- Full recognition of the importance (or even existence) of the turbulent internal boundary layer (TIBL) has been quite recent and thus there exist only limited measurements to characterize it, to define its changes during diurnal cycles, and especially to describe its importance to plume behavior. Such aspects as description of pollutant interactions with the TIBL in terms of trapping and fumigation are still incomplete.

- Limited effort, in fact almost no effort, has been devoted to documentation of the water surface temperature as it relates to the intensity of local wind circulations, to atmospheric stability over water, or to the dynamical aspects of the TIBL.

- Dispersion and trajectories in the offshore direction have been almost completely ignored, especially as pollutants carried by offshore flows might recirculate to onshore locations.

- Tracer field measurements conducted in the Great Lakes area are lacking.

- Among the tracer experiments conducted in the Gulf Coast region, greater attention was devoted to deposition than to dispersion. Thus, in spite of what appears to be a reasonably good data base, considerable effort is still needed to determine the special considerations needed for dispersion in that coastal combination.

- Only a few of the many tracer releases were conducted at heights equivalent to reactor building height.

- Almost no measurements have been conducted during conditions when the land was colder than the water.

7.0 RECOMMENDATIONS FOR REANALYSIS WORK

As is discussed in the above sections, several sets of data have been isolated that, if reanalyzed, could provide partial information for NRC's current data needs. It is believed that the highest priority among the possible reanalysis tasks should be placed on those tasks that could provide information either supplemental to or complementary to current efforts by NRC on the SEADEX field measurement program.[1] The reanalysis tasks listed below are conceived to provide information which would extend the forthcoming SEADEX findings to a broader range of coastal conditions and will assist in generalizing those findings. In order of priority the following tasks are recommended.

- Develop characteristic coastal dispersion coefficient values (sigma-y and sigma-z) that reflect coastal terrain complexity. Merge these values with other coefficient values developed by previous investigations into a form appropriate for inclusion in handbooks.

- Define the diurnal or cyclical aspects of transport, dispersion phenomena at different coasts. Stress detail that might result in recirculations.

- Assemble dispersion modeling studies conducted for coastal combinations as completed by previous investigators. Interpret and combine findings in a way to be applicable to NRC's current needs.

- From existing data sets, develop coastal wind trajectory prediction methods.

- From existing data sets, assemble climatological summaries of conditions found in coastal regions. Combine with other partial climatological summaries for coastal regions as completed by other investigators.

- From existing data sets, establish data sets that can be employed as independent data for the evaluation of the findings from the SEADEX program.

- From existing data sets, broaden and generalize findings made in the SEADEX program.

[1]SEADEX (Shoreline Environment Atmospheric Dispersion Experiment) is a field measurement program initiated by the NRC to generate data bases which will be used to evaluate dispersion models appropriate for nuclear power plants located in coastal zones.

8.0 RECOMMENDATIONS FOR FUTURE FIELD MEASUREMENTS

It is seen that much additional information can be generated by parallel efforts to do reanalysis work and conduct new field measurements. Fulfilling NRC's data needs for application to licensing decisions, confirmation of regulations, standards, and guides, and for site characterizations will be accomplished only through implementation of a long-term study effort. Some of the field measurements needed are of course being addressed through the design of the SEADEX program and others will be addressed through design of subsequent field measurement programs. From the vantage point of this present review study, the needed measurements are described and discussed in Section 6.0, but for the purpose of emphasis are tabulated here:

- Measure dispersion in characteristic meandering flows.
- Measure dispersion during transition periods.
- Measure dispersion through characteristic diurnal cycles.
- Measure dispersion for long-term periods (4 to 24 hours).
- Measure dispersion of puff emissions.
- Conduct studies to determine formation of, diurnal changes of, and behavior of pollutants influenced by the TIBL.
- Measure dispersion in the offshore direction.
- Measure dispersion when the land is cooler than the water.

Incorporation of these types of measurements into future programs will ensure that these efforts will not duplicate works that have already been conducted, but rather will provide additional information into the nature of processes that have not been completely defined.

REFERENCES

AeroVironment Incorporated, 1980: Data Submission for Offshore Tracer Study in Ventura County, Volume I - Tracer Gas and Meteorological Data. Report Number DP-80-056. Pasadena, California, 220 pp.

AeroVironment Incorporated, 1980: Data Submission for Offshore Tracer Study in Ventura County, Volume II - Doppler Acoustic Radar Data. Report Number DP-80-056. Pasadena, California, 381 pp.

Allison, J. K., A. V. Duffield, and J. M. Morton, 1970: Meteorological Analog Test and Evaluation - First Field Test Operation. Melpar Meteorological Research Laboratory, Contract Number DA-42-007-AMC-339(V), Falls Church, Virginia, 160 pp.

Angell, J. K. and D. H. Pack, 1965: A Study of the Sea Breeze at Atlantic City, New Jersey Using Tetroons as Lagrangian Tracers. Monthly Weather Review, Volume 93, Number 8, pp. 475-493.

Angell, J. K., D. H. Pack, L. Machta, C. R. Dickson, and W. H. Hoecker, 1972: Three-Dimensional Air Trajectories Determined From Tetroon Flights in the Planetary Boundary Layer of the Los Angeles Basin. Journal of Applied Meteorology, Volume 11, pp. 451-471.

Anlauf, K. G., P. Felin, H. A. Wiebe, and O. T. Melo, 1980: Nanticoke Shoreline Diffusion Experiment. June 1978, Part IV, submitted to Atmospheric Environment.

Anthes, R. A., 1978: The Height of the Planetary Boundary Layer and the Production of Circulation in a Sea Breeze Model. Journal of the Atmospheric Science, Volume 35, pp. 1231-1239.

Beers, N. R., 1947: Sea-breeze Circulation. Journal of Meteorology, Volume 4, p. 74.

Berlyand, M. E., 1967: To the Theory of the Industrial Emission Dispersion in the Atmosphere of a Coastal Zone. Idojaras, Volume 71, Number 2, pp. 65-72.

Bierly, E. W. and E. W. Hewson, 1963: Atmospheric Diffusion Studies near a Lake Shore. Journal of Applied Meteorology, Volume 2, pp. 390-396.

Biggs, W. G. and M. E. Graves, 1962: A Lake Breeze Index. Journal of Applied Meteorology, Volume 1, pp. 474-480.

Blanton, J. O., L. L. Bailey, D. W. Hayes, and A. S. Dicks, 1978: Data Report #1 - Oceanographic and Meteorological Data 15 km off the Coast of Georgia. Georgia Marine Science Center. Technical Report 78-6, 44 pp., Available from Georgia Marine Science Center.

Blanton, J. O., L. L. Bailey, D. W. Hayes, and A. S. Dicks, 1978: Data Report #2 - Oceanographic and Meteorological Data 15 km off the Coast of Georgia. Contract Number DOE/SR-01025 TI, 56 pp.

Bifford, Jr., I. H. and D. A. Gillette, 1972: The Influence of Air Origin on the Chemical Composition and Size Distribution of Tropospheric Aerosols. Atmospheric Environment, Volume 6, pp. 463-480.

Bower, Jr., C. A. and E. C. Renger, 1974: Fog and Wind Regimes of the Eureka-Arcata Coastal Region of Northern California. Dugway Proving Ground Technical Report Number DPG-FR-M600P, Dugway, Utah, 144 pp.

Bowne, N. E., 1973: Diffusion Rates. Proceedings of the 66th Annual Meeting of the Air Pollution Control Association (#73-13.0), Chicago, Illinois, 4 pp.

Brookhaven National Laboratory, 1979: Data Summary for Evaluation of the Transport and Diffusion Climatology of the United States East and Gulf Coasts. Report Number BNL-51098. Upton, New York, 465 pp.

Burda, T. J., 1976: An Objective Prediction Scheme for the Boston Sea Breeze. M.S. thesis, Department of Meteorology, University of Maryland, College Park, Maryland, 112 pp.

Bush, K. and S. L. Kupferman, 1980: Wind Stress Direction and the Alongshore Pressure Gradient in the Middle Atlantic Bight. Journal of Physical Oceanography, Volume 10, Number 3, pp. 469-471.

Byers, H. R. and H. R. Rodebush, 1948: Causes of Thunderstorms of the Florida Peninsula. Journal of Meteorology, Volume 5, pp. 275-280.

Cass, G. R. and F. R. Shair, 1980: Transport of Sulfur Oxides within the Los Angeles Sea Breeze/Land Breeze Circulation System. Preprints of the Second Joint Conference on Applications of Air Pollution Meteorology and the Second Conference on Industrial Meteorology. New Orleans, Louisiana, American Meteorological Society, Boston, Massachusetts, pp. 320-327.

Church, H. W., 1976: The Atmospheric Dispersion Model as Used in the Reactor Safety Study, Wash-1400. Preprints of the Third Symposium on Atmospheric Turbulence Diffusion and Air Quality, Raleigh, North Carolina, American Meteorological Society, Boston, Massachusetts, pp. 188-191.

Coleman, J. M. and S. P. Murray, 1978: Coastal Sciences: Recent Advances and Future Outlook. Office of Naval Research. Technical Report Number 253, 24 pp.

Cox, E. L., W. D. Foster, and V. S. Palmer, 1958: Comparison of Simulant Decay Rates and Area Coverages (V). U.S. Army Chemical Corps Research and Development Command, Report Number 287, Frederick, Maryland, 84 pp.

Craig, R. A., 1949: Vertical Eddy Transfer of Heat and Water Vapor in Stable Air. Journal of Meteorology, Volume 6, pp. 123-133.

Craig, R. A., I. Katz, and P. J. Harney, 1945: Sea Breeze Cross Sections from Psychrometric Measurements. Bulletin of the American Meteorological Society, Volume 26, Number 10, pp. 405-410.

Cramer, H. E., R. K. Dumbauld, F. A. Record, and R. N. Swanson, 1970: Titan III-D Toxicity Study. GCA Corporation for the Department of the Air Force, Report Number TR-70-3-A, pp. 30-54.

Cramer, H. E., H. L. Hamilton, G. M. DeSanto, 1965: Atmospheric Transport of Rocket Motor Combustion By-Products, Volume 1 - Data Analysis and Prediction Technique. GCA Corporation (Contract Number N123[61756]34567[PMR]), 156 pp.

Cramer, H. E., H. L. Hamilton, G. M. DeSanto, 1965: Atmospheric Transport of Rocket Motor Combustion By-Products, Volume 2 - Experimental Design and Field Installation. GCA Corporation (Contract Number N123[61756]34567[PMR]), 46 pp.

Cramer, H. E. and F. A. Record, 1970: Diffusion Studies at the Diablo Canyon Site. GCA Corporation for Pacific Gas and Electric Company, 43 pp.

Daubek, H. G., W. L. Dotson, J. V. Ramsdell, P. W. Nickola, 1969: The Mountain Iron Diffusion Program: Phase II, South Vandenberg: Volume 3, Battelle - Pacific Northwest Laboratories (BNWL-572, Volume 3), 223 pp.

DeFant, F., 1951: Local Winds. Compendium of Meteorology, American Meteorological Society, Boston, Massachusetts, p. 655.*

Dexter, R. V., 1958: The Sea Breeze Hodograph at Halifax. Bulletin of the American Meteorological Society, Volume 39, Number 5, pp. 241-247.

Dieterle, D. A. and A. G. Tingle, 1976: A Numerical Study of Mesoscale Transport of Air Pollutants in Sea-Breeze Circulations. Preprints of the Third Sumposium on Atmospheric Diffusion and Air Quality, Raleigh, North Carolina, American Meteorological Society, Boston, Massachusetts, pp. 436-441.

REFERENCES (Cont'd)

DiVecchio, R. A. and D. B. Smith, 1976: Performance of a Recent Formulation for Rate of Growth of Boundary Layers near Shorelines. Preprints of the Conference on Coastal Meteorology, Virginia Beach, Virginia, American Meteorological Society, Boston, Massachusetts, pp. 124-125.

Donn, W. L., P. L. Milic, and R. Brilliant, 1956: Gravity Wavesand the Tropical Sea Breeze. Journal of Meteorology, Volume 13, pp. 356-361.

Echols, W. T. and N. K. Wagner, 1972: Surface Roughness and Internal Boundary Layer near a Coastline. Journal of Applied Meteorology, Volume 11, pp. 658-662.

Edinger, J. C., 1959: Changes in the Depth of the Marine Layer over the Los Angeles Basin. Journal of Meteorology, Volume 16, Number 3, pp. 219-226.

Edinger, J. G., 1963: Modification of the Marine Layer over Coastal Southern California. Journal of Applied Meteorology, Volume 2, pp. 706-712.

Edinger, J. G. and R. A. Helvey, 1961: The San Fernando Convergence Zone. Bulletin of the American Meteorological Society, Volume 42, Number 9, pp. 626-635.

Eidsvik, K. J. and Hansen, F. K., 1972: Turbulent Diffusion in the Surface Boundary Layer of Near Neutral Stratified Flows Along Four Valleys. Interim Report VM-6 Forsvarets Forskningsinstitutt, Norwegian Defense Research Institute, Kjeller, Norway, 50 pp.

Eigsti, S. L., 1978: The Coastal Diurnal Wind Cycle at Port Arkansas, Texas. Report No. 4, University of Texas Atmospheric Science Group, Austin, Texas.*

Elliott, W. P., 1958: The Growth of the Atmospheric Internal Boundary Layer. Trans. Amer. Geophys. Union, Volume 39, p. 1048.*

Elliott, W. P. and M. L. Barad, 1964: Operational Prediction of Diffusion Downwind From Line Sources. AFCRL-64-163, Air Force Surveys in Geophys. No. 156.*

Emberlin, J. C., 1981: A Sulfur Hexafluoride Tracer Experiment from a Tall Stack over Complex Topography in a Coastal Area of Southern England. Atmospheric Environment, Volume 15, Number 9, pp. 1523-1530.

REFERENCES (Cont'd)

Estoque, M. A., 1961: A Theoretical Investigation of the Sea Breeze. Quarterly Journal of the Royal Meteorological Society, Volume 87, p. 136.*

Estoque, M. A., 1962: The Sea Breeze as a Function of the Prevailing Synoptic Situation. Journal of the Atmospheric Sciences, Volume 19, pp. 244-250.

Ettenheim, Jr., G. P. and C. L. Crum, 1967: Matagorda Depostion Trails. Meteorology Research, Inc. Report Number MRI67-FR-468, Altadena, California, 76 pp.

Fisher, E. L., 1960: An Observational Study of the Sea Breeze. Journal of Meteorology, Volume 17, pp. 645-660.

Fisher, E. L., 1961: A Theoretical Study of the Sea Breeze. Journal of Meteorology, Volume 18, pp. 216-233.

Fosberg, M. A. and M. J. Schroeder, 1966: Marine Air Penetration in Central California. Journal of Applied Meteorology, Volume 5, pp. 573-589.*

Frank, N. L. and D. L. Smith, 1968: On the Correlation of Radar Echos over Florida with Various Meteorological Parameters. Journal of Applied Meteorology, Volume 17, pp. 712-714.

Frenzen, P. and R. L. Hart, 1972: Atmospheric Dispersion Over Water Inferred From Turbulence Statistics. Argonne National Laboratory, ANL-7960, Part IV, pp. 74-83.*

Frizzola, J. A. and E. L. Fisher, 1963: A Series of Sea Breeze Observations in the New York City Area. Journal of Applied Meteorology, Volume 2, pp. 722-739.

Gamo, M., S. Yamamoto, and O. Yokoyama, 1977: Diffusion of Pollutants in the Atmospheric Boundary Layers--Airborne Measurements of the Internal Boundary Layer above the Coastal Area. Proceedings of the Fourth International Clean Air Congress, Tokyo, Japan. The Japanese Union of Air Pollution Prevent Associations.

Geisler, J. E. and F. P. Bretherton, 1969: The Sea-Breeze Forerunner. Journal of the Atmospheric Sciences, Volume 26, pp. 82-95.

Gentry, R. C. and P. L. Moore, 1954: Relation of Local and General Wind Interaction near the Sea Coast to Time and Location of Air-Mass Showers. Journal of Meteorology, Volume 11, pp. 507-511.

Gifford, F. A., 1975: Atmospheric Dispersion Models for Environmental Pollution Applications. Lectures on Air Pollution and Environmental Impact Analyses. American Meteorological Society, Boston, Massachusetts, pp. 35-58.

Gifford, F. A., 1976: Turbulent Diffusion-Typing Schemes: A Review. Nuclear Safety, Volume 17, Number 1, pp. 63-86.

Giroux, H. D., L. E. Hauser, L. H. Teuscher, and P. E. Testerman, 1974: Power Plant Flume Tracing in the Southern California Marine Layer. Preprint, Symposium on Atmospheric Diffusion and Air Pollution, American Meteorological Society, Santa Barbara, pp. 238-245.*

Gotaas, Y., 1975: Atmospheric Dispersion in Valleys, VM-34, Part I, II Interim Report Forsvarets Forskningsinstitutt, Norwegian Defense Research Institute, Kjeller, Norway, Part I - 60 pp., Part II - 19 pp.

Grinnell, S. W., W. A. Perkins, F. X. Webster, D. H. Hutchison, and P. A. Leighton, 1950: Quarterly Report Number 3, August-September-October 1950. Stanford University Contract Number DA-19-108-CML-450, Stanford, California, 64 pp.

Grinnell, S. W., W. A. Perkins, D. H. Hutchison, J. S. Sandberg, and P. A. Leighton, 1951: Quarterly Report Number 5, February-March-April 1951. Stanford University Contract Number DA-19-108-CML-450, Stanford, California, 40 pp.

Hall, C. D., 1954: Forecasting the Lake Breeze and its Effects on Visibility at Chicago Midway Airport. Bulletin of the American Meteorological Society, Volume 35, Number 3, pp. 105-111.

Hallanger, N. L., G. R. Herd, G. Shortley, and R. L. Stearman, 1959: Further Study of the Camp Cooke Aerosol Dissemination Trails. Booz Allen Applied Research, Inc. Report Number BAARINC-PRO-R-3, Bethesda, Maryland, 97 pp.

Hamilton, H. L., 1965: Atmospheric Transport of Rocket Motor Combustion By-Products, Volume 3 - Data Supplement. GCA Corporation (Contract Number N123[61856]34567[PMR]), 204 pp.

Harrison, R. M. and H. A. McCartney, 1980: Ambient Air Quality at a Coastal Site in Rural Northwest England. Atmospheric Environment, Volume 14, pp. 233-244.

Haugen, D. A. and J. J. Fuquay, 1963: The Ocean Breeze and Dry Gulch Diffusion Programs, Volume I, Hanford Laboratories, Contract Number AT(45-1)-1350 (Atomic Energy Commission), 240 pp.

Haugen, D. A. and J. H. Taylor, 1963: The Ocean Breeze and Dry Gulch Diffusion Program, Volume II, Air Force Cambridge Research Laboratories, Contract Number WS 107A-2, 100 pp.

Haurwitz, B., 1947: Comments on the Sea-Breeze Circulation. Journal of Meteorology, Volume 4, pp. 1-8.

Hayes, G. L., 1946: Sea Breezes and Forest Fires. Bulletin of the American Meteorological Society, Volume 27, p. 539.

Hewson, E. W., G. C. Gill, and E. W. Bierly, 1960: Atmospheric Diffusion Study at the Enrico Fermi Nuclear Reactor Site. Progress Report No. 2 (under contract with the Power Reactor Development Company), Department of Civil Engineering Meteorological Laboratories, University of Michigan.*

Hewson, E. W., G. C. Gill, and G. J. Walke, 1963: Smoke Plume Photography Study. Big Rock Point Nuclear Plant, Charlevoix, Michigan, Program Report No. 3, Report 04015-3-P, University of Michigan, Ann Arbor, Michigan.*

Hinds, W. T. and P. W. Nickola, 1967: The Mountain Iron Diffusion Program: Phase I, South Vandenberg: Volume 1, Battelle-Pacific Northwest Laboratories (BNWL-572 Volume 1), 276 pp.

Hinds, W. T. and P. W. Nickola, 1968: The Mountain Iron Diffusion Program: Phase I, South Vandenberg: Volume 2, Battelle-Pacific Northwest Laboratories (BNWL-572 Volume 2), 258 pp.

Hoff, R. M., N.B.A. Trivett, M. M. Millan, P. Fellin, K. A Anlauf, H. A. Wiebe, and R. Bell, 1980: The Nanticoke Shoreline Diffusion Experiment, Part III. Ground Based Air Quality Measurements - Atmospheric Environment.*

Hosker, R. P., Jr., 1974: A Comparison of Estimation Procedures for Over-Water Plume Dispersion. Preprint, Symposium on Atmospheric Diffusion and Air Pollution, American Meteorological Society, Santa Barbara, pp. 281-287.*

Hsu, S. A., 1969: Land- and Sea-Breeze Fronts near 50 cm on the Gulf Coast. Bulletin of the American Meteorological Society, Volume 50, Number 11, pp. 880-882.

Hsu, S. A., 1970: Coastal Air-Circulation System: Observations and Empirical Model. Monthly Weather Review, Volume 98, Number 7, pp. 487-509.

Hsu, S. A., 1973: Dynamics of the Sea Breeze in the Atmospheric Boundary Layer: A Case Study of the Free Convection Regime. Monthly Weather Review, Volume 101, Number 3, pp. 187-194.

Hsu, S. A., 1975: Atmospheric Dispersion Characteristics in Coastal Environments. Preprints of the Third International Ocean Development Conference. Tokyo, Japan, Volume IV, pp. 77-91.

Hsu, S. A., 1977: Boundary-Layer Meteorological Research in the Coastal Zone. Geoscience and Man, Volume XVIII, pp. 99-111.

Hsu, S. A., 1977: Atmospheric Dispersion Characteristics in the Louisiana Coastal Zone. Coastal Studies Institute, Technical Report Number 229, Louisiana State University, Baton Rouge, Louisiana, 29 pp.

Hsu, S. A., 1979: Mesoscale Nocturnal Jetlike Winds within the Planetary Boundary Layer over a Flat, Open Coast. Boundary-Layer Meteorology, Volume 17, pp. 485-494.

Hsu, S. A., 1980: Research in Coastal Meteorology: Basic and Applied. Preprints of the Second Conference on Coastal Meteorology (Number 1.1), Los Angeles, California. American Meteorological Society, Boston, Massachusetts, pp. 1-7.

Huh, O. K., 1976: Detection of Oceanic Thermal Fronts off Korea with the Defense Meteorological Satellites. Reprint from Remote Sensing of Environment, Volume 5, pp. 191-213.

Jehn, K. H., 1973: A Sea Breeze Bibliography, 1664-1972. Report Number 37, Atmospheric Science Group, College of Engineering, University of Texas, Austin, Texas, 51 pp.

Jenson, N. D., 1979: Simultaneous Measurements of Turbulence Over Land and Water. Boundary-Layer Meteorology.*

Johansson, T. B., R. E. Grieken, and J. W. Winchester, 1976: Elemental Abundance Variation with Particle Size in North Florida Aerosols. Journal of Geophysical Research, Volume 81, Number 6, pp. 1039-1046.

Johnson, W. B., E. Shelar, R. E. Ruff, H. B. Singh, and L. Salas, 1975: Gas Tracer Study of Roof-Vent Effluent Diffusion at Millstone Nuclear Power Station. Stanford Research Institute, Menlo Park, California, SRI Project Number 3588, 295 pages.

Junge, C. E., 1969: A Study of Aerosols in Pacific Air Masses. Journal of Applied Meteorology, Volume 8, pp. 340-347.

REFERENCES (Cont'd)

Kauper, E. K., 1979: Ozone Transport along the Southern California Coast. Preprints of the Fourth Symposium on Turbulence, Diffusion, and Air Pollution (No. 11.3), Reno, Nevada, American Meteorological Society, Boston, Massachusetts, pp. 620-623.

Keen, C. S. and W. A. Lyons, 1978: Lake/Land Breeze Circulations on the Western Shore of Lake Michigan. Journal of Applied Meteorology, Volume 17, Number 12, December 1978, pp. 1843-1855.

Keen, C. S., W. A. Lyons, and J. A. Schuh, 1979: Air Pollution Transport Studies in a Coastal Zone Using Kinematic Diagnostic Analysis. Journal of Applied Meteorology, Volume 18, Number 5, May 1979, pp. 606-615.

Kerman, B. R., R. E. Mickle, R. V. Portelli, and P. K. Misra, 1980: The Nanticoke Shoreline Diffusion Experiment, Part II. Internal Boundary Layer Structure - submitted to Atmospheric Environment.*

Kimble, G. H. T. and Collaborators, 1946: Tropical Land and Sea Breezes. Bulletin of American Meteorological Society, Volume 27, pp. 99-113.

Kojima, H. and T. Sekikawa, 1978: Notes and Correspondence - Effect of Land on Aerosols in Oceanic Atmosphere under the Westerly Monsoon. Journal of the Meteorological Society of Japan, Volume 56, Number 1, pp. 57-60.

Lague, J. S., E. M. Irvine, and R. F. Lavery, 1980: Validation of Alternative Turbulence Typing Models for Estimating Air Quality Effects of Coastal Sources Near Rough Terrain. Second Joint Conference on Applications of Air Pollution Meteorology - Conference Papers, New Orleans, Louisiana, 3 pp.

Lamb, B. K., A. Lorenzen, and F. H. Shair, 1978: Atmospheric Dispersion and Transport within Coastal Regions - Part I. Tracer Study of Power Plant Emissions from the Oxnard Plain. Atmospheric Environment, Volume 12, pp. 2089-2100.

Lamb, B. K., F. H. Shair, and T. B. Smith, 1978: Atmospheric Dispersion and Transport within Coastal Regions - Part II. Tracer Study of Industrial Emissions in the California Delta Region. Atmospheric Environment, Volume 12, pp. 2101-2118.

Lavoie, R. L., 1972: A Mesoscale Numerical Model of Lake-Effect Storms. Journal of the Atmospheric Sciences, Volume 29, pp. 1025-1040.

Lee, S. C., 1977: A Systems Study of Marine Fog Situations. University of Missouri-Rolla, Report Number 72-76-0180, 86 pp.

Leopold, L. B., 1949: The Interaction of Trade Wind and Sea Breeze, Hawaii. Journal of Meteorology, Volume 6, pp. 312-320.

Lenschow, D. H., 1973: Two Examples of Planetary Boundary Layer Modification over the Great Lakes. Journal of the Atmospheric Sciences, Volume 30, pp. 568-580.

Lettau, H. and J. Zabransky, 1968: Interrelated Changes of Wind Profile Structure and Richardson Number in Air Flow and Land to Inland Lakes. Journal of Atmospheric Sciences, Volume 25, pp. 718-728.

Lewellen, W. S. and M. E. Teske, 1976: A Second-Order Closure Model of Turbulent Transport in the Coastal Planetary Boundary Layer. Preprints of the Conference on Coastal Meteorology, Virginia Beach, Virginia, American Meteorological Society, Boston, Massachusetts, pp. 118-123.

Loncar, E., 1978: Diffusivity Potential of Bakar's Bay. Preprints of the WMO Symposium on Boundary Layer Physics Applied to Specific Problems of Air Pollution, Norrkoping, World Meteorological Organization, Geneva, Switzerland, pp. 279-285.

Lowry, W. P., 1959: Energy Budgets of Several Environments under Sea-Breeze Advection in Western Oregon. Journal of Meteorology, Volume 16, pp. 299-311.

Lyons, W. A., 1972: The Climatology and Prediction of the Chicago Lake Breeze. Journal of Applied Meteorology, Volume 11, pp. 1259-1270.

Lyons, W. A., 1975: Turbulent Diffusion and Pollutant Transport in Shoreline Environments. Lectures on Air Pollution and Environmental Impact Analyses, American Meteorological Society, Boston, Massachusetts, pp. 136-208.

Lyons, W. A., 1978: Turbulent Diffusion and Pollutant Transport in Shoreline Environments. Lectures on Air Pollution and Environmental Impact Analysis, American Meteorological Society, Boston, Massachusetts, pp. 136-208.*

Lyons, W. A. and H. S. Cole, 1973: Fumigation and Plume Trapping on the Shores of Lake Michigan during Stable Onshore Flow. Journal of Applied Meteorology, Volume 12, pp. 494-510.

Lyons, W. A., J. C. Dooley, C. S. Keen, J. A. Schuh, and K. R. Rizzo, 1974: Detailed Field Measurements and Numerical Model of SO_2 From Power Plants in the Lake Michigan Shoreline Environment. Contract Report to Wisconsin Electric Power Company, by Air Pollution Analysis Laboratory, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin, 218 pp.*

Lyons, W. A. and C. S. Keen, 1976: Computed 24-Hour Trajectories of Aerosols and Gases in a Lake/Land Breeze Circulation Cell on the West Shore of Lake Michigan, preprints, 6th Conference on Weather Forecasting and Analysis, American Meteorological Society, Albany, pp. 78-83.*

Lyons, W. A. and L. E. Olsson, 1972: Mesoscale Air Pollution Transport in the Chicago Lake Breeze. Journal of the Air Pollution Control Association, Volume 22, Number 11, November 1972, pp. 876-881.

Lyons, W. A. and L. E. Olsson, 1973: Detailed Mesometeorological Studies of Air Pollution Dispersion in the Chicago Lake Breeze. Monthly Weather Review, Volume 101, Number 5, pp. 387-403.

Lyons, W. A., E. R. Sawdey, J. A. Schuh, R. H. Calby, and C. S. Keen, 1981: An Updated and Expanded Coastal Fumigation Model. Proceedings of the 74th Annual Meeting of the Air Pollution Control Association (Number 81-31.4), Philadelphia, Pennsylvania, 15 pp.

Lyons, W. A., J. A. Schuh, and M. McCumber, 1979: Comparison of Observed Mesoscale Lake Breeze Wind Fields to Computations Using the University of Virginia Mesoscale Model. Fourth Symposium on Turbulence Diffusion and Air Pollution. Reno, Nevada, January 15-18, 1979, pp. 572-575 (Preprint Volume).

Maas, S. J. and P. R. Harrison, 1977: Dispersion over Water: A Case Study of a Nonbuoyant Plume in the Santa Barbara Channel, California. Preprints of the Joint Conference on Applications of Air Pollution Meteorology, Salt Lake City, Utah. American Meteorological Society, Boston, Massachusetts, pp. 12-15.

Mahlman, J. D. and W. J. Moxim, 1978: Tracer Simulation using a Global General Circulation Model Results from a Midlatitude Instanteous Source Experiment. Journal of the Atmospheric Sciences, Volume 35, pp. 1340-1374.

Mak, M. K. and J. E. Walsh, 1976: On the Relative Intensities of Sea and Land Breezes. Journal of the Atmospheric Sciences, Volume 33, pp. 242-251.

McCallister, M. A., 1974: A Theoretical Study of Meteorological Effects of the Dispersion of Atmospheric Contaminants in the Coastal Environment. M.S. Thesis, Naval Postgraduate School, Monterey, California, 61 pp.

McCreary, J., 1976: Eastern Tropical Ocean Response to Changing Wind Systems: With Application to El Nino. Journal of Physical Oceanography, Volume 6, pp. 632-645.

McPherson, R. D., 1970: A Numerical Study of the Effect of a Coastal Irregularity on the Sea Breeze. Journal of Applied Meteorology, Volume 9, pp. 767-777.

Meroney, R. N., 1975: Modeling of Atmospheric Transport and Fumigation at Shoreline Power Plant Sites. Proceedings, 2nd U. S. National Conference on Wind Engineering Research, Wind Engineering Research Council, Fort Collins, Colorado.*

Meroney, R. N., J. E. Cermak, and B. T. Yang, 1975: Modeling of Atmospheric Transport and Fumigation at Shoreline Site. Boundary-Layer Meteorology, Volume 9, pp. 69-90.*

Meyer, J. H., 1971: Radar Observations of Land Breeze Fronts. Journal of Meteorology, Volume 10, pp. 1224-1232.

Miller, R. L., 1966: Victoria Diffusion Trials, Volume I. Meteorology Research, Inc., Report Number MRI66-FR-374, Altadena, California, 184 pp.

Miller, R. L., 1966: Victoria Diffusion Trails, Volume II, Part A. Meteorology Research, Inc., Report Number MRI66-FR-374, Altadena, California, 332 pp.

Miller, R. L., 1966: Victoria Diffusion Trials, Volume II, Part B. Meteorology Research, Inc., Report Number MRI66-FR-374, Altadena, California, pp. 334-658.

Minott, D. H. and D. L. Shearer, 1977: Development of Vertical Dispersion Coefficients for Shoreline Environment. TRC Project Number 72607, Report Number COO-4026-2, Wethersfield, Connecticut.

Minott, D. H. and D. L. Shearer, 1979: Measurements of the Vertical Dispersion Rate in Deep-Valley Terrain. Preprints of the Fourth Symposium on Turbulence, Diffusion, and Air Pollution, Number 4.10, Reno, Nevada. American Meteorological Society, Boston, Massachusetts, pp. 229-236.

REFERENCES (Cont'd)

Minott, D. H., D. L. Shearer, and R. S. Marker, 1977: Devevelopment of Vertical Dispersion Coefficients for Deep-Valley Terrain. TRC Project Number 72607, Report Number COO-4026-3, Wethersfield, Connecticut.

Misra, P. K., 1979: Dispersion from Tall Stacks into a Shoreline Environment. Atmospheric Environment.*

Misra, P. K., 1980: Verification of a Shoreline Dispersion Model for Continuous Fumigation. Boundary-Layer Meteorology (In Press).*

Misra, P. K. and A. McMillan, 1980: On the Dispersion Parameters of Plumes from Tall Stacks in a Shoreline Environment. Boundary-Layer Meteorology (In Press).*

Miyake, M., M. Donelan, G. McBean, C. Paulson, F. Badgley, and E. Leavitt, 1970: Comparison of Turbulent Fluxes over Water Determined by Profile and Eddy Correlation Techniques. Quarterly Journal of the Royal Meteorological Society, Volume 96, pp. 132-137.

Miyake, M., R. W. Stewart, and R. W. Burling, 1970: Spectra and Cospectra of Turbulence Over Water. Quarterly Journal of the Royal Meteorological Society, Volume 96, pp. 138-143.

Moroz, W. J., 1967: A Lake Breeze on the Eastern Shore of Lake Michigan: Observations and Model. Journal of the Atmospheric Sciences, Volume 24, pp. 337-355.

Moroz, W. J. and E. W. Hewson, 1966: The Mesoscale Interaction of a Lake Breeze and Low Level Outflow from a Thunderstorm. Journal of Applied Meteorology, Volume 5, pp. 148-155.

Munn, R. E. and T. L. Richards, 1967: The Lake Breeze at Douglas Point, Ontario. Proceedings of the Tenth Conference on Great Lakes Research, International Association of Great Lakes Research, pp. 231-239.

Munn, R. E., M. S. Hirt, and B. F. Findlay, 1969: A Climatological Study of the Urban Temperature Anomaly in the Lakeshore Environment at Toronto. Journal of Applied Meteorology, Volume 8, pp. 411-422.

Neumann, J., 1951: Land Breezes and Nocturnal Thunderstorms. Journal of Meteorology, Volume 8, pp. 60-67.

Neumann, J., 1977: On t[illegible] Rotation Rate of the Direction of Sea and Land Breezes. Journal of the [illegible]mospheric Sciences, Volume 34, pp. 1913-1917.

REFERENCES (Cont'd)

Neumann, J. and Y. Mahrer, 1971: A Theoretical Study of the Land and Sea Breeze Circulation. Journal of the Atmospheric Sciences, Volume 28, pp. 532-542.

Neumann, J. and Y. Mahrer, 1974: A Theoretical Study of the Sea and Land Breezes of Circular Islands. Journal of the Atmospheric Sciences, Volume 31, pp. 2027-2039.

Nonhebel, G., 1971: Air Pollution Problems from Large Power Stations. Modern Steam Plant Practice Convention (#C61/71), Netherlands, pp. 1-14.

O'Brien, J. J. and R. D. Pillsbury, 1974: Notes and Correspondence - Rotary Wind Spectra in a Sea Breeze Regime. Journal of Applied Meteorology, Volume 13, pp. 820-825.

Ogawa, Y. and W. G. Hoydysh, 1977: Sea Breeze Effects on Diffusion: A Wind Tunnel Study of Fumigation and Plume Trapping. Proceedings of the Fourth International Clean Air Congress, Tokyo, Japan. The Japanese Union of the Air Pollution Prevention Associations.

Pack, D. H. and J. K. Angell, 1963: A Preliminary Study of Air Trajectories in the Los Angeles Basin as Derived from Tetroon Flights. Monthly Weather Review, Volume 91, No. 10-12, p. 583.*

Parmenter, F. C., 1976: Evidence of a Low-Level Jet Stream in the Western Gulf of Mexico. Proceedings of the Seventh Conference on Aerospace and Aeronautical Meteorology and Symposium on Remote Sensing, Melborne, Florida, pp. 312-317.

Parsons, C. L. and M. E. Williams, 1979: The Effect of the Sea Breeze Circulation on Surface Ozone Levels at Wallops, Virginia. Journal of Geophysical Research, Volume 84, Number C12, pp. 7863-7868.

Passarelli, R. E. and R. R. Braham, 1981: The Role of the Winter Land Breeze in the Formation of Great Lake Snowstorms. Bulletin of the American Meteorological Society, Volume 62, Number 4, April 1981, pp. 482-491.

Pearce, R. P., 1955: The Calculation of the Sea-Breeze Circulation in Terms of Differential Heating Across the Coastline. Quarterly Journal of the Royal Meteorological Society, Volume 81, p. 351.*

Pease, C. H., R. J. Stewart, and J. E. Overland, 1979: Report on FY-78 Numerical Modeling in the Strait of Juan de Fuca and Puget Sound. NOAA Technical Memorandum ERL MESA-38, Boulder, Colorado.

Petersen, E. W., 1971: Comments on "A Numerical Study of the Effect of a Coastal Irregularity on the Sea Breeze." Journal of Applied Meteorology, Volume 10, pp. 599-601.

Petterssen, S. and P. A. Calabrese, 1959: On Some Weather Influences Due to Warming of the Air by the Great Lakes in Winter. Journal of Meteorology, Volume 16, pp. 646-652.

Phillips, D. W., 1972: Modification of Surface Air over Lake Ontario in Winter. Monthl Weather Review, Volume 100, Number 9, pp. 662-670.

Pielke, R. A. 1974: A Three-Dimensional Numerical Model of the Sea Breezes over South Florida. Monthly Weather Review, Volume 102, pp. 115-139.

Pond, S., S. D. Smith, P. F. Hamblin, and R. W. Burling, 1966: Spectra of Velocity and Temperature Fluctuations in the Atmospheric Boundary Layer over the Sea. Journal of the Atmospheric Sciences, Volume 23, pp. 376-386.

Pond, S., E. W. Stewart, and R. W. Burling, 1963: Turbulence Spectra in the Wind over Waves. Journal of the Atmospheric Sciences, Volume 20, pp. 319-324.

Portelli, R. V., 1978: Shoreline Diffusion Experiments on the North Shore of Lake Erie. Presented at the 71st Annual Meeting of the Air Pollution Control Association, Houston, Texas, June 26-30.

Portelli, R. V., 1979: The Nanticoke Study: Experimental Investigation of Diffusion from Tall Stacks in a Shoreline Environment. Presented at the NATO-CCMS Conference, Rome, Italy.*

Prahm, L. P., H. S. Buch, and U. Thorp, 1974: Long Range Transport of Atmospheric Pollutants Over the Atlantic. Preprint, Symposium on Atmospheric Diffusion and Air Pollution, American Meteorological Society, Santa Barbara, pp. 190-195.*

Prophet, D. T., 1961: Survey of the Available Information Pertaining to the Transport and Diffusion of Airborne Material over Ocean and Shoreline Complexes, Aerosol Laboratory Technical Report No. 89, Stanford University, Stanford, California.

Rai, D., J. S. Touma, and Keith M. Parker, 1980: An Observational Study of Diffusion in Lake Shore Environment. Preprints, Conference on Coastal Meteorology, American Meteorological Society, pp. 16-21.

Rao, S. T. and P. J. Samson, 1976: A Note on the Sea Breeze Regime. Environmental Modeling and Simulation. U.S. Enviromental Protection Agency, Office of Research and Development and Office of Planning and Management.

Rappolt, T. J., 1981: Summary Report: Synopsis and Critique of SF_6 Tracer Gas Experiments Conducted by BLM and CARB in the Santa Barbara Channel. Energy Resources Company, Inc., LaJolla, California, 28 pp.

Rappolt, T. J., 1981: A Synopsis and Critique of SF_6 Tracer Gas Experiments Conducted by BLM in the Santa Barbara Channel. Energy Resources Company, Inc., LaJolla, California, 35 pp.

Raynor, G. S., 1978: Effects on Atmospheric Diffusion of Meteorological Processes in Coastal Zones. Air Quality Meteorology and Atmospheric Ozone, ASTM STP 653, pp. 199-212.

Raynor, G. S., R. M. Brown, and S. SethuRaman, 1976: A Comparison of Diffusion from a Small Island and a Nearby Ocean Site. Preprints of the Conference on Coastal Meteorology, Virginia Beach, Virginia. American Meteorological Society, Boston, Massachusetts.

Raynor, G. S., R. M. Brown, and S. SethuRaman, 1976: Experimental Data from Coastal Diffusion Tests. Brookhaven National Laboratories, Upton, New York, Report Number BNL-21998, 502 pp.

Raynor, G. S. and J. V. Hayes, 1980: Transport and Diffusion Climatology of the U.S. Atlantic and Gulf Coasts. Preprints of the Second Conference on Coastal Meteorology (Number 2.6), Los Angeles, California. American Meteorological Society, Boston, Massachusetts, pp. 30-33.

Raynor, G. S. and J. V. Hayes, 1976: A Study of the Transport and Diffusion Climatology of the U.S. East Coast. Preprints of the Conference on Coastal Meteorology, Virginia Beach, Virginia. American Meteorological Society, Boston, Massachusetts.

Raynor, G. S., P. Michael, R. M. Brown, and S. SethuRaman, 1975: Studies of Atmospheric Diffusion from a Nearshore Oceanic Site. Journal of Applied Meteorology, Volume 14, pp. 1080-1094.

Raynor, G. S., P. Michael, and S. SethuRaman, 1979: Recommendations for Meteorological Measurement Programs and Atmospheric Diffusion Prediction Methods for Use at Coastal Nuclear Reactor Sites. Report Number NUREG/CR-0936, BNL-NUREG-51045. Brookhaven National Laboratory, Upton, New York, 60 pp.

Record, F. A., R. N. Swanson, H. E. Cramer, and R. K. Dumbauld, 1970: Analysis of Lower Atmospheric Data for Diffusion Studies. GCA Corporation, Report Number TR-69-15N, 126 pp.

Richards, T. L., H. Dragert, and F. R. McIntyre, 1966: Influence of Atmospheric Stability and Over-Water Fetch on Winds over the Lower Great Lakes. Monthly Weather Review, Volume 94, Number 7, pp. 448-453.

Riehl, H., 1949: Florida Thunderstorms and Rainfall. Journal of Meteorology, Volume 6, pp. 289-290.

Rizzo, K. R. and W. A. Lyons, 1977: Acoustic Sounder Measurements of the Summer Mixing Depths in a Coastal Environment. Preprints of the Joint Conference on Applications of Air Pollution Meteorology, Salt Lake City, Utah. American Meteorological Society, Boston, Massachusetts.

Robinson, L. H., D. L. Eberly, and H. E. Cramer, 1965: Meteorology and Atmospheric Diffusion in the Vicinity of the Humboldt Bay Power Plant. Pacific Gas and Electric Company Report, Meteorological Office.

Runca, E., P. Melli, and P. Zannetti, 1976: Computation of Long-Term Average SO_2 Concentration in the Venetian Area. Applied Mathematical Modeling, Volume 1, pp. 9-15.

Sandberg, J. S., F. S. Duckworth, S. W. Grinnell, R. W. McMullen, F. X. Webster, W. A. Perkins, and P. A. Leighton, 1952: Stanford Quarterly Report 1856-3, April-May-June 1952, Studies in Aerosol Cloud Behavior. Stanford University Contract Number DA-18-064-CML-1856, Stanford, California, 101 pp.

Sandberg, J. S., F. S. Duckworth, S. W. Grinnell, R. W. McMullen, F. X. Webster, W. A. Perkins, and P. A. Leighton, 1952: Stanford Quarterly Report 1856-4, July-August-September 1952, Studies in Aerosol Cloud Behavior. Stanford University Contract Number DA-18-064-CML-1856, Stanford, California, 141 pp.

Sandberg, J. S., L. H. Kratzer, F. S. Duckworth, S. W. Grinnell, R. W. McMullen, F. X. Webster, W. A. Perkins, and P. A. Leighton, 1953: Stanford Quarterly Report 1856-6, January-February-March 1953, Studies in Aerosol Cloud Behavior. Stanford University Contract Number DA-18-064-CML-1856, Stanford, California, 71 pp.

Sandberg, J. S., W. J. Walker, R. H. Thuilier, 1970: Fluorescent Tracer Studies of Pollution Transport in the San Francisco Bay Area. Journal of the Air Pollution Control Association, Volume 20, pp. 593-598.

Schacher, G. E., C. W. Fairall, and K. L. Davidson, 1980: Atmospheric Marine Boundary Layer Mixing Rates in the California Coastal Region. Naval Postgraduate School for the California Air Resources Board, Report Number NPS-61-80-003, 115 pp.

Schacher, G. E., K. L. Davidson, C. A. Leonard, D. E. Spiel, and C. W. Fairall, 1981: Offshore Transport and Diffusion in the Los Angeles Bight-I, NPS Data Summary, Report Number NPS-61-81-004. Naval Postgraduate School, Monterey, California, 55 pp.

Schacher, G. E., K. L. Davidson, C. A. Leonard, D. E. Spiel, and C. W. Fairall, 1981: Offshore Transport and Diffusion in the Los Angeles Bight-II, NPS Data Summary, Report Number NPS-61-81-025. Naval Postgraduate School, Monterey, California, 109 pp.

Schmidt, F. H., 1947: An Elementary Theory of the Land- and Sea-Breeze Circulation. Journal of Meteorology, Volume 4, pp. 9-15.

Schroeder, M. J., M. A. Fosberg, O. P. Cramer, and C. A. O'Dell, 1967: Marine Air Inversion of the Pacific Coast: A Problem Analysis. Bulletin of the American Meteorological Society, Volume 48, Number 11, pp. 802-808.

Schultz, H. B., N. B. Akesson, and W. E. Yates, 1961: The Delayed "Sea Breezes" in the Sacramentio Valley and the Resulting Favorable Conditions for Application of Pesticides. Bulletin of the American Meteorological Society, Volume 42, Number 10, pp. 679-687.

Septoff, M., L. J. Brunton, and L. H. Teuscher, 1977: Results of an Offshore Dispersion Program Conducted at the San Onofre Nuclear Generating Station. Preprints of the Joint Conference on Applications of Air Pollution Meteorology, Salt Lake City, Utah. American Meteorological Society, Boston, Massachusetts.

SethuRaman, S., 1979: Structure of Turbulence Over Water During High Winds. Journal of Applied Meteorology, Volume 18, pp. 325-328.*

SethuRaman, S. and G. S. Raynor, 1979: Effects of Changes in Upwind Surface Characteristics on Mean Wind Speed and Turbulence near a Coastline. Fourth Symposium on Turbulence, Diffusion, and Air Pollution, American Meteorological Society, pp. 48-51.

SethuRaman, S. and G. S. Raynor, 1980: Comparison of Mean Wind Speeds and Turbulence at a Coastal Site and an Offshore Location. Journal of Applied Meteorology, Volume 19, pp. 15-21.*

Shearer, D. L., 1981: TRC Project Note Number 76-EPRI Plume Model Validation Project. TRC Project Number 1289-2502-C.4 Available from EPRI.

Shearer, D. L. and D. H. Minott, 1976: Applicability of U.S. Army Tracer Test Data to Model Validation Needs of ERDA. TRC Project Number 72607, Report COO-2851-1, Wethersfield, Connecticut.

Shearer, D. L. and D. H. Minott, 1977: Development of Vertical Dispersion Coefficients for Rolling Terrain Environments. Preprints of the Joint Conference on Applications on Air Pollution Meteorology, Salt Lake City, Utah. American Meteorological Society, Boston, Massachusetts.

Shearer, D. L., D. H. Minott, and G. R. Hilst, 1977: Development of Vertical Dispersion Coefficients for Rolling Terrain Environments. TRC Project Number 72607, Report COO-4026-1, Wethersfield, Connecticut.

Sheih, C. M., 1981: Pasquill-Tayler Dispersion Parameters Over Water Near Shore. Atmospheric Environment, Volume 15, pp. 101-105.*

Sheih, C. M., P. Frenzen, and R. L. Hart, 1979: Atmospheric Dispersion Over Water Near Shoreline Environments. Preprints of the Fourth Symposium on Turbulence, Diffusion, and Air Pollution, (Number 10.4), Reno, Nevada. American Meteorological Society, Boston, Massachusetts.

Sheih, C. M., P. Frenzen, and R. L. Hart, 1980: Atmospheric Dispersion Over Water Near Shoreline Environments. Journal of Applied Meteorology, Volume 19, pp. 497-504.

Sheih, C. M., P. Frenzen, and R. L. Hart, 1980: Measurements of Lagrangian Atmospheric Dispersion Statistics Over Open Water. Journal of Applied Meteorology, Volume 19, Number 5, pp. 497-504.

Shinn, J. H., 1969: Analysis of Wind Data from a South Carolina Coastal Forest. U.S. Army Electronics Command Atmospheric Laboratory, Report Number ECOM-6036, Forst Huachuca, Arizona, 34 pp.

Showalter, A. K., 1949: Land and Sea Breezes. Journal of Meteorology, Volume 6, pp. 365-366.

Sivertsen, B., 1973: Meteorolgical Data from Troms, North Norway, 1969-1970. Norwegian Institute for Air Research, Job Number 48-VM/138, Kjeller, Norway, 126 pp.

Slade, D. H., 1962: Atmospheric Diffusion Over Chesapeake Bay, Monthly Weather Review, Volume 90, pp. 217-224.*

Slade, D. H., 1968: Meteorology and Atomic Energy. Prepared for the United States Atomic Energy Commission, 445 pp.

Smith, T. B., 1964: Micrometeorological Investigation of Naval Missile Facility Point. Arguello, California, MRI 64 FR-167, Volumes I and II, Final Report, Contract Number (123)-(61756) 32885A(PMR), Meteorology Research, Inc., Altadena, California.

Smith, T. B. and K. M. Beesmer, 1967: Bolsa Island Meteorological Investigation. Meteorology Research, Inc., Report Number MRI67-FR-650, 57 pp.

Smith, T. B. and B. L. Niemann, 1969: Shoreline Diffusion Program. Oceanside California, Meteorology Research, Inc., Report Number MR169 FR-860, 3 volumes.

Smith, T. B. and M. A. Wolf, 1963: Vertical Diffusion from an Elevated Line Source over a Variety of Terrains. Part A - Final Report to Dugway Proving Ground, Meteorology Research, Inc., Contract Number DA-42-007-CML-545, Report Number MR163-FR-71, 40 pp.

Staley, D. O., 1957: The Low-Level Sea Breeze of Northwest Washington. Journal of Meteorology, Volume 14, pp. 458-470.

Stearn, M. E., 1954: Theory of the Mean Atmospheric Perturbations Produced by Differential Surface Heating. Journal of Meteorology, Volume 20, pp. 495-502.

Tingle, A. G. and J. R. Bjorklund, 1973: Simulation of Mesoscale Winds over Complex Terrain using a Three-Layer Shallow-Fluid Analogy. H. E. Cramer Company for the Deseret Test Center, Report Number TR-73-401-01, 101 pp.

Tingle, A. G. and D. A. Dieterle, 1976: A Numerical Study of Pollutant Distributions in Sea Breeze Circulations. Preprints of the Conference on Coastal Meteorology, Virginia Beach, Virginia. American Meteorological Society, Boston, Massachusetts.

Turner, D. B., 1979: Atmospheric Dispersion Modeling-A Critical Review. Journal of the Air Pollution Control Association, Volume 29, Number 5, pp. 502-519.

Van der Hoven, I., 1967: Atmospheric Transport and Diffusion at Coastal Sites. Nuclear Safety, Volume 8, Number 5, pp. 490-499.

Vaughan, L. M., 1967: Matagorda Deposition Trials Diffusion and Deposition of Large Particles with Fall Velocities in the Range of 10 to 50 cm/sec. Metronics Associates, Inc., Technical Report Number 140, Palo Alto, California, 51 pp.

Vaughan, L. M., 1966: Particulate Diffusion, 1965 Victoria Diffusion Trials. Metronics Associates, Inc., Technical Report Number 126, Palo Alto, California, 33 pp.

Venkatram, A., 1977: A Model of Internal Boundary Layer Development. Boundary-Layer Meteorology, Volume 11, p. 419.

Venkatram, A., 1977: Internal Boundary Layer Development and Fumigation. Atmospheric Environment, Volume 11, p. 479.

Volkov, Y. A., V. P. Kukharets, and L. R. Tsvang, 1968: Turbulence in the Atmospheric Boundary Layer above Steppe and Sea Surfaces. Atmospheric and Oceanic Physics, Volume 4, Number 10, pp. 1026-1041. Translated by A. B. Kaufman.

Walsh, J. E., 1974: Sea Breeze Theory and Applications. Journal of the Atmospheric Sciences, Volume 31, pp. 2012-2026.

Walther, E. G., 1976: Predicting the Transport of Air Pollutants from the Navajo and Kaiparowits Generating Stations into Lake Powell. Preprints of the Third Symposium on Atmospheric Turbulence, Diffusion, and Air Quality, Raleigh, North Carolina. American Meteorological Society, Boston, Massachusetts.

Warner, J. and J. W. Telford, 1963: Some Patterns of Convection in the Lower Atmosphere. Journal of the Atmospheric Sciences, Volume 20, pp. 313-318.

Wexler, R., 1946: Theory and Observations of Land and Sea Breezes. Bulletin of the American Meteorological Society, Volume 27, pp. 272-287.

Wilhelmsen, R., 1981: Southern California Air Quality Model Validation Study. Bureau of Land Management, Department of Interior, Final Report, Los Angeles, California.

Wiseman, Jr., W. J. and A. D. Short, 1976: Mesoscale Thermal Variations Along the Arctic North Slope. Assessment of the Arctic Marine Environment: Selected Topics, Institute of Marine Science, University of Alaska, Fairbanks, pp. 229-240.

Wolfe, Jr., E. K. and W. W. Dorrell, 1956: Comparison of Simulant Decay Rates in Field Tests (U). Chemical Corps Research and Development Command Biological Warfare Laboratories Assessment Division, Special Report Number 273, Fredrick, Maryland, 96 pp.

Yu, T. W. and N. K. Wagner, 1970: Diurnal Variation of Onshore Wind Speed Near a Coastline. Journal of Applied Meteorology, Volume 9, pp. 760-766.

NRC FORM 335 (7 77) U.S. NUCLEAR REGULATORY COMMISSION **BIBLIOGRAPHIC DATA SHEET**	1. REPORT NUMBER *(Assigned by DDC)* NUREG/CR-2754 PNL-4292
4. TITLE AND SUBTITLE *(Add Volume No., if appropriate)* Critical Review of Studies on Atmospheric Dispersion in Coastal Regions	2. *(Leave blank)*
	3. RECIPIENT'S ACCESSION NO.
7. AUTHOR(S) Donald L. Shearer and Robert J. Kaleel	5. DATE REPORT COMPLETED MONTH June YEAR 1982
9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)* TRC Environmental Consultants, Inc. 8775 East Orchard Road Suite 816 Englewood, CO 80111 for Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352	DATE REPORT ISSUED MONTH September YEAR 1982
	6. *(Leave blank)*
	8. *(Leave blank)*
12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)* Division of Health, Siting and Waste Management Office of Nuclear Regulatory Research U. S. Nuclear Regulatory Commission Washington, D. C. 20555	10. PROJECT/TASK/WORK UNIT NO.
	11. CONTRACT NO. FIN B2384
13. TYPE OF REPORT technical	PERIOD COVERED *(Inclusive dates)* June 1981 - June 1982
15. SUPPLEMENTARY NOTES	14. *(Leave blank)*

16. ABSTRACT *(200 words or less)*

This report was prepared in an attempt to assess the current information and data bases that exist based on studies conducted in coastal regions. Reports covering research and meteorological measurements conducted for industrial purposes, utility needs, military objectives, and academic studies have been obtained and critically reviewed. The report provides an interpretation of the extent of existing usable information, an indication of the potential for tailoring existing research toward present NRC information needs, and recommendations for several follow-up studies which could provide valuable additional information through reanalysis of the data. Emphasis was placed on the identification and acquisition of data from atmospheric tracer studies conducted in coastal regions. A total of 225 references were identified which deal with the coastal atmosphere, including meteorological and tracer measurement programs, theoretical descriptions of the relevant processes, and dispersion models.

17. KEY WORDS AND DOCUMENT ANALYSIS	17a. DESCRIPTORS
17b. IDENTIFIERS/OPEN-ENDED TERMS	

18. AVAILABILITY STATEMENT	19. SECURITY CLASS *(This report)*	21. NO. OF PAGES
Unlimited	unclassified	
	20. SECURITY CLASS *(This page)* unclassified	22. PRICE $

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

FOURTH CLASS MAIL
POSTAGE & FEES PAID
USNRC
WASH. D. C.
PERMIT No. G 67

120555078877 1 ANRB
US NRC
ADM DIV OF TIDC
POLICY & PUBLICATIONS MGT BR
PDR NUREG COPY
LA 212
WASHINGTON DC 20555