Intergovernmental Oceanographic Commission

Workshop Report No. 85

IOC Workshop on Coastal Oceanography in Relation to Integrated Coastal Zone Management

Kona, Hawaii, 1-5 June 1992

UNESCO

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5	IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources; Kingston, Jamaica, 17-22 February 1975.	E (out of stock) S
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7	Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/UNESCO/EAC; Nairobi, Kenya, 25 March-2 April 1976.	E, F, S, R
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13	Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area; Port of Spain, Trinidad, 16-18 January 1978.	E, S
14	IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas; Abidjan, Côte d'Ivoire, 2-9 May 1978.	E, F
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17 Suppl.	Papers submitted to the Joint *IOC/WMO Seminar on Oceanographic* Products and the IGOSS Data Processing and Services System; Moscow, 2-6 April 1979.	E
18	IOC/UNESCO Workshop on Syllabus for Training Marine Technicians; Miami, 22-26 May 1978 (UNESCO reports in marine sciences, No. 4 published by the Division of Marine Sciences, UNESCO).	E (out of stock), F, S (out of stock), R
19	IOC Workshop on Marine Science Syllabus for Secondary Schools; Llantwit Major, Wales, U.K., 5-9 June 1978 (UNESCO reports in marine sciences, No. 5, published by the Division of Marine Sciences, UNESCO).	E (out of stock), E, S, R, Ar
20	Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources; Bandung, Indonesia, 17-21 October 1978.	E
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22	Third IOC/WMO Workshop on Marine Pollution Monitoring; New Delhi, 11-15 February 1980.	E, F, S, R
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26	IOC Workshop on Coastal Area Management in the Caribbean Region; Mexico City, 24 September-5 October 1979.	E, S
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30	International Workshop on Marine Pollution in the South-West Atlantic; Montevideo, 10-14 November 1980.	E (out of stock) S
31	Third International Workshop on Marine Geoscience; Heidelberg, 19-24 July 1982.	E, F, S
32	UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime; Paris, 27 September-1 October 1982.	E, F, S
32 Suppl.	Papers submitted to the UNU/IOC/UNESCO Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime; Paris, 27 September-1 October 1982.	E
33	Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR); Halifax, 26-30 September 1963.	E
34	IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa); Tenerife, 12-17 December 1963.	E, F, S
35	CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific; Suva, Fiji, 3-7 October 1983.	E
36	IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, 28 May-2 June 1984.	E
36 Suppl.	Papers submitted to the IOC/FAO Workshop on the Improved Uses of Research Vessels; Lisbon, 28 May-2 June 1984.	E
37	IOC/UNESCO Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs; Colombo, 8-13 July 1985.	E
38	IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region; Basrah, Iraq, 8-12 January 1984.	E
39	CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific; Suva, Fiji, 24-29 September 1985.	E
40	IOC Workshop on the Technical Aspects of Tsunami Analysis, Prediction and Communications; Sidney, B.C., Canada, 29-31 July 1985.	E
40 Suppl.	IOC Workshop on the Technical Aspects of Tsunami Analysis, Prediction and Communications, *Submitted Papers;* Sidney, B.C., Canada, 29-31 July 1985.	E
41	First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2); Dakar, Senegal, 28 October-1 November 1985.	E
43	IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean; Venice, Italy, 23-25 October 1985.	E
44	IOC-FAO Workshop on Recruitment in Tropical Coastal Demersal Communities; Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986.	E (out of stock) S
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45	IOCARIBE Workshop on Physical Oceanography and Climate; Cartagena, Colombia, 19-22 August 1986.	E
46	Reunión de Trabajo para Desarrollo del Programa "Ciencia Oceánica en Relación a los Recursos No Vivos en la Región del Atlántico *Sud-occidental*"; Porto Alegre, Brazil, 7-11 de abril de 1986.	S
47	IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence; Townsville, 1-6 December 1966.	E
48	IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on 'Ocean Science in Relation to Non-Living Resources (OSNLR)'; Havana, Cuba, 4-7 December 1986.	E, S
49	AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on 'El Niño'; Guayaquil, Ecuador, 27-31 October 1986.	E
50	CCALR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR); Paris, France, 2-6 June 1987.	E
51	CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations; Lae, Papua-New Guinea, 1-8 October 1987.	E

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FOREWORD

During its decade old existence in the Pacific Region, Pacific Congresses on Marine Science and Technology (PACON) remained concerned with the marine science, engineering and policy issues of the Pacific. At this fifth Congress, PACON 92, held in Kona, Hawaii, 1-5 June 1992, two special workshops, namely Pacific Basin Marine Science Organizations, and IOC (Intergovernmental Oceanographic Commission) Workshop on Coastal Oceanography in Relation to Integrated Coastal Zone Management, were successfully conducted. This report relates to the IOC Workshop for which support was provided by Intergovernmental Oceanographic Commission. PACON International wishes to thank the IOC for funding this workshop and Dr. Gunnar Kullenberg for his support in initiating this action at PACON 92, and hopes that IOC will continue such workshops at future PACON Conferences.

SUMMARY OF THE WORKSHOP

This special workshop session discussed the positive and negative relationships which exist between coastal ocean science and its use in furthering coastal zone management purposes. It was brought out that many nations during the coming decade will begin to develop and implement coastal zone management programmes, particularly due to recommendations from the Intergovernmental Panel on Climate Change, the Intergovernmental Negotiating Committee for A Framework Convention on Climate Change, and the United Nations Conference on Environment and Development; and the fact that there is a clear need for integrated decision making which addresses complex coastal problems and issues. There will be a great demand for oceanographic data and information as coastal states develop their programmes while conducting inventories, developing data bases, and other data intensive activities.

During coastal management programme implementation, there is a need for ocean science to provide answers to complex resource conflicts. Presentations were made which showed the value of coastal oceanography to address issues such as water quality and fishery management, measures to reduce coastal erosion, and the siting of facilities which affect coastal waters. The panel looked into the importance of coral reef ecosystems, how they are affected by anthropogenic inshore influences, and how they serve as a barometer of the health of coastal waters and climate change such as sea level rise. The utility of monitoring their health and conducting retrospective analysis based on information that can be extracted from samples was demonstrated.

Panel members also discussed the difficulties coastal managers have with oceanographic data and how to use it, its timeliness,etc. It was pointed out that in many cases, coastal zone management decisions are not based on science, either because it is not available, because of political influences, or that the managers do not have the scientific background to bring the science and management needs together. One of the new measures to look forward to was demonstrated by making information more useful to managers by use of PC's and relational data bases reducing vast amounts of information to graphics and charts. Data on currents, bathymetry, water quality, etc., can all be manipulated on simple, low-cost PC systems.

Finally, panel members and the audience discussed some of the issues the IOC may want to consider in the future as it seeks to lend its support for the effort of developing integrated coastal resource management that lies ahead for the international community.

COASTAL OCEANOGRAPHY IN RELATION TO INTEGRATED COASTAL ZONE MANAGEMENT

by Ben Mieremet
International Affairs Specialist
National Ocean Service
National Oceanic and Atmospheric Administration

ABSTRACT

Ever since the environmental movement began in the late 1960's and early 1970's, the need to provide better scientific information to satisfy the demands of integrated resource management decision making has continued to increase in scope and importance. The demands of a more enlightened public, as well as the courts, to use science and improved technology to minimize environmental damage caused by development activities now places great expectations on scientists, resource managers, administrators and politicians. Scientific knowledge, or the lack of it, can make or break proposed development projects and coastal activities. Because most of these activities affect coastal waters, coastal zone management needs data and information that can be provided by coastal oceanography. The two must work together if the goal of sustainable development is to be achieved.

The Coastal Zone

The coastal zone includes both the area of land subject to marine influence and the area of sea subject to land and land-use influence; although the outer boundary limits of both may be set for administrative purposes, which may or may not fully reflect the interaction between the land/water interface. Within the coastal zone we find major population and transportation centers, important agricultural activities, economically significant industries such as fishing and tourism, and places to site important structures such as energy and sewage treatment facilities.

The richness and diversity of the natural resources found within the coastal zone are generally well known. Coastal areas and habitats (mangrove swamps, estuaries, wetlands, seagrass beds, coral reefs, deltas, dunes, etc.) are biologically productive but fragile and susceptible to degradation through human activities as well as natural events. While the coastal zone already supports the majority of the world's population, because of its economic and cultural importance, coastal areas will be expected to absorb most of the future population increase. Already heavily stressed in places, this additional population load will increase development-related impacts leading to increased human-induced pollution, habitat loss with concomitant loss of fish and wildlife species, coastal erosion, saltwater intrusion, and increasing vulnerability to coastal hazards including sea level rise associated impacts.

Integrated Coastal Zone Management

The problems associated with rapid coastal growth, depletion and destruction of fragile resources, and the strategic importance of coastal zone environments for coastal nations has forced many to seek solutions that would allow for the continued utilization of coastal resources for economic development without causing irreparable harm to the resources. Selected forms of coastal zone management (to include viewing coastal resources and resource uses comprehensively rather than as singular resource issues, and to integrate the many conflicting uses and needs into a balanced decision making process), have become the means most often employed by nations seeking these solutions.

While difficult to define because of the many variations employed, the integrated coastal zone management process has be defined as:

a dynamic process in which a coordinated strategy is developed and implemented for the allocation of environmental, socio-cultural, and institutional resources to achieve the conservation and sustainable multiple use of the coastal zone.[1]

The overall goal of coastal zone management (CZM) is to protect, preserve and restore natural resources where possible and necessary; and to encourage growth and development through sound planning which uses an interdisciplinary, integrated look at the environmental consequences of activities and projects; and, weighing and evaluating those consequences in accordance with adopted policies.

Currently, the United States is celebrating 20 years of CZM experience with a Federal, state and local government partnership. While some States such as California (through *The San Francisco Bay Conservation and Dĕvelopment Commission* which was established in 1965) and Washington (through passage of *The Shorelines Management Act of 1970*) began their pioneering efforts at CZM early on, it wasn't until the passage of the *Federal Coastal Zone Management of 1972*[2] (CZMA) that substantial sums of funds were made available to the coastal states to both develop and implement their programs. The two phases of program development and program implementation are important to remember when considering how coastal oceanography relates to CZM and are briefly described later in this report. Twenty-nine of 35 coastal states and territories are implementing CZM programs and 5 more are currently in the process of developing programs under the voluntary program supported by the CZMA.

Twenty years experience and several evolutionary revisions to the CZMA (showing that CZM is indeed a "dynamic" process) has provided both the management and the scientific community with some insights into the need for data to satisfy the demands of management. Fortunately, other countries have also started their development of CZM, and as many 44 out of 148 coastal nations and semi-sovereign states have been identified as having some form of CZM.[3] However, this is only a beginning, leading several organizations of the international community to encourage all coastal nations to begin the CZM development/implementation process.

International Coastal Zone Management Initiatives

During the last three years, several important initiatives to encourage the use of CZM to achieve sustainable development and to plan for potentially serious long-term natural hazard impacts such as may be anticipated from accelerated sea level rise have provided additional impetus for the development of CZM.

In 1990, the Coastal Zone Management Subgroup of Working Group III-Response Strategies of the Intergovernmental Panel on Climate Change (IPCC) came out with a recommendation in the First Assessment Report on Global Climate Change that: "By the year 2000, *coastal nations should implement comprehensive coastal zone management plans.*"[4] Specifically looking at the issue of how coastal nations may adapt or respond to future accelerated sea level rise scenarios, it was quickly recognized that the process of CZM program building needed to begin as soon as possible if both the human and natural resource costs associated with impacts and response options are to be kept to least cost. Additional recommendations included the need to strengthen research at understanding and predicting changes in sea level and other impacts of global climate change; encourage the development of a global ocean observing system; and, to support the widespread dissemination of data and information on sea level change. It was noted that the sharing of this type of information for developing countries was critically important for preparation of CZM plans.

The Intergovernmental Negotiating Committee For a Framework Convention On Global Climate Change has echoed this call to action for much the same reason. Article 4, para 1.(e) calls for commitments to: " Cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, ..."[5]

The United Nations Conference on Environment and Development (UNCED) through AGENDA 21 also encourages coastal nations to utilize the full panoply of tools of CZM to deal with all the issues besetting the coastal zone including impacts of global climate change. Some of the things called for under Chapter 17 of AGENDA 21 are listed in Table 1. Much of that called for (impact assessments, systematic observations, information management systems, preparing profiles, etc.) will require the information derived by coastal oceanography and likewise, the coastal oceanography community may need to look at some new priorities encouraged by AGENDA 21 at UNCED.

Agenda 21 - Chapter 17 - Oceans

Encourages coastal states to:

1. develop and implement integrated coastal management programs;
2. promote the development and application of environmental accounting methods that reflect changes in value resulting from uses of coastal areas (pollution, erosion, loss of habitat);
3. prepare coastal profiles identifying critical areas, including eroded zones, physical processes, development patterns, user conflicts;
4. use environmental impact assessment, systematic observations and follow-up of major projects including the systematic incorporation of results in decision-making;
5. develop contigency plans for human induced and natural disasters (oil spills, sea level rise);
6. conduct periodic assessment of the impacts of external factors and phenomena to ensure that the objects of integrated CZM are met;
7. ensure that information for management purposes should receive priority support in view of the intensity and magnitude of the changes occurring in the coastal and marine areas; and
8. cooperate in the development of necessary coastal systematic observation, research and information management systems.

Coastal Oceanography

In order to make informed decisions about complex coastal management issues which require trade-offs, mitigation measures, and sometimes denial of projects, coastal managers need to have a substantial base of information from many different disciplines of science and engineering. Oceanographic information, but more specifically coastal oceanography that focuses the physical, biological, chemical, meteorological and fisheries elements of oceanography to the nearshore area, becomes crucial to comprehensive and integrated decision making. The impacts of excessive nutrient loads and toxins into estuaries; coastal currents and oil spill trajectories; the loss of wetlands and seagrass beds to the quantity of fishery resources available for harvest; monitoring the health of coastal ecosystems and predicting future scenarios given current and projected conditions; are but a few of the many types of issues needing further information to be included in the often complicated web of integrated decision making.

Take for example the siting of a marina in a bay or inlet. This area may also include choice shellfish beds used by commercial fisherman. The marina is enclosed and circulation patterns change along with increased pollution. The marina is a success and the demand increases for additional boat slips and a 2nd and 3rd marina apply for permits to build. Soon the shellfish beds must be closed due to contamination which adversely impacts the commercial fisherman. What isthe cause of the pollution and can it be attributed to the marina (1, 2, or 3), an upstream source or a "red tide" event? Which future marina permit must be denied because the water body can no longer accept the pollution loads or the changes in circulation patters? Is mitigation possible? To answer these types of questions, coastal decision makers definitely need the data and information to be provided by the men and women in boats and hip boots with vials and flasks and computer models. Absent scientific input on which to base a decision, a decision will be made "in the dark" which may lead to court challenges or a further worsening of the environmental situation.

One of the problems associated with CZM decision making relates to the nature of the decisions to be made. National and/or state issues may relate to offshore energy facility siting, fisheries management, protection of biodiversity; regional or multi-state issues may involve a shared water body such as an estuary in which nutrient loads enter the water body from multiple sources throughout the shared watershed; and local level decisions may involve the cumulative impacts of numerous pier structures in a major new housing development that may soon overwhelm the carrying capacity of a small river to support other functional uses. In each case, the type and amount of data will differ, as will the costs.

There is an illustrative example in the United States which stresses the new found importance of scientific information to CZM decision making. At the national level, Outer Continental Shelf (OCS) oil and gas lease sales have become very controversial, especially in the States of Florida and California. Strong opposition from coastal residents and Congressional moratoria on leasing vast areas of the ocean persuaded President Bush to establish a special OCS Leasing and Development Task Force to look at three upcoming lease sales during 1990. The sales were for the northern and southern coast of California and southwestern Florida. A great deal of information was available through the studies and impact statements prepared by the Department of the Interior's Mineral Management Service. The Task Force requested the service of the distinguished National Academy of Sciences/National Research Council to review the information that was available for decision making. After a special committee reviewed the information, they released the report: "The Adequacy of Environmental Information For Outer Continental Shelf Oil and Gas Decisions: Florida and California."[6] Upon reviewing the information for completeness and scientific quality, they found the information to be inadequate in one respect or another for each of the three lease sale areas. In each case, they looked at the physical oceanographic information, the ecologic and socioeconomic information.

Lease Sale Area	Physical Oceanographic	Ecologic	Socioeconomic
Southwestern Florida	Marginal	Inadequate	Inadequate
Northern California	Adequate	Adequate	Inadequate
Souther California	Inadequate	Adequate	Doubtful

"Scientists Warn of Lack of Data on Offshore Drilling", "Report Dims Prospects for Offshore Oil", and "Scientists: More data needed on offshore drilling" were a few of the newspaper headlines at the time. While not the only reason, the lack of adequate scientific data played a large role in President Bush canceling the lease sales. Thus we can see not only a greater reliance on, but even higher expectations for the use of scientific information in decision making. Since the collection of scientific information is an expensive undertaking, it has great implications for future decision making placing as much a burden on the scientific community as well as the management community.

Some Viewpoints of Coastal Managers Regarding Data Needs

Since 1989, the National Oceanic and Atmospheric Administration (NOAA) has attempted to ensure that more data and information conducted by its offices would be useful to managers through a "Science for Decision Making" and "Science for Solutions" program. After nearly 20 years of experience, coastal managers in the United States were brought together through several workshops to identify what they consider the future data needs and priorities would be so NOAA could consider how one of their constituent groups could be better served. An abbreviated listing of the priorities identified will not only highlight the need for coastal oceanographic information but also how certain needs have cropped up over the years during implementation. For example, during the early stages of CZM implementation, the concern over secondary and cumulative impacts was not a priority concern. After the CZM process has established itself, and particularly in rapid growth areas, there is a recognition that the "carrying capacity" of a land and/or water ecosystem may become compromised. Once again, sound planning and regulatory management will need the data to identify when a system is healthy or being severely degraded.

Some of the issues listed by workshop participants include:

- o There is a great need for bathymetric data, particularly near-shore (estuaries and bays).
- o The scale of data/information must be larger as the managers interest is usually in smaller systems (i.e., scale of 1:2,000 vs. 1:24 or 48,000).
- o Tools to address cumulative impacts (levels of stress on systems) is often a first priority issue as well as wetland mapping.
- o Functional values of wetlands are not as important as evaluating mitigation and restoration techniques.
- o There is a need for the assessment, synthesis, evaluation and distribution of existing data and the need to put it in "layman" terms.
- o There needs to be an ongoing dialogue between managers and researchers.

- o Research must be designed with an eye towards transferability.

- o Many states are beginning to develop and use Geographic Information Systems (GIS), including offshore elements such as sediments, fisheries, marine birds, etc., and need the information to go into those systems.

Workshop Issues and Questions

There were a number of issues and questions brought up by a workshop that seek to describe the relationship between coastal oceanography and coastal zone management or science and management.

Why is coastal oceanography important to coastal zone management?
The answer is clear and simple on its face but the clarity can easily get lost in the realities of real world problems. Wise management decisions regarding onshore or offshore activities should be based on a foundation of adequate data and information given the resources to be utilized or that are at risk. Knowledge of resources (i.e., chemical, biological and physical properties) and the resultant interaction with human activities is fundamental to achieving the goal of sustainable development. This is one of the major purposes of conducting environmental assessments and presenting decision makers with an array of alternatives and their consequences. However, many decisions are made in the absence of adequate data because the data is not available and may take too long to obtain, is too costly to obtain, or may be beyond the scope of current capabilities (e.g.,understanding cumulative impact limits) thereby making the information tentative, at best.

What role should coastal oceanography play in CZM program development?
When coastal states first begin to develop a CZM program (usually a 3-5 year process), there is a need for a great deal of data and information on coastal resources on a strategic scale (wetlands and other resource inventories, water quality, coastal hazards including erosion and inundation zones, etc.). This data is necessary in understanding the problems and issues that need to be addressed by the program and what types of policies are required to provide solutions. Coastal atlases are often produced showing onshore/offshore resources in order to identify what resources may be affected by future development. Thus the work is usually one of collecting and using existing information, or conducting short-term surveys to collect additional information through universities, other agencies, or consulting firms as CZM agencies usually do not have the personnel or authority to conduct oceanographic work. While the information may be useful for developing plans and policies, it is usually not used for making decision on specific projects.

What role should coastal oceanography play in CZM program implementation?
After a CZM program begins its implementation phase through planning and regulatory management, managers require information on which to base decisions on specific activities and projects. The siting of energy and transportation facilities, housing and other coastal developments soon brings home the realization that data and information must be more specific and its purposes more direct to the issues. Cause and effect, monitoring and predictive tools and infor-

mation become more important. Can impacts be minimized and mitigated, what will be the secondary and cumulative impacts of issuing multiple permits in this area? Most often the managers are forced with being reactive to development projects; and needed data, if it is not provided by a project proponent, must be obtained through other means. This is often where the conflict comes in between the science of coastal oceanography which may require data streams over long periods before analytical assessments or predictions can be made, and the short-term requirements of CZM.

Should CZM support long-term (2-5 or more years) coastal oceanographic research activities? While the answer is a clear "yes" because of the nature of many of the decisions that need to be made (e.g., identifying the extent and nature of coastal currents and developing oil spill trajectory models prior to making decisions on off-shore oil and gas leasing may take several years to complete), experience shows that CZM has problems supporting long-term research because budgets are usually developed for an annual appropriation with results required annually. This experience may not be unique to the United States under the CZMA. Consequently, CZM organizations are usually not capable of supporting research institutions or agencies over long periods of time and must rely on the proponents of agency actions or other outside sources to fund such research. Consequently, CZM managers look for short-term solutions from research that may need to span several years. Naturally, CZM instituted at a national level may be more capable of supporting long-term research to develop baseline data, etc. through better funding and coordination with other institutions, than CZM instituted at the local level.

What future initiatives can the IOC take to ensure that coastal oceanographic data and information can be used by emerging CZM programs in developing nations?
This question should not be limited to developing nations but all nations participating in CZM. Three areas, at a minimum, should be considered during the years to come if the IOC has not already done so. They include: 1) the need to identify priority research needs so that international resources (financial or otherwise) may be focused on research that will serve the international community at-large; 2) serve as a focal point for coastal oceanographic science and information, or participate with other international organizations, to further the goals of technology transfer (e.g., what is the state-of-the-art in predicting nutrient over-enrichment related events and theirconsequences or related computer modelling experiences) and education (through publications and workshops); and, 3) to serve as a warning on the more regional and global issues that individual states may not be aware of but which may benefit their management efforts (e.g., global warming trends affecting coral reefs and coastal aquatic vegetation) through long-term observation and monitoring conducted by IOC member or participating states.

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Management of Water Quality and Salmon Fisheries in a Vancouver Island Fjord

by

D. Stucchi

Alberni Inlet, located on the southwestern coast of Vancouver Island, B.C. (Fig. 1), has many of the characteristics typical of a fjord. It is a long (70 km), narrow (2 to 3 km), and steep-sided coastal feature. It has several sills that define two main basins; a smaller, 15 km, long inner basin of maximum depth 130 m, with a 40 m sill separating it from the larger (45 km), and deeper (300 m) outer basin. The outer basin connects with the open Pacific Ocean through Barkley Sound — a broad, deep 100 m sill region. At the head of Alberni Inlet, the Somass River provides most of the freshwater discharge to the fjord. The substantial amount of freshwater discharged by the Somass River creates a two layer structure in the fjord: a thin 2 to 4 m thick brackish water surface layer; and a more saline, thicker lower layer. The character of this vertical stratification varies considerably as the amount of freshwater discharge changes.

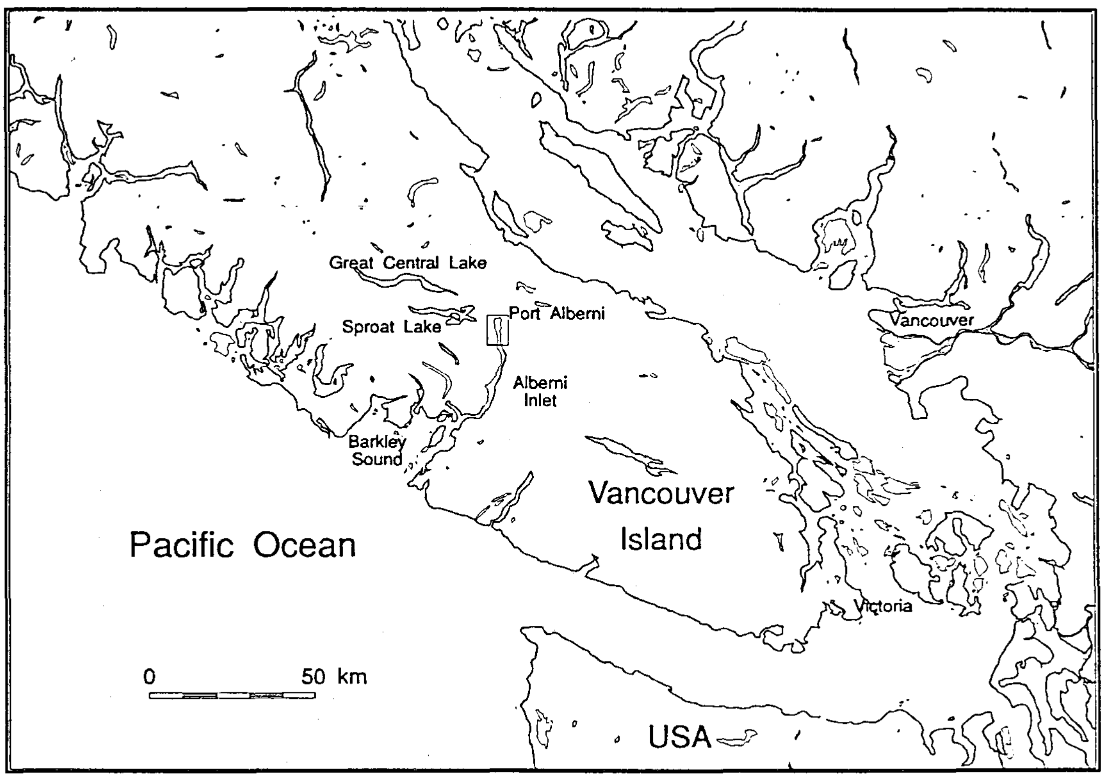

Figure 1. Site map of Vancouver Island showing Alberni Inlet and the specific study area (boxed).

Alberni Inlet and the surrounding areas are rich in natural resources and there are multiple users of these resources each making different demands on the waters of the inlet. The fishery and forestry sectors are the principal users of the inlet though recreational usage is increasing.

The numerous tributary streams, lakes and waters of Alberni Inlet support a valuable fishery resource. The waters of the inlet provide a rearing habitat for the fisheries resource and a migratory path for salmonids on their way to and from their natal streams and lakes. In economic terms the fishery is worth about $25 million annually and is based in large part on the 5 species of Pacific salmon which this region supports. Particularly valuable as a commercial fishery, are the Sproat and Great Central Lake sockeye salmon (*Oncorhynchus nerka*) stocks (Waldichuk 1987). Other components of the fishery are an Indian food fishery, sports or recreational fishery, and aquaculture operations in the fjord.

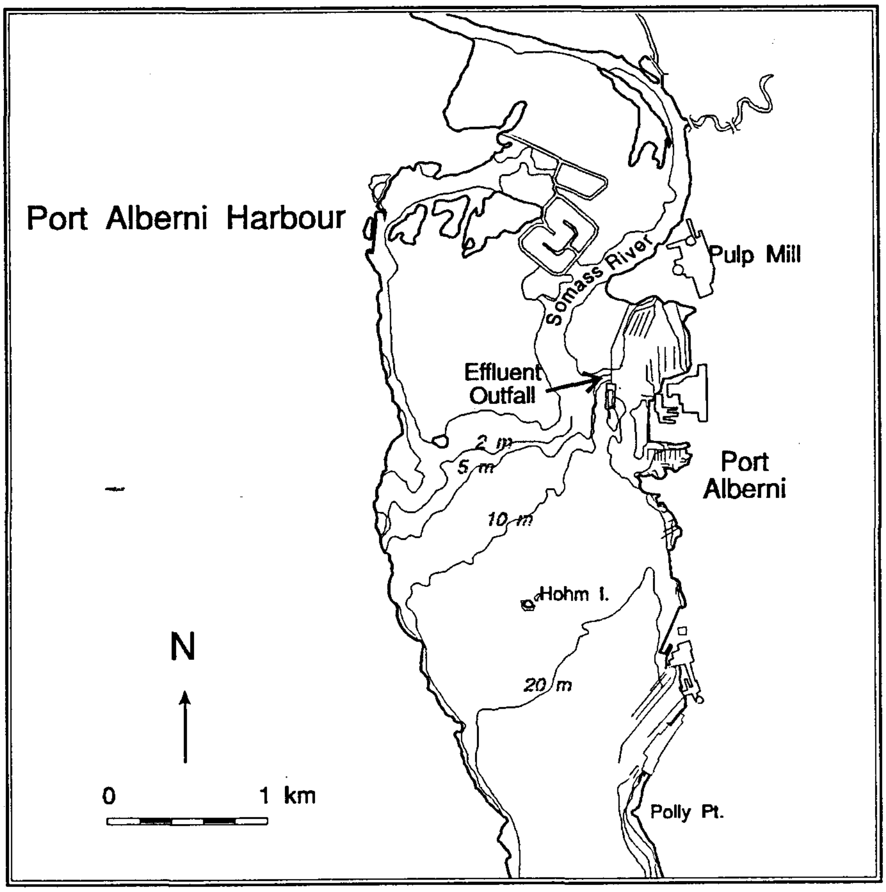

Figure 2. Site map of Port Alberni harbour showing location of pulp mill, effluent discharge and other features of relevance.

The surrounding forest resource supports a large forest products industry that has a number of conversion mills (pulp mill and saw mills) located in Port Alberni. The industry uses Alberni Inlet as a transportation corridor for both raw and finished products, for storage and handling of raw logs and as a receiving environment for their effluent. Logging operations, manufacturing of building materials, and pulp and paper production employ about 3000 people. The pulp and paper sector alone accounts for an annual payroll of $75 million and annual sales of $170 million.

The discharge of effluent (Fig. 2) from the pulp mill has created a water quality problem that poses a threat to the valuable salmonid stocks that migrate through the harbour waters, and has also reduced the habitat available to the fisheries resource. Because of the environmental concerns regarding the water quality and the discharge of contaminants and toxic chemical, many researchers have studied this fjord over the years, starting with classic work of Dr. J. P. Tully (1949). The motivation for our study, a portion of which we describe in this contribution, relates specifically to the concerns over the deteriorating dissolved oxygen conditions and the need to understand the role of physical and chemical oceanographic processes in this problem.

In this paper, we describe the changes and trends in water quality since the establishment of the pulp mill, and the present nature of the low dissolved oxygen conditions (spatial and temporal characteristics). We also identify and discuss the causes of the problem and specifically identify the oxygen uptake by the sediments as a key component. We report on the losses incurred in the 1990 sockeye run and the multiple factors responsible for the unusual events of that year. This paper concludes by reporting on broad range of activities and initiatives that the various stakeholders in this coastal zone are pursuing to better understand, monitor and manage the water quality problem and fisheries.

Dissolved Oxygen Problem

The particular problem in the harbour is the severe depletion of the dissolved oxygen (DO) content of the harbour waters caused by the pulp mill's effluent. We are fortunate in the case of Alberni Inlet that Tully (1949) conducted extensive oceanographic and water quality surveys in the inlet and harbour before establishment of the pulp mill. Starting in 1954, the environmental staff at the Port Alberni pulp mill monitored, and continue to monitor water quality at a number of stations in the harbour. The comparison between pre-mill and present DO concentrations, in the harbour (north of Polly Pt.) during the summer months, clearly demonstrates that a pronounced decline has occurred over the years (Fig. 3). The decline in DO has been most severe in the deeper (5 to 15 m), sub-halocline layer where approximately a 60% reduction (4 ppm) in average concentration has occurred. Furthermore, analyses of historic water quality monitoring data by consultants (Birch, 1989, and Hodgins, 1989) have identified the presence of a statistically significant declining trend in the DO concentration (Fig. 3).

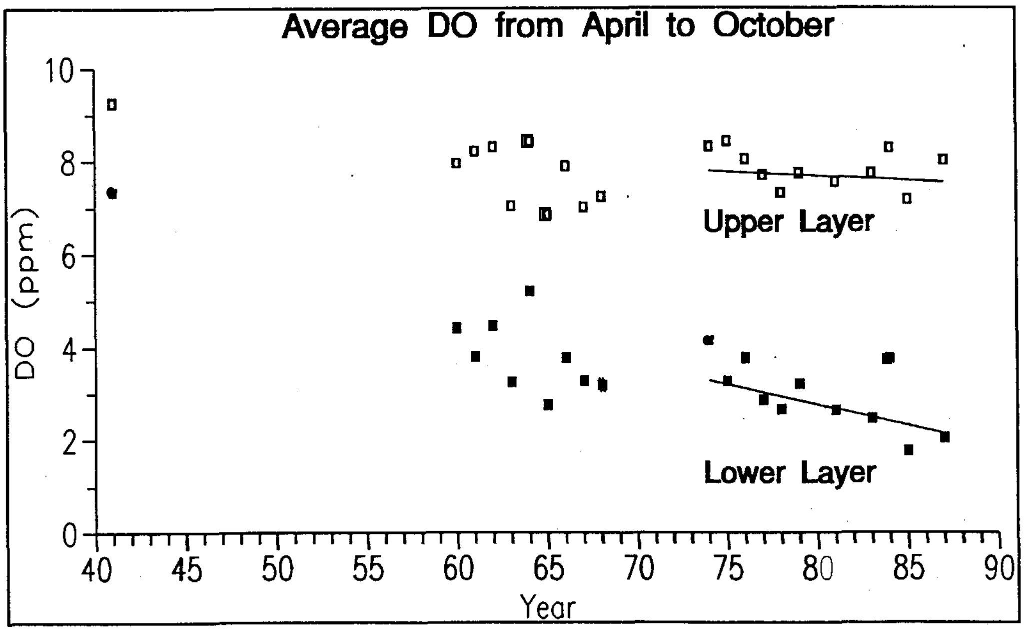

Figure 3. Average dissolved oxygen concentration in the period from April to October, in both the upper (open square) and lower layer (filled square), from 1940 to 1987.

Figure 4 provides a depth-time perspective of dissolved oxygen contours in the middle of the harbour. This figure shows clearly the severely depressed DO conditions that persist in the summer and fall of 1990, as well as the shorter lived event in May. We see a progressive deterioration in DO concentrations from June to October followed by a sudden improvement in the upper part of the water column. The DO concentrations are lowest (as low as 0.5 ppm) at the bottom and migrate upwards in the water column to a point where the 3 ppm contour hovers around 5 m depth. The onset of the fall rain storms and the associated surge in run-off re-establish the surface brackish layer with its near saturation concentration of dissolved oxygen.

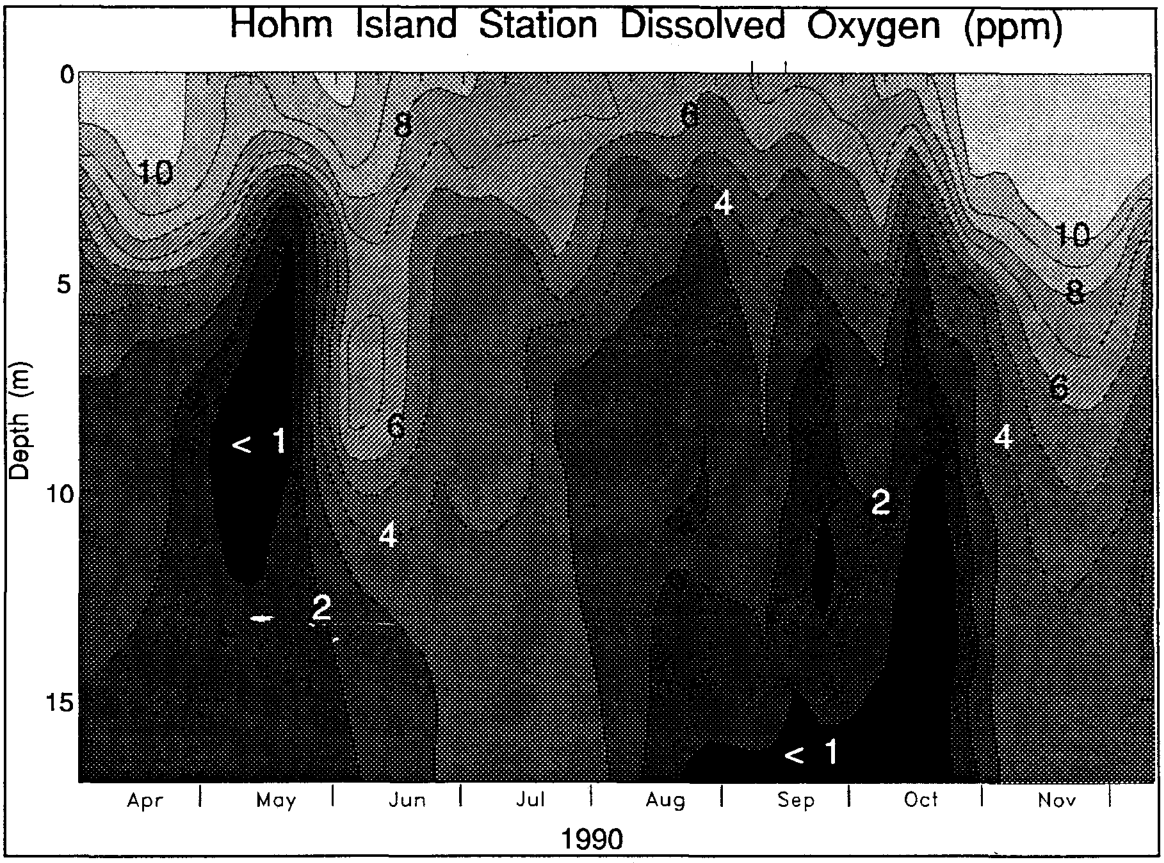

Figure 4. Depth-time contours of dissolved oxygen (ppm) at the Hohm Island station from April to December 1990.

Figure 5 gives a spatial perspective of the DO problem within the inner 10 km of the fjord. We see that the lowest DO concentrations (1.5 ppm) are inside the harbour (up-inlet of Polly Pt.), and furthermore the lowest DO values are present at or near the bottom. Further out in the deep waters (> 50 m) of the inner basin DO values are low (3 ppm) but not as low as the values from the head of the inlet near the bottom. The thin surface brackish layer has high DO values that persist out to and beyond the 10 km point.

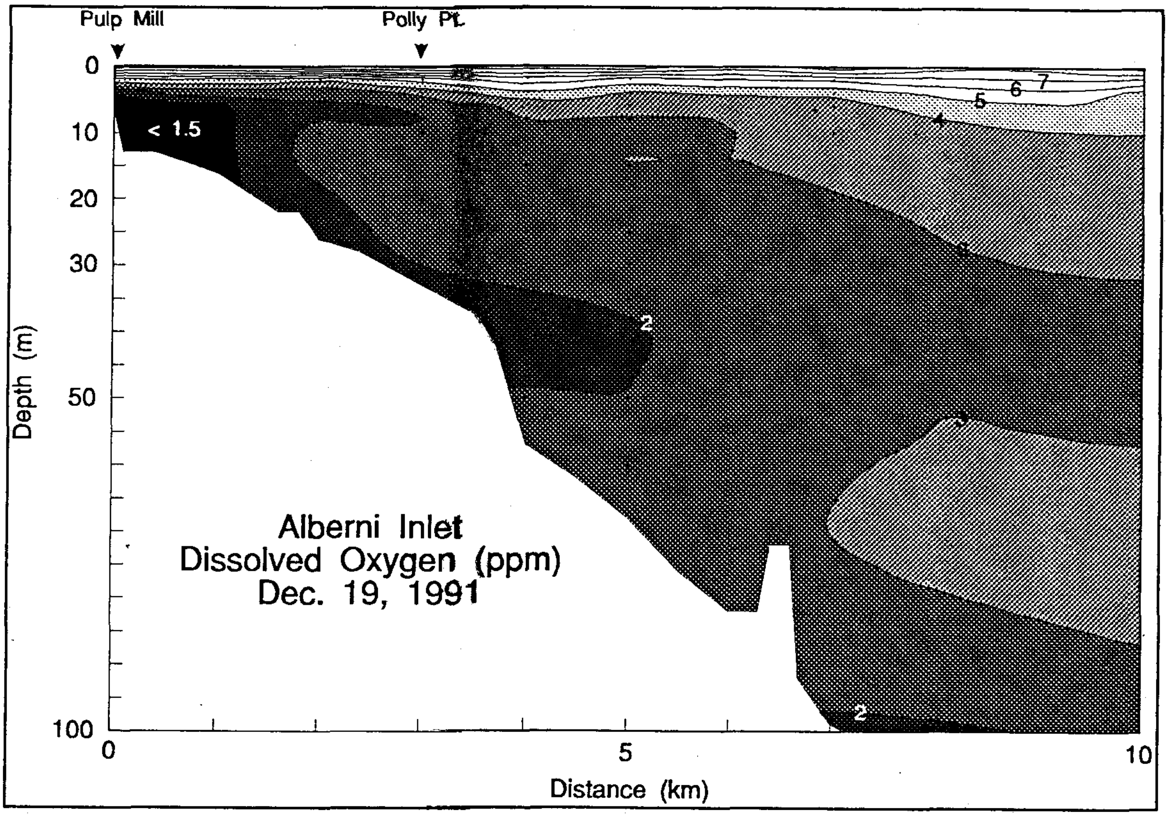

Figure 5. Dissolved oxygen (ppm) contours plotted along the axis of the fjord from the head out to a distance of 10km.

Causes

Natural variability in processes such as run-off, winds and tides cannot account for the changes from pre-mill conditions observed in the DO field of the harbour. The reductions in DO concentrations are of anthropogenic origin, and the pulp mill is the dominant source of oxygen demanding substances discharged to the harbour. The oxygen demand from the mill's effluent is exerted in two ways: 1) the liquid portion of the effluent discharged into the surface layer exerts a biochemical oxygen demand (BOD) there, and 2) the suspended solids in the effluent settle, covering about 40% of the harbour bottom, where they are decomposed by micro-organism. These micro-organisms take oxygen from the overlying water to satisfy their metabolic and respiratory requirements. This latter demand is termed sediment oxygen demand (SOD).

The monitoring data, and other data collected by Institute of Ocean Sciences and consultants to the pulp mill indicate that the very low DO levels observed in the lower layer waters are produced inside the harbour, most probably from the elevated SOD. First, the observations that the lowest dissolved oxygen values are next to the bottom and inside the harbour suggest that local oxygen uptake by the sediments is important. Second, we have the appropriate conditions for an elevated SOD in that sediments rich in organic solids from the pulp mill effluent and from log storage areas cover a substantial portion of the harbour bottom (Hodgins 1989). We also know that the pulp mill discharges daily about 9 tonnes of solids, of which about half settles onto the harbour bottom (Hodgins 1989). Lastly, recent *in situ* measurement of the SOD using benthic chambers or respirometers based on the design of Murphy and Hicks (1986) have verified that there is indeed an elevated SOD in the harbour (Stucchi *et al* 1992). The measurements indicate that the SOD is largest near the effluent discharge point and decreases with distance down inlet.

The importance of the SOD to the oxygen budget of the lower layer only becomes important in the absence of a vigorous circulation in this lower layer. We can reasonably expect that the gravitational circulation induced by runoff will be more energetic during periods of high run-off. Also, we know that density variations on the continental shelf at the mouth of Alberni Inlet produced by the fluctuating offshore winds are able to drive energetic intermediate water exchanges (Stucchi 1982). These intermediate or above sill level exchanges are most energetic during the winter months, though isolated storms in summer may also drive an intermediate water exchange. Thus the observation that depressed DO conditions are most persistent during the summer months is consistent with a reduced gravitational circulation (low run-off) and period of quiescent intermediate water exchanges. Advection of low oxygen water from outside the harbour may precondition the harbour waters but the magnitude of the depression of oxygen concentrations inside the harbour indicates that advection is not solely responsible.

1990 Sockeye Run

Returns of sockeye to Alberni Inlet during 1990 followed the expectations of fisheries managers in some respects but exhibited marked departures in others. The estimated magnitude (500,000 fish) and return timing (most stock present by late July to early August) of sockeye adults to the terminal marine area of Alberni Inlet closely followed pre-season expectations during 1990. However, persistent drought conditions (low flow, high temperatures) between July and October delayed by 2 to 8 weeks the migration of sockeye from Alberni Inlet to their natal lakes. High river temperatures were especially important here as there is a demonstrable relation between delay in sockeye passage through the Somass River and temperatures higher than 18°C. Although high temperatures may be sufficient to delay migration, low DO condition present between July and October (Fig. 4) may also have contributed to the delay.

Acoustic surveys indicated that the daytime depth preference for adult sockeye holding for weeks throughout Alberni Inlet, including the harbour area, ranged between 10 and 30m. These are sub-halocline depths where oxygen concentrations (< 3 ppm) that are known to physiologically impair adult salmon stocks (Birtwell and Harbo 1980). Prolonged exposure to these conditions not only added to cumulative stress on sockeye adults but also exposed them to a rapidly expanding population of parasitic copepods to further challenge fish viability. Sockeye sampled from the Inlet from late August to the end of September were infected heavily enough with parasitic copepods ("sea lice") to induce some prespawn mortality directly. Finally, as salmon approached the Somass River during the interval from July to October, moving from deeper waters to surface layers, they faced stressfully high water temperatures and suboptimal dissolved oxygen concentrations. Thus successive mortality events in the inlet and lower river were undoubtedly the result of interactions among climate events, fish behaviour (migration delay, depth selection) and stressful water quality conditions (high temperature and low DO).

We must view the role of dissolved oxygen in the 1990 losses of sockeye from a multifactorial perspective. First, and perhaps most importantly, drought conditions remained unbroken by any storm events between July and October with the result that high water temperatures and low discharge in the Somass River effectively blocked the migration corridor for sockeye returning to

Sproat and Great Central Lakes. We suspect that these climatic conditions also produced oceanographic conditions that emphasized the importance of SOD in the oxygen budget of the harbour waters. Given prolonged holding (from 2 to 8 weeks) in Alberni Inlet, water quality conditions became another factor that exacerbated the cumulative stress for salmon and possibly contributed to their mortality.

Fisheries managers attempted to stimulate migration of those fish holding in the inlet by increasing the flow of the Somass river. This measure failed to attract more fish into the river though it did stimulate the fish already in the river. At the same time, the pulp mill reduced its effluent discharge in an attempt to improve the water quality in the harbour. Water quality did not improve; DO concentration remained unchanged or deteriorated further.

The fish were seriously stressed and several mortality events occurred for unspawned fish in Alberni Inlet and in the waters of the lower Somass. Approximately 100,000 adult sockeye perished during their migration through Alberni Inlet and the Somass River. In addition, the production from the fish that did spawn was lower than normal by an amount equivalent to a loss of 135,000 adults. In total, fisheries scientists and managers estimate the losses in the 1990 sockeye run to be 235,000 adult fish or in economic terms a loss of 5 to 8 million dollars.

Coastal Zone Management

It is apparent from the preceding discussions that there are many users of this coastal zone (defined as Alberni Inlet, its tributaries, lakes and surrounding water shed), each imposing their own, and sometimes conflicting demands on the resources of this coastal zone. The concern over the deteriorating water quality in Port Alberni harbour and the losses incurred in the 1990 sockeye run have produced a number of activities aimed at managing this coastal zone. These activities include research initiatives, monitoring, pollution abatement measures and the development of management plans for key components of this coastal zone.

The research initiatives can be divided into two groups, oceanographic studies and fisheries studies. Consultants to the mill and government scientists are measuring and modelling the important sediment oxygen demand processes and the advection of oxygen by currents in the fjord. Researchers at the University of British Columbia are developing 2 dimensional (x-z) fjord circulation models which will eventually also include the dissolved oxygen terms. Fisheries researchers are investigating the effects of low DO, toxic chemicals, temperature and salinity on fish health and behaviour. Sonic tagging of adult sockeye in Alberni Inlet and water column simulators (laboratory tanks) will be used to observe the movement and behaviour of the salmon.

Monitoring of oceanographic and water quality parameters has greatly improved in the last year. The pulp mill now samples at regular intervals out to a distance of 10 km from the head of the inlet, with more frequent sampling during the critical summer months. Furthermore, greater attention is now directed towards quality control of the monitoring data. The monitoring data set is valuable since we have learned much about the state of the environment, its variability and trends. We use these data to assist us in the management of the fisheries resources, as well as in the interpretation of the factors affecting these resources and their habitat.

The pulp mill is currently constructing additional secondary treatment facilities that will enable treatment of all the mill waste water and further reduce the BOD and suspended solids discharged into the harbour. Other long-term initiatives include the increased usage of dry land sorting operations, better spill detection systems and usage of different bleaching techniques and better process control to reduced AOX/Dioxins levels in the effluent. The regulatory agencies both federal and provincial have and are continuing to develop stringent site specific effluent regulations for this pulp mill. Also, the dumping of dredged wood wastes at the 5 km dumpsite is being stopped.

As a direct result of the losses in the 1990 sockeye run the Department of Fisheries and Oceans has developed a contingency plan to manage the sockeye runs if there are migration delays. It consists of a core of routine activities for monitoring environmental conditions and the status of returning adult salmon stocks. It also details supplementary actions to be taken if a critical migration delay appears to be developing. The contingency plan has also generated a number of pilot programs and mitigation options which are now being analysed and tested.

The events of the summer of 1990 have emphasized the need for integrated approaches to the management of the Somass River system. The Somass River is not only a major habitat component supporting the fisheries resource, but also has a strong influence on the oceanography of the inlet. There are multiple users of this river system (hatcheries, wild salmon stocks, pulp mill, agriculture, etc.) and at times they have conflicting requirements. Efforts are currently being made to better represent the interests of the different users and to develop a Somass River watershed plan.

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OCEANOGRAPHICAL CONDITIONS AND COASTAL EROSION IN THE GULF OF THAILAND

by Suphat Vongvisessomjai

Division of Water Resources Engineering, Asian Inst. of Tech., GPO. Box 2754, Bangkok 10501

ABSTRACT

Information on oceanographical conditons is required to understand physical processes in the coastal zone for purposes of coastal zone management, i.e. (i) winds and waves are required to explain coastal erosion, (ii) tidal and coastal currents are required to describe convective and dispersive processes of coastal pollution, (iii) tracks and strength of cyclones for alleviating their hazards, etc. This paper provides the oceanographical conditons in the Gulf of Thailand and uses them to investigate the coastal erosion problem.

Coastlines in the Gulf of Thailand with dominant changes, such as the Chao Phraya river mouth and the east coast of the peninsula, have been selected to determine the erosion/accretion by analysis of available satellite imageries (Landsat 1-5) together with topographic maps and aerial photographs. Severe coastline erosion can be found on the west of the Chao Phraya river mouth (-500 m), and in Phetchburi (-200 m) and Hua Hin (-100 m). The decrease of the silt supply from the Chao Phraya river resulted in a net erosion since the accretion by the silt supply is less than the erosion by the wave action, while the decrease of sand supply alongshore or from nearby streams and the construction of rigid walls on beaches are the causes of erosion along the shorelines of Petchburi and Hua Hin. Headlands or offshore breakwaters are recommended to remedy the shoreline erosions of Petchburi and Hua Hin.

INTRODUCTION

Importance of the Study

Due to the booming tourism and economy in Thailand, the value of land along coastlines is extremely expensive. Severe coastline erosions are found on the west of the Chao Phraya river mouth, and at Phetchburi and Hua Hin. It is important to find the rates and causes of these erosions and recommend remedial measures. The locations of coastlines selected for this study are shown in Fig. 1, the head of the Upper Gulf of Thailand and the east coast of the Peninsula. Soil types along the studied coastlines are shown in Fig. 2.

This paper is written from Research Report of the National Research Council of Thailand entitled Coastal Morphology with Emphasis on Coastal Erosion and Coastal Deposition. Causes of Coastal Erosion and Remedial Measures are added.

Cause of Coastal Erosion

There are several causes of coastal erosion due to both natural processes and manmade activities, such as, (i) Wave and wave induced current; (ii) Decrease of sediment supply from rivers; (iii) Constructing a reflective boundary on the shoreline; (iv) Trapping of alongshore sediment supply by coastal structures; (v) Land subsidence or sea level rise; and (vi) Mining of sand or shell. The first three are seen to be the major factors in causing shoreline erosion of the study area. The decrease of the silt supply from the Chao Phraya river to its mouth resulted in the net erosion since the accretion by the silt supply is less than the erosion by the wave agitation, while the decrease of sand supply and the construction of rigid walls on the shoreline are major causes of erosion at Phetchburi and Hua Hin.

Shoreline accretion and erosion results from the balance of sediment influx and breaking waves which in turn depends on wind speed and direction and available fetch lengths. Winds over Thailand generated by northeast and southwest monsoons and cyclones from the South China Sea are first presented and are then used to calculate waves in deepwater using the method proposed by Silvester and Vongvisessomjai, 1970. The relevant data for this study are therefore related to oceanographical conditions which are presented below.

OCEANOGRAPHICAL CONDITIONS

Thailand has a tropical climate characterised by two major seasons. The southwest monsoon from mid-May through September - during which hot moist equatorial air masses traverse the country - brings moderate to heavy rains; the southwest winds generate moderate waves along the eastern seaboard of the Gulf of Thailand and along the west coast of the southern peninsula in the Andaman Sea. The northeast monsoon, from November to mid-March, brings a reversal of air movement. The northeast winds generate waves along the east coast of the southern peninsula of Thailand; the waves along the coast of the eastern seaboard of the Gulf of Thailand are very small during this period. The retreat of the southwest monsoon in September and October is frequently accompanied by peak wind and wave intensity caused by the passage of cyclones generated in the South China Sea. Cyclone tracks (Fig. 3) tend to pass north of Thailand in the first half of the year, across the land mass in September, and during October through December pass over the Gulf on a westerly course, moving further south as the year progresses. These tropical storms cause the extreme wind, sea and current conditons, all of which are the worst design conditions. These storms are now predictable at their genesis from satellite photos, and radio warnings can be spread to vessels to take refuge if the track is approaching.

Wind

The prevailing winds can be summarized as follow:

1. Prachuap Khiri Khan Northward (includes the coastal areas in the eastern part)

During the northeast monsoon, the prevailing winds are from the north and east during the early season, becoming quite variable and southerly. Wind speeds are between 4-8 kts. Winds in the spring transition are quite variable with about the same winds speed as those in the late northeast monsoon season. In the southwest monsoon season, the prevailing winds are more persistent from the south and west. Also, the wind speeds of Sattahip, Ko Sichang and Chonburi are stronger than in any other seasons.

2. South of Prachuap Khiri Khan

The winds are generally in the east during the northeast monsoon season, with stronger winds during the end of the season. During summer, wind directions are quite similar to those in winter season, but speeds decrease. In the southwest monsoon season, along the northern portion of this region, the winds become stronger while those of the areas from Songkhla southward are comparatively weaker. Wind speeds are mostly 5 kts and, except in Narathiwat, from the south and west. In the fall transition, winds begin to be variable and light. These wind speeds start to increase as the northeast monsoon progresses over the country. Surat Thani experiences weak winds (2-3 kts) throughout the year while Songkhla has stronger winds, especially of 11-12 kts during the late northeast monsoon season.

Fig. 4 shows monthly wind-roses of Sattahip, Hua Hin, and Bangkok from 5 years observations, while Fig. 5 is for Bandon, Surat Thani.

Wave

The longest fetch length in the Gulf of Thailand is almost 1000 km from the southeast, through the Gulf opening to the South China Sea, which is about 330 km wide. The width of the Upper Gulf of Thailand between Sattahip and Hua Hin is about 100 km (Fig. 1)

Wave heights are generally moderate in all areas, and even the most exposed Gulf areas have, over half the time, no waves over 0.25 m. Most wave data are computed from wind data using the method proposed by Sivester and Vongvisessomjai, 1970. Fig. 6 shows the probabilities of the occurrence of significant wave height and wave period along the eastern seaboard at Ao Phai or Ko Sichang and Sattahip while Fig. 7 is for the east coast of southern Thailand near Surat Thani (Khanom and Ko Samui).

The waves in the Upper Gulf of Thailand (Fig. 6) are the smallest due to the small fetch length and weaker southwest winds. The waves near Surat Thani (Khanom and Ko Samui in Fig. 7) are larger due to stronger northeast winds and longer fetch length. The waves in the South China Sea coming to Songkhla, Pattani and Narathiwat are more severe due to the stronger northeast winds and much longer fetch lengths.

Littoral Drift

When breaker characteristics are known, the longshore transport rate Q_s as shown in Fig. 8 can be computed from the longshore component of energy flux in the surf zone P_{ls} (Coastal Engineering Research Center, 1984).

The immerged weight transport rate $I_{ls} = 0.77\, P_{ls}$

where $I_{ls} = (p_s - p)ga\, Q_s$

$$P_{ls} = \frac{pg}{16} H_b^2 C_g \sin 2\alpha_b$$

in which p_s = density of sand; p = density of seawater; g = gravitational acceleration a' = correction factor for pore space = 0.6; H_b = breaker height; C_g = wave group celerity and α_b = breaking angle.

The breaker characteristics (H_b and α_b) depend on deepwater wave characteristics (H_0 and α_0) and bottom topography or beach slope. As waves travel from deepwater, they change height and direction due to refraction, shoaling, and the bottom friction.

Refraction is the bending of wave crests due to the slowing down of that part of the wave crest which is in shallower water. As a result, refraction tends to decrease the angle between the wave crest and bottom contour. Thus, for most coasts, refraction reduces the breaker angle and spreads the wave energy over a longer crest length. Shoaling is the change in wave height due to conservation of energy flux. As a wave moves into shallow water the wave height first decreases slightly, and then increases continuously to the breaker position, assuming friction and refraction effects are negligible. Bottom friction is important in reducing wave height where waves must travel long distances in shallow water.

When breaker characteristics are not known, the longshore transport rate Q_s can be computed from the deepwater wave characteristics. The following formula can be used for open coastlines with rather uniform topography. (Coastal Engineering Research Center, 1984).

$$Q_S(m^3/\,\text{month}) = 169{,}300 f H_0^{5/2} F(\alpha_0)$$

where $F(\alpha)$ = $[(\cos \alpha_0)^{1/4} \sin 2\alpha_0]$ is the direction term.
f is the decimal frequency of wave.
H_0 is the deepwater wave height in metre.
α_0 is the deepwater angle between wave crest and shoreline.

Tide

Yin Fuh (1977) studied tides in Gulf of Thailand whose topography is shown in Fig. 9. Numerical results indicated that both diurnal K1 and semi-diurnal M2 tides are reflected from the shoreline along the Gulf as shown in Figs. 10 and 11 respectively while types of tide in the Gulf of Thailand are shown in Fig. 12.

METHOD OF APPROACH

Location of Study

The locations of coastlines selected for this study are shown in Fig. 1, the head of the Upper Gulf of Thailand and the east coast of the peninsula. These shorelines are formed by sediments carried by rivers draining into the Gulf of Thailand: the head of the Upper Gulf by the Chao Phraya river, the Thachin river and the Maeklong river; the Phetchburi by the Phetchburi river; Hua Hin by the Pranburi river; the Pattani bay by the Pattani river; the southernmost shoreline of Thailand receives a huge sediment supply from Malaysian rivers, namely the Kolok and Kelantan rivers. Other sources of sediment along these shorelines are from small streams draining into the Gulf of Thailand. The resulting soil types along the studied shorelines are shown in Fig. 2 which is taken from Moormann and Rojanasoonthon, 1972.

Data for Study

Bands 4 and 7 of imageries of Landsat 1-5 are used for the shorelines of the head of the Upper Gulf of Thailand in the vicinity of the mouths of the Chao Phraya river, the Thachin river and the Maeklong river. Topographic maps of scale 1:50,000 produced by Royal Thai Survey Department, Navigation maps produced by Harbour Department and aerial photographs are used in the analysis.

Equipment for Mapping

PROCOM-2 is used in projecting imageries from Landsat which can be adjusted to any scale in producing maps of shorelines. Shorelines in various years are then superimposed to show the changes; a planimeter is used in finding areas of erosion and accretion.

RESULTS ON COASTAL MORPHOLOGY

The locations of shoreline used in this study to determine their chronological changes are shown in Fig. 1. They are the Chao Phraya river mouth (A); along the east coast of the peninsula from Samut Songkhram province to Phetchburi province (1), Ban Bang Kaew (2), Hua Hin (5) and Prachuap Khiri Khan (9); further south at Songkhla lagoon inlet (14), Laem Tachi of Pattani (15) and Bang Nara river mouth of Narathiwat (16). Two large sand spits can be seen in the south at Nakorn Si Thammarat and Pattani. All four shorelines of Area A are taken from satellite imageries; three shorelines are analysed each for Areas 1 to 13, the first two are aerial photographs and the last one is satellite imagery. Shorelines of Areas 14 to 16 are taken from navigation maps.

The Chao Phraya River Mouth

The lower Chao Phraya plain is classified as a geologic depression with mountainous borders to the west and northeast. This depression zone stretches from the Gulf of Thailand to as far north as Sukothai province. The depression is filled with alluvial, brackish and marine deposits. The total depth of these deposits in Bangkok is between 500 and 2000 m. There are at least six underlying aquifers, which are interjected with layers of clay. The thickness of each clay layer is about 10 to 30 m. The uppermost stratum is a clay deposit, known as the Bangkok clay, about 25 m deep. This uppermost layer can be subdivided into the weathered clay layer from 0 to 4 m, the soft clay layer from 4 to 15 m deep, and the stiff clay layer from about 15 to 25 m deep.

Bangkok Port, the most important port of Thailand, is located on the east bank of the Chao Phraya river about 27 kilometres from the river mouth (Fig. 1). The navigation channel is maintained by dredging to a depth of 10 metres below the mean sea level. Most dredged material is dumped along the eastern shoreline resulting in accretion there.

Fig. 13 shows the western and eastern shorelines of the Chao Phraya river mouth in the years 1969, 1973, 1979 and 1987. These shorelines have been formed by the sand and silt from the river. The waves from the south attack these shorelines and cause erosion. The western shoreline had been eroded for an area of -7.2×10^6 m^2 form 1969 to 1987 with the maximum eroded distance of -500 m. The eastern shoreline, however, is replenished by the dredged material, resulting in a net accretion area of $+3.4 \times 10^6$ m^2 from 1969 to 1987.

Samut Songkhram - Phetchburi

This section of shoreline (Fig. 14) is supplied by sand and silt from the Maeklong river in the north and the Phetchburi river in the middle section, therefore, most of the shoreline is accreting. From 1954 to 1974, the accretion area was +1,466,000 m^2 and the eroded area = -194,000 m^2, a net accretion area of +1,272,000 m^2.

Ban Bang Kaew

The shoreline of Ban Bang Kaew (Fig. 15) has suffered from severe erosion in the past due to the northeast monsoon waves. From 1954 to 1974 much of the shoreline eroded about -200 m, with the corresponding eroded area of -1,355,000 m^2 and accretion area of +1,254,000 m^2. the Department of Land Development requested AIT (Asian Institute of Technology) and RID (the Royal Irrigation Department of Thailand) to help protect the shoreline from erosion. A series of 14 offshore breakwaters 30 m long and 120 m apart (Fig. 16) were constructed in October 1985 to protect 2,000 m shoreline from Komnaram Temple to Bang Kaew Canal. After 3 years, the 1988 shoreline has accreted for a distance of +150 m of the 1974 shoreline instead of the erosion in the past.

Hua Hin

Similar to the shoreline of Ban Bang Kaew in the past, the shoreline of Hua Hin (Fig. 17) has suffered from severe erosion. From 1954 to 1988, the shoreline has been eroded for a distance of -100 m, with a net eroded area of -2,146,000 m^2.

Prachuap Khiri Khan

Prachuap Khiri Khan bay (Fig. 18) is located between two rock outcrops. Because the bay is almost symmetric in the north and south, it is influenced by both north and south littoral drifts. A canal in the middle of the coast serves as a dividing point of accretion in the north and erosion in the south. From 1954 to 1974, the northern shoreline of the bay accreted in area of +120,000 m^2, while the southern part eroded -232,000 m^2.

Songkhla Lagoon Inlet

Songkhla lagoon is formed by sand transported along the coastline creating a sand barrier between the lagoon and the sea. About ten small rivers drain into the lagoon. The lagoon serves as one of the important freshwater resources in the south and a breeding ground for shrimp and fish.

The inlet of the lagoon is fixed in the north by a mountain and a huge sand spit in the south (Fig. 19). The high freshwater discharge from the lagoon helps maintain the inlet. A 700 m jetty was constructed in 1968 at the south of the inlet to trap the littoral drift from the south.

As seen in Fig. 19, the shoreline south of the jetty has advanced significantly: From 1968-1971 with accretion area of +153,000 m^2; negligible change from 1971-1973; accretion of +115,200 m^2 from 1973-1975; and accretion of +113,600 m^2 from 1975-1978. In 1978 the shoreline advanced more than +400 m that the depth of water at the tip of the jetty on the beach side is rather shallow (about 1 m below the mean sea level), therefore, the littoral drift from the south started to bypass the jetty, which has a very short effective length, thus resulting in the slow accretion of the shoreline.

Laem Tachi of Pattani

The Tachi sand spit is formed by northerly littoral drift. The sand spit provides shelter for Pattani bay from the northeast and east waves. The bay is rather shallow due to silt carried by the Pattani river (Fig. 1). Between 1981 and 1985 the sand spit accreted +400,000 m^2 (Fig. 20).

Bang Nara River Mouth

Bang Nara river mouth (Fig. 21) has active sand spits on both sides. The sand spits change every year due to large littoral drift along this coast. The spits generally move in a northwesterly direction, and are cut by the waves when there are too long. The migration of the sand spits, caused by a high rate of sedimentation at the river mouth, creates problems for navigation of fishing and cargo boats.

REMEDIAL MEASURES

Remedial measures can be grouped into two, namely nonstructural and structural controls. The nonstructural method would be cheaper and should be tried first since it is based on the natural response of the beach in order to dissipate wave energy through the breaking process.

Natural Response of Beach and Nourishment

There are two general types of dynamic beach response to wave action: response to normal conditions and response to storm conditions. Normal conditions prevail most of the time, and the wave energy is easily dissipated by the beach's natural defense mechanisms. However, when storm conditions generate waves containing increased amounts of energy, the coast must respond with extraordinary measures, such as sacrificing large sections of beach and dune. In time the beach may recover, but often not without a permanent loss.

The sloping beach and beach berm are the outer line of defense in absorbing most wave energy; dunes are the last zone of defense in absorbing the energy of storm waves that overtop the berm. Although dunes erode during severe storms, they are often substantial enough to afford complete protection to the land behind them. Even when breached by severe storm waves, dunes may gradually rebuild naturally (over a period of several years) to provide protection during future storms. When the natural protection system fails during large storms, the first solutions frequently chosen are quasi-natural methods such as beach nourishment or artificial sand-dune building. Such solutions retain the beach as a very effective wave energy dissipater and the dune as a flexible last line of defense.

Structural Control

Shoreline stabilization by seawall and revetment are introduced when costly buildings or roads are endangered. The seawall would protect the buildings behind it but the seawall would cause erosion and shoal downcoast of it as shown in Fig. 22(a). The sandy beach in front of the seawall would also be eroded due to sand transported offshore caused by reflected waves from the seawall.

Offshore breakwaters or headlands are employed when partial protection of shoreline is sufficient. These structures will diffract waves and change currents nearshore favourable for sand deposition behind them, see Fig. 22(b). This method has been used quite successfully at Ban Bang Kaew, Petchburi. The layout of 14 offshore breakwaters and their cross-section are shown in Fig. 16.

It is to be noted that the reflected waves and eroding action in front of the seawall as shown in Fig. 22(a) are also present in front of the headland or the breakwater shown in Fig. 22(b). However, the eroding actions are much less due to the deeper water available. Even though embayment is created, it resulted in a net accretion since the headland or the breakwater is located away from the shoreline.

Groins can, under favourable conditions, protect shoreline erosion as far as their extremities. Beyond the end of groins, erosion continues, see Fig. 22(c). It is to be noted that the headland or the offshore breakwater presented earlier would be more suitable for control of shoreline erosion.

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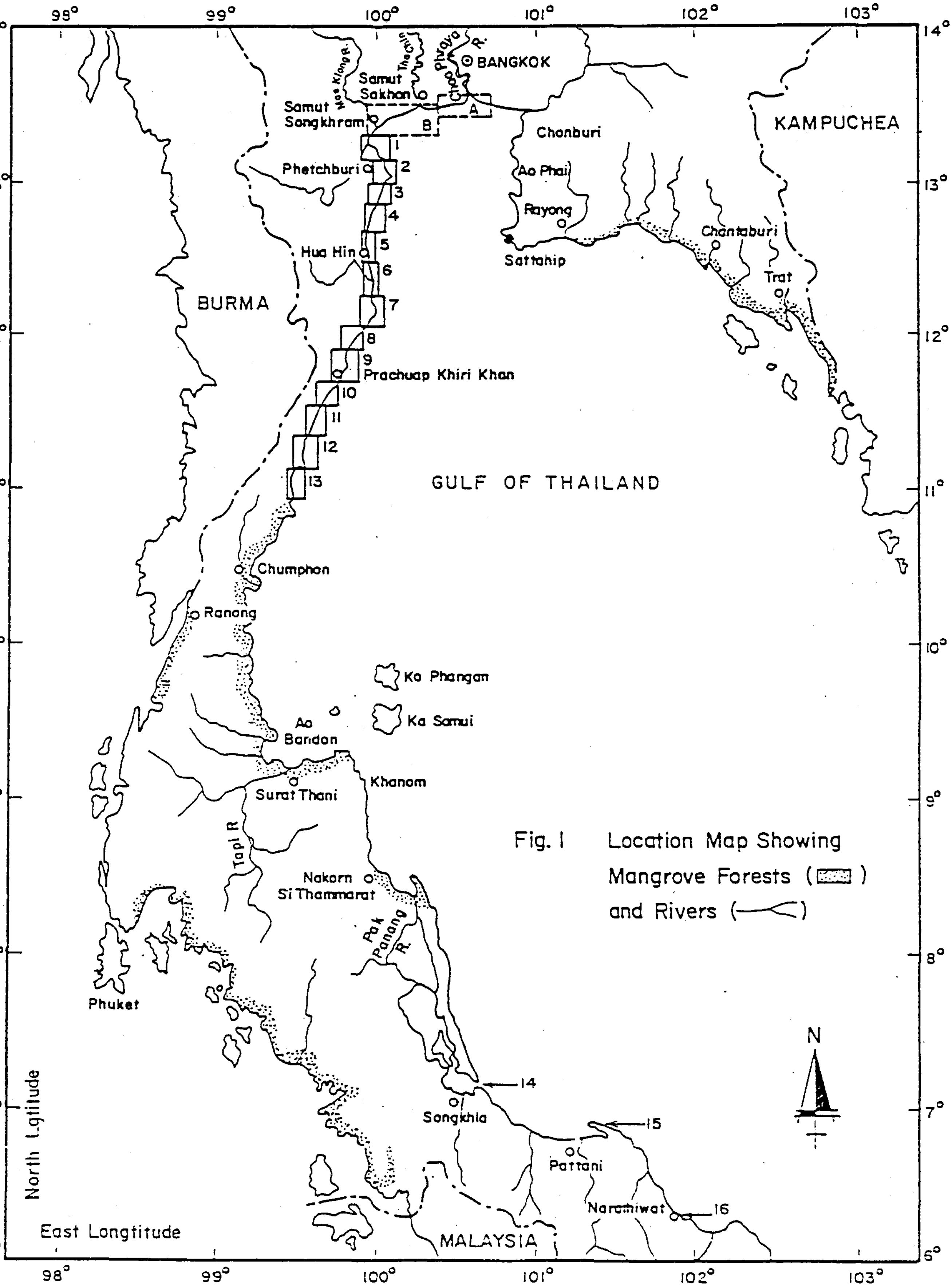


Fig. 1 Location Map Showing Mangrove Forests ( ) and Rivers ( )

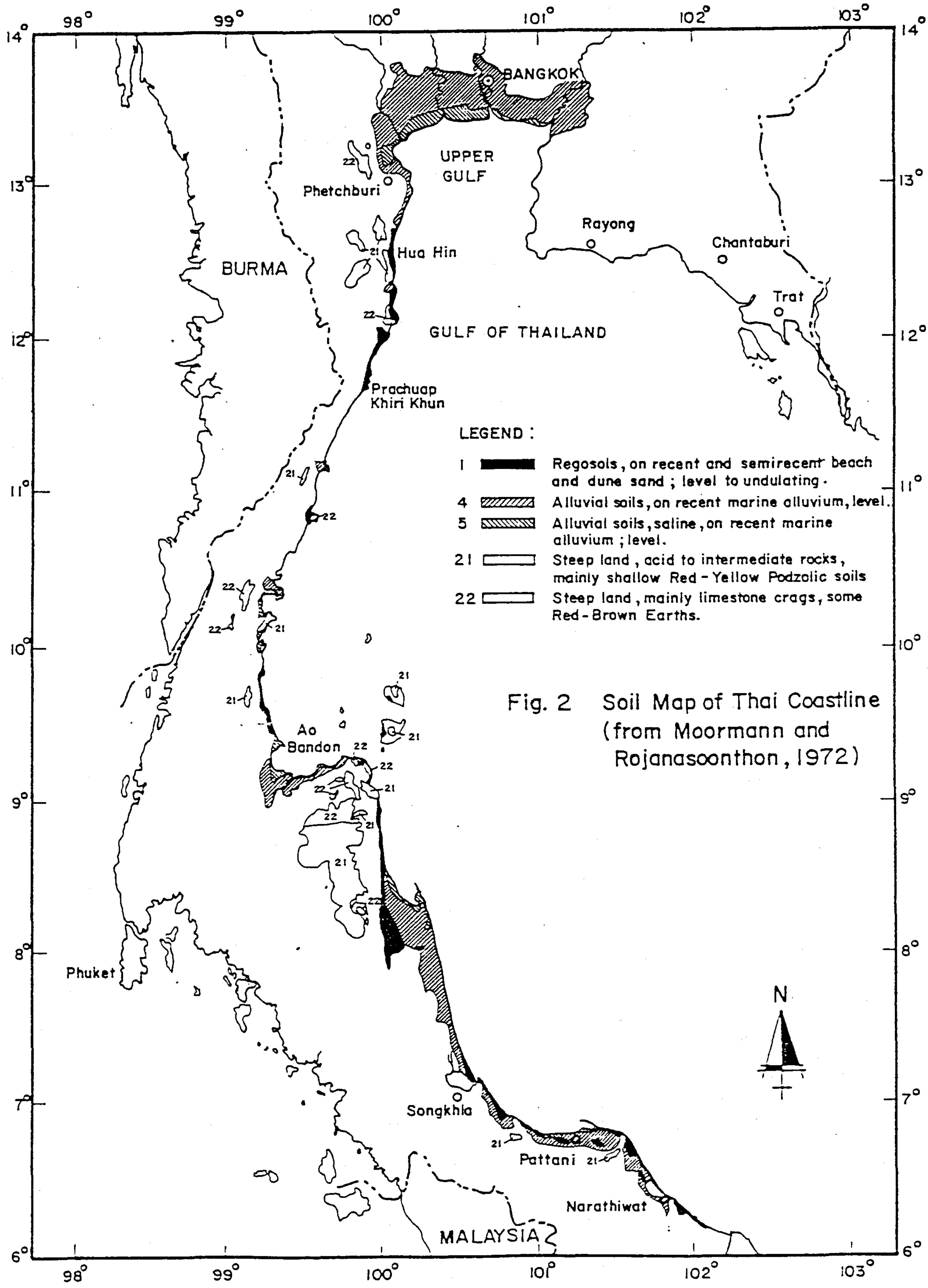


Fig. 2 Soil Map of Thai Coastline (from Moormann and Rojanasoonthon, 1972)

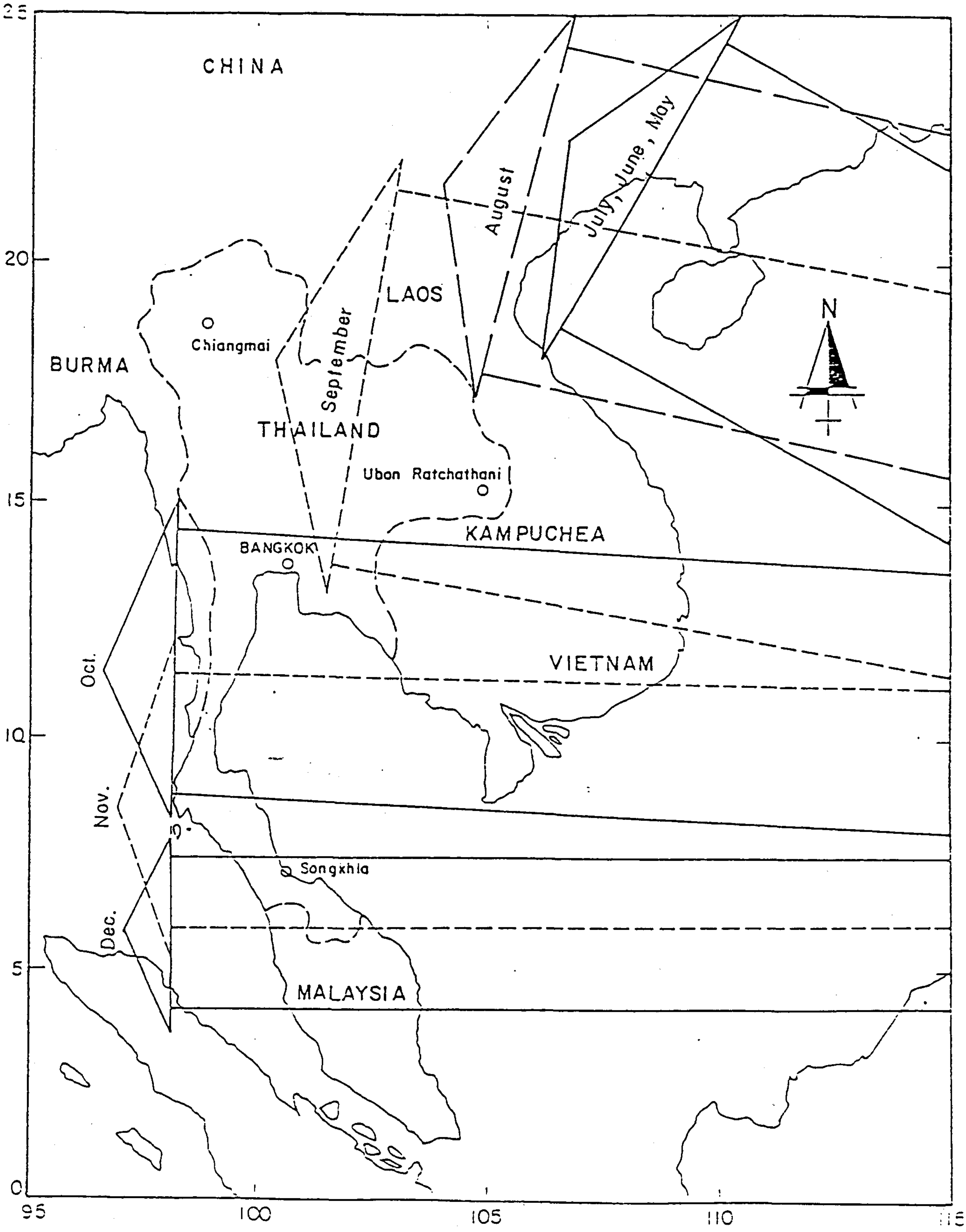


Fig. 3 - General Tracks of Cyclones over Thailand

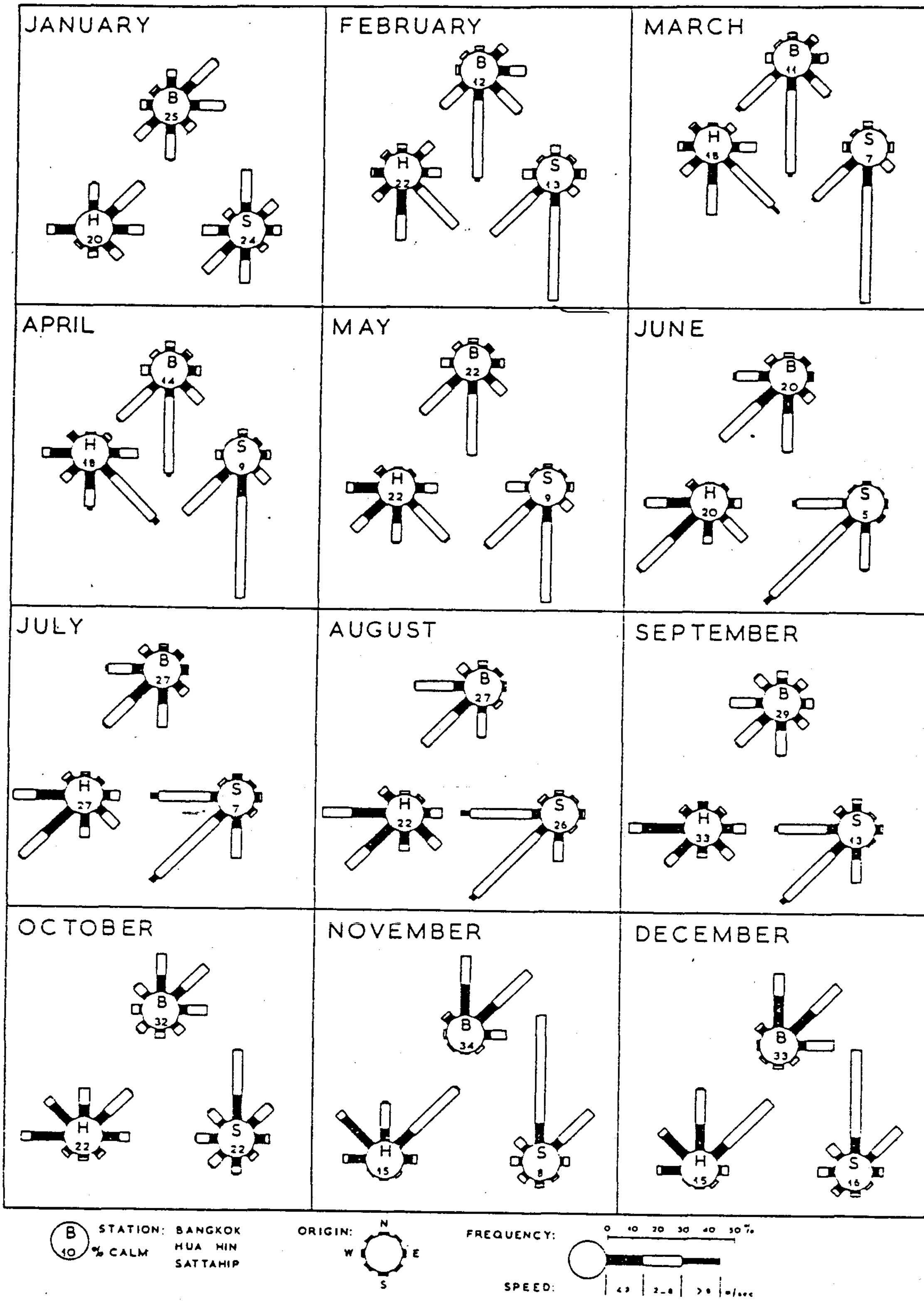


Fig. 4 Wind - Roses of Sattahip, Hua Hin and Bangkok

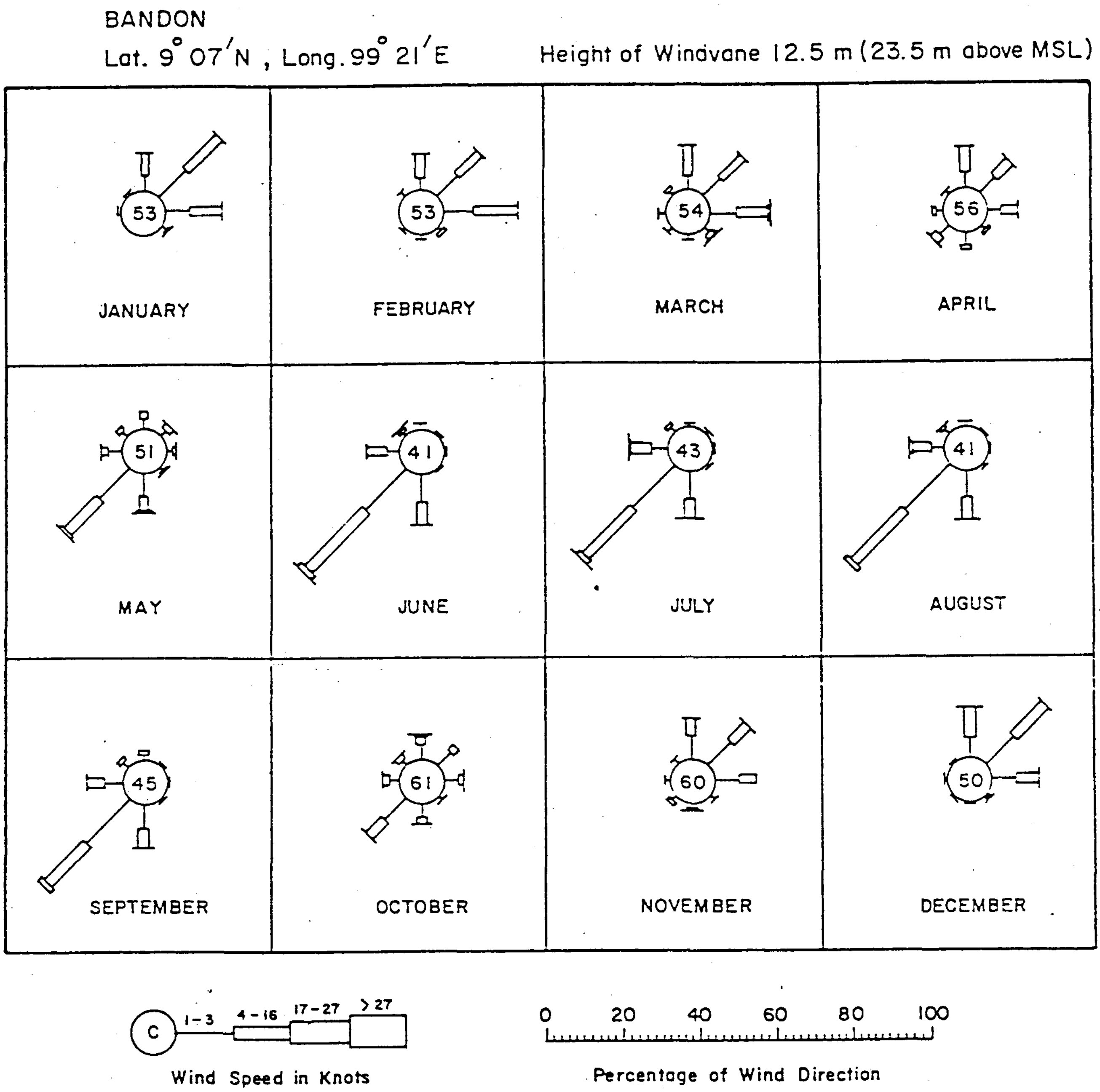


Fig. 5 – Monthly Wind-Rose at Bandon, Surat Thani

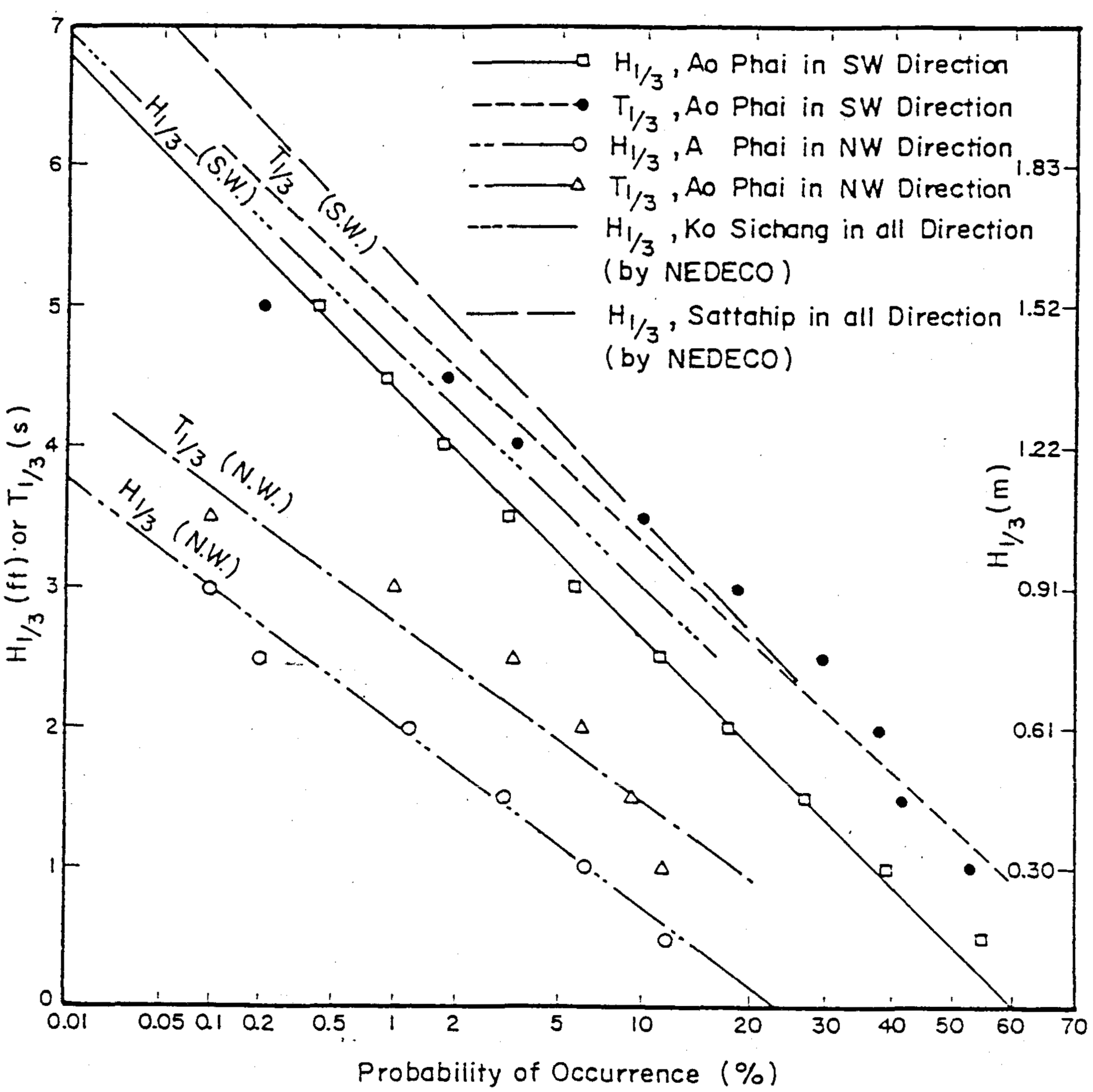


Fig. 6 – Probability of Occurrence of Significant Wave Height and Wave Period along the Eastern Seaboard

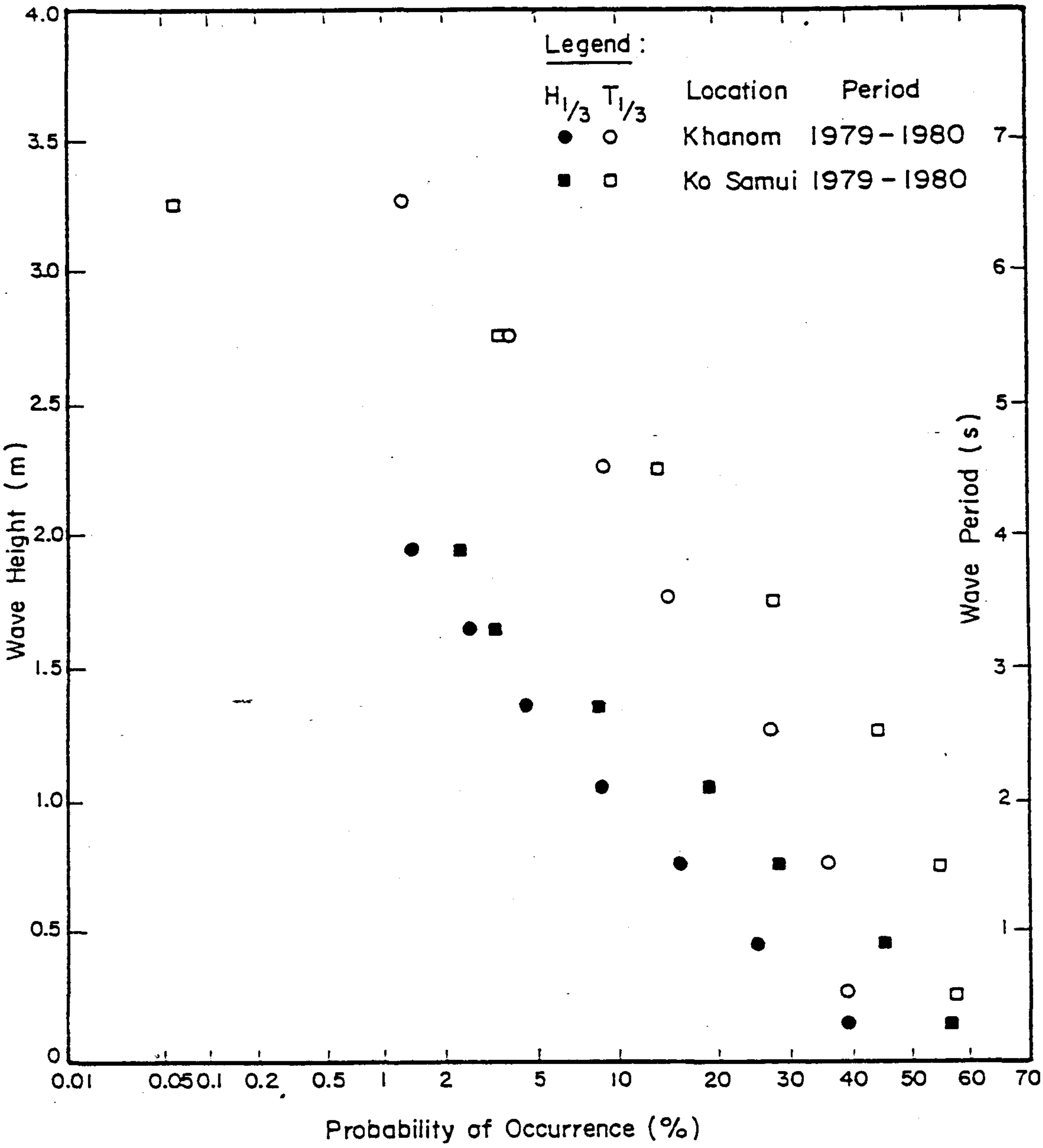


Fig. 7 - Probability of Occurrence of Significant Wave Height and Wave Period of Khanom and Ko Samui (Surat Thani)

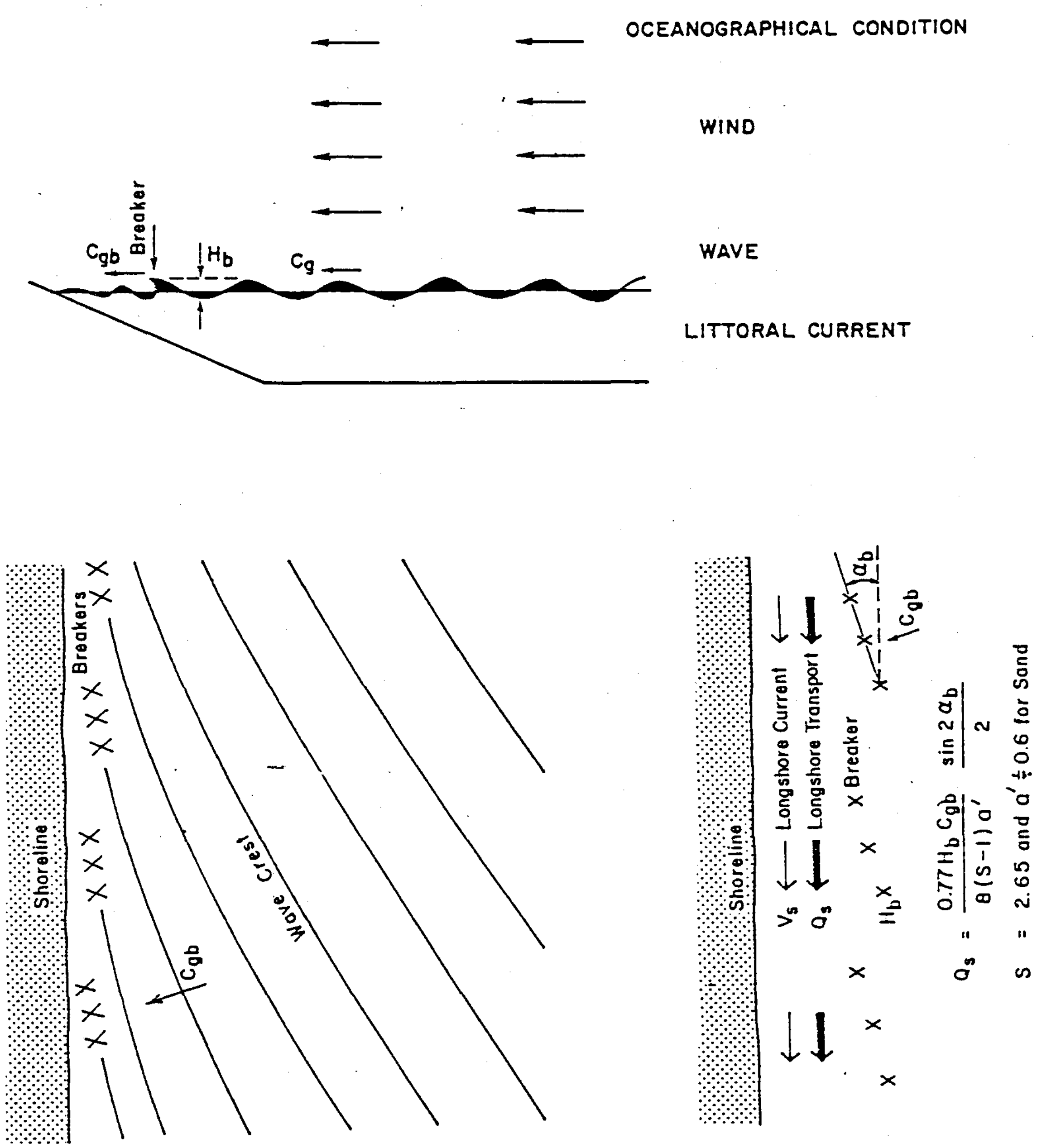


Fig. 8 Generation of Longshore Current by Breaking Wave and Its Longshore Transport Rate

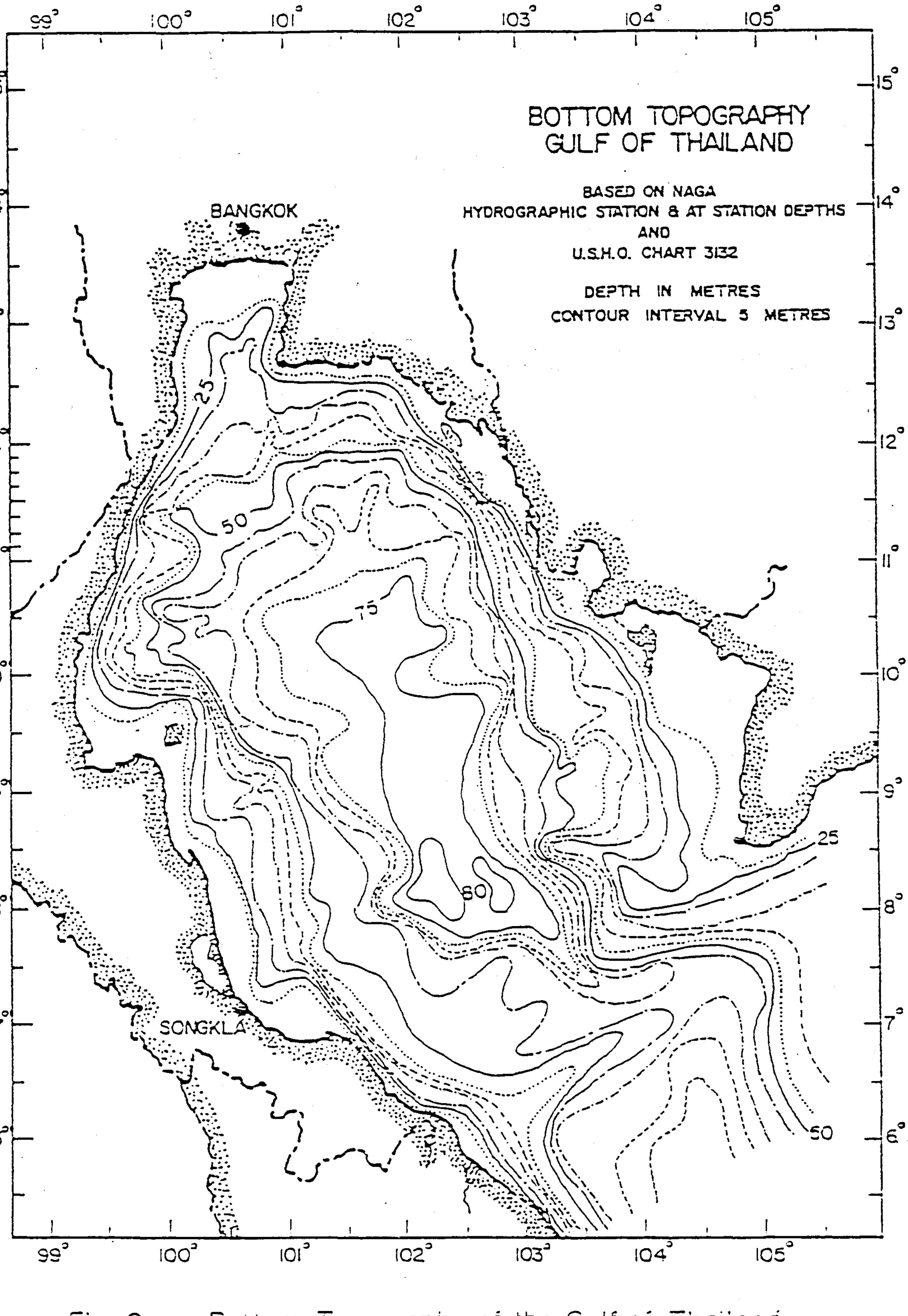


Fig. 9 - Bottom Topography of the Gulf of Thailand

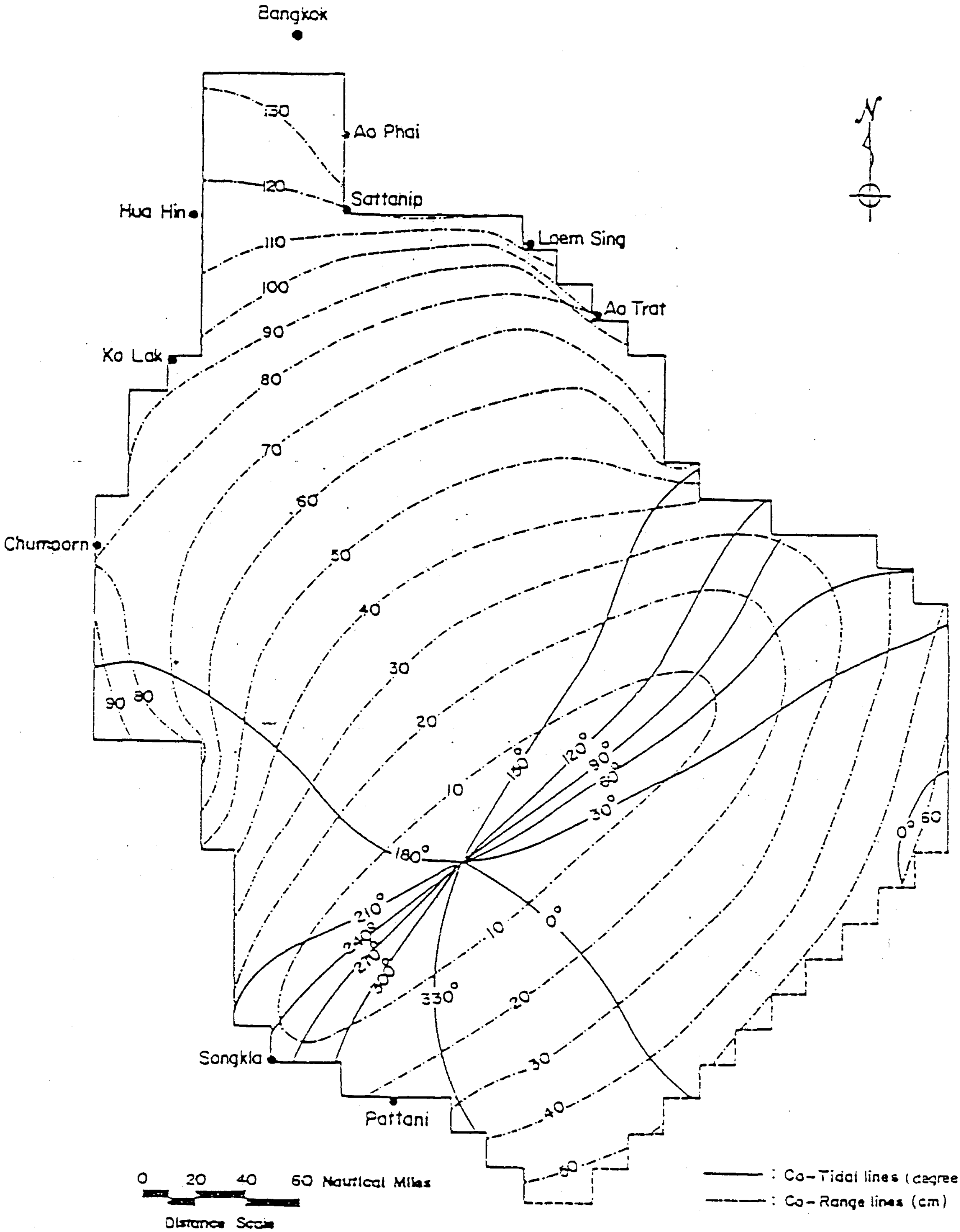


Fig. 10 - Tidal Chart of the K_1 Component

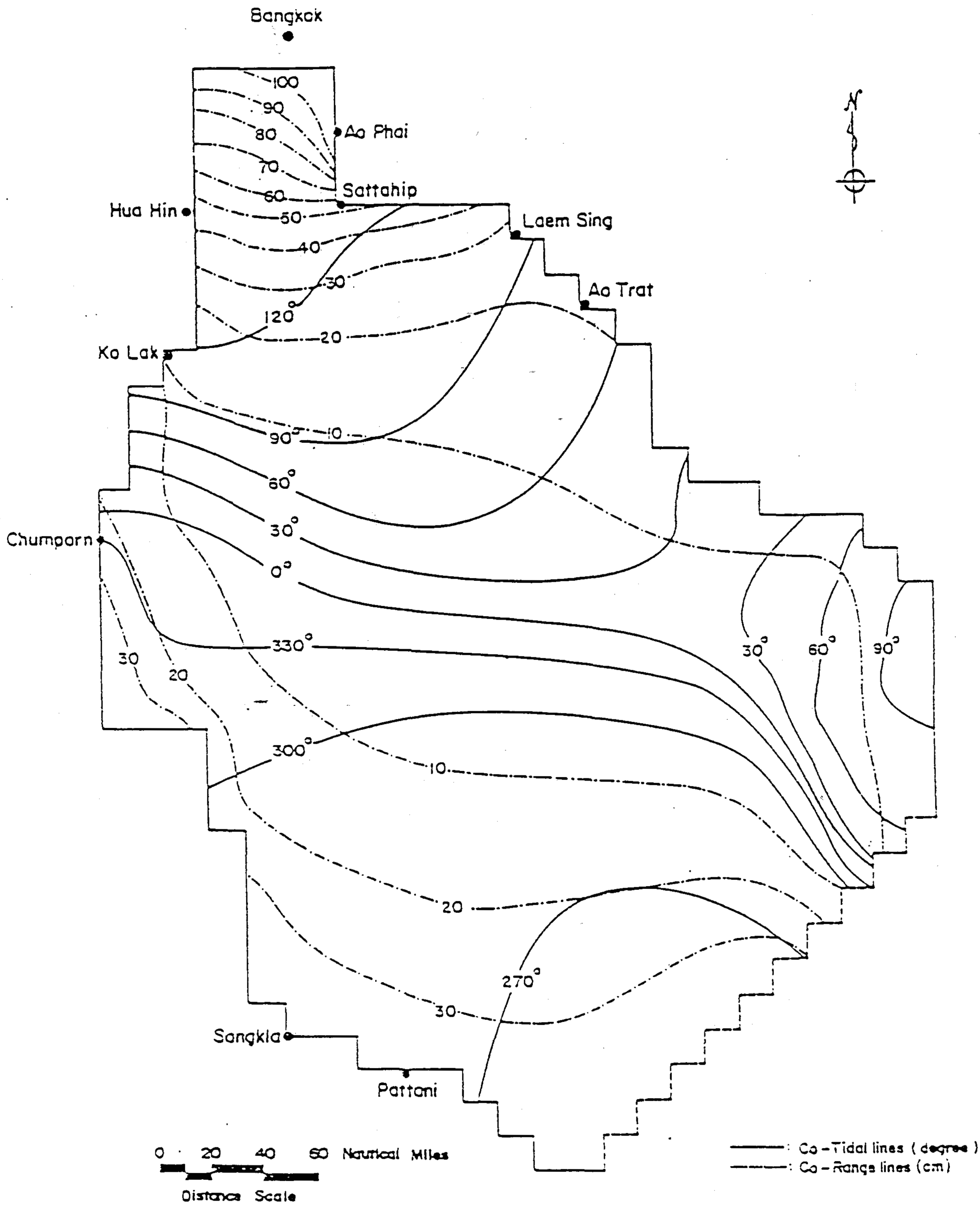


Fig. II - Tidal Chart of the M_2 Component

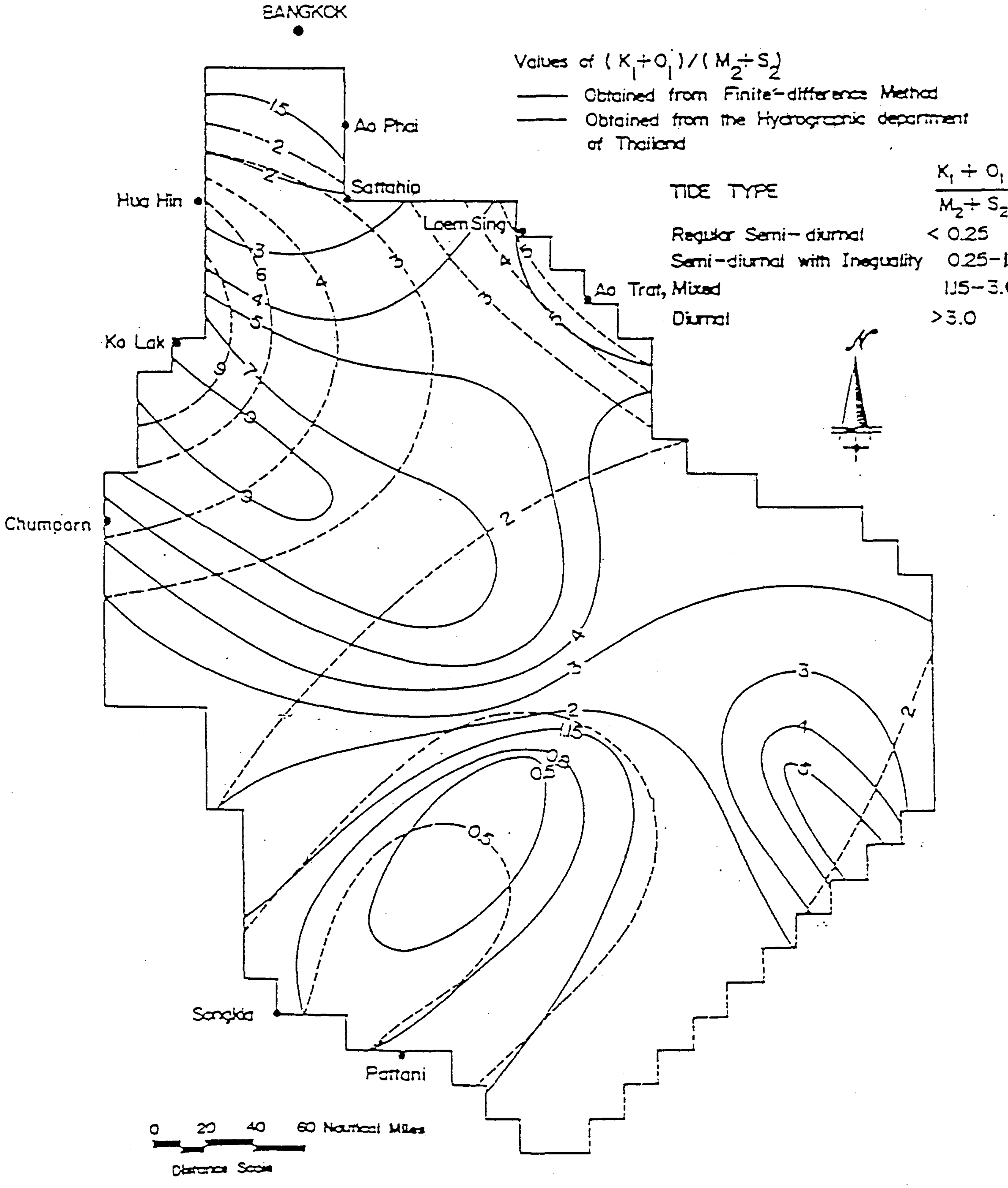


Fig. 12 - Types of Tide in the Gulf of Thailand

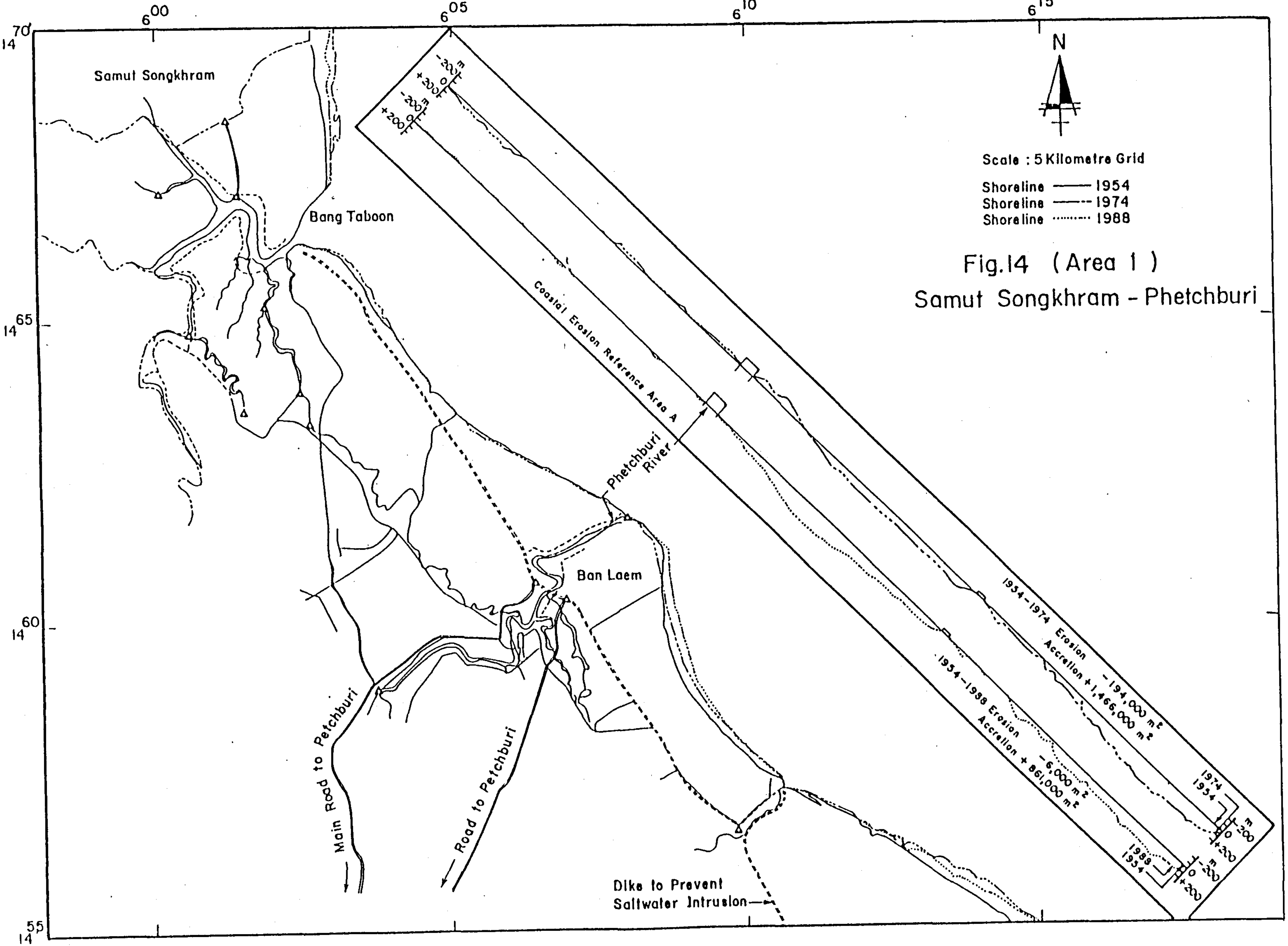


Fig.14 (Area 1)
Samut Songkhram - Phetchburi

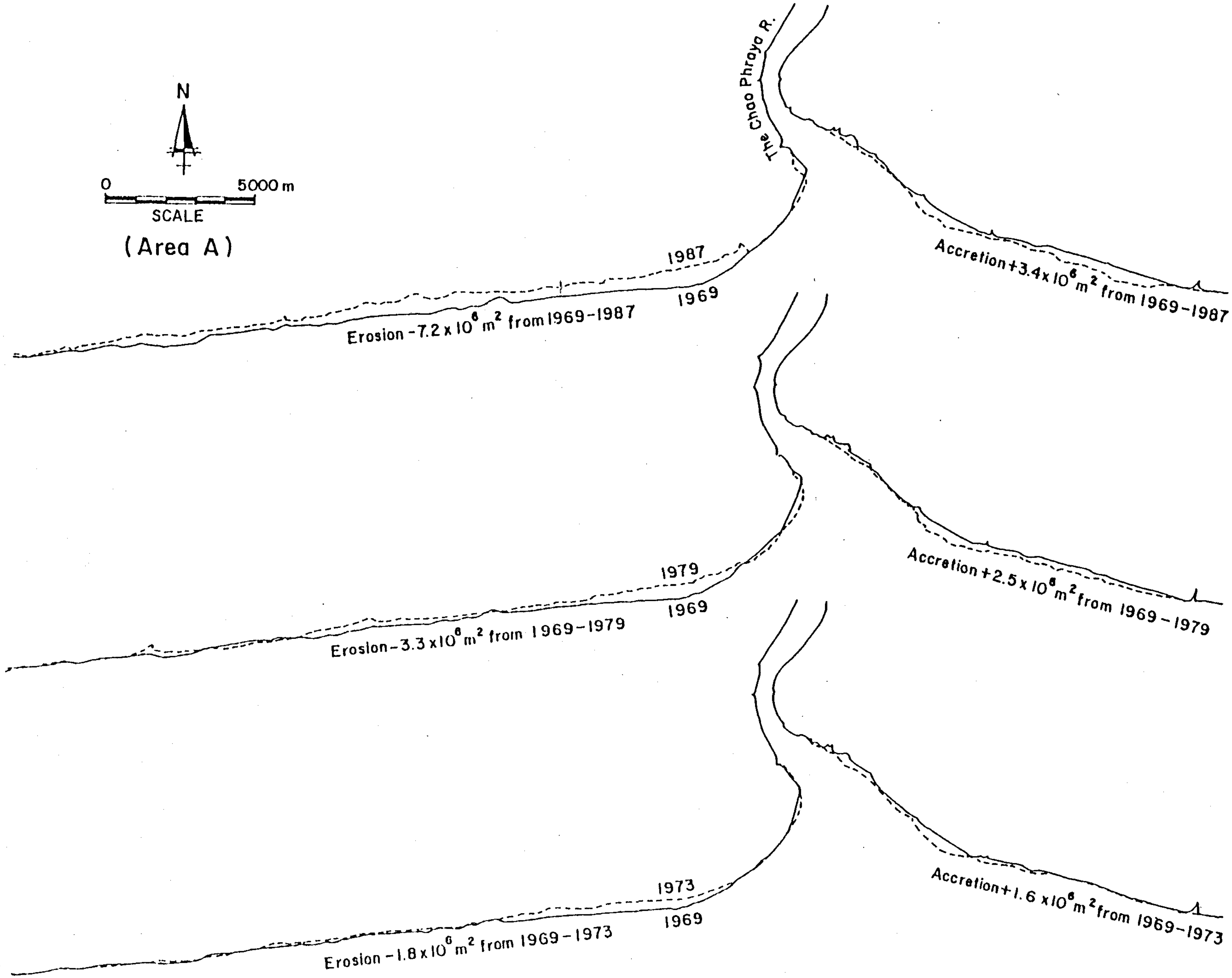


Fig. 13 The Chao Phraya River Mouth

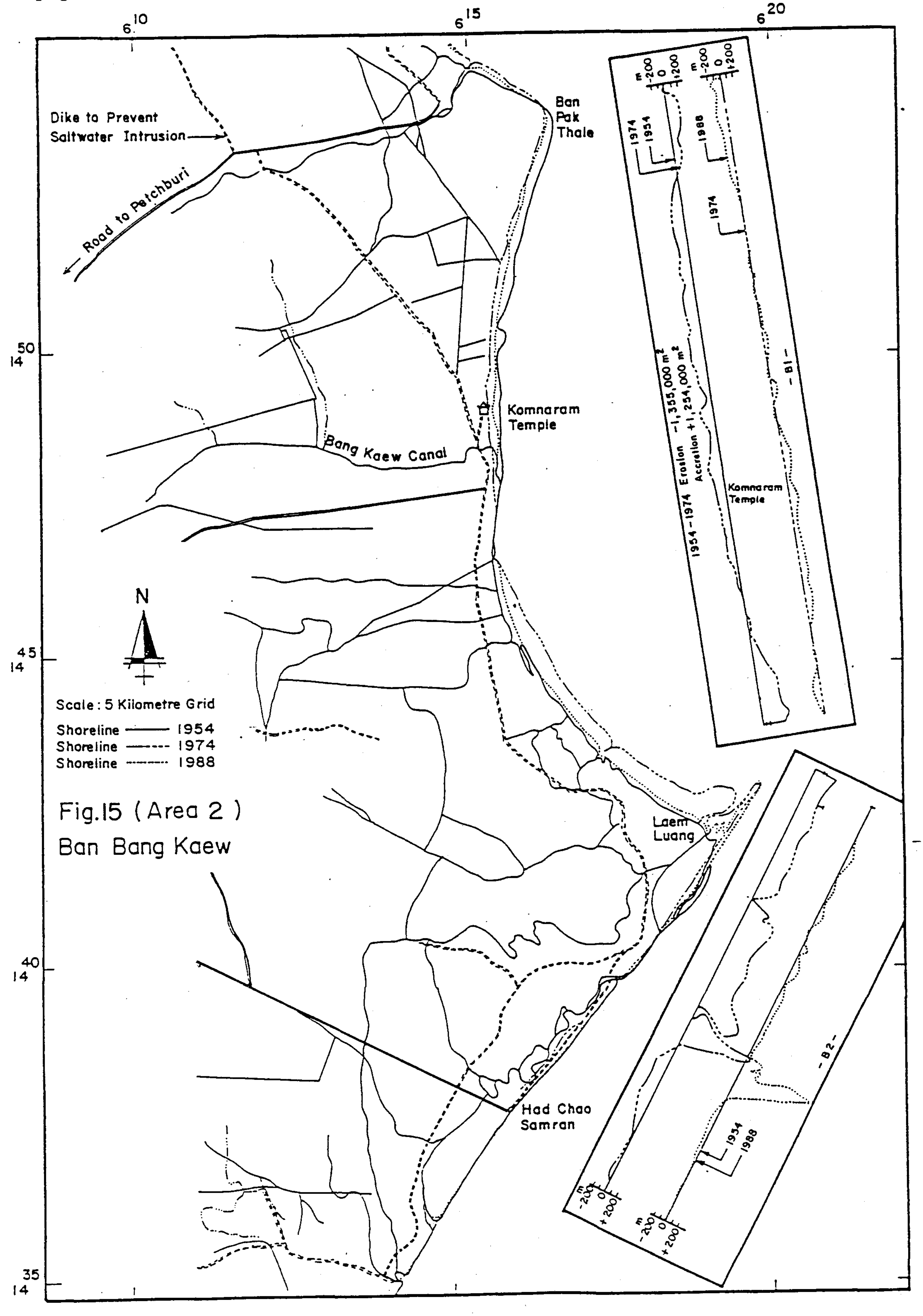


Fig.15 (Area 2)
Ban Bang Kaew

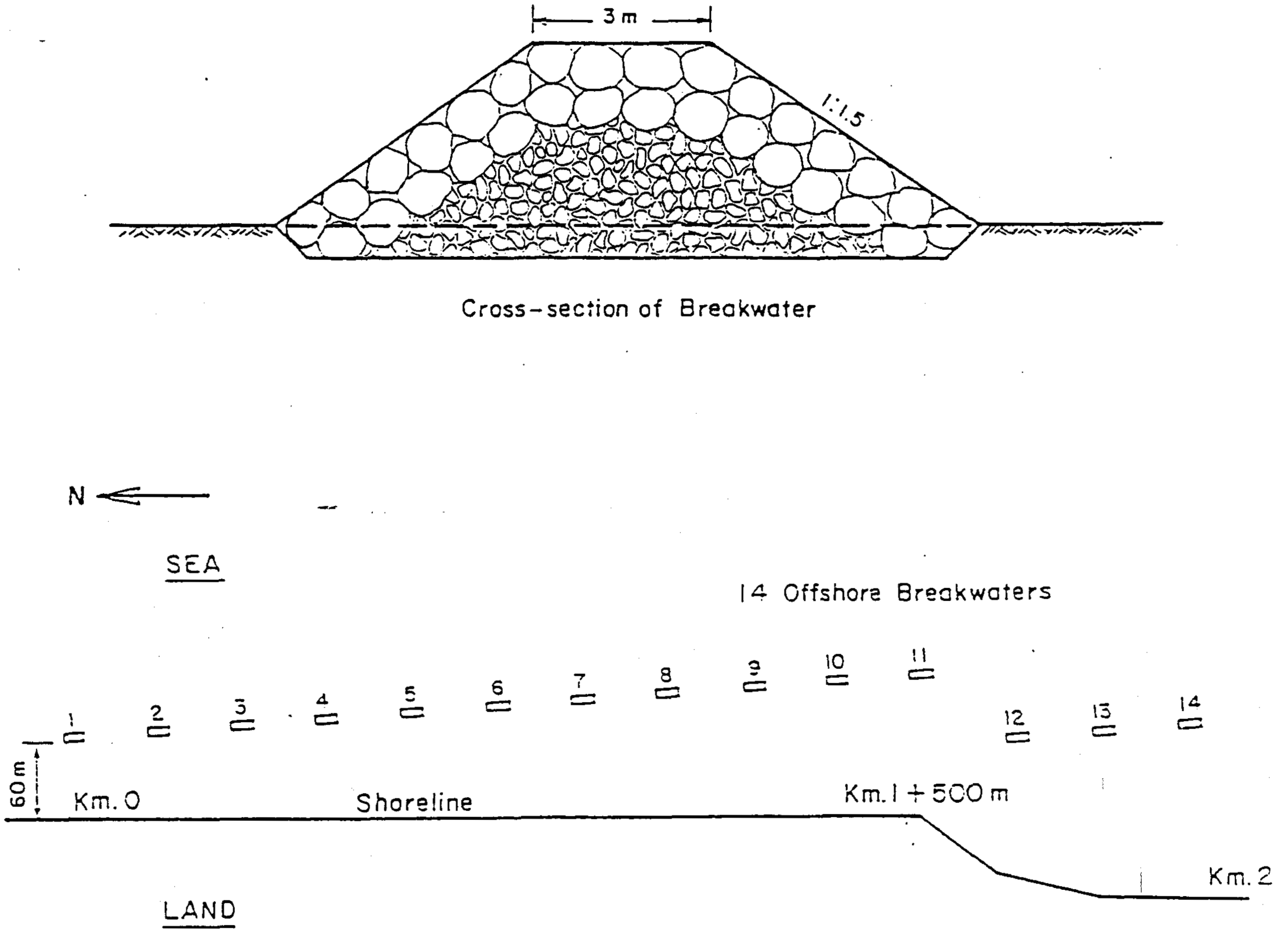


Fig. 16 Sketch of Offshore Breakwater Layout at Ban Bang Kaew

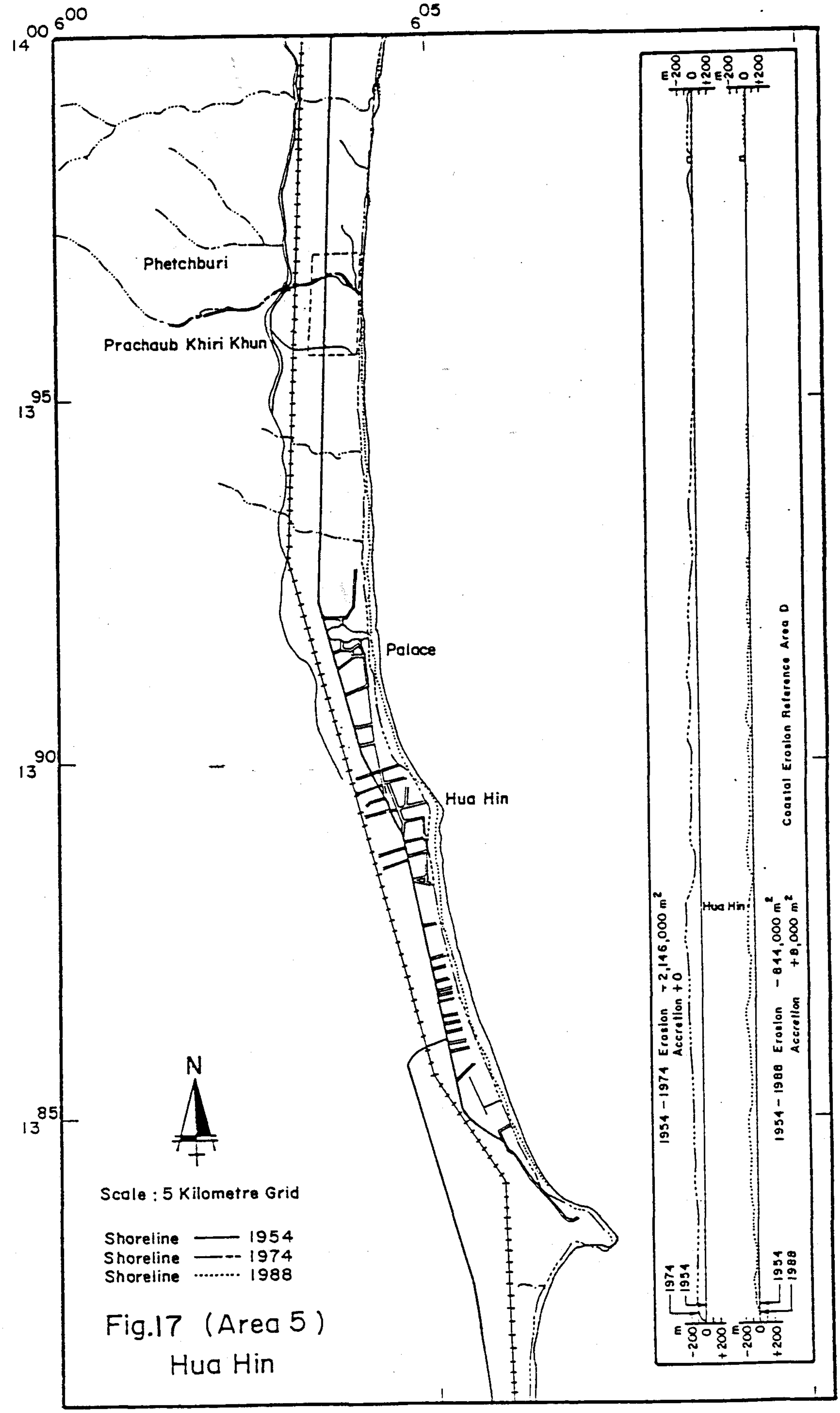


Fig.17 (Area 5)
Hua Hin

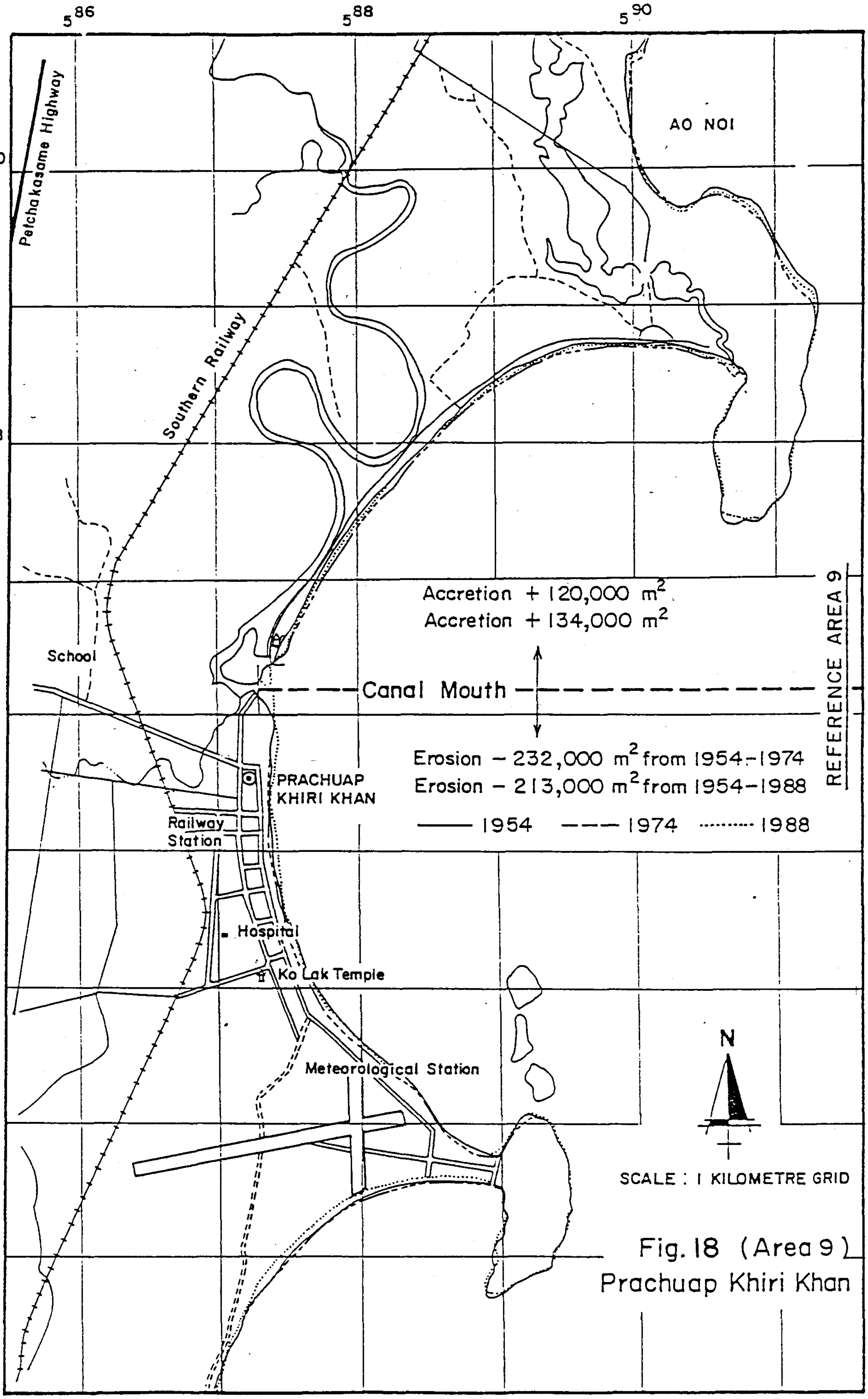


Fig. 18 (Area 9)
Prachuap Khiri Khan

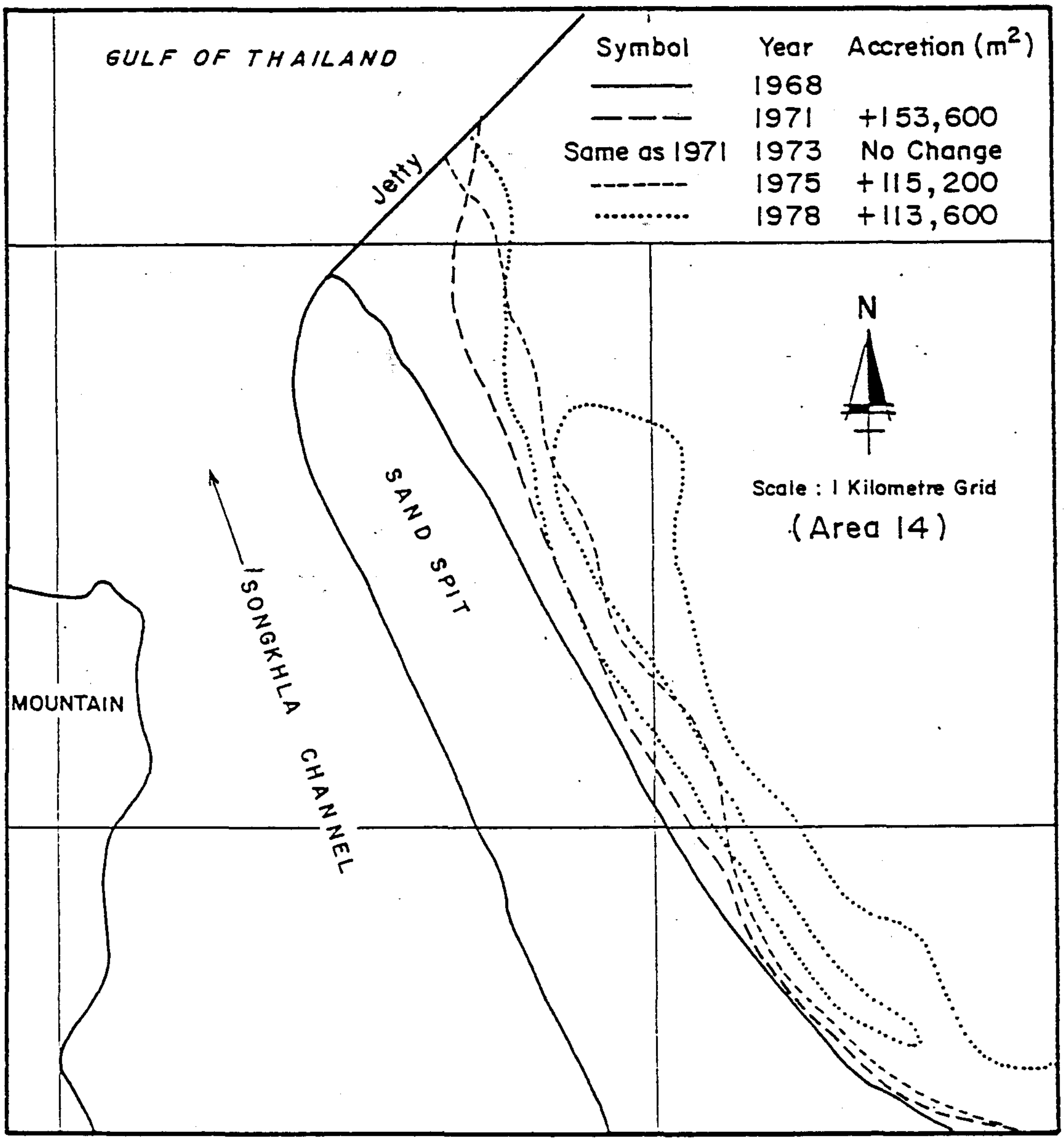


Fig. 19 Songkhla Lagoon Inlet

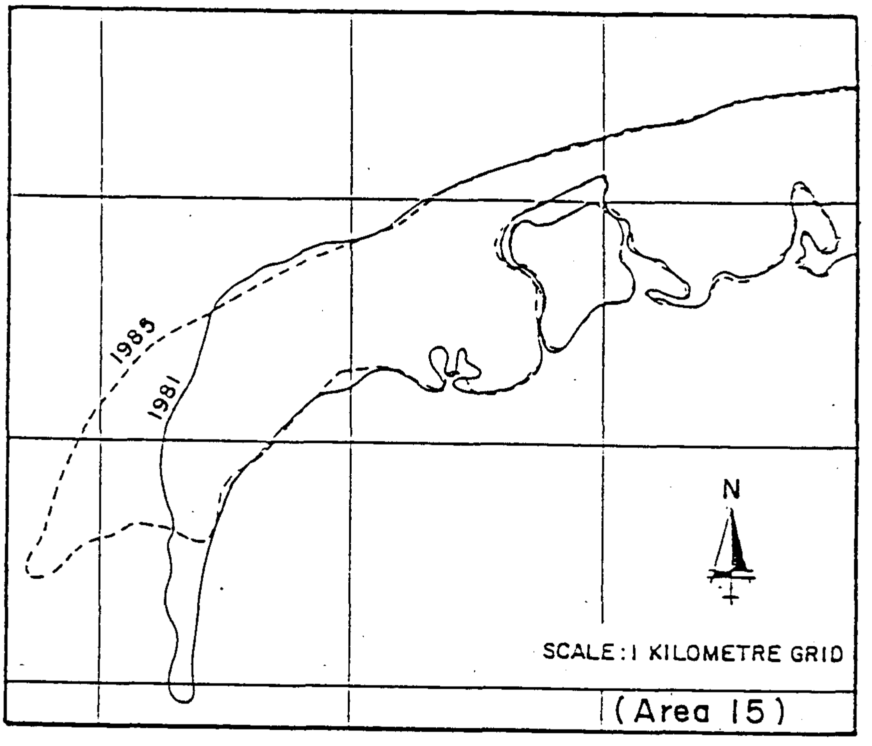


Fig. 20 Sand Spits of Laem Tachi (Pattani)

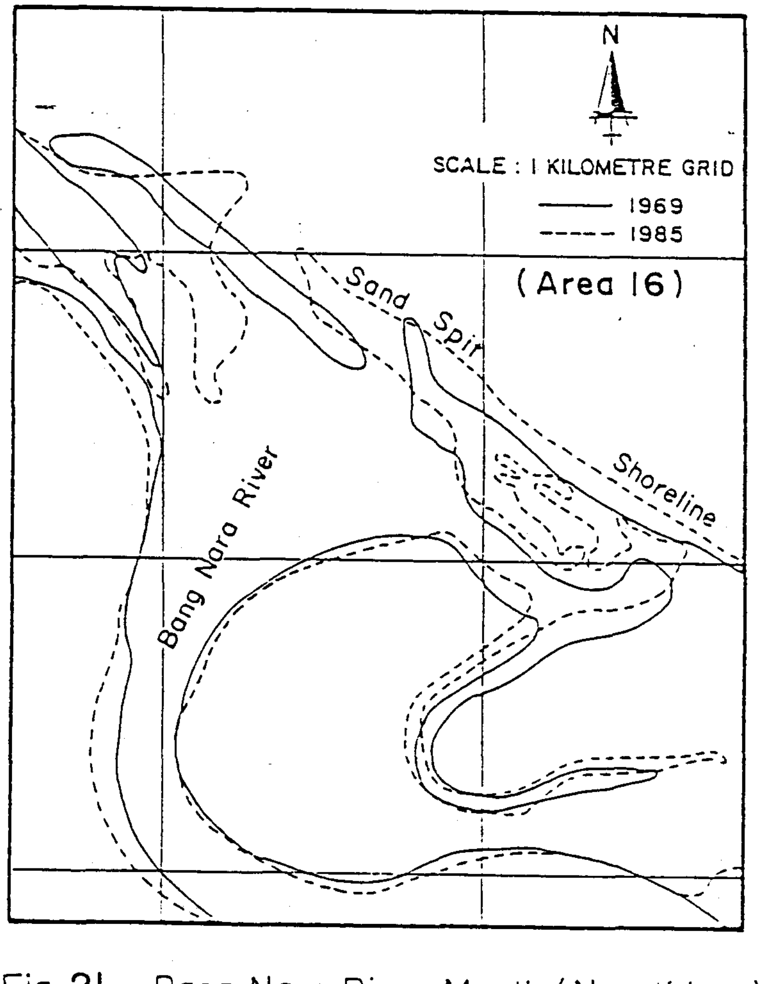
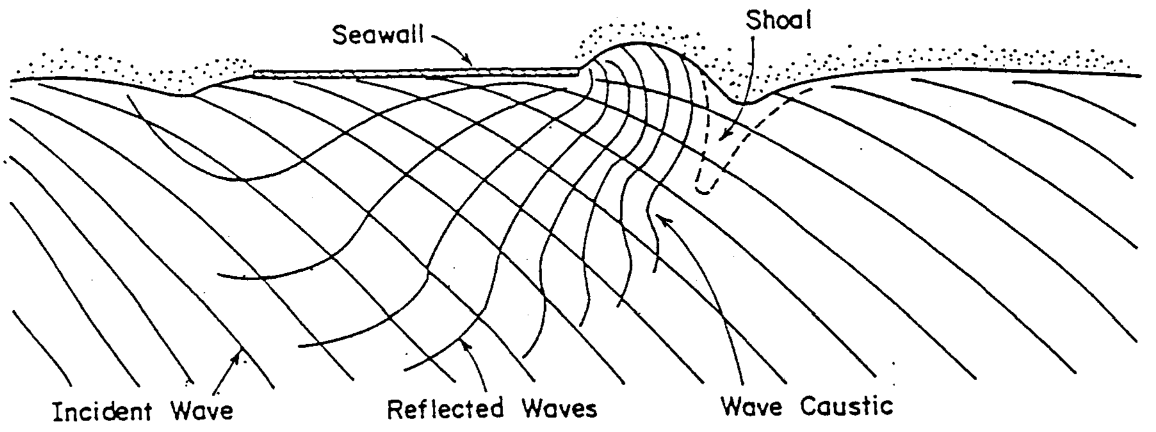
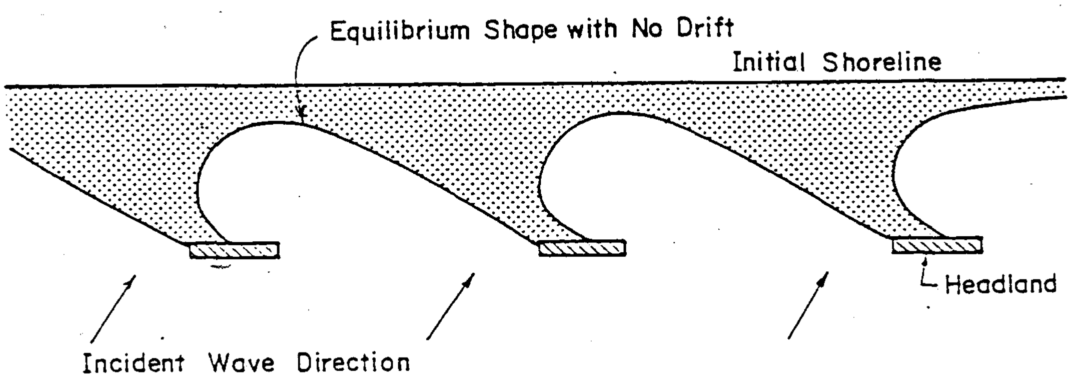


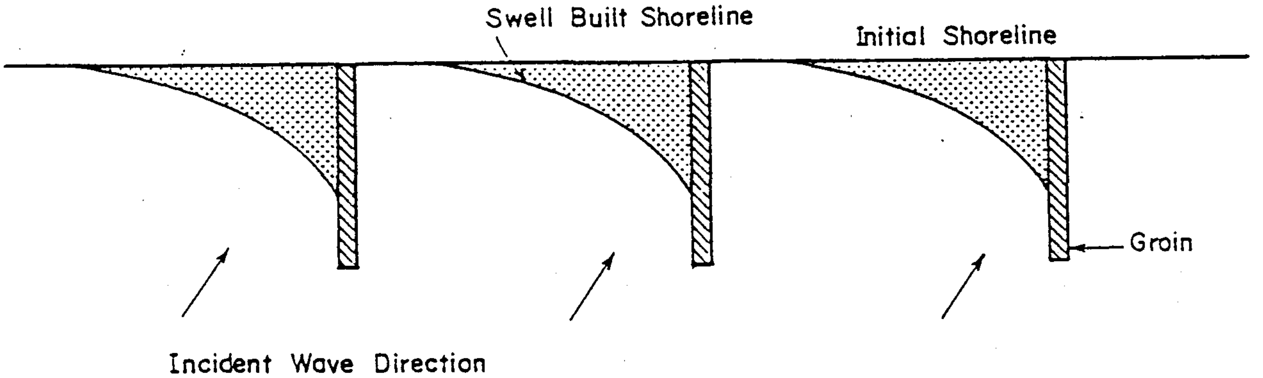
Fig. 21 Bang Nara River Mouth (Narathiwat)



(a) Scour near Seawall



(b) Headland or Offshore Breakwater



(c) Groin

Fig. 22 Comparison of Wave Action near (a) Seawall (b) Headland and (c) Groin

Influence of Changjiang River Plume on Hangzhou Bay:

Implication for sewage outfall siting

by

Su Jilan
Second Institute of Oceanography
State Oceanic Administration
Hangzhou, Zhejiang, China 310012

Worldwide there is a high population of people living close to the sea. In many cases economic development of such a community exerts increasing pressure on its coastal marine environment, which in turn may hinder its further development. Therefore, rational and sensible coastal zone management is both desirable and necessary to ensure continuous economic growth while maintaining a healthy coastal environment at the same time.

Decisions on coastal zone management issues must be based on knowledge of the state, as well as the dynamics, of the coastal environment. The ocean is, however, a complicated system. A developing country has neither the resources nor the time to first under its coastal environment and then to develop its coastal economy. One viable way is to have a general knowledge about the oceanography of its coastal waters through a general survey and, if possible, also a follow-up monitoring program.

I. General Survey of Seas adjacent to China

At the end of the 50's China launched a general survey of its shelf seas. From this survey a general description of the shelf circulation was gained. Based on this knowledge monitoring sections were set up later on in the 60's. These data are found to be useful sometimes in addressing coastal problems.

In the early 80's China initiated a nationwide coastal zone survey at a time that its coastal economy began rapid expansion. Another general survey with special emphasis on islands and their surrounding waters are currently underway. The findings of these surveys have been used as bases for drawing up guidelines for coastal zone development by the provincial governments. People also use these information to initiate related environmental impact study after a proposed project is approved.

In this paper I shall present an example of a different kind. In this example a sewage outfall project was proposed, but there was no clear plan for an environmental impact study. At that time we were about to initiate a research motivated by the findings arising from the coastal zone general survey. We expanded the study to include more disciplines so that it can address someaspects of the environmental impact of the proposed project.

II. Hangzhou Bay

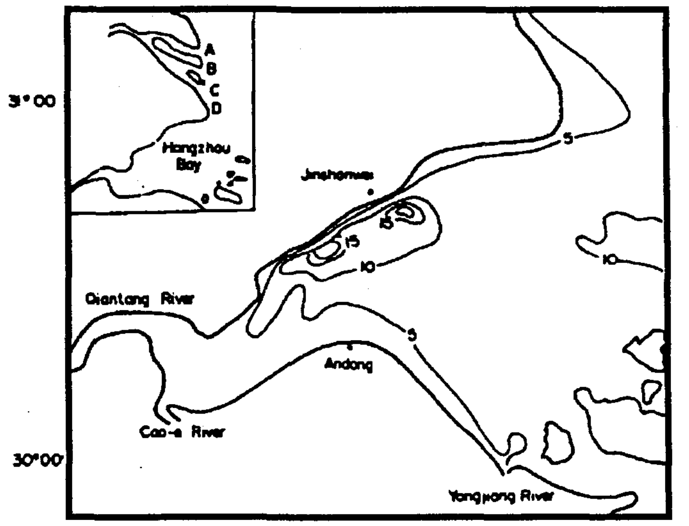


Fig. 1. Map of Hangzhou Bay. Cape Nanhui is to the north of the baymouth. Depth is in meters. (Insert: A—Beizhi waterway; B—Beigang waterway; C—Beicao waterway; D—Nancao waterway.)

Hangzhou Bay lies just to the south of the Changjiang Estuary (Fig. 1). It is a typical funnel-shaped bay, whose width is about 100 km at the mouth and narrows to around 20 km some 100 km to the west. The tidal range is about 2.5 m at the mouth and increases rapidly to a macro-tidal scale along the bay owing to the sharp reduction of the bay width. The Bay has an average of about 10 m. Its bottom topography is relatively flat except for a 25 km stretch of deep channel along the north shore. There are extensive tidal flats along the south shore, extending 10 km offshore near Andong (Fig. 1). The river discharge upstream of the Bay has an annual average rate of about 1,300 cubic meters per second. Seaward of Hangzhou Bay there is an important fishing ground of the East China Sea. A few species of anadromous fish travel through the Bay to spawn upstream.

Waste water, mainly municipal, discharged upstream of the Bay amounts to about 400 thousand cubic meters per day. In addition, there are one large refinery, one petrochemical plant and one nuclear power plant along the north shore of the Bay

III. The Proposed Shanghai Sewage Outfall Project

Shanghai is one of the world's largest metropolis. Its daily discharge of industrial and municipal waste water altogether is about 5 million cubic meters. Currently about 5 percent of this waste water is discharged into the Changjiang River Estuary (Fig. 2). The waste water has undergone physical treatment, by which the particles have settled out and then been removed. Satellite imageries show that the discharged waste water can be traced visually for 6 to 10 km from its discharging point. The city is proposing to construct another sewage outfall with a capacity to carry 20 percent of the city's waste water load. The proposed outfall was to be built at the tip of the Nanhui Capė at the northern edge of the mouth of Hangzhou Bay (Fig. 1). Concerns were expressed by various sectors of the neighboring communities on the impact of the waste discharge on the marine environment in the Hangzhou Bay and its adjacent waters.

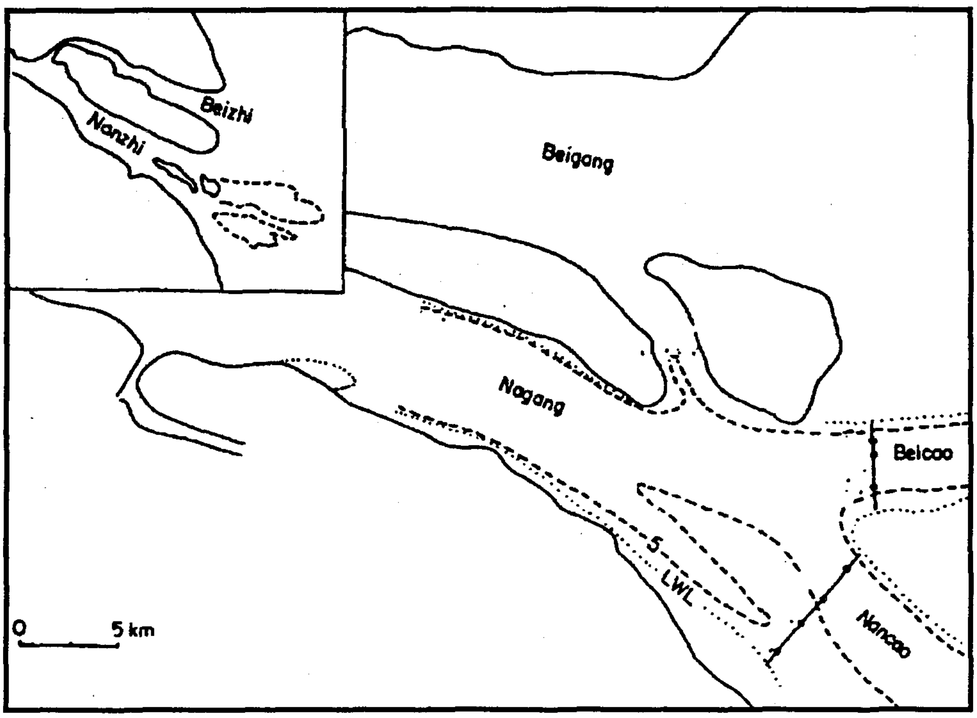


Fig. 2. Map of Changjiang Estuary. The present sewage outfall of the Shanghai City is located at the shore near the south boundary of the map.

IV. The Secondary Changjiang River Plume

Changjiang is the third largest river in the world, discharging at an annual average rate of about 30,000 cubic meters per second. The River branches in three successive hierarchies as it enters the East China Sea (Fig. 2). At the river mouth there are four waterways, namely, starting from the north, the Beizhi, Beigang, Beicao and Nancao waterway. Together, the Beigang and the Beicao waterways carry almost all of the Changjiang discharge. The front of the principal Changjiang River plume is about 50 km off the coast of the Nanhui Cape during the winter and around 100 km during the summer. In the estimates given above the bottom position of the 30 ppt isohaline isused as an index for the outer limit, i.e., the front, of the plume.

The Changjiang estuary system is such that there is a net landward flux through the southernmost waterway, the Nancao (Su and Wang, 1986). Within Nancao, however, there is a net seaward flow near the south shore, carrying some of the Changjiang discharge (Fig. 3). Consequently, this fresher discharge near the south shore forms a secondary Changjiang River plume versus the more saline landward net-flow through the rest of the Nancao waterway (Su and Wang, 1989).

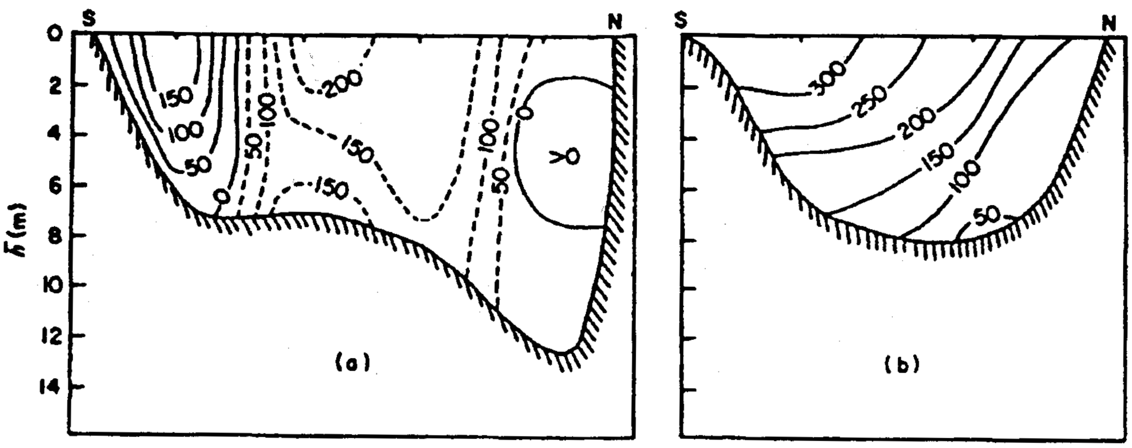


Fig. 3. Distribution of the net water transport per unit area through (a) Nancao waterway and (b) Beicao waterway. Unit is in one-thousandth cubic meter per second per square meter.

V. Influence of the Secondary Changjiang River Plume on the Marine Environment of the Hangzhou Bay

Because of the proximity of the Changjiang Estuary and the Hangzhou Bay there is a strong interaction between these two estuaries. We carried out two successive field observation programs in both December 1987 and summer 1988 to study the influence of the secondary Changjiang River plume on the marine environment of the Hangzhou Bay. The study was an interdisciplinary one, covering physical, chemical, sedimentary, as well as some biological aspects.

It is found that there is a front running in the NE-SW direction from the bay mouth near the Nanhui Cape to the south shore in the Hangzhou Bay. This front is actually the merging of the secondary Changjiang River plume front and the plume front from the upstream of the Bay. During neap tides in the low runoff season (winter) these two plumes can be clearly identified (Fig. 4). At other times the two plumes connect together and become a coastal-front like feature (e.g., Fig. 5). Floats with a van at 3 m below the surface were found to have a net drift in the southwest direction into the bay when deployed at the front, during either northerly or southerly winds.

Fig. 4. Bottom salinity distribution in Hangzhou Bay during neap tide in December of 1987.

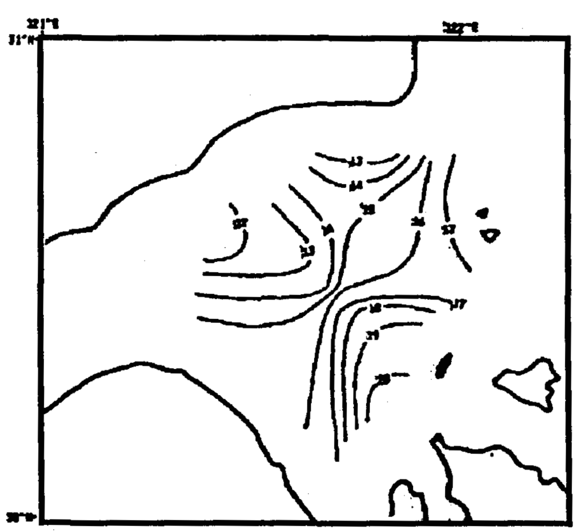


Fig. 4. Bottom salinity distribution in Hangzhou Bay during neap tide in December of 1987.

On the low salinity side of the front there is a high turbidity zone in the bottom layer (Fig. 6). Above this zone the concentration of the suspended matter is also higher (Fig. 7a), which can also be readily identified from satellite imageries (Fig. 7b). High concentrations of phytoplankton, bacteria and particulate organic matters are also found in the frontal zone.
Both distributions of the clay content and the manganese content of the bottom sediment show similar alignment with the front east of the tidal flats near the south shore (Fig. 8). Other heavy metal contents of the bottom sediment show similar distribution patterns. (These heavy metal contents are within the normal native range of the sediment particles themselves.)

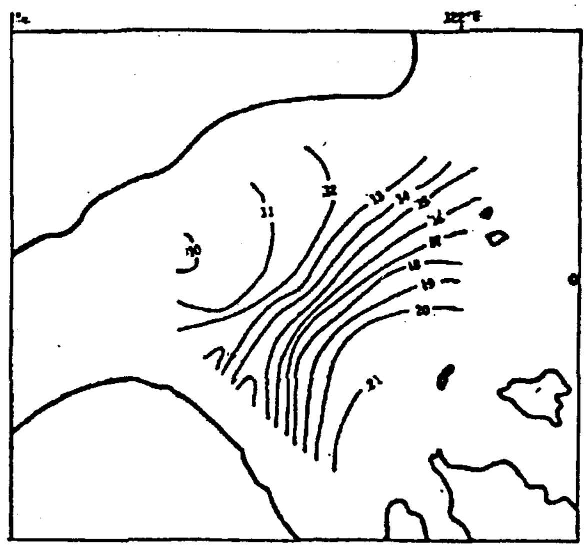


Fig. 5. Bottom salinity distribution in Hangzhou Bay during spring tide in December of 1987.

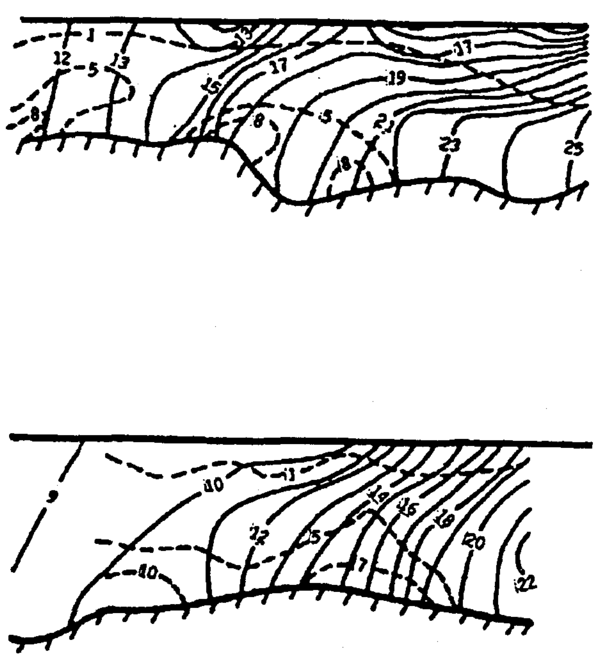


Fig. 6. Distribution of the salinty (solid line) and suspended matter (dashed line) at two sections across the fromt in the Hangzhou Bay during neap tide in August 1988. Unit for the suspended matter concentration is in one-tenth kilogram per cubic meter.

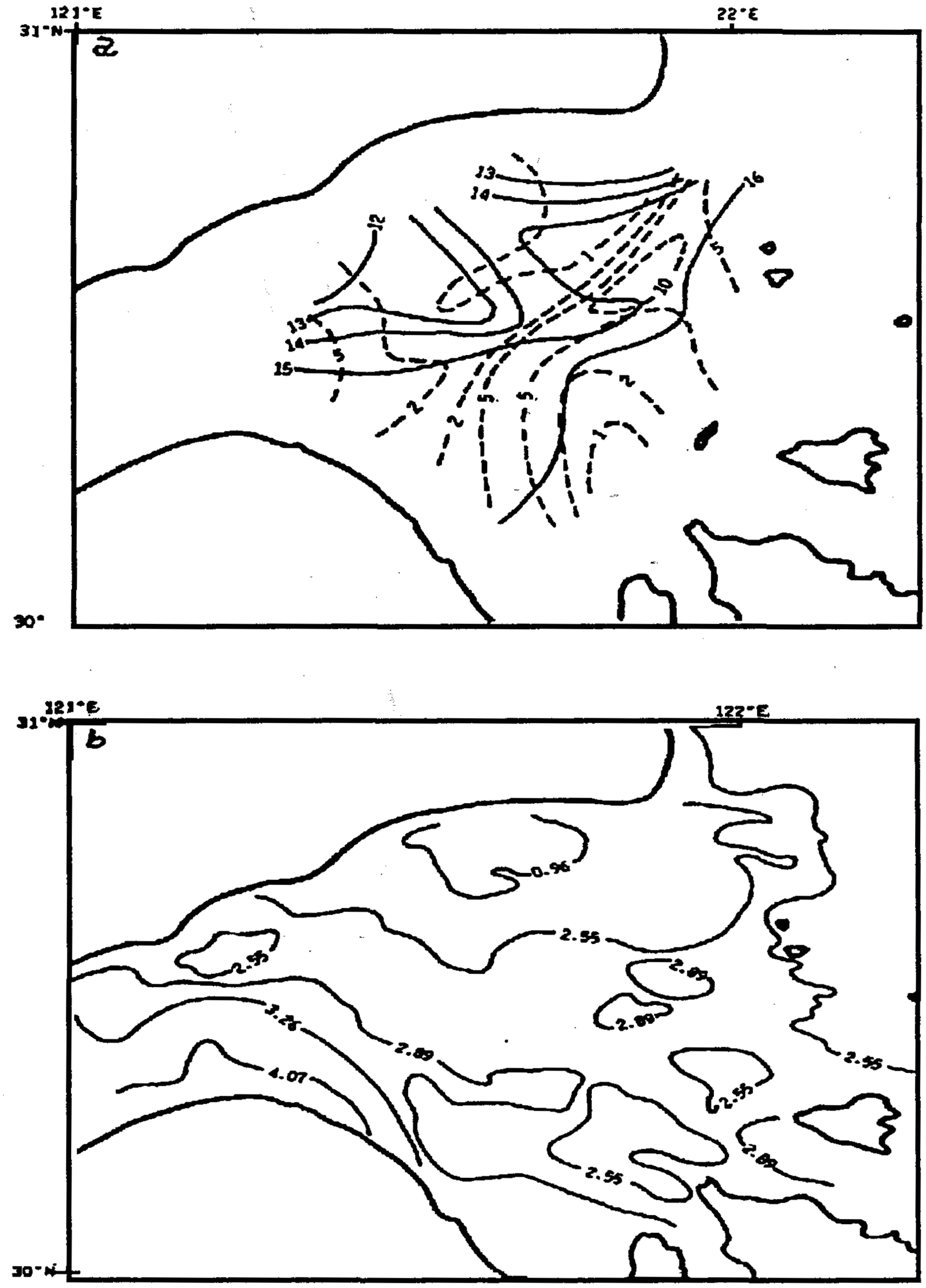


Fig. 7. (a) Surface distributions of the salinity (solid line) and suspended matter (dashed line) and (b) surface suspended matter distribution derived from the visible light imagery of NOAA-9 satellite. Both were during neap tide in December of 1987. Unit for the suspended matter concentration is in one-tenth per kilogram per cubic meter.

VI. Concluding Comments

Our Hangzhou Bay study has shown that the secondary Changjiang River plume plays an important role in the circulation of the Hangzhou Bay. This plume is likely to concentrate the pollutants discharged along the shores of the Nanhui Cape inside its frontal zone and to transport them into the Bay along the front. Partly as a result of our study a large-scale marine environmental study is being planned for Hangzhou Bay and the neighboring waters. One of the goal of this planned project is to address the siting of the proposed sewage outfall for Shanghai.

This example illustrates the importance of the coastal oceanography studies for coastal zone management issues.

Fig. 8. The clay content percentage isolines (solid line) and the manganese content isoline (dashed line) of the bottom sediment in the Hangzhou Bay. The manganese content is in ppm. (Courtesy of Fen Yingjung and Liao Xiangui)

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Science and Coastal Zone Management

by

Dr. Michael Hamnett[1]
Coordinator
Center for Development Studies
Social Science Research Institute
University of Hawaii

Editor's note: Dr. Michael Hamnett's presentation was in the form of questions and discussion points and not in a written paper format. Nevertheless, the questions posed and the answers proposed are very appropriate and stimulating to the exploration of science/management relationships and his outline is provided in full.

MOST POLICY MAKERS AND SCIENTISTS AGREE:

- o OUR OCEAN AND COASTAL RESOURCES SHOULD BE MANAGED BASED ON BEST AVAILABLE SCIENTIFIC KNOWLEDGE ABOUT THOSE RESOURCES.

- o NOAA AND OTHER AGENCIES PROVIDE CONSIDERABLE FINANCIAL SUPPORT FOR SCIENTIFIC ACTIVITY TO IMPROVE COASTAL RESOURCE MANAGEMENT.

- o MOST COASTAL ZONE MANAGEMENT DECISIONS ARE NOT BASED ON SCIENCE

WHY?

- O THERE IS AN INADEQUATE SCIENTIFIC UNDERSTANDING OF MOST COASTAL PROCESSES?

- O COASTAL ZONE MANAGERS DO NOT MAKE USE OF SCIENTIFIC INFORMATION AVAILABLE WHEN MAKING DECISIONS?

- O SCIENTISTS AND COASTAL ZONE MANAGERS LIVE IN TWO DIFFERENT CULTURES?

1. Dr. Michael Hamnett is also a Senior Policy Analyst with the Pacific Basin Development Council located in Honolulu, Hawaii

WHAT IS COASTAL ZONE MANAGEMENT?

- o COASTAL ZONE MANAGEMENT AT THE NATIONAL LEVEL OF GOVERNMENT IN THE U.S. WAS 1ST ENACTED INTO LAW IN 1972

- o CZMA PROVIDED A FRAMEWORK TO SET UP PARTNERSHIPS BETWEEN FEDERAL GOVERNMENT AND STATE, TERRITORIAL AND COMMONWEALTH GOVERNMENTS

  - FEDS PROVIDE FUNDING FOR STATE\TERRITORIES\ COMMONWEALTHS TO DEVELOP MANAGEMENT PLANS. SEVERAL NEW PLANS ARE NOW BEING DEVELOPED

  - FEDS PROVIDE FUNDING TO STATES TO IMPLEMENT THEIR PLAN—THERE ARE NOW 29 APPROVED PROGRAMS

  - FEDS ADMINISTER GRANTS, MONITOR PROGRAMS AND PROVIDE TECHNICAL ASSISTANCE

- o WHAT COASTAL PROBLEMS DO CM PROGRAMS ADDRESS?

  - DIMINISHING ACCESS TO COAST FROM DEVELOPMENT

  - COASTAL EROSION

  - OTHER COASTAL HAZARDS

  - DEGRADATION OF CULTURAL RESOURCES: ARCHAEOLOGICAL SITES

  - DEGRADATION OF UNIQUE HABITATS

  - LOSS OF WETLANDS

  - NON-POINT SOURCE POLLUTION

- o STATE\TERRITORIAL\COMMONWEALTH PLANS ARE LARGELY REGULATORY

  - AIMED AT CONTROLLING HUMAN ACTIVITY THAT HAS A NEGATIVE IMPACT ON COASTAL RESOURCES

  - RELY HEAVILY ON PERMITS AS A REGULATORY TOOL
  - MANY STATES, INCLUDING HAWAII, MODIFIED EXISTING REGULATORY SYSTEMS TO QUALIFY FOR CZM FUNDS

MANY STATES HAVE NETWORKED PROGRAMS

WHY DON'T COASTAL RESOURCE MANAGERS RELY MORE ON SCIENCE TO ASSIST THEM IN COASTAL ZONE MANAGEMENT?

1. THERE IS AN INADEQUATE SCIENTIFIC UNDERSTANDING OF MOST COASTAL PROCESSES.

o EXAMPLE — NON-POINT SOURCE POLLUTION: WHAT SCIENCE IS RELEVANT?

- FEDS SAY NON-POINT SOURCE POLLUTION IS CONTRIBUTING TO DEGRADATION OF HABITATS: REEFS, WETLANDS, STREAMS AND RIVERS—TAKE CORAL REEFS

- SCIENCE MIGHT PROVIDE BASELINE INFORMATION ABOUT REEF HABITATS

- SCIENCE MIGHT HELP US UNDERSTAND POPULATION DYNAMICS OF CORAL, FISH AND OTHER ORGANISMS THAT MAKE UP A REEF HABITAT

- SCIENCE MIGHT HELP US UNDERSTAND HOW DIFFERENT STRESSORS AFFECT DIFFERENT SPECIES OF CORALS OR FISH

- SCIENCE MIGHT HELP US UNDERSTAND THE SOURCE OF THESE STRESSORS AND THE RELATIVE IMPORTANCE OF EACH SOURCE

- SCIENCE MIGHT HELP US UNDERSTAND THE RELATIVE EFFECTIVENESS OF DIFFERENT TYPES OF CONTROL TECHNOLOGIES?

o IS THERE ADEQUATE SCIENTIFIC INFORMATION ON THE STATE OF CORAL REEFS, THE POPULATION DYNANMICS OF CORAL HABITATS, THE AFFECTS OF STRESSORS ON REEF ORGANISMS, THE SOURCES AND RELATIVE IMPACTS OF THOSE STRESSORS, AND THE RELATIVE EFFECTIVENESS OF CONTROL TECHNOLOGIES?

o WHERE CAN COASTAL ZONE MANAGERS GO TO GET ACCESS TO THIS INFORMATION?

2. COASTAL ZONE MANAGERS DO NOT CONSULT THE SCIENTIFIC LITERATURE AND SCIENTI STS WHEN MAKING DECISIONS

- SCIENTISTS ARE REWARDED FOR PUBLISHING IN REFEREED JOURNAL ARTICLES AND BOOKS: ARE SCIENTIFIC JOURNALS ACCESSIBLE TO DECISION-MAKERS?

- COASTAL ZONE MANAGERS ARE REWARDED FOR RESPONDING TO POLITICAL DECISIONS IN A TIMELY MANNER: CAN A MANAGER TAKE TIME TO CONSULT THE SCIENTIFIC LITERATURE?

- SCIENCE IS VERY SPECIALIZED: FROM THIS LIST OF WHAT SCIENCE MIGHT CONTRIBUTE TO REDUCING NON-POINT SOURCE POLLUTION, HOW MANY DIFFERENT BOOKS AND JOURNAL ARTICLES WOULD A MANAGER HAVE TO CONSULT?

- COASTAL MANAGERS MUST BE GENERALISTS: CAN STATE AND LOCAL GOVERNMENTS AFFORD TO EMPLOY THE WHOLE RANGE OF SPECIALISTS NEEDED TO REDUCE NON-POINT SOURCE POLLUTION?

- SCIENTIFIC LANGUAGE IS VERY TECHNICAL: WILL DECISION-MAKERS UNDERSTAND THE AVERAGE JOURNAL ARTICLE ABOUT CORAL REPRODUCTION?

- COASTAL MANAGERS MUST DEAL WITH POLITICIANS AND THE GENERAL PUBLIC: CAN COASTAL MANAGERS AFFORD THE TIME TO LEARN THESE SPECIALIZED LANGUAGES OF THE SCIENTIFIC FIELDS THAT COULD CONTRIBUTE TO REDUCING NON-POINT SOURCE POLLUTION?

- FOR UNIVERSITY SCIENTISTS, TENURE AND PROMOTION ARE GENEERALLY BASED PRIMARILY ON PUBLICATION RECORD: WILL TIME SPENT ON HELPING A COASTAL ZONE MANAGER UNDERSTAND A PROBLEM AND EVALUATE OPTIONS MEAN TIME AWAY FROM RESEARCH THAT WILL RESULT IN ACADEMIC PUBLICATIONS?

- COASTAL MANAGEMENT PROGRAMS ARE GENERALLY POORLY FUNDED: DO COASTAL MANAGEMENT PROGRAMS HAVE THE FUNDS TO CONTRACT THE FULL RANGE OF SCIENTIFIC TALENT THAT WILL BE REQUIRED TO DEVELOP AN EFFECTIVE NON-POINT SOURCE POLLUTION POLICY AND PROGRAM?

- THE ADVANCEMENT OF SCIENCE IS FURTHERED THROUGH THE DEVELOPMENT AND TESTING OF HYPOTHESES AND CONTRIBUTIONS TO SCIENTIFIC THEORY: WILL AN EVALUATION OF POLICY OPTIONS FOR REDUCING NON-POINT POLLUTION CONTRIBUTE TO THE ADVANCEMENT OF SCIENCE?

- THE ADVANCEMENT OF COASTAL ZONE MANAGEMENT IS FURTHERED THROUGH THE DEVELOPMENT OF EFFECTIVE POLICIES AND PROCEDURES: WILL AN INVESTMENT OF TIME AND MONEY IN DEVELOPING A SCIENTIFIC BASIS FOR MANAGEMENT DECISIONS RESULT IN BETTER POLICIES AND PROCEDURES?

3. SCIENTISTS AND COASTAL ZONE MANAGERS LIVE IN DIFFERENT CULTURES

   - THEIR VALUES ARE DIFFERENT
   - THEY DEFINE PROBLEMS IN DIFFERENT WAYS
   - THEIR REFERENCE GROUPS ARE DIFFERENT
   - THEY ARE REWARDED FOR DIFFERENT KINDS OF ACCOMPLISHMENTS
   - THEY SPEAK DIFFERENT "LANGUAGES"

HOW DO WE BRIDGE THE CULTURE GAP?

o DEVELOP A CADRE OF TRANSLATORS

o CHANGE THE INCENTIVE SYSTEMS

o PROVIDE OPPORTUNITIES FOR CROSS-CULTURAL COMMUNICATION

Integrated Data Management: A New Approach to the Dissemination of Ocean Data

by William Schramm
Director
NOAA Center for Ocean Analysis and Prediction
Monterey, California

Government agencies around the world collect, manage, analyze and disseminate a wide variety of oceanographic data and products. The users of the data and products are the governmental agencies themselves, the research and education communities and the private sector. Because it is a world ocean, however, the value of this information is worldwide and not limited to the local area where it is collected.

Historically there have been three factors that have restricted government's ability to meet these responsibilities in a way that would satisfy all of the users. The first problem is structural in the sense that there are a large number of different government offices and agencies that each have responsibility for a particular data type. For a user that requires only one type of data for a particular region this is not a problem. Once that user has found out where the data is and who to contact it becomes a simple matter to request the data. For a user, however, who needs multiple data types from multiple regions it can be a time consuming exercise in frustration trying to find out where different data sets reside and who to contact at each site. A second problem with the present system is that different data sources manage and disseminate data in a large number of different formats. Again, for the user of multiple data types this is a real problem that requires reformatting the different data sets so they can be integrated together. The third problem is that there are windows of non- availability when data is in the process of being moved from collecting activity to an archive center. For an oceanographic report from a ship, for example, this window of non- availability might be 90 days.

The solution to the problems noted above is to implement a distributed relational data base management system (RDBMS) that will integrate different data types into a single data base. Such a data base could reside at a particular site or it could exist at several sites, each with different parts of the overall data base, linked together in a distributed system. Implementing this solution, even at a single site, has not been possible in the past because of the number of different offices in different organizations that are involved with oceanographic data and products. It was everyone's problem but no one's problem in the sense that no single office had the responsibility to come up with a solution. In the fall of 1988, however, the United States National Oceanographic and Atmospheric Administration (NOAA) created the Center for Ocean Analysis and Prediction (COAP) as a unique "NOAA" facility. COAP has the specific goal of promoting intra-agency, inter-organizational and international cooperation. The creation of COAP, therefore, provided NOAA with an opportunity to address the problems in ocean data management that result from the organizational structure.

One of the first projects assigned to COAP was, in fact, the implementation of an integrated data management system that will provide users with quicker and easier access to ocean data and products. The objectives of the Integrated data management project at COAP are:

1. To meet the requirements of the NOAA Coastal Ocean Program (NCOP) with regard to data base management and data dissemination. It is the NCOP that is funding this work at COAP.

2. To make available to the oceanographic user community, from a single source, as much oceanographic data and as many oceanographic products as possible. The system should be able to manage the three primary generic types of environmental data which are: images such as satellite images, gridded data from numerical models, and observational data with latitude, longitude and time attributes.

3. To provide user access, through a number of communications options, to the data and products and to provide those data and products in a number of standard formats. The system should be very flexible and able to manage any data set that falls within the three generic data types listed above without regard to the size of the files or the number of data sets.

4. To interact with the users to insure that COAP is meeting their needs. Users should be able to request data for any geographical area and time window and receive that data (images, model output and/or observations) co-registered. Data should be available in several standard formats such as binary (BUFR and GRIB), ASCII and CDF and the user should be able to specify which format is desired.

5. To minimize costs by using existing software when possible and low cost hardware systems. Implementing a system such as the one outdined above would have been very expensive and a time consuming exercise a few years ago. Due to the benefits of rapidly changing technology and to the benefits of collaboration with the U.S. Navy Department, however, COAP is implementing the system in a very short time period for very litde money.

The heart of the COAP integrated data management system consists of RDBMS software developed by the Naval Research Laboratory (NRL) facility in Monterey as part of their NEONS project. NRL Monterey has invested over four years and several million dollars into the development of NEONS and it is being used at a number of Navy sites for data base management of environmental data. The NEONS DBMS has the following functionality's that are essential for an integrated system that will process the variety of ocean data that will be made available from COAP:

* Data acquisition and ingest
* Data base handling
* Image processing

* Interactive graphics
* Data blending and analysis
* Archival support
* User interface
* Data out devices
* Data communications

To insure that the system will keep pace with the developments in the DBMS field the NEONS system was built around a commercial DBMS "engine". The advantages of this approach are as follows:

* Complex software development is done by DBMS experts
* Standard interface tools such as SQL are provided
* Network communications to support a distributed system
* Variety of storage and access mechanisms are supported
* Applications port across hardware platforms
* Economical growth path for evolving technology

The Navy has given COAP the NEONS software, at no cost, for use within NOAA and this represents a significant savings for NOAA. As developed by NRL, Monterey, NEONS meets about 90% of the NOAA/COAP needs for the RDBMS component of our integrated ocean data management system. To meet the other 10% of our needs COAP is working with the staff of NRL to make the necessary modifications and/or enhancements to the system. The technical specifications for the NRL~COAP RDBMS are:

* Handles a wide variety of environmental data types
* Provides high-level logical access to data
* Design is expandable and flexible
* Interfaces are available for interactive browse
* Automatic data ingest, delete and transfer
* Minimum software development
* Maximum I/O performance and minimum storage

Looking ahead, COAP and NRL will jointly support the maintenance, evolution further distribution of this system. Within NOAA it has been given the National Climate Data Center in Asheville, the Environmental Research Laboratory in Boulder, and the Climate Analysis Center in Washington D.C. The software has also been given to the governments of Canada and Australia.

The second major software component to the overall system involves communications. Access to the data base will be provided through several communications options. The first will be through a network of dedicated circuits linking major NOAA centers such as Monterey and Washington, D.C. A second option will be through the INTERNET system which links universities. A third option will be through a dial-in system. The system will also support LAN connections for local users. The reason for the different communications options is that there will be a variety of different users for the data and products being made available and no one communications access system would serve all of them. In this area COAP has also been able to obtain, from the Navy, the necessary software at no cost to NOAA. The Fleet Numerical Oceanography Center (FNOC) has provided us with the latest update to their Naval Oceanographic Data Distribution System (NODDS). This software can be installed on a simple PC. Used with a modem a user can access the COAP data base and download data over normal telephone lines. The Software also includes applications modules for displaying the data on the PC if the user desires.

The final component for the system is the hardware. Thanks to the recent advances in computer technology it is now possible to implement an integrated data base management system on a fast and powerful, but inexpensive computer. COAP will be using a RISC/UNIX computer with a speed in excess of 20 MIPS and lots of mass storage. A fast machine is necessary because of the need to pack and unpack the data.

The data and products that will be integrated into the COAP system will come from a variety of sources in addition to those generated at COAP. These sources in addition to those generated at COAP. These sources will include:

* The Fleet Numerical Oceanography Center
* The Ocean Products Center
* The Naval Oceanographic and Atmospheric Research laboratory
* The National Oceanographic Data Center
* Etc, etc.

It is intended that the system, as installed at COAP, will focus on near real time data and products and provide access to the most recent 30 days of ocean observations, numerical ocean model output and satellite images. The RDBMS will also incorporate selected historical data sets, bathymetry and geographical data sets. The system is in fact very flexible and will handle the following generic data types:

1. Images
   a. Satellite coordinates
   b. Registeredcoordinates

2. Gridded data
   (registered coordinates + levels)

3. Lat-Lon-Time data
   (random lat-lon coordinates)

A RDBMS, such as the one described in this paper, that has been designed to handle generic data types has the following characteristics: simplified design, simplified access, less software and easy to extend and modify.

The Integrated Data Management system being implemented at COAP and made available to other NOAA facilities will, in fact, meet the objectives discussed in this paper. It will integrate data acquisition, data management and data dissemination into an complete system and provide quicker, better and cheaper access to ocean data and products.

The challenge for the larger world community is to move towards an integrated data management system such as the one described in this paper that will support the need for more data exchange. As the world gets smaller we must learn from each other and work together on common goals including the protection and preservations of the world's oceans.

No.	Title	Languages
52	SCOR-IOC-UNESCO Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere; Paris, 6-10 May 1985.	E
53	IOC Workshop on the Biological Effects of Pollutants; Oslo, 11-29 August 1986.	E
54	Workshop on Sea-Level Measurements in Hostile Conditions; Bidston, UK, 28-31 March 1988	E
55	IBCCA Workshop on Data Sources and Compilation, Boulder, Colorado, 18-19 July 1988.	E
56	IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Cleveland, Australia, 24-30 July 1988.	E
57	IOC Workshop on International Co-operation in the Study of Red Tides and Ocean Blooms; Takamatsu, Japan, 16-17 November 1987.	E
58	International Workshop on the Technical Aspects of the Tsunami Warning System; Novosibirsk, USSR, 4-5 August 1989.	E
58 Suppl.	Second International Workshop on the Technical Aspects of Tsunami Warning Systems, Tsunami Analysis, Preparedness, Observation and Instrumentation. *Submitted Papers*; Novosibirsk, USSR, 4-5 August 1989.	E
59	IOC-UNEP Regional Workshop to Review Priorities for Marine Pollution Monitoring Research, Control and Abatement in the Wider Caribbean; San José, Costa Rica, 24-30 August 1989.	E, F, S
60	IOC Workshop to Define IOCARIBE-TRODERP proposals; Caracas, Venezuela, 12-16 September 1989.	E
61	Second IOC Workshop on the Biological Effects of Pollutants; Bermuda, 10 September-2 October 1988.	E
62	Second Workshop of Participants in the Joint FAO-IOC-WHO-IAEA-UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region; Accra, Ghana, 13-17 June 1988.	E
63	IOC/WESTPAC Workshop on Co-operative Study of the Continental Shelf Circulation in the Western Pacific; Bangkok, Thailand, 31 October-3 November 1989.	E
64	Second IOC-FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP); Phuket, *Thailand*, 25-31 September 1989.	E
65	Second IOC Workshop on Sardine/Anchovy Recruitment Project (SARP) int he Southwest Atlantic; Montevideo, Uruguay, 21-23 August 1989.	E
66	IOC *ad hoc* Expert Consultation on Sardine/Anchovy Recruitment Programme; La Jolla, California, USA, 1989.	E
67	Interdisciplinary Seminar on Research Problems in the IOCARIBE Region; Caracas, Venezuela, 28 November-1 December 1989.	E (out of stock)
68	International Workshop on Marine Acoustics; Beijing, China, 26-30 March 1990.	E
69	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
69 Suppl.	IOC-SCAR Workshop on Sea-Level Measurements in the Antarctica; Leningrad, USSR, 28-31 May 1990.	E
70	IOC-SAREC-UNEP-FAO-IAEA-WHO Workshop on Regional Aspects of Marine Pollution; Mauritius, 29 October - 9 November 1990.	E
71	IOC-FAO Workshop on the Identification of Penaeid Prawn Larvae and Postlarvae; Cleveland, Australia, 23-28 September 1990.	E
72	IOC/WESTPAC Scientific Steering Group Meeting on Co-Operative Study of the Continental Shelf Circulation in the Western Pacific; Kuala Lumpur; Malaysia, 9-11 October 1990.	E
73	Expert Consultation for the IOC Programme on Coastal Ocean Advanced Science and Technology Study; Liège, Belgium, 11-13 May 1991.	E
74	IOC-UNEP Review Meeting on Oceanographic Processes of Transport and Distribution of Pollutants in the Sea; Zagreb, Yugoslavia, 15-18 May 1989.	E
75	IOC-SCOR Workshop on Global Ocean Ecosystem Dynamics; Solomons, Maryland, USA, 29 April-2 May 1991.	E
76	IOC/WESTPAC Scientific Symposium on Marine Science and Management of Marine Areas of the Western Pacific; Penang, Malaysia, 2-6 December 1991.	E
77	IOC-SAREC-KMFRI Regional Workshop on Causes and Consequences of Sea-Level Changes on the Western Indian Ocean Coasts and Islands; Mombasa, Kenya, 24-28 June 1991.	E
78	IOC-CEC-ICES-WMO-ICSU Ocean Climate Data Workshop Goddard Space Flight Center; Greenbelt, Maryland, USA, 18-21 February 1992.	E
79	IOC/WESTPAC Workshop on River Inputs of Nutrients to the Marine Environment in the WESTPAC Region; Penang, Malaysia, 26-29 November 1991.	E
80	IOC-SCOR Workshop on Programme Development for Harmful Algae Blooms; Newport, USA, 2-3 November 1991.	E
81	Joint IAPSO-IOC Workshop on Sea Level Measurements and Quality Control; Paris, 12-13 October 1992.	E
82	BORDOMER 92: International Convention on Rational Use of Coastal Zones. A Preparatory Meeting for the Organization of an International Conference on Coastal Change; Bordeaux, France, 30 September-2 October 1992.	E
83	IOC Workshop on Donor Collaboration in the Development of Marine Scientific Research Capabilities in the Western Indian Ocean Region; Brussels, Belgium, 12-13 October 1992.	E
84	Workshop on Atlantic Ocean Climate Variability; Moscow, Russian Federation, 13-17 July 1992.	E
85	IOC Workshop on Coastal Oceanography in Relation to Integrated Coastal Zone Management; Kona, Hawaii, 1-5 June 1992.	E