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JOINT GROUP OF EXPERTS ON THE SCIENTIFIC ASPECTS
OF MARINE POLLUTION
- GESAMP -

REPORTS AND STUDIES

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MARINE POLLUTION IMPLICATIONS OF COASTAL AREA DEVELOPMENT

UNITED NATIONS

CONTENTS

I. INTRODUCTION

Terms of Reference

1. The terms of reference of the Working Group are set out in the Report of the Eighth Session of GESAMP, paragraph 56, II, viz:

> To formulate guidelines for the assessment of the marine pollution implications of specific coastal area developments, particularly for the purpose of providing assistance to developing countries.

2. The following experts participated:

Dr. H.A. Cole (Chairman)
Dr. M.J. Cruickshank
Mr. R. Gerard
Mr. J. Goodman
Dr. G. Kullenberg
Professor L. Mendia
Mr. H.R. Oakley
Professor F.M. El-Sharkawi
Dr. M. Waldichuk
Dr. L.D. Neuman (Technical Secretary, UN)

Report Objectives

3. The purpose of the report is to give basic guidelines for the assessment of the effects of coastal area development on the marine environment and its resources. The report is not intended to be an exhaustive compendium, but rather offers a practical guide for users having limited scientific, technical and/or economic resources.

4. The potential users of the information provided in this report are many. They include:

(a) Government administrators concerned with decisions regarding the planning of coastal area development and the location of particular activities so that the best can be made of available resources.

(b) Local and central government officers responsible for the maintenance of living resources, amenities, public health and public services generally.

(c) Engineers, architects, builders, etc. concerned with design and construction of facilities that will both affect and be affected by the coastal and marine environment.

(d) Industrialists whose activities are located in coastal and marine areas and whose primary responsibility is to produce a satisfactory return on investment.

5. The need for rational environmental management and impact assessment of proposed developments can be justified on both economic and political grounds. It may also stem from the desire to avoid destruction of existing resources which may be needed for future development or which are required for subsistence or protection. In order to make maximum use of coastal environments and resources, it is often necessary to take into account the interaction between different systems. For example, regulation of river flow by dam construction can significantly alter a delta or estuary system. The definition of a coastal area for management purposes should therefore be broad enough to encompass all activities which may affect the local area in question. A basic strategy for solving coastal environmental problems requires more than the statement that a particular coastal area merits protection and preservation; quantitative evidence should be supplied. For example, in relation to the preservation of mangroves, the trees often serve as a source of renewable energy for local inhabitants. The importance of this use should be evaluated. Other renewable living resources of a mangrove forest, such as oysters, crustacea and fish, may provide subsistence and should be carefully assessed so that they can be taken into account when weighing the losses against the benefits of development.

5a. The contents of this report, especially the suggestion made in the text for the types and methods of observation, are intended to provide guidance, particularly for developing countries, on the simpler techniques that can be used in making preliminary investigations. It is not the intention of this report to suggest that these studies are all that are necessary. More detailed investigations are likely to be necessary as plans for development progress. Indeed, it is recommended that more thorough Environmental Impact Assessments should be undertaken before a major development is initiated, the need for which was recognized by the United Nations Development Programme (UNDP) and the World Bank. These more detailed investigations may well require the use of more sophisticated techniques which go beyond those described in this report.

6. Strong arguments for preservation oc coastal ecosystems need to be presented in the face of pressure for development. Preservation for the sake of aesthetics, existing amenities or simply because a coastal ecosystem is thought to be worth preserving is not necessarily a compelling enough argument. However, short-term gains from development should always be weighed against the value of renewable resources in perpetuity.

7. The coastal planning process and environmental impact assessment should help the decision-maker appreciate the benefits and costs of his actions both in the short-term and the long-term. By avoiding irrevocable mistakes early in the planning stage, future remedial actions will be feasible and may be less costly. Where funds are insufficient for immediate provision of any or all measures to reduce adverse effects, the planning process may still allow scheduling of future activities to minimize impacts.

8. A comprehensive programme of coastal area development and management requires general and detailed information on the coastal environment as well as social, economic and demographic data on coastal activities including human settlement and industry. Within this context, the present report addresses the question of the basic data required and their acquisition. Because the objective of the data collection is to provide information on the potential effects of coastal development activities, there are some limitations placed on the amount and kinds of data required. The group believes, however, that assessments must be based on adequate information regarding conditions in the marine environment. Section II of the report describes programmes for collecting the basic and essential data. The programmes are separated according to the different scientific or technological disciplines and specific modifying considerations such as latitude and special ecosystems (e.g., estuaries and oceanic islands) are discussed.

9. Because the environmental data requirements are extremely broad, it is necessary to adapt a multidisciplinary approach to baseline studies. To assist in implementing such an approach, a methodology has been developed in Section III which provides a framework within which to place the basic programmes of observations. A summary of the steps to be taken in reaching a decision on project implementation and siting in a coastal area is given (Figure 1). The decision-making process should include comparison with alternatives and definition of performance standards involving the opinions of those affected by the project directly and indirectly. The evaluation of alternative actions must be carried out in light of those legal, financial and cultural factors which are

external to the project but put limits on the options available.

10. The preliminary site selection process requires that certain criteria be met at an early stage in the planning process. Examples of site characteristics and their importance for particular coastal development activities are presented in Table 1.

11. After possible locations have been identified, baseline studies are undertaken to provide information needed for predicting the effects of development and for identifying natural conditions and human activities which may adversely affect the development itself. When the baseline characteristics have been ascertained it is possible to estimate the potential impact of a development activity on the marine and coastal environments. To illustrate the manner in which an early appreciation of these effects may be reached, a series of three matrices has been constructed leading logically from (1) the changes caused by the activity to (2) the effects such changes have on the marine environment to (3) the implications of these environmental alterations on other use of the coastal area.

12. Once the environmental impacts of the selected development activity have been identified, the step-wise procedure in Figure 1 can then be followed to the point at which a decision must be taken on the acceptability of these impacts. The choice ranges from rejecting a proposed site to accepting it with or without measures to mitigate the environmental effects.

13. The general methodology focusses attention upon the environmental information that would be most useful in deciding upon the best use for the resources of a coastal area. With this knowledge, the basic observational programme can be defined and developed. From the many possible developments, the Working Group considered a number of specific activities which not only cover different aspects of environmental assessment, but should also be of interest to developing countries. Finally, a series of examples is given to illustrate the methodology.

14. The programmes described in Section II are based upon sound scientific principles and well-tested techniques which have been extensively and successfully employed. They have been formulated so that they will require a minimum of trained manpower and technical facilities, such as ships, instruments and data-processing devices. At the same time they will yield the required basic information for allowing a preliminary

assessment of the suitability of a site for a given type of development, as well as its possible impact on the marine environment. These relatively simple observations may still be used profitably when more sophisticated technology is available. The various technological measures required for protecting the environment are not discussed in detail inasmuch as treatment of sewage and industrial wastes is described elsewhere (e.g., GESAMP, Report of the Fourth Session, Geneva 19-23 September, 1972).

15. Clearly such programmes cannot be complete and additions may be required for special areas or cases. However, it was considered both possible and useful to formulate simple general basic information-collecting programmes. A first step in all cases is the collection and evaluation of pertinent existing information from both published and local records. Where sources of pollution are known, methods are described for assessing their importance.

II. BASIC PROGRAMME OF OBSERVATIONS

Introduction

16. The basic data required for a preliminary evaluation of the pollution implications of coastal area development, and to assess the potential of an area for development, can conveniently be related to:

(a) physical oceanography and meteorology;

(b) biological and chemical conditions;

(c) seabed conditions (bathymetry, sediment transport and bottom deposits);

(d) living resources (particularly those already exploited);

(e) existing discharges of sewage and industrial effluents;

(f) physical characteristics of the coast, including freshwater discharges.

17. In completing the following sections of the report, special attention has been given to likely situations in developing countries. The possibility of working at different levels of sophistication in respect of available methods and instrumentation has been borne in mind. Some consideration has also been given to the influence of particular types of coastal areas (e.g., deserts, low-lying wetlands, areas with river discharges). latitude (arctic, temperate, tropical) and the presence of distinctive fringing features (mangroves, coral reefs), as well as regional characteristics (semi-enclosed sea, adjacent extensive shallow continental shelf, etc.).

18. General synoptic large scale information giving an overview of some of the conditions in an area, obtained by means of sophisticated modern remote sensing techniques, can reveal frontal zones and upwelling areas where marine productivity is often high, as well as yielding information on coastal structure, bathymetry and topography, freshwater sources and runoff. Because such information is very valuable for initial planning, a sampling programme using these techniques is briefly discussed at the outset. Although a very sophisticated technology is used, a service

has been developed[1/] which is generally available at a reasonable cost. However, it is noted that some local expertise may be required to adequately interpret and usefully apply this information.

Aerial and remote sensing observations

19. Satellite imagery and aerial photogrammetry may serve as useful adjuncts to field observations for providing basic information for planning coastal area development. When used in conjunction with existing coastal charts, important parameters can sometimes be recognized including:

sea wave characteristics
features of surface circulation
seabed morphology
sources and patterns of anomalous water
dispersion characteristics
coastal landforms
standing water on shore
coastal vegetation types
erosional and depositional features
offshore reefs.

20. Reasonably quantitative values can generally be derived from remotely-sensed observations, but at least one site visit by the interpreter is necessary to correlate the actual conditions with the image because, on occasion, false targets have shown up. Refinements of interpretation, such as wave and current data, can be carried out on site. The data thus developed may be used in the preparation of base maps for further planning. Obvious limitations of sites based on coastal landforms or surface drainage, may be presented in map form at an early stage. By this means, more definitive surveys on the ground can be limited to areas of particular relevance to planned activities.

1/ The EROS (Earth Resources Observations Systems) programme is within the United States Department of the Interior and is managed by one of the Interior's Bureaus, the US Geological Survey. Landsat is the current name for the series of satellites formerly known as ERTS (Earth Resources Technology Satellites). Landsat imagery can be ordered directly from EROS Data Center, Sioux Falls, South Dakota 57198, USA). Recognizing the value of imagery taken from space for resource evaluation and other purposes, the World Bank has produced a "Landsat Index Atlas of the Developing Countries of the World" to assist developing countries in the acquisition of information needed for developmental planning. Information on the availability of the Landsat Index Atlas can be obtained through: The World Bank, Cartography Division, Room N-619, 1818 H Street, N.W. Washington, D.C. 30933, USA.

21. After preliminary interpretation of satellite or aerial photographic data obtained from national archives or other standard sources, more detailed or specific aerial photographic information may be desired. A relevant example is provided by studies recently carried out in the New York Bight, eastern USA, of an area heavily used for waste disposal. Satellite imagery available from US Government sources showed an area of discoloured water about 10 km. in length which was identified as the effluent from acid dumping operations. However, the scale of the image was too small to allow detailed interpretation. As the dumping operations were a regularly scheduled and continuing activity, the investigators obtained a series of aerial photographs of this operation under a variety of wind and wave conditions using a light aircraft and hand-held camera. This relatively low-budget study allowed estimates to be made of mixing rates and residence times under a variety of natural conditions. The investigators were also able to identify a seasonally persistent discontinuity or shear zone parallel to the coast which allowed interpretation of existing general circulation data as well as planning of additional measurement programmes.

22. Where no existing natural tracers , e.g., silt in suspension, are available for aerial investigations of coastal circulation, simple techniques are available for continuous (hours to days) introduction of water-soluble dyes from the shore, a small boat or anchored buoy. Instantaneous dye injections can be made by dropping containers of liquid dye to the sea surface from the photographing aircraft. Sequential near vertical photographs of the resulting dye patterns can provide qualitative information on circulation and mixing processes. Provided that a large enough range of natural mixing conditions can be observed, so that flow directions and a series of concentrations can be estimated, information on dispersion characteristics can be obtained. Where the aerial photographic observations are accompanied by more quantitative data obtained by ground investigations (as described in the section on physical oceanography and meteorological observations), better estimates of dispersion are possible (see also para. 47).

23. Aerial photography and satellite imagery may prove useful for monitoring the presence of pollutants in the marine environment. Satellite sensors capable of detecting most pollutants have not yet been developed but oil spills have, in some cases, been detected from space. Along coastal areas it may be possible to observe major damage to ecosystems by recognizing the impact of spills on nearshore and shoreline flora and to utilize repetitive coverage to assess environmental degradation over a long period of time.

24. The opportunities for using remote sensing in coastal area investigations are numerous. The relatively low cost and ease of obtaining satellite images in many locations, suggests that they be considered more frequently in the future. Where helicopters and light airplanes can easily be secured, the flexibility and rapid reconnaissance possible by aircraft may be particularly attractive. In this report, it is not possible to discuss fully a basic programme of remote sensing observations. The bibliography, however, lists several sources of further information on the subject.

Navigation and positioning

25. In coastal waters, variations of water conditions often occur over small distances and it is essential to have a quick and precise way of determining positions of sampling stations. Quite often the coast line has characteristic features which can be used as land marks for positioning by means of compass bearings or sextant angles. Such landmarks can be hills, steep headlands, bays, capes, outstanding trees or houses which can be identified or are marked on a chart. Two different landmark bearings will give a fairly good position and the same bearings should always be used. The stations can be identified by their bearings to given landmarks. The depth is another useful positioning characteristic, especially in coastal zones, and the depth should usually be recorded at each sampling position. Frequently, posts forming coincidence lines can be established on the shore for positioning and painted in different ways for identification. Coincidence lines can be used to identify a complete section, and the stations arranged according to the depth contour or at regular intervals along the section.

26. Fronts, i.e., boundaries between different water masses, or lines separating zones of different current and mixing conditions, are sometimes connected to topographic bottom features, fresh water outlets, bays or inlets and capes. The fronts can often be detected by changes in

water colour and normally oscillate between extreme positions. Hence it is always useful to note such features as form lines, apparent changes of colour and their positions during surveys.

27. Positioning and navigation out of sight of the coast require more advanced technical equipment such as is normally found on merchant ships, research and survey ships and the larger fishing vessels, i.e., radar, echosounders and special navigation systems such as Loran and Decca. These instruments can be backed by the use of a sextant and other orthodox position-finding equipment.

Physical oceanography and meteorological observations

28. In the coastal zone, physical oceanographic parameters are, to a large extent, influenced by the form of the coastline and its topography, and the meteorological and climatic conditions. There is also a feedback from the sea to the atmosphere and to the coast, e.g., by low sea temperatures generating fog conditions and by wind-generated waves eroding the coast. It should be noted that pollutants are transferred not only from the land and atmosphere to the sea but also from the sea to the land and much debris (e.g., floating garbage, tar balls, seaweeds) is deposited on beaches. Sea salts may also be deposited on land and are responsible for a variety of adverse effects. Transport occurs from the sea to the air, e.g., by wave breaking.

29. Pollutants from harbours, or offshore structures are often carried alongshore for substantial distances to other coastal areas and can adversely change conditions required for recreational purposes, tourism or other uses such as marine parks, aquaculture or desalination plants. This process can create an international problem when harmful substances from one country affect coastal areas of another country. Transport and dispersal of pollutants discharged by rivers and outfalls are controlled by water movements and characteristics.

It is for these and related reasons that basic physical observations are required for making decisions regarding the optimal use of all the coastal resources.

30. The first step in the programme is to collect and evaluate existing data. These may be found in navigational tables and charts, at nearby ports, coastguard and pilot stations, airports and meteorological stations as well as by talking with people having extensive local knowledge such as fishermen and farmers. For many oceanic areas basic descriptions of surface currents, winds, surface salinities and temperatures are available in ocean atlases (see references). Normally such information must, however, be supplemented with more detailed data specially collected from the area in question. In parts of the world where major natural disturbances occur, such as earthquakes, hurricanes or El Niño type ocean current changes, historical records should be consulted for information on periodicity of occurrence and impact.

31. Complementary investigations will usually be needed to meet the assessment requirements. Any existing data should then be used for planning the additional observations. It is often convenient to divide the types of investigations into three categories:

(i) surveys or baseline studies - designed to give an integrated but short-term picture of the conditions;

(ii) observations at specific points to give a time series of data so that seasonal fluctuations and trends in the baseline picture can be detected;

(iii) special studies, e.g., current measurement programmes, wave observations and *in situ* dispersion experiments, to obtain the necessary understanding of the processes so that predictions can be made.

These studies can be more or less sophisticated, but in general they should be:

(a) tailored to the type of locality (bay, open coast, fjord, estuary) and the needs;

(b) co-ordinated with other studies, i.e., biological, chemical and also cost/benefit;

(c) adjusted to the research potential of the country.

32. Currents and water exchange with adjacent areas will influence the dispersal of pollutants and the concentration of substances in different parts of the area. Hence information on water circulation, both mean and time dependent, is of primary importance in almost all cases. Salinity and temperature distributions will also influence both the vertical and horizontal spreading of substances and should therefore be determined. Other factors which have a bearing on the quality of the conditions of the coast and in the water are wave conditions, tidal variations, turbidity and light penetration. Meteorological factors, such as wind strength and direction, the incidence of sunny and rainy periods, and temperature differences between land and the sea, influence the conditions on the coast as do water circulation, salinity and temperature distributions, and wave heights. It may therefore be important to obtain basic information about all these meteorological factors. (Reference should be made to GESAMP Reports and Studies No. 1, Annex IX, 1975 for general information on nearshore circulation and dispersion conditions).

33. All this can be studied in greater or lesser detail; the depth of the study required can only be judged in conjunction with the contemplated biological and chemical studies. It will also depend critically on the priority uses and future plans for the area. It is primarily the biological survey which can tell us how sensitive the area is likely to be to changes in environmental conditions. Many chemical parameters, in addition to salinity and temperature, can be used as indicators of the rate of water renewal and the natural load on the system, e.g., dissolved oxygen, nitrate and phosphate. The co-ordination of the physical, biological and chemical studies is of central importance.

34. The time-span of the programme will have to be case-adjusted but generally all seasons should be covered. The desirable degree of extension of the study area alongshore and offshore will depend upon the coastal type, the bathymetry, priority uses and the vicinity of other developments and national boundaries. A fjord and a bay should be covered from the inner part to well outside the sill or demarcation line. An estuary should normally be covered from the upstream limit of the salt wedge until open sea conditions are reached.

Basic programmes

35. Much information regarding the circulation can be obtained by means of drifters (surface, internal and bottom) and a suitable network of salinity and temperature stations. The latter should also be used for chemical and biological sampling. The turbidity of the water should be recorded. Water level variations can be studied by simple means to establish the tidal influence. Wind and waves should be observed in conjunction with the station work. The programme should also allow a survey under a range of seasons and conditions, e.g., very calm, after heavy rain (accompanied by runoff) so that the extreme conditions may be assessed, and should not be done merely as a fixed routine in time.

36. Drifters, e.g., in the form of vertical current crosses or vertically mounted window shades, connected by a thin line to a small surface float, can be released along a section at right angles to the coast (Fig.2). In a fjord or estuary they should be released inside and outside, so that the exchange between the embayment and the open sea can be determined. Drifters can, in this way, be used to depths of about 30 m. Positioning can often be done by means of coincidence lines established for the purpose by using coloured triangles mounted on poles on the shore (Fig.3), or by means of anchored marker buoys (see also paras. 32 - 34). The time required to drift a given length is determined and the direction is found by means of a compass. The wind velocity is measured using a hand anemometer, and the direction is found from the compass. Turbidity variations can often be estimated satisfactorily by using a Secchi disc (Højerslow 1978). Wave period and length can be measured using a line and a piece of wood (Fig.4). Water level fluctuations can be observed by means of a staff marked in decimeters (Fig.5). The level is read off at convenient time intervals (e.g., 2, 4, 6 hours). It is important that these observations should always be done in the same way. In Table 2 the first level programme is summarised, giving the minimum instrumentation and other facilities required, together with the data format and sampling distribution. Some notes on the treatment of oceanographic data are presented in appendix A. For further details standard oceanographic works may be consulted (see bibliography).

37. The most important information to be obtained relates to the intensity and direction of the currents, water exchange and renewal, and stratification in semi-enclosed areas. The possible implications of a pollution load are generally more serious in areas of weak currents and slow water renewal than in areas of intense circulation and rapid water exchange. In the former case it is likely that more detailed studies will be needed to obtain more quantitative information. In addition to the current direction,wind force and direction and the tidal conditions should be observed.

38. Persistent winds with a component parallel to the coast can generate an onshore or offshore flow component in the surface water layer. Onshore currents occur when the coast is on the right looking downwind in the northern hemisphere but on the left in the southern hemisphere. Offshore flow is generated with the reverse wind direction. There will also be a flow parallel to the coast, often stronger than the offshore or onshore component. The offshore flow may be compensated by a subsurface onshore flow and vertical motion towards the surface (upwelling) (Fig.6). This mechanism can transfer nutrients from deep water to the surface, which may cause increased biological production. The influence of topographic features on circulation can be inferred from drifter measurements. If special flow regimes are found to occur, more detailed studies may be needed.

39. The following comments are intended to facilitate sampling. Although the sampling pattern adopted will always depend to a certain extent upon local conditions some general rules can be given. When the water column is homogeneous, sampling at the surface (0-1 m), mid-depth and near the bottom may be sufficient. But when marked vertical density steps or variations due salinity or temperature are identified then some water samples above and below should always be taken. It is normally advisable to sample according to a regular horizontal pattern with an equal spacing between stations. The section should, as far as practicable, be orientated at right angles to the coast or depth contours or the centre line of estuaries.

40. Current measurements with the current cross or window shade markers can be made very reliably; the surface floats should be as small as possible in order to minimize the influence of winds, waves and surface currents. They can also be extended so that one or more markers are allowed to drift freely and their paths determined. This gives information on the water transport pattern in the area.

41. Waves heights are difficult to establish; repeated measurements must be made on each occasion to obtain a reliable mean value. A marked staff is held perpendicular to the wave direction by a cord, or thrust firmly into the sea bed, and the time for a crest to pass a given distance is measured using a stop watch. The wave length can be estimated by means of a float on a cord which is paid out to such a length that the boat and the float are on adjacent wave crests (Fig.4). These relatively simple observations will yield basic information on wave conditions for various wind speeds and directions. Such information is required for an assessment of sand transport and erosion conditions. For this purpose, information is also required on the type of beach material, the slope of the beach and the characteristics of the sediments below low water mark.

42. The depth of light penetration (directly related to productivity) can be estimated fairly well from the Secchi disc readings (see Fig. 7). This depth should be related to the bottom depth, the vertical stratification and the current distribution. Its seasonal variations are also of interest.

43. Clearly all these observations should be made during different weather conditions and at different seasons. It is important that a fixed programme be followed with a regular time schedule and the same sampling pattern. The programme should not be changed in the middle of the investigation. Interpretation of the observations has to be related partly to the biological and chemical conditions and also to potential uses. For instance, persistent eddies or weak currents suggest weak exchange and slow mixing with open sea water, implying risk of accumulation of pollutants. Such a current structure can also indicate local recirculation which must be considered carefully in relation to, for example, the siting of power plants requiring cooling water. Stratification

may occur in coastal waters and usually results in suppressed dispersion and recirculation in the form of compensating flows that are set up by certain wind conditions. Such features must be considered in relation to sewage disposal by pipelines or dumping, and also in relation to dredging operations. Upwelling can occur, both at the coast and over banks, and is more or less directly coupled to the wind field, as well as being influenced considerably by the occurrence of capes and canyons.

44. Normally a straightforward plotting of the observations described above will reveal all the features which may need more detailed studies. The programme described would give basic information on stratification, current velocities and directions, dispersion efficiency and water renewal, and tidal and wind influences on water level and currents, and would make it possible to interpret basic studies of biology and chemistry in relation to the physical characteristics. It would not yield time series and spectral distributions of properties, details of special features of currents such as coastal jets, for example, in relation to the spread of oil pollution.

Further investigations

45. Further investigations may be required when the possible environmental implications of a specific proposed development are being considered. Subsequent programmes might include special observations of features revealed by the initial programme, often requiring more sophisticated instrumentation. The content of these programmes should take account of:

(i) the results of the initial studies, including biological, physical and chemical investigations;

(ii) the type of coast, i.e., estuary, delta, fjord, open coast with beach or rocky shores;

(iii) the type of development contemplated, and various alternatives, as well as potential conflicts of interest.

In some cases it will be concluded that more detailed studies are required of the currents, mixing conditions, water level variations, and the amount of suspended matter and dissolved substances in the water.

46. With regard to the currents, a time series over a period of a few months to a year makes it possible to study the different periods of variability and to couple these to meteorological and other factors. Such observations can be obtained by means of moored current meters, some of which are now equipped with sensors for temperature and salinity. These current measurements can also be used to study the mixing conditions in greater detail.

47. In cases where hazardous pollutants may be expected to reach fishing grounds or beaches, or other areas used for swimming or recreation, it is often advisable to carry out some tracer study, e.g., by dye releases from the anticipated discharge point under a variety of tide and wind conditions. Rhodamine B dye dissolved at a concentration of about 30% in acetic acid is commonly used as an artificial tracer to investigate the mixing conditions in coastal waters. The dye may also be used for following the drift of the marked water, giving information on the extent of movement of contaminated water for different weather conditions, how much of it may reach the coast and if it will enter bays or other semienclosed areas, such as lagoons. The dispersion rate can also be calculated from the spread of the dye patch but this requires a boat with a fluorometer and other special equipment and trained personnel. Time-lapse aerial photography with fixed-wing aircraft can be used to follow the movement and spread of dye patches. With fluorometer data for ground truth, aerial photographs can provide useful information on dispersion (see: paragraphs 19-24, Aerial and Remote Sensing Observations).

48. It is also possible to use a slightly more complicated method with radioactive tracers. Often bromine -82 in the form of ammonium bromide is used, which can be traced by means of a counter towed behind the ship and will give similar information to that provided by the dye tracer. Bacteria occurring in the water as a result of human activities, e.g., sewage outfalls, can also be used as tracers for water movements and dilution. For example, water samples taken in the surface water can be analysed for *Escherichia coli* as a possible indicator of faecal pollution. The amount of *E. coli* can be used as an indicator of water quality for shellfish production and bathing. Since different kinds of bacteria are influenced

in different ways by natural conditions, such as salinity, temperature and amount of organic material, comparisons between different areas and conditions or between the occurrence of different bacteria should only be made with great caution. However, studies of the abundance of E. coli in given locations may be very informative, particularly in relation to changing environmental conditions. It may often be advantageous to combine a tracer study with a water quality requirement based on an acceptable concentration of bacteria in the water. The natural dilution is determined by means of a tracer study and this combined with normal engineering design criterial for, for example, sewage outfalls, gives the expected amount of bacteria for various options of design, such as the length and depth of the outfall.

Chemical and biological observations

49. Many chemical characteristics of coastal waters, in contrast to those of offshore waters, are constantly undergoing change, for example, because of land runoff and other terrestrial influences. Salinity changes seasonally as precipitation increases from the dry season to the wet season and back to the dry season again. Organisms living in the coastal environment are normally adapted to the constantly changing water and atmospheric conditions. Inflow of wastewaters from urban communities and from industry may, however, change not only the salinity, turbidity and light penetration but also the chemistry of the water. Nutrients may be increased and may stimulate algal production. Heavy metal concentrations may reach undesirable levels through bioaccumulation in shellfish. Other persistent substances, such as organochlorines, may accumulate in living resources to levels considered unacceptable for human consumption. The uptake of heavy metals and persistent organics by certain species, e.g., mussels, provides a way of monitoring the presence of such polluting substances.

50. Estuarine processes have a profound effect on the physical and chemical characteristics of the water. When fresh water mixes with sea water, sediments present in colloidal suspension in the fresh water are flocculated and precipitated. In the process, other materials present in the water are scavenged by the floc and deposited in the sediments. Consequently, estuarine sediments accumulate many substances carried toward the sea by rivers. For this reason, estuarine sediments downstream of

industrial outfalls are sometimes heavily loaded with metals, organochlorines and biodegradable organic substances. Estuarine flora and fauna may thus be exposed to rather high concentrations of pollutants in both the water and sediments if there is a heavy input of sewage and industrial wastes upstream. Metals and persistent organochlorines may be available for uptake and bioaccumulation by bottom organisms. Moreover, transformation by biological processes may occur, leading, for example, to the production of methyl mercury deposited in the sediments thus making this potentially very harmful substance available for uptake by bottom organisms. The same may also apply to other metals and metalloids, such as lead, arsenic and selenium, but these have been less closely studied.

51. A general preliminary evaluation of the chemical and biological characteristics of the coastal system does not require sophisticated equipment or techniques. The first step in any preliminary evaluation is to obtain a reliable bathymetric chart of the area. Tidal predictions are also essential, especially if there is a large tidal range. Such information is usually available, if not for the specific area, at least for the region. Sampling plans for both chemical and biological characteristics should be related to the tidal cycle. If the area has significant river inflow, some indication of the magnitude of freshwater discharge is very desirable, particularly the seasonal variations.

52. It is important to select stations for sampling in such a way that significant chemical and biological characteristics and variations with the tide and runoff are recorded. Most stations will be selected for multipurpose observations, including hydrographic measurements; others may be chosen for continuous sampling and measurements over a tidal cycle. Because of the enormous task often involved in processing samples, especially in enumeration and identification of organisms, it is advisable to restrict the number of stations to those necessary to provide essential information. It may be profitable to add some further stations at a later stage, if the additional information they would provide is considered vital to give a more complete picture of the situation. To obtain seasonal variations, at least one year of observations is needed. Ideally, the timing of surveys should be related to natural physical cycles. However, if such frequency is too costly and time-consuming, there should be a minimum of four surveys to cover the seasons.

53. Sampling depths are usually dictated by the vertical stratification of physical properties. Simple and reasonably reliable sensors for recording continuous vertical profiles of salinity and temperature are now available. Such devices give an indication of the extent of vertical mixing and of the amount of interlayering of waters with different salinity and temperature characteristics. During the warmer months of the year, even a bathythermograph cast will give a good indication whether the water is vertically mixed, from the vertical temperature profile. Suitable sampling patterns are described in paragraph 39 and Table 3.

54. If biological sampling is carried out with bottles, it is advisable to use plastic sampling equipment, such as Van Dorn bottles. Care should be taken to allow sufficient time for both reversing thermometer equilibration, and to ensure that the water sample in the bottle is fully representative of the sea water at that depth.

55. When a vessel is on station for a hydrographic cast or to take samples, it is often convenient and desirable to record other information. For example, as indicated in the previous section, weather conditions should be noted, especially wind speed and direction. A Secchi disc reading gives an indication of the colour and clarity of the water. Surface characteristics (oil, film, algae, scum or clean surface) should be noted. A bottom sample taken with a small, clamshell type of grab can quickly show the character of the sediments and presence of benthic organisms, but it should be appreciated that bottom animals are often very patchily distributed.

56. Basic chemical determinations which should be made on water samples include salinity, dissolved oxygen, pH and alkalinity. Nutrient constituents (phosphate, nitrate, nitrite, and silicate) should also be measured, in particular in areas of potential input from sewage or industrial wastewaters. Standard handbooks on chemical methods in oceanography (see bibliography) give details of the procedures for sampling and analysis. Careful sampling, adequate sample preservation and reliable methods of analysis are essential if repeatable results are to be obtained. It is often advisable to use the same analyst for the various variables throughout the programme period. Besides the

sampling bottles and a winch with suitable wire rope, the specific needs for both samples and analysis are simple. For example, a standard 250-ml medicine bottle with screw cap and a teflon liner for a tight seal is adequate for a salinity sample. Usually, a salinometer of the conductivity type is used for salinity determinations. However, the standard titration with silver nitrate dispensed from a Knudsen burette is still used for chlorinity determinations from which salinity can be derived. In all procedures, standardization is carried out with a seawater standard of known chlorinity ("Eau de Mer Normale") obtainable from the Institute of Oceanographic Sciences, Wormley, U.K.

57. A standard 300-ml B.O.D. bottle with ground-glass stopper and flared top for a water seal is well suited for dissolved determinations using the Winkler method. The whole procedure can be carried out on board small vessels with some bench space available. Often a dissolved oxygen "kit" is constructed to expedite setting up on shipboard.

58. Samples for nutrients should be processed immediately on board ship or deep frozen for later analysis in the laboratory. An inexpensive colorimeter with filters or a simple spectrophotometer is desirable for nutrient analysis, although simple Nessler tubes can be utilized to give results of adequate precision for ordinary needs.

59. Chlorophyll (used as an indication of productivity) can be measured by techniques similar to those used for nutrients. Primary productivity measurements are, however, now usually carried out by the carbon-14 method (Strickland and Parsons, 1972). The procedure is relatively straightforward. It requires the use of a scintillation counter or other radioactivity counting system, equipment which is not available in all marine laboratories. However, there are several laboratories which can provide a service in productivity measurements by the carbon-14 method.

60. Primary productivity measurements can also be made by the simple "light and dark bottle" technique, where the oxygen released during photosynthesis is measured by the Winkler titration (Strickland and Parsons, 1972). The carbon-14 method gives the <u>net</u> productivity of phytoplankton, whereas the light and dark bottle technique gives the <u>gross</u> productivity of all organisms present, as represented by the difference in dissolved oxygen in bottles giving photosynthesis (light) and respiration (dark).

61. If analysis for metals and organochlorines are needed, specialized techniques for sampling, extraction and analysis are required. New laboratories embarking on marine environmental programmes are not advised to become involved in such analyses until they are prepared to engage extensive resources in trained manpower, time and funds, and are pressed with a compelling need for such information. As basic equipment, a laboratory must have access to an atomic absorption spectrophotometer for metals analysis and a gas chromatograph for organochlorines. Analysis of petroleum hydrocarbons is most conveniently done by U/V fluoroscence. More advanced analytical laboratories have a coupled gas chromatograph and mass spectrometer with a dedicated computer to evaluate concentrations of the latter compounds. If there is a strong need for analyses of persistent pollutants that can only be done by such sophisticated techniques, it may be expedient to contract with a reliable specialized commercial laboratory rather than to set up for the analyses in house. In that case, the main requirements would be careful sampling and sample storage to avoid contamination and deterioration.

62. Analyses of persistent substances, such as metals and organochlorines, in sediments and organisms produce many of the same problems as their analysis in water. However, these substances are usually present in higher concentrations in marine sediments and organisms than in water and do not require the same degree of concentration prior to analysis. Collection and preparation of samples for analysis, nevertheless, requires great care to avoid contamination and to ensure total extraction of the material to be measured. Because unreliable analyses may easily lead to wrong conclusions are are a waste of money and manpower, the value of contracting with a specialized laboratory is again emphasized. Observations, chemical sampling and analyses for different purposes are summarized in Table 3.

63. Biological sampling can be carried out on a simplified basis with inexpensive basic equipment. Standard plankton nets, used in vertical hauls for zooplankton, will provide an opportunity to measure plankton volumes per unit area or per unit volume. (See UNESCO or SCOR references listed in the bibliography for the procedure). Because they require only a small amount of time, vertical plankton hauls could be made just prior to or following hydrographic casts. Plankton volumes and wet weights can easily be obtained by standard procedure using ordinary volumetric laboratory glassware and a balance. Enumeration and identification of plankton requires specialist training.

64. Some basic information on benthic organisms can be obtained even by the non-specialist. For example, a series of stations can be sampled in the intertidal zone during low tide on several transects. All that is needed is a standard sized frame, e.g., $1/8m^2$ within which the upper sediments are scraped off to a stated depth (e.g. 2cm) with an ordinary mason's trowel. The organisms are washed out of the sediment on a sieve of suitable mesh size and weighed wet and after drying for biomass determinations. It is useful also to record the character of the bottom materials, because certain groups of benthic animals prefer particular types of sediments. Specialists can be used to identify and enumerate species if necessary.

65. Fish populations in nearshore coastal waters can be surveyed in a general way by standard techniques using trawls of various types in deeper water and beach seines in shallow water at selected stations (see, however, section on Living Resources Evaluation below). In some areas, traps for fish and invertebrates (e.g., prawns, crabs and lobsters) can be used. With a little training dominant fish species can be identified although the task is greatly increased in some tropical waters by the large number of closely related species and the lack of systematic studies. Their size (fork length and weight) can be readily measured for basic fisheries statistics. Weights of fish and an estimate of total numbers can give a measure of fish biomass. Stomach contents can be identified by groups of organisms with a

little training, although the food organisms are sometimes digested beyond recognition. Experts are needed for identification to genera or species. This information is useful in developing some hypothesis regarding the food chains leading to exploitable stocks of fish, but assessment of commercial fisheries and their potential yield should be based on the methods described in paras. 79-83.

66. The biological data obtained in this way several times per year (e.g., in monthly surveys) can provide significant information on areal distribution of biomass, the most abundant species and seasonal variation. This information can then be related to feeding by fish and wildlife. The impact of development can then be considered in terms of effects on the food supply and habitats of commercially important species. Study over a basic one-year period should give a reasonably good indication of the importance of particular organisms in the food chains that terminate in exploitable species.

SEABED CHARACTERISTICS

Submarine Morphology

67. Seabed morphology is of concern in any coastal development plan because of its strong influence upon marine biota, sea-water circulation and sedimentation in coastal regions. The absence or presence of a continental shelf (depths 200 m) is of great significance in determining the extent to which a coastal area is likely to become polluted. The capacity for diluting a given contaminant will normally be lower in broad shelf areas than in those characterized by steep offshore slopes which allow the larger-scale oceanic circulation to impinge upon the coast. Local features of the submarine topography can also be significant, e.g., the presence of submarine canyons may bring oceanic type water close to shore despite broad shelves. Such canyons

may also interrupt the longshore transport of bottom sediment. Extensive reefs and shoals, including man-made structures, may interfere with near-shore circulation, alter sea swell and waves and support distinct biological communities. Topographic depressions or troughs may trap bottom water and organic material and, in the extreme, may produce anoxic conditions.

68. Charts of the general features of the sea floor topography are available for most coastal regions of the world. New surveys may be required in some areas to detail such features as channel depths, natural shelf canyons, reefs and shoals which may be important to a particular development plan. The necessary information may be obtainable by using simple techniques such as "lead line" measurements from a small boat. Where more extensive contouring of the sea floor is critical to the development plan, surveys should be made using a precision recording echo-sounder accompanied by accurate navigation. Side-scan sonar may be even more useful in some applications. Consideration must be given to the possibility of unstable geologic conditions which might present hazards to any sea floor installations. The identification of these features requires the application of seismic or sub-bottom profiling. These conditions might include instability (slumping) of sediments, the presence of active fault zones, and, where drilling might be carried out, the presence of shallow gas pockets.

69. It is important to take into account potentially economic mineral deposits, the exploitation of which might have an impact on other developments at a later date. For example, extrapolation from land might indicate target areas offshore for heavy minerals already known to exist on shore. Deposits of sand and gravel or shells will, in most cases, be exposed at or near the seabed and may be identified during sea floor sampling (e.g., for biological purposes) or sub-bottom profiling. Other deposits such as oil and gas, massive sulphides, geothermal reservoirs or freshwater aquifers may be identified from regional geologic trends or surface expressions within the particular area.

Sedimentation

70. A knowledge of the marine sediments, including their transport and deposition, is required for coastal development planning. Careful study of the upper part of the sedimentary record, in particular may reveal effects within historic time which show the response of the system to natural forces and human activities. Natural changes may be more important than those induced by or likely to be induced by human activities. Knowledge of the nature of the

sediments can help in understanding the origin, pathway and fate of suspended material carried with the circulating waters.

71. A knowledge of the natural sedimentary regime provides a model to assist the planning of coastal development activities which may produce suspended particulate material, e.g., dredging, construction of sewerage and other types of outfalls, and deposit of solid waste. It is also important in predicting the fate of certain pollutants which attach to natural particles as is the case with many organic compounds, radionuclides and heavy metals found in wastes. These sediment-bound substances may later accumulate in bottom-living animals.

72. In areas where river waters with their suspended sedimentary load come in contact with saline marine waters, flocculation of the particles occurs leading to deposition in the estuary. Examples exist of pollutants introduced inland into rivers which move with the suspended sediment and become deposited in the estuary. Development activity in the estuary, particularly dredging, may then move the polluted sediment to an offshore area with possible effects upon marine biota.

73. The most significant changes in sediment transport and distribution may take place in a very short time period and completely override day-to-day processes. Major storms will bring about greater changes within a few hours than may occur in years under normal conditions. Furthermore, these extreme conditions are almost impossible to study while they are taking place and must be assessed after the disturbance has passed. The effects upon coastal developments of such major disturbances of bottom sediments, unless anticipated, could prove disastrous. In this regard, a careful study of historical records and charts will help to identify both steady and catastrophic changes which have shaped the sediment pattern of a coastal region.

74. The procedures for sampling nearshore marine and estuarine sediments are relatively simple. Conventional coring devices are tubes which are forced into the sediment and which, when withdrawn, retain cores with the sedimentary layers (strata) relatively undisturbed. Coarse surface sediments may be sampled with a small grab or a bucket sampler. Direct observations by diving can also provide information on bottom sediment conditions. The amount and type of sediment reaching a particular site may be monitored using sediment traps. These are simple open-topped containers placed at the sea floor to collect and retain all material settling from above.

75. As noted earlier, photographs and images from earth orbiting satellites are available from United States Government sources for many coastal areas and provide useful general data on land forms and in some cases circulation patterns. More specifically, the use of aerial photography or direct observation from aircraft in clear weather can be extremely useful in studying circulation and sedimentation patterns of a coastal region. Frequently a turbid discharge may be observed from a river or existing outfall, and may be distinguished as a plume entering clearer water, so that its distribution may be plotted. Dye tracers may be introduced where other visible plumes are lacking. Aerial photography from a light aircraft, using an ordinary hand-held camera, can be used to document such plumes. For comparability, all photographs should be taken as nearly vertically as possible and at a uniform altitude: 500 metres is a useful height. Aerial photographs taken at different stages of tide can provide a picture of surface currents and movements of introduced material. Such techniques are, however, expensive and require special expertise.

LIVING RESOURCE EVALUATION

76. Pollution arising from the development of coastal areas for a wide variety of purposes may affect the living resources. The following are among the more important ways by which damage may be done:

(1) direct kills by the discharge of poisonous or otherwise harmful substances;

(2) tainting, e.g., by oil or phenols, so that fish, shellfish, seaweeds and other sea produce becomes inedible;

(3) accumulation by fish, shellfish, other invertebrates or seaweeds of metals or persistent organic substances to such an extent as to render them unsuitable for human consumption;

(4) contamination by pathogenic bacteria, viruses or other organisms carried in sewage which are liable to cause disease in man if seafood is eaten raw or insufficiently cooked;

(5) alteration of the coastal water or shore environments so that they are rendered unusable for commercially valuable fish, shellfish, etc. with consequent damage to the livelihood of local fishermen.

(6) input of organic matter or sewage may reduce dissolved oxygen (D.O.) levels and/or increase nutrient levels thereby affecting the composition and abundance of phytoplankton and other organisms.

77. Development may also result in the modification of the shoreline and coastal margin to such an extent as to interfere materially with the landing and marketing of fish catches. A convenient harbour and well-placed servicing and repair facilities for fishing vessels may no longer be available.

78. The two most important steps towards an assessment of the likely impact of a projected development are clearly to establish what living resources the coastal area supports and what wastes are likely to be discharged. Only the former is dealt with here: the latter is covered in another section of the report.

Estimation of living resources

79. A fishery comprises the fishermen, the gear they use, the stocks they exploit and the catches they land. Information is required under these four sub-heads related to seasons and fishing areas.

80. The simplest and cheapest way of obtaining this information is by recording the landings, daily if possible, otherwise on a sample basis. If landings are made at a few points only, or there is a central market where most of the catch is sold, the task is much simplified. The most important data to record are the weights landed, the total amount and the quantities of the more common and more valuable kinds and the size ranges, the areas from which they were taken, the numbers and sizes of the fishing vessels employed and particulars of the fishing gear used. Fears that returns may be used for taxation purposes can usually be dispelled by undertakings to quote only totals from which individual contributions cannot be determined.

81. In addition to systematic recording of landings, questions need to be asked about seasonal influxes of particular kinds of fish, shellfish, etc., but in quite a short time a picture of the relative productivity and economic importance of particular areas of coastal water will begin to take shape.

Systematic recording of this kind, even over a period of only a few weeks, is likely to be vastly more informative than any but the most comprehensive of fishing surveys conducted throughout the year. Thorough evaluation by fishing survey of the resources of any but a very limited area (a few square miles only) is a major undertaking requiring a well-equipped vessel with a wide range of fishing gear. Limited surveys may, however, be required later of particular grounds established by market sampling as important and considered to be directly within the influence of probable harmful discharges.

82. Spawning grounds of adult fish and nursery areas for juveniles are often different from those which the adults occupy at other times of the year. Often juveniles occur in shallow waters near the shore. Both fish and crustaceans may spend part of their life cycle in estuaries. Where streams discharge, and in estuaries, the possible existence of migratory fish or crustacea should be investigated. Sampling programmes should be designed bearing in mind these possible seasonal and geographic variations in distribution. Seasonal programmes should be designed bearing in mind these possible seasonal and geographic variations in distribution. Seasonal differences in availability of exploited resources will be known to fishermen, and the prevalence of juveniles on particular fishing grounds can often be detected from the size range in the landed catches.

83. If coastal waters adjacent to a proposed development area are not fished, enquiry at the nearest fishing port should reveal whether their potential is truly unknown or whether they have been examined on a trial basis and found to be unproductive. In such areas shores should be searched for commercially valuable shellfish (molluscs and crustaceans) and other edible invertebrates or seaweeds which might be exploited in the future. The possibility of uses for other purposes than food should be borne in mind. If the resources of coastal waters are truly unknown some limited surveys with trawl and gill nets and a general purpose trap may be unavoidable. Only approximate quantification of possible yield will, however, be possible.

Assessment of edible quality of fish and shellfish

84. In addition to establishing the general nature, distribution and abundance of the living resources, it is necessary to determine their suitability as food from a public health standpoint. The characteristics of most concern are

the presence of concentrations of potentially harmful metals (mercury, cadmium and lead in particular) and persistent organochlorine substances (e.g. pesticide residues such as dieldrin, DDT and its derivatives and also PCBs). Analyses will also provide a base-line against which changes resulting from development can be assessed. Such analyses must be made by experienced analysts working in a laboratory equipped with up-to-date apparatus capable of giving reproducible results. Detailed analysis for oil hydrocarbons is particularly difficult and results from an area not previously studied may be hard to interpret. The assessment of risks from the transmission of disease by the consumption of polluted shellfish is dealt with in para. 95 below.

85. Fish and shellfish may become inedible because of absorption of tainting substances; those most commonly encountered are oil and phenols but several aromatic organic chemicals are suspect. Enquiries need to be made of fishermen regarding the occurrence of tainted fish or shellfish, but care must be taken to distinguish taints due to pollutants from natural "off flavours" produced by seasonal feeding on particular marine organisms. The occurrence of naturally poisonous fish or shellfish should be ascertained; where they occur this is usually well known to fishermen who almost invariably eat a proportion of their catch.

86. The notes above refer to fish and shellfish but the range of living resources is from whales to seaweeds. The range of seafoods landed in any coastal area needs to be established and will become evident from the regular recording of the landings recommended as an essential first step in establishing a basis for the assessment of pollution implications.

Sensitivity of marine life

87. Concentration upon the assessment of the abundance and distribution of living resources of fish, shellfish, seaweeds, etc., may be criticised for its neglect of possible damage to other marine life, including the unicellular phytoplankton on which production ultimately depends. Such criticism would be justified if it could be shown that these organisms were more susceptible to pollutants than fish and shellfish or their juveniles and larvae and that this was reflected in loss of production in polluted waters. It is, however, generally accepted that the sensitivity of molluscan and crustacean larvae to the commoner pollutants is similar to that of other components in the marine plankton. Some changes in the make-up of phytoplankton communities may occur in semi-enclosed waters, such as estuaries and fjords, as the result of

pollution (e.g., addition of nutrients) but these are not necessarily harmful; production may be increased. The protection of the exploitable living resources will therefore also serve to protect marine life generally. The only major exception seems to be the protection of seabirds from oil which is liable to cause heavy losses, particularly of auks, penguins and certain sea ducks. Such losses may be of more than local importance since many birds are migratory and some are used as food or as sources of down. It is therefore necessary to make inquiries regarding the existence of major seabird colonies and the prevalence of migratory wildfowl.

KNOWN SOURCES OF POLLUTION

SEWAGE DISCHARGES

Introduction

88. For the present purpose "sewage" is defined as the essentially liquid wastes from urban communities and includes discharges from municipal and industrial activities, which enter the municipal sewerage system.

89. Municipal sewers may carry varying amounts of surface water run-off depending on the design of the system. Where separate systems for fine and surface water drainage are provided, some pollution will be experienced from the surface water run-off. This will include oil, dirt and spillages from paved areas. Where a combined system is used, the rate of flow in the sewers increases significantly in wet weather and storm water overflows may be necessary to regulate the flow and reduce the cost of the system. Such overflows will, of course, be polluting.

90. Domestic sewage contains faecal matter and waste water from household activities, and is characterised by high biochemical oxygen demand (BOD), suspended solid concentrations and faecal coliform content. The commercial and industrial activities associated with municipal development vary widely, but it is now generally accepted that industrial waste discharged into municipal sewers should be controlled so as to exclude matter which might constitute a hazard in the sewerage system, damage the fabric of the sewers or present undue difficulty in treatment and disposal.

91. Although sewage can often be safely and economically discharged to the sea, the location of the discharge point and the design of the outfall works must be related to the anticipated use of the coastal waters and the quality of seawater required. The flushing characteristics of the proposed discharge area should be established, at least in general terms, so that the likely patterns of dispersion and dilution of sewage can be determined and taken into account at the planning stage. Such sea outfalls are most satisfactory in open coastal areas, where currents, wind and tidal conditions ensure rapid dilution and dispersal without return to beaches. Estuaries with good flushing characteristics may also prove very satisfactory for siting sewer outfalls, especially if the system is designed with storage facilities so as to permit discharge at specified states of thet tide. The most difficult situations occur when the proposed discharge point is located in a semi-enclosed bay or inlet, an estuary with limited flushing, or in any coastal area where free water exchange is impeded, e.g., in a lagoon behind a coral reef. In such situations effective treatment of the sewage is required before discharge of the effluent.

92. Generally to be acceptable a sewage outfall should meet the following requirements:

1. Discharges through the outfall should be adequately treated and/or disinfected, or the outfall so located as to safeguard waters used for bathing, water skiing, or other aquatic sports.
2. Discharged wastes should not contain materials in quantities that would be significantly harmful to marine life or birds after initial dilution, or cause hazards to human health.
3. Discharge should not result in the appearance of grease, oil or oily slicks, gross floating solids or visible material of sewage origin in waters used for bathing, or lead to unsightly conditions on beaches.
4. The discolouration of the water near the discharge point should not be such as to cause objectionable conditions in recreational areas.
5. Discharged wastes should not give rise to sewage odours at beaches.
6. The outgall should be so located as to take advantage of favourable currents to prevent deposition of solids and should be sited and constructed so as to produce adequate initial dilution.

93. The main points of concern in relation to sewage disposal are danger to health, damage to living resources, harm to amenities and interference with recreational pursuits. Where dispersal conditions are poor, excessive depletion of oxygen and deposition of organic matter may occur near the outfalls and locally be very damaging to living resources. Interference with other industrial or commercial uses of the coastal waters must also be considered. Expert examination of each individual proposal to discharge sewage is necessary to ensure that the agreed objectives are met. It may be necessary to exclude certain potentially very harmful industrial wastes from a combined sewage and industrial waste disposal system and to treat them at source; possible examples are those containing substantial amounts of mercury, cadmium or PCBs.

94. In a developing area with a high potential for tourism, the importance of planning the sewage disposal system so as to maintain freedom from harmful contamination on recreational beaches can hardly be stressed too strongly. Although no association has been established between disease and bathing in temperate waters, there seems to be agreement that extended bathing in polluted sea water increases the probability of contracting one or more of a variety of minor ailments particularly those affecting the eye, ear, nose and throat. It is therefore important that such coastal bathing waters be sufficiently free of pathogenic microbiological organisms to pose no significant risk to human health through water borne infections. So it is advisable to adopt a cautious policy. There is no doubt that the ability to demonstrate that all practicable steps have been taken to exclude sewage contamination from key recreational areas is an important asset in attracting tourists.

95. Freedom from sewage contamination is also essential in areas used for shellfish or seaweed culture. Specific risk to health can arise from the consumption of filter feeding shellfish taken from sewage contaminated waters, particularly where such shellfish may be eaten raw or only partially cooked. There is extensive evidence of the spread of diseases to man following the consumption of polluted shellfish. When shellfish are taken from polluted areas or handled under unsatisfactory conditions of hygiene, they present a high risk to the consumer, and this risk will increase in frequency as greater

quantities of shellfish are consumed. Shellfish therefore pose special problems to public health authorities in the areas of production and during handling, processing and transport to the consumer. Although systems of purification for mulluscan shellfish such as oysters, mussels and clams are available, it is much preferable in a developing area to design sewage disposal systems so as to prevent contamination. The possibility of secondary contamination with sewage organisms at the point of landing or during preparation for sale should also be borne in mind in the siting of markets and processing plants and in relation to their water supplies. It is generally highly undesirable to store shellfish temporarily, pending sale, in harbours or in seawater pumped from areas adjacent to occupied premises. Edible molluscan shellfish and any other seafood products eaten uncooked should be examined for sanitary quality by a method which determines faecal Escherichia coli rather than total coliforms. The results of analyses can usually be interpreted in terms of edible quality by reference to the publications of FAO and WHO (see bibliography). The assessment of the significance as a health risk of any sewage contamination found requires, inter alia, knowledge of the local prevalence of such water-borne diseases as typhoid, cholera and infectious hepatitis and is a matter for public health experts.

96. Comprehensive investigations are expensive therefore, the scope, and the depth of the assessment should be related to the scale of the problem and the sensitivity of the marine environment. Even with the most careful and complete examination there will, however, be uncertainties and, because of this, adequate flexibility should be provided in the design of the disposal system to enable changes in development and future requirements to be met. The main points of concern are listed below: the aim should be to ensure that the least cost combination of treatment and of outfall length is arrived at which satisfies the water quality criteria set for the anticipated use(s) of the coastal waters.

Engineering Considerations

97. Some of the principal engineering considerations which govern the practicability and cost of measures required to minimise the effect of development on the quality of coastal waters are described below. It is evident that these aspects should be taken into account at the earliest stage of development planning, when much can be done to influence the pattern of development, so as to avoid later difficulties and costly remedies. For example, development should not be located in the most sensitive areas or remote from the most suitable positions for effluent outfalls. During the planning phase, suitable sites should be allocated for possible treatment works, and the development of industry which gives rise to toxic or intractable waste discharges should be discouraged. Thus, the alternative solutions to potential environmental problems should be outlined while planning is in a fluid stage, and the difficulties recognised before development decisions are taken.

98. Coastal area development may affect the quality of coastal waters in a number of ways - directly, through the construction of docks, harbours, retaining walls and similar marine works; and indirectly, but often more significantly, through increased discharges of surface water and domestic and industrial waste waters.

99. Drainage for both surface and foul waters will normally follow natural falls to rivers, estuaries or the coast, and discharge into the nearest available body of water. It is feasible to shift the points of concentration or to transfer collected waste to other areas by installing lift or pumping stations, but it should be noted that they will entail continuous operating costs, use energy and require skilled maintenance. For example, domestic wastes from a population of 100,000 pumped through 100 m head may require an annual energy supply of about 40 megawatts.

100. The choice of disposal system is governed by the cost and the practical difficulties of drainage to suitable sites, of treatment before disposal, and of conveying the treated effluent to the selected point of discharge. The engineering task is to select the least cost system, taking into account the value of amenities, social benefits, energy and land use as well as the more obviously directs costs of construction, operation and maintenance. The following sections outline in simple terms some of the principal considerations which need to be taken into account.

Drainage

101. Foul and surface water drainage systems normally follow natural falls, and transference of flows from one catchment area to another can only be achieved at some cost. Unless there are over-riding reasons to the contrary, discharge of surface water, foul sewage and industrial effluents will therefore be to naturally occurring streams, or to estuaries or coastal waters. The protection of such waters from the effects of development should therefore be kept in mind in the planning stage and it may be preferable to move the development into a less sensitive area, rather than be forced to such expensive solutions as the realignment of drainage systems, or provision of comprehensive treatment works. For any given situation, however, there will be choices in the type and degree of the polluting liquors, and in the location of the points of discharge outfall.

Treatment Works

102. Treatment of domestic sewage and industrial effluents can be carried out at the point of origin or after collection. For urban communities it is now accepted as more practical, economic and satisfactory to collect sewage in gravity sewer systems for treatment at centralized works, than to provide septic tank or cesspool treatment at individual properties. For industries, however, consideration always needs to be given to the alternatives of pretreatment of the effluent before discharge into the sewer system, or of treatment after mixture with other industrial effluents or domestic sewage.

103. The construction and operation or treatment works brings its own difficulties. Apart from the high cost which may be entailed, there may be problems of competing land use, of energy consumption, of by-product disposal and of aesthetics. Some forms of simple treatment (e.g. oxidation ponds) need large flat areas, but more sophisticated treatment works are more compact; as a rough guide, land requirements can vary from 2 to 10 hectares per 100,000 population served. Unfortunately, the points of concentration of natural drainage, on banks of rivers and estuaries and by the coast, are often those areas most in demand for industrial, commercial, urban or recreational purposes.

104. More sophisticated and compact works often reauire higher energy use, and this may be an important consideration in developing countries. Thus a works serving 100,000 people, based on a conventional activated sludge treatment process treating effluent to a normally high standard, may require an annual energy supply of about 30 megawatts.

105. In the treatment of sewage, sludge is produced which is difficult to treat and dispose of without creating new problems. If industrial discharges are properly controlled so that the sludge is sensibly free from toxic material, then disposal of the sludge on agricultural land or dumping at sea may, under suitably controlled conditions and under properly chosen circumstances, cause little interference or damaging side effects; in particular situations such disposal might even be beneficial, e.g., improvement of soil structure and addition of nutrients. If not, then expensive means have to be adopted to concentrate the sludge by removing the bulk of the water prior to storage in waste areas or incineration and ash disposal.

106. Both in the disposal of sludge, and in the establishment and operation of treatment works, amenity considerations may be of importance. There are emotive objections against works for the treatment of sewage and more tangible arguments in respect of their visual impact, and the noise and odour problems which may arise. These can be reduced but not eliminated by proper control measures at additional cost.

Outfalls

107. Considering the difficulties of establishing and operating a sewage treatment works in a developing area, it may appear attractive to construct an extended outfall to enable foul wastes to be discharged to a suitable area well away from the coast after minimal treatment, but the design and construction of such outfalls has its own problems. The selection of points of discharge with respect to dilution, dispersal and potential pollution are discussed elsewhere. From the practical viewpoint it is necessary to ensure that the outfall will be self-cleansing and that suspended solids in the sewage will not accumulate and block the pipeline. This dictates a minimum size and the maintenance of adequate velocities, and because the friction loss in conveying liquids through pipelines is a direct function of the velocity and an inverse function of size, difficulties may arise in long outfalls of small diameter. For example, the hydraulic head required to sustain a velocity of 1m per second in an outfall 1000m long is about 1m for an outfall of 1m diameter, but 20m for an outfall only 0.1 diameter.

108. The outfall needs to be protected both from natural forces and from damage from other uses of the coastal waters (e.g., fishing trawls or ships' anchors). For these reasons it is usual to bury the outfall below the sea bed except for the point or points at which discharge is to take place. If the sea bed is composed of soft alluvial materials this presents no great difficulty, but the stability of such material in times of storm, or with the changing current patterns that frequently occur in estuaries, needs to be taken into account. If the sea bed is rocky, the cost of trenching to bury the outfall may be considerable.

109. Outfall pipes have been built of concrete, protected steel, aluminium, polyvinyl chloride (PVC), high density polyethylene (HDPE), and cast iron. Construction of sea outfalls can be carried out in a number of ways - they can be floated out and sunk; pulled by a powerful winch through a prepared trench after construction in parallel strings on land; lowered in strings or in sections from floating or 'walking' platforms; or (in suitable strata) constructed by tunnelling under the sea bed and breaking through to the surface at the required points. Each method has limitations of size and circumstances. In order to establish the best method and the cost of construction, detailed information is required on the topography of the coastal strip and of the sea bed; the geological nature of the sea bed and underlying strata; the pattern of waves and currents; the incidence of storms; the clarity of the water; the occurrence of fog; the movements of shipping; and the location of suitable ports and harbours or construction sites where outfalls or platforms could be built and launched. A comprehensive investigation to provide all the necessary information requires both skill and experience, and time.

110. It is evident that accurate prediction of the nuisance and beach contamination potential of any proposed outfall location is difficult; certain factors can, however, be used as guides to judgement in the location and design of an outfall for the discharge of sewage and industrial wastes:

1. Water of sufficient depth to ensure adequate jet dispersion.
2. A multiport diffuser outfall is preferred, and should be, as far as practicable, across the principal direction of current flow.
3. A significant range of temperature difference from bottom to surface, especially during seasons when beaches are in use, is highly desirable.

4. Where feasible, the greater part of the pipeline should be buried. Alternatively, good anchorage and protection must be provided to avoid the hazard of a broken pipeline.
5. Adequate currents past the diffuser to ensure good dilution and dispersion and to prevent local deposition of solids are highly desirable.
6. Outlet should generally be located so as to take advantage of any existing resideual currents away from recreational beaches or shellfish beds which need to be protected.

Disposal of sewage into the sea

111. The strategy of the action to be taken varies according to the assessment of the existing sewerage systems and the anticipated uses of coastal waters. The following data are of primary importance:

(a) In assessing the existing situation

1. - characteristics of existing sewage systems: separate, combined, collection points, location of outfalls, storm overflows;
2. - quantity and quality of urban discharges - resident and seasonal population, average and maximum flow; dissolved and suspended solids, BOD, COD, oil and fats, nutrients;
3. - pollution loads from industrial wastes (especially potentially toxic and persistent substances); evaluation of equivalent population;
4. - existing regulation for disposal of the erfluents; and
5. - use(s) and quality of coastal waters.

(b) In the development of the area

1. - land use forecast: estimated quantity and quality of domestic and industrial waste waters;
2. - type of sewage network development anticipated (separate, combined);
3. - pollution forecast from surface water run-off and land drainage (rivers and surface water sewerage);

4. - intended use(s) of coastal area;
5. - assessment of physical and chemical characteristics of the coastal waters;
6. - nature and extent of living and other resources;
7. - possible location of outfalls and location of sewage treatment plant;
8. - degree of treatment required and length of submarine outfall.

(c) Technical and financial detail

1. - feasibility, design and capital and annual running costs of treatment plant and outfall;
2. - cost/efficiency analysis of alternative technical solutions.

INDUSTRIAL WASTE DISCHARGES

Introduction

112. There is a wide variety of industrial effluents emanating from a host of manufacturing processes and other industrial activities. Each has its special characteristics and affects the environment in a particular way. The trend is toward recovery of more and more useful products from industrial wastes because stricter regulatory requirements to prevent pollution of receiving waters. In some instances this has made it economical to recover more material and thereby reduce the amount of treatment necessary.

113. Industrial wastes may be discharged (sometimes after treatment) through sewers or directly through pipe-lines with outfalls on the coast or in estuaries. Coastal waters may also receive the polluting loads of rivers containing wastes from industries sited inland and sometimes in another country. Some important pollutants (e.g., lead in motor vehicle exhaust discharge and sulphur dioxide, SO_2) may be carried substantial distances through the atmosphere and discharged with rain. In assessing the existing levels of industrial wastes in an area proposed for development these possibilities should be borne in mind.

Determining the nature of industrial wastes

114. The nature and potential polluting characteristics of industrial wastes can be determined in a general way by reference to the processes from which they are derived, e.g., steel making, oil refining, food processing, paper and pulp production, but detailed confirmation can only be provided by factory managers or the sewerage authorities in the case of wastes discharged to sewers. In many industrial processes, especially those involving complex organic substances, the exact composition of the waste may be in doubt because of the interaction of different substances and progressive breakdown of effluents before discharge. Where industrial wastes are discharged directly to the sea, in addition to determining constituents of wastes by analysis of effluents, it is desirable to make analyses of biota or sediments in the area of discharge for a limited range of particular substances likely to be present and known to be important potential pollutants (e.g., metals and organochlorine substances). In the case of organic wastes, it will be necessary to assess the environmental conditions in the immediate vicinity of outfalls by determination of, for example, biological oxygen demand (BOD), chemical oxygen demand (COD), percentage of organic matter in the sediments, and turbidity of receiving waters. The amount of floating residues will need to be assessed and may be important in an area of value for tourist purposes.

115. Only a few of these analyses are relatively simple, e.g., measurement of dissolved oxygen and determination of organic matter in sediments by percentage loss on ignition. Some require complex instrumentation (gas/liquid chromatotography, atomic absorption spectrophotometry) and careful training of analysts before reliable results can be obtained. However, standard recommended methods have been described and facilities for training can often be arranged through appropriate United Nations Organizations. (Appropriate references can be found in the bibliography).

Broad classification of industrial wastes

116. Industrial effluents may be broadly classified according to their physical and chemical characteristics, their behaviour in receiving waters and the way in which they affect the aquatic environment and aquatic organisms:

(1) Dissolved organic substances including toxic, persistent and biodegradable materials;
(2) Dissolved inorganic substances including nutrients;
(3) Insoluble organic substances;
(4) Insoluble inorganic substances;
(5) Radioactive materials.

117. In most cases wastes are water-borne, and where they are insoluble in water, material is either transported in suspension or as bedload, e.g., mine tailings, or floating on the water, e.g., oil. Because most industrial effluents are freshwater-borne, if discharged at the surface they will tend to float on sea water and, if released through a submarine outfall, will rise and may reach surface waters. Some effluents may be directly toxic to aquatic life, e.g., cyanides, phenols, sodium pentachlorophenate, or they may alter the properties of the receiving waters rendering them unsuitable for aquatic life in the immediate vicinity of the outfall, e.g., through oxygen depletion by decomposition of organic substances. Some substances may be bioaccumulated and possibly lead to longer-term problems.

Relative importance of different industrial wastes

118. For the living resources (fish, shellfish, etc.) potentially the most damaging pollutants are (a) persistent and toxic substances which may be accumulated in living organisms to levels very much above those present in the ambient seawater; (b) large volume high-BOD wastes, which may cause serious local deoxygenation and lasting alterations in bottom conditions near outfalls; and (c) substances causing objectionable taints in fish, shellfish and other seafoods. The substances in group (a) are principally metals and their compounds (mercury, cadmium and lead are perhaps the most important in a marine context) and complex toxic organochlorine substances resistant to biological breakdown (e.g., dieldrin, DDT, PCBs). Their presence in fish, shellfish, etc. used as food may render them unacceptable on public health grounds. High BOD wastes are discharged by slaughter houses, food processing factories, sugar and forest product industries and many others. The principal known tainting substances are phenols and certain petroleum hydrocarbons, but a much wider range of organic compounds are suspect.

119. From the point of view of the preservation of amenities and the development of tourism, the most objectionable industrial wastes are (a) oil, (b) organic wastes causing deoxygenation, discoloration, floating scums,

objectionable smells or persistent turbidity, and (c) large volume inert wastes (e.g., mine tailings, stone slag, waste from coal-fired power stations, or "red mud" from bauxite reduction) causing, inter alia, visible deposits on beaches and turbid water.

Application of analytical information to design of industrial waste treatment discharge facilities

120. Evaluation of the effects of a particular industrial effluent requires a knowledge of the volume discharged per day and its basic character, i.e., whether it is largely fresh water, whether it is highly toxic or contains substances which may be bioaccumulated and whether it is rich in organic substances which could deplete the dissolved oxygen in the receiving waters. The same kind of information would be required concerning receiving waters as in the case of sewage disposal. In essence, a mass balance must be developed to determine the concentrations of effluent which would prevail in the receiving waters under steady-state conditions. Then one must determine whether these concentrations will exceed the maximum permissible levels based on the toxicity of the effluent to marine aquatic life, or the accumulation of constituents to unacceptable levels in the biota, or whether they might lead to undesirable reduction of dissolved oxygen concentrations. Ideally, one would prefer to have a safety factor of say 10, or at least be able to satisfy the worst condition conceivable on a seasonal basis. These types of objectives will determine the degree of treatment that should be applied. The appropriate disposal of residual sludges has to be considered as a part of the required treatment for industrial wastes as well as for sewage. Although much can be learned from previous experience, it is essential to monitor the effects of a given type of industrial discharge to validate predictions and to assist in future planning of similar discharges. Relevant information regarding some aspects of industrial wastes and their disposal can be found in GESAMP publications, e.g., Reports and Studies No. 2, 1976, (Review of Harmful Substances).

SPECIAL ENVIRONMENTAL CONSIDERATIONS

121. The paragraphs below describe very briefly certain coastal habitats and environmental characteristics which require special consideration when planning the development of a coastal area. These are examples only; an appreciation should be made of the special features of any area proposed for development.

122. Estuaries, coral reefs and lagoons are often sought as sites for development because they provide low-lying land suitable for construction of marinas, residential accommodation, tourist hotels, shipping ports and deep harbours at comparatively low cost. However, there are usually substantial environmental penalties that have to be paid and these should be fully examined.

123. Deltas are formed by the deposition of sediment from rivers draining into coastal waters. They are part of the estuarine ecosystem. Deltas often have marshes which can be easily filled for construction. However, marshes are important as a food source for birds and fish inhabiting estuaries and other coastal waters. They also serve as nursery grounds for young fish. Moreover, deltas can be inadvertently destroyed by developments not necessarily impinging directly on the delta itself. For example, elimination or reduction of the riverine silt load that feeds the delta can result in the delta being cut back, because the rate of erosion by littoral currents exceeds the rate of sediment deposition. Placement of coastal structures such as breakwaters, jetties and groynes in inappropriate locations can interfere with currents and cause erosion in one part of a delta and deposition in another.

124. Coastal spits and lagoons are often formed naturally by littoral drift of sediment and deposition between points of land. Wave action can produce a bar which connects two points of shoreline or the mainland shore with an island. Lagoons formed behind such spits and bars often provide desirable habitats for fishes, molluscs and other aquatic wildlife. Lagoons are invariably associated with atolls in the South Pacific, formed by coral growth on the upper periphery of subsiding sea mounts. In this situation they also constitute special ecosystems with distinctive populations of fishes and invertebrates. Man-made developments on these lagoons or on spits can modify the ecosystem through interference with water movement and drift of sediments. Moreover, disposal of

sewage and industrial wastes into lagoons and into waters partly confined by spits can lead to acute local pollution.

125. Mangroves contribute to the scenic character of many semi-tropical and tropical areas and have some aesthetic appeal for tourists. They are important in maintaining the integrity of a coastal area against erosion by runoff and littoral currents. Their contribution as a living resource should not be underrated. The wood represents a renewable energy source, besides having a potential as a building product and raw material for pulp and paper production. However, perhaps the greatest attribute of the mangrove is that it provides suitable rearing ground and the needed food for various aquatic species that can be harvested annually, such as oysters, crabs and certain fishes.

126. Coral reefs provide a habitat for many folourful reef fishes and invertebrates which are regarded as an important amenity by recreational divers and tourists visiting these waters. However, coral reefs also provide protection as natural breakwaters against wave action from the open ocean. Such pollutants as oil and suspended solids, that affect the colonial coral fauna, or the photosynthetic processes of algae living symbiotically with the corals, may kill coral animals and lead to ultimate destruction of the reefs by the action of waves and swell.

Estuaries

River discharge

127. Where river discharges occur, they are important in determining the characteristics of coastal waters. Because fresh water floats on sea water, river water inflow contributes to stratification in coastal waters. River water may also contribute to turbid conditions in the coastal zone because it often contains a great deal of suspended matter from erosion in the drainage basin. River water may or may not contain biologically important substances such as nutrients and dissolved organics. Depending on the degree of urbanization and industrialization upstream, there may be substantial loads of sewage and industrial wastes. Therefore, any programme for coastal area pollution control must take into account pollution abatement and control in rivers discharging to the estuaries under consideration. However, a major ecological effect of river water is that it is a diluting medium for sea water, and therefore leads to brackish conditions, which are occupied by a range of specially adapted organisms.

128. The seasonal variation of river discharge may have severe consequential effects. For instance, the annual flood in many rivers leads to a large input of mud, silt and sand into the delta and inundation of the flood plain, enriching it with nutrients and dampening it for a luxuriant growth of vegetation. The penetration of sea water as a "salt wedge" along the bottom of a river channel is severely restricted during periods of heavy river discharge, and it may be completely pushed back to sea. In these circumstances, organisms existing in the salt wedge would likewise be washed into the sea, or be destroyed by the freshwater inflow, except for those species having a wide salinity tolerance.

129. Low river flow also provides special conditions in the estuary and in nearby waters. The salinity increases substantially in the sub-surface waters, and the extent of freshwater influence on the coastal zone is appreciably diminished. A salt wedge along the bottom of the river channel becomes re-established. Marine species tend to re-enter the estuarine system.

130. Some of the more sophisticated methods of stream flow measurement involve dilution of salt or dye. Others require a meter to measure the current. A simple technique to measure stream flow involves the timing of a piece of wood or other floating material through a measured distance on a calm day. The calculated speed of river movement can be used, with the cross-sectional area of the stream, to give the river discharge in volume (cubic metres) per unit time (second). Because the flow is usually faster at midstream than nearshore by a factor of about 4/3, an adjustment of the discharge estimate can be made, depending on where the current measurement was made.

131. River flow is usually measured at some point upstream beyond tidal influence. The technique often used is a daily manual recording of water level on a calibrated staff. Automated water-level recorders are now available providing a continuous record on punched or magnetic tape. Water levels are related to river discharge by an appropriate curve based on a standard calibration procedure.

132. The physical and chemical characteristics of the river water can be determined by sampling weekly, or at least once per month (to obtain seasonal changes) at a representative point in the stream. Temperature measurements are the most easily made. Measurements of suspended sediment load can provide an estimate of the annual sedimentary contribution of the river to the delta. Chemical analysis of the river water for phosphate,

nitrate/nitrite, and silicate will provide a measure of the nutrient contribution to the estuary. Other chemical constituents may also be measured in a river that is known to have been polluted upstream, e.g., heavy metals, chlorinated hydrocarbons, petroleum hydrocarbons and wood fibres. These analyses are much more complex than the previous ones, require not only access to a good analytical laboratory and some experience but also special attention to sampling and the preservation of samples.

133. It should be noted that river influences in the sea can be extremely widespread when the flow is large, e.g., the Amazon, Ganges and Congo rivers, or very local when the discharge is small. Deposition of suspended material and pollutants would tend to occur in the river mouth, where fresh water meets sea water, and in other areas of reduced flow, for example, where circulation is impeded by man-made structures.

Estuarine Ecosystems

134. An estuarine ecosystem is generally regarded as quite complex, and to understand the details of the interdependence of its components may require at least a five-year study. However, the significance of an estuary for support of particular aquatic living resources can be established in as little as six months investigation. Such a limited study can sometimes determine the feasibility or desirability of proceeding with a particular type of development.

135. A first examination of the estuary would include an estimation of its contribution to the support of known living resources. This would include local estuarine fisheries, such as those for oysters and shrimp. Then one must obtain an estimate of migratory species (fish and crustaceans), which rely on the estuary for feeding or breeding or migration from the river to the sea and return. Some species may use the estuary for spawning because of the availability of a suitable substrate for egg deposition, e.g., Pacific herring seek eel grass and other rooted aquatics for spawning. The presence of aquatic bird life should be noted. Migratory waterfowl may use the estuary as a feeding stopover during their seasonal migration, or as a nesting site. Although wildfowl are usually regarded only as a recreational asset, they are sometimes used as a source of food and down. The international character of migratory waterfowl should not be overlooked.

136. Once it has been established that an estuary is vital for support of certain living resources, then an investigation should proceed to determine how this support is rendered. Ideally, the study should provide for a multidisciplinary approach, to obtain information on appropriate aspects of biology, fisheries and marine geology. In the absence of this, a great deal can still be learned by concentrating upon priority components of the ecosystem. After a preliminary review of fish landings, a suggested first priority is an assessment of the fish and shellfish populations in the estuary, both indigenous and migratory. Shellfish beds can be surveyed relatively easily by area and density measurements. The finfish surveys are somewhat more complicated.

137. A technique that seems to be suitable for assessment of fin fisheries in many estuaries is beach seining at selected stations. Such sampling must be conducted at frequent enough intervals (weekly or biweekly) to identify the periods of peak migration for different species. Information on length and weight of fish caught can be readily acquired with simple measurements. Stomach samples should be obtained from a range of sizes, and contents weighed and identified, if not yet fully digested, for species commonly eaten. The stomach contents can soon determine the preferred food of the fish, and if this happens to be only a few species, important links in the food chain can be identified. This information, combined with the duration of stay of migratory species in the estuary, can establish the level of importance of the estuary in the life history of these species. The food supply in the estuary for juvenile salmonids, for example, usually consists of benthic crustaceans. Simple benthic surveys of the intertidal delta can be made at low tide with sampling at designated stations using a standard area wooden frame (quadrat) which is laid on the bottom, and the bottom material and organisms contained therein are scooped up to a depth of about 2 cm. The organisms present are sieved out, identified and weighed. In this way, the benthic biomass and the main contributing species can be determined. It is also useful to record basic information on the character of the sediments.

138. A preliminary estimate of the importance of the contribution of zooplankton to the food supply on non-bottom fish species can be obtained by plankton tows at high tide in the delta and in deeper water beyond. Again, it is useful to determine plankton volumes and the commoner species collected in standard tows to provide data on biomass and major species present.

139. The sources of carbon (the basis of animal and plant production) in the system (excluding human input) are likely to be:

(a) rooted vegetation in the intertidal zone or just above high tide;
(b) phytoplankton;
(c) benthic algae; and
(d) detritus brought downstream.

Preliminary observation can sometimes identify the major base of the food chain. For example, a turbid freshwater inflow may mean low primary productivity from phytoplankton. Large sedge meadows and vast field of eel grass may mean a significant contribution of carbon from these sources. More detailed examination of phytoplankton, benthic algae and rooted aquatics requires the services of specialists to measure the productivity of these forms.

140. Along with the biological studies, certain physical and chemical observations should be made by basic techniques sometimes involving what is referred to as "hipwader oceanography". Water samples can be taken from shallow-bottomed boats or actually in hip waders for temperature, salinity, dissolved oxygen and nutrients. Observations can be made on currents through intertidal channels using very simple techniques, such as timing the drift of a piece of wood. Wave action in the delta can be noted. The movement of fresh water can sometimes be identified by its special characteristics, such as siltiness or colour.

141. The physical, chemical and biological information should be integrated to obtain a picture of the interaction of various components in the estuarine ecosystem. This would provide useful information in assessing effects of any alterations in the estuary through various types of construction and should lead to a better understanding of the impact of pollution. Although the above review is generally applicable to estuaries, the examples have been drawn mainly from temperate conditions, the special features of tropical estuaries and river systems, e.g., mangroves, receive further examination below.

<u>Climatic influences</u>

142. Climate is an important factor affecting the pollution implications of coastal area development. The impact of an oil refinery, for example, on a semi-tropical coastline will be very different from that on an ice-bound Arctic shore. Geographical latitude may, however, give a rough indication

of climate but may be somewhat misleading, unless it is considered in relation to the continental and oceanic effects which may have an amplifying or moderating effect on the climate. For instance, the coast of western Europe receives the moderating effect of the Gulf Stream, and areas at 60°N in Norway are much more temperate than those on the north-east coast of Canada at the same latitude.

143. The principal effects are related to temperature, although precipitation can have a significant impact on coastal activities. These climatic factors can influence coastal vegetation, which may be an important aspect of habitats for awuatic wildlife. Various formal systems, taking into account the principal factors distinguishing climatic types, have been in use by geographers for many years (see for example the Koppen system, Ackerman, 1941).

144. The consequences of temperature on coastal area development are worth examining in some detail. Temperature affects the rate of metabolism of all aquatic organisms. But, from the point of view of pollution, the significant impacts of temperature stem from its effects on the rate of metabolism of bacteria and other micro-organisms, which are responsible for decomposition of organic substances, and on the speed of chemical processes. An oil spill in the tropics is rapidly degraded because of the high rate of activity of decomposing microorganisms. Since the activity of bacteria at high latitudes is very much slower than in the tropics, a similar oil spill in the Arctic or Antarctic, in the presence of ice, will endure for a protracted period.

145. The character of the shoreline materials in high Arctic areas differs from that in lower latitudes by virtue of the temperature difference. Permafrost, pengo areas and ice demand special attention in coastal construction. The stability of the shoreline may be highly dependent on preservation of the integrity of the subsoil by frost (sub-zero temperatures). Shore structures in ice-infested waters must be designed in such a way that they can withstand the pressures of pack ice. The use of offshore structures, such as drilling rigs, or pipelines, must be planned with respect to known incidence of icebergs and sea ice conditions, and provision for avoidance or protection against such drifting masses of ice, which may scour the bottom to depths of 500 metres, must be carefully considered.

146. Warm tropical waters may suffer acute effects, such as severe oxygen depletion, from a major oil spill or from the disposal of a large volume of biodegradable organic wastes or heated water. This is due to the rapid action of decomposing mecroorganisms at the high temperatures. Such an effect may be noted also during the warm summer months in temperate latitudes. However, the highly adverse effects of acute spills of organic substances are relatively short-lived, since the rapid biodegradation stabilizes the organic materials quickly. Therefore, the effects would be essentially short-term with rapid restoration of the environment. In continuous disposal, the decomposition of organic material can lead locally, near the outfall, to a continuing state of acute degradation of renewable resources in tropical waters. In contrast to Arctic waters, however, once such discharges are discontinued, a tropical or sub-tropical system should restore itself quickly by natural processes.

147. Some care must be taken in the clearance of tropical forests for farming or other development, where conditions may result in enhanced erosion, in the formation of laterites and in leaching of the surface nutrients followed by baking, rendering the soil more or less sterile.

148. Certain features inherent in latitude situations can be of benefit to the planner. The Trade Wind regions, for example, are characterized by very persistent and predictable wind systems. Recognizing such features in the planning phase of a port development will have many practical advantages.

Island Ecosystems

149. The following discussion of the special characteristics of island ecosystems is not concerned with such large islands as New Zealand, New Guinea, Borneo or the larger islands of Japan and the Philippines, nor with Arctic or Antarctic islands. The land area-to-coastline length ratio is generally much greater for a continental coastline than in the island situation. This has a bearing on the magnitude of continental climatic effects, volume of freshwater runoff and input of wastes and other substances from island sources. It has a bearing also on the magnitude of oceanic influences, such as oceanic current systems, prevailing winds, ocean waves, swell and tsunamis and the availability of marine living resources.

150. Island ecosystems differ in many physical respects from those of continental shorelines. This has some bearing on the need for protection against pollution and destruction of vital habitats during coastal area development. Islands, in general, are not endowed with vast amounts of particular types of coastal ecosystems. It has been said that if Thailand eliminated one-third of its mangroves for rice paddies this could probably be justified on the basis that the surviving mangroves would be sufficient to meet all the foreseeable needs that Thailand might have from this natural resource. In contrast, many tropical and sub-tropical islands could not afford to lose that proportion of their mangroves and still have a viable remainder. The same consideration might apply to coral reefs.

151. Oceanic island ecosystems in sub-tropical and tropical areas have the special attributes of warm water, sunshine and delightful beaches, which make them attractive recreational resorts for tourists from the colder, temperate climates. For this reason, a principal industry on such islands is tourism, with the associated need to protect water and beach quality, coastal fauna and flora and the aesthetic values of the recreational areas.

152. Some of the factors which differ most and must be treated accordingly when applying techniques developed for continental shores to oceanic islands are described below.

Climate

153. Surrounded by water, oceanic islands generally have a moderate climate without large seasonal variations. They are influenced by oceanic wind systems, such as the Trades, which are quite predictable both daily and seasonally. Islands with mountains or sizeable hills may receive most of the precipitation on the windward side and be quite dry on the lee side. Wind-driven currents and waves are generally predictable and can be expected from the direction of prevailing winds.

Waves, Swell and Tsunamis

154. Unprotected oceanic island shorelines are perhaps best characterized by continuous wave and surf action. This has a great impact on shoreline installations and beaches. Protection in the form of breakwaters is required for boat basins and wharves. However, recreational surfing can benefit from such waves and swell. Perhaps the most devastating waves are tsunamis arising from seismic disturbances. Catastrophes from these long waves are well known, for example, in the Hawaiian Islands. Although there is now an International

Tsunami Warning System, little can be done in the design of coastal facilities to prevent devastation by these relatively rare monster waves.

Oceanic Current Systems

155. Most oceanic islands are swept by quasi-permanent current systems. On the side of the island receiving the impact of the current, the usual split with water flow on both sides of the island will occur. On the lee side, there will be a wake, having almost the same configuration as the wake behind a large ship. These currents will have an impact not only on shore structures but will also affect the transport and dispersion of pollutants.

III. A METHODOLOGY FOR DETERMINING THE IMPLICATIONS OF COASTAL AREA DEVELOPMENT ACTIVITIES

Introduction

156. In an attempt to promote a common understanding of the effects of coastal activities on the coastal and marine environment, a procedure has been developed that relates development activity to environmental effects and potential uses, in a series of tables and matrices. It is hoped that this will prove useful in the analysis of the factual information collected. In particular, it may direct attention to considerations which might otherwise be overlooked.

157. Before a rational decision can be made regarding the use of a particular marine resource, adequate information is needed under the following sub headings:

1. The activities considered for siting in the coastal or marine environment and their siting requirements.
2. The residuals of these activities, especially the wastes produced, and the physical changes that they may cause in the coastal and marine environment.
3. The biological and other effects of the wastes and physical changes.
4. The impact that a selected activity may have on other potential uses as a result of environmental changes.

Site Selection Table

158. Table 1 lists important site characteristics related to particular development activities to be located within the coastal environment. There are, however, other important factors in the decision-making process and also interactions between uses that can create conflicts to be resolved. These other factors include:

i) fresh water supplies;
ii) labour availability;
iii) soil conditions;
iv) liability to flooding.

Pollution Assessment Matrices

Matrix Contents and Use

159. A number of matrices have been developed that can assist the analyst to determine environmental effects and potential use conflicts. The

list of uses is not exhaustive but, for those selected, the residuals (wastes) and effects are those which are considered to be the most important. Once residuals are identified, appropriate effort can be allocated to determine their quantitative significance. The entries in the matrices have been made by the members of the Working Group for the general case in the light of their experience. Individual readers are encouraged to examine these entries carefully in relation to their own circumstances.

160. Matrix 1 relates selected coastal area activities to the residuals (wastes) they produce and to direct changes in the physical environment resulting from these activities.

Notes

(a) The activities listed are those for which site characteristics are defined in Table 1.

(b) The residuals (wastes) identified are those associated with current practice in carrying out the activity.

(c) The symbol 'X' placed at an intersection denotes a relationship with a pronounced effect. Minor effects are noted by the symbol '(X)'. Such relationships may be either direct or secondary - or through the action of other items identified by 'X' in other columns for the same activity.

(d) The matrix identifies the presence of interactions but not their relative importance. The development of tourism and recreational activities, for example, gives rise to sewage and dredge spoil but no attempt is made to determine whether the effect of sewage is worse than that of spoil. The precise significance of each effect must be evaluated specifically for each site.

161. Matrix 2 relates wastes to effects on the marine environment.

Notes

(a) As with the first matrix, significant relationships are identified by X at the appropriate intersections; minor relationships have '(X)' placed at the intersection.

(b) In virtually every situation the ecological equilibrium of an area may be affected by one or more residuals in the form of a change in the character of the habitat or some aspect of the food web due to alterations in primary productivity, fauna, or flora.

(c) As with the previous matrix, the fact that an effect is identified in a qualitative assessment does not imply that its relative importance is high.

162. Matrix 3 relates effects to alternative uses and completes the cause-effect sequence. This matrix permits one to identify rapidly the sensitivity of "other uses" to effects commonly associated with residuals. The other uses selected cover a wide range of developments but the list is not comprehensive. It does not include, for example, military activities, chemical manufacturing plants, wildlife conservation, coal mining or metal ore extraction and processing. The characteristics of particular uses and their scale may differ substantially from place to place and each example must be considered individually.

163. In order to provide a convenient summary of the relationships represented by the matrices, a matrix overview has been prepared. It presents the three matrices in a combined format which allows the relationships to be followed more easily. For example, mining for construction materials may produce industrial waste water, dredge spoil and affect water circulation, among other results. These wastes and changes in physical conditions have a number of effects upon the marine environment including the six listed. These effects will have potential impacts upon other uses of the coastal area such as the six selected. It is possible to select any group of activities and examine their impacts concurrently to determine potential use conflicts and environmental consequences.

Special Notes on Wastes Discharged in Coastal Areas

164. Because of the frequency of their presence and their significance, special attention must be drawn to the discharge of industrial and municipal wastes. The following additional material on waste disposal is designed to elucidate items in the matrices which may need more detailed consideration.

Sewage

165. As already noted, the implications of the uncontrolled disposal of sewage into the marine environment are mainly related to public health which may be direct for bathers and indirect for consumers of sea food. Amenities may be seriously impaired. Water supply to sea water desalination plants is also adversely affected by heavy sewage pollution.

166. The effects of sewage on living resources depend mainly on the depletion of oxygen near outfalls; in areas with restricted water exchange eutrophication phenomena could occur as a consequence of the nutrients that are carried by sewage. The nature of the sewage depends upon the socio-economic characteristics of the communities involved, e.g., domestic, industrial, farming.

167. The assessment of the impact of sewage on the marine environment is based on the availability of four types of information concerning:

1. characterization of waste waters;
2. natural characteristics of the receiving marine environment;
3. intended uses of the receiving marine environment and water quality criteria associated with these uses;
4. feasibility of preventive actions and technical measures to reduce impact of sewage discharge.

168. <u>The characterisation of waste waters</u>

(i) population served (number of inhabitants and seasonal fluctuation);

(ii) average daily sewage flow; maximum daily flow;

(iii) sewerage system used (separate, combined);

(iv) epidemiological conditions;

(v) daily per capita water supplied;

(vi) economic trends in the community served;

(vii) outfall characteristics and sites;

(viii) physical and chemical characteristics of discharge: (suspended solids, pH, BOD, COD, phosphates, detergents, heavy metals and other substances, according to nature of the community served).

169. <u>The natural characteristics of the receiving marine environment</u> influence the state of contaminants and their effects and are a function of such physical conditions as tides, currents, nature of bottom, shoreline profile and shoreline geometry, as well as of the marine ecosystems present. Possible interactions of pollutants in the marine environment (synergistic and antagonistic) must also be considered.

170. The definition of quality criteria for coastal areas depends on the intended uses as defined by the local authorities or in regional development plans. The discharge standards for the effluents should be fixed according to water quality criteria tailored to the natural capacity of the receiving marine environment to disperse or reduce the impact of pollutants, and to the particular contaminants included in the discharges.

171. The feasibility of preventive actions (restraints on urban development, tourism and recreation), and of technical measures for marine pollution abatement, should be assessed in the light of cost/benefit and cost/efficiency analysis, according to the local manpower availability, local energy constraints, space availability and opportunities for re-use of effluents and sludges. Figure 3 presents an outline of the available techniques for the treatment of urban raw sewage before disposal into the marine environement.

Industrial waste waters

172. The effects of the disposal of industrial waters depends basically upon the amount and chemical nature of the contaminants included. In addition to a vast range of soluble, mainly inorganic, substances derived from industrial activities, potentially damaging wastes of the following groups may also be present:

1. biodegradable organic wastes, e.g., from food industries, tanneries, paper and pulp mills, pharmaceutical manufacture, etc.;
2. persistent organic wastes, e.g., from pesticide manufacture, chemical and pharmaceutical industries;
3. insoluble inorganic wastes, often in large volume, e.g., from cement and fertiliser manufacture, iron and steel and other metallurgy plants, bauxite reduction, mining, etc.

173. The extent of the effects produced by the discharge of industrial wastes on the different components of a particular ecosystem depends on several factors, the most important of which are:

(a) the physical, chemical and biological properties of the polluting agents;

(b) the duration of the effects (i.e., persistency) and bio-accumulative capacity;

(c) the concentration of the specific class of pollutants in the environment under consideration;

(d) the occurrence of chemical interactions between the pollutants;

(e) the natural characteristics of the receiving waters (factors influencing dilution, dispersion, absorption, sedimentation, oxidation, bacteriostasis, primary and secondary productivity, predominant species in the fauna, etc.).

174. The assessment of potential pollution in a geographically defined marine environment cannot be based on observations or data relating to other marine regions. An effective programme of pollution prevention should be capable of adaptation to local socio-economic and political conditions and be endowed with a certain amount of flexibility from the outset. These are the basic lines it should follow:

(a) definition of the intended uses of the coastal areas;

(b) definition of quality criteria for the coastal areas in the light of the intended uses;

(c) definition of effluent quality standards in the light of the desirable coastal water quality criteria;

(d) choice of the type or types of industry to establish in the coastal areas;

(e) definition of the constraints to be imposed according to the type of industry;

(f) assessment of economic and technical assistance available for the development of suitable preventive technologies for the industries concerned.

Other Municipal and Industrial Wastes

175. In addition to waste waters, communities and industries produce, directly or indirectly, other residuals which can affect the marine environment when they are discharged. As mentioned in the matrices, these include:

Urban Runoff. Rain and washing waters collected separately from roads, squares, markets, etc., and drained by the urban sewage network, contain a higher grit and dust load, possibly more oil, but a lower bio-load than sewage. The concentration of potential pollutants is likely to be lower.

Agricultural. This category includes waters drained naturally by canals from land used for farming activities. In addition to manure and other waste products of farming industries (milk products, poultry wastes, etc.), possible pollutants may include suspended solids, detergents, other bio-degradable substances, fertilizers and pesticides.

Garbage. This includes the waste solids from domestic and municipal activities, partly organic but with varying amounts of plastics, metals, etc.

Organic Solid Wastes. These arise from industrial activities processing organic products, e.g., pulp and paper mills, slaughter houses, vegetable and fish processing plants, etc.

Inorganic Solid Wastes. These arise from industrial activities processing minerals (e.g., cement) and from those producing metals (e.g., iron and steel plants).

Sludges. These include the by-products of waste water treatment plants as well as substances collecting at the bottom of reservoirs for industrial liquid products.

Floating Solid Wastes. The intermediate waste products of industrial processes (pulp and paper mills, tanneries, fish processing plants, oil refineries, etc.) are included here.

Scum. Scums may arise from the discharge of partially treated waste waters. They may also form as emulsions on the surfaces of containers for industrial liquid products (e.g., in oil refineries) for which they may be discharged in effluents.

IV. CONCLUSIONS

176. It is generally agreed that sound decisions on the location of coastal area development and on the constraints placed on the design, construction and use of industrial, housing, service and recreational facilities, should only be based on the analysis of facts, data and observations. A basic programme for the collection of the information appertaining to the marine environment, in a broad sense, needed to assess the implications of development has been described in the preceding sections of this report. Although written from the point of view of those primarily concerned with marine pollution, the report has necessarily included wider aspects of the environment, e.g., the preservation of amenities. It seeks to define a strategy of coastal land use which, although giving protection to natural resources, will not interfere unduly with development.

177. There are powerful economic forces which tend to concentrate a high proportion of such development in coastal lands and, particularly, around estuaries and inlets. For purposes of trade and communication, ports and harbours usually have to be provided. If industries are developed which either depend upon imported raw or semi-processed materials or the export of primary natural products (e.g., food, timber, minerals or oil) or manufactured goods, then necessarily the coastal strip is the first choice for their location. Another powerful incentive may be the feasibility of cheaper disposal systems for waste than would be possible at an inland location.

178. The subject of pollution control in coastal waters is therefore an important one which should be given attention in forward planning before any major decisions are made on the siting of development. Moreover, it should be appreciated, at the outset, that the foreign exchange to be earned through tourism and natural recreational facilities (e.g., sport fishing, surfing and coral reef exploration) may form a significant part of the national budget. Such income is very largely dependent upon the maintenance of an "unspoiled" atmosphere and experience has shown that tourists are fickle and, although they will tolerate a considerable degree of development for purely housing and recreational purposes, the intrusion of ill-placed industrial activities (such as oil terminals and refineries) may have a strong deterrent effect. Inadequate or badly-sited sewage disposal facilities may be equally damaging. The development of a local fishing industry may, however, be attractive to tourists.

179. There is a wealth of experience in developed countries from which to draw but a very large part of this is based upon temperate water conditions; the extent to which extrapolation can safely be made to tropical and sub-tropical conditions is uncertain. Nevertheless, the principles upon which national planning should be based, and the main sources of damage from marine pollution, are reasonably well established. The potentially most harmful pollutants from existing processes have been identified and their effects are known, at least in a general way. Methods of assessing the productivity of both living and other natural resources have been developed and the ways in which their exploitation may affect the marine environment have been studied. Although the bulk of this work has been done in northern temperate conditions, the methods can be adapted to the study of tropical conditions without much difficulty. It is accepted that some mistakes have been made (mercury pollution is a good example), but there is no good reason why the errors of developed countries should be repeated when industrial or touristic development takes place for the first time.

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ILLUSTRATIVE EXAMPLES

Example 1: Tourism and Recreation, including Recreational Fishing

Introduction

1. Tourism and recreation are affected by a series of factors which influence the opportunities provided by the seashore and coastal waters for relaxation and enjoyment. Whether a visitor to the coast, seeking recreation, derives pleasure from the seashore and facilities available there depends to some extent on individual taste, but the amenities generally enjoyed include clean water, a sandy beach, sunshine and a sea breeze. Some people visit a beach for peace and quiet, and prefer some degree of of isolation, while others may be gregarious and enjoy the bustle of human activity. Or they may wish to go on a fishing trip away from the seashore. There are limits in either direction on the volume of users; no one really enjoys overcrowding, and few people like to be totally alone.

Preliminary site requirements

2. Table I lists a series of factors which are important with regard to the development of tourism and recreation. These include ambient water quality, shoreline energy regime, nature of beach and seabottom, residence time of introduced substances, local weather and climate and seawater circulation. The basic information necessary to assess these factors will be provided by the observational programme set out in this report but, in addition, special visits must be made during the appropriate seasons to the coastal area being considered for the purpose of assessing how well it meets the established popular criteria for tourism and recreation. Aesthetic values are important but difficult to quantify. Convenience is also important, especially in relation to access, including air travel. There must be a quality of attraction which can usually be sensed but not readily defined in physical terms.

3. Certain important characteristics of a beach, which cannot be observed or estimated too well visually, must be measured to ensure its safety. These include strength of currents and wave heights, particularly during periods of strong onshore winds. Large waves and surf could hamper recreational activities and even be dangerous for swimmers and small boats.

Example 1 - 2

On the other hand, a powerful swell and surf may be desirable for surf-board riders. If dangerous rip currents for swimmers are present, how frequent are they? Coliform counts (particularly faecal coliforms) should be made during different seasons to obtain an indication of the degree of sewage contamination during the heavy tourist seasons, so the development of an effective sewage disposal system should be uppermost in the mind of the planner.

Preliminary environmental impact assessment

4. Matrix 1 identifies the wastes and changes in the physical environment likely to result from the development of a coastal area for tourism. Those most likely to be significant are the production of sewage, domestic garbage, solid wastes of various kinds, oil and changes resulting from development in shoreline profile and beach conditions. Matrix 2 enables the planner to make a quick assessment of the effects on the environment of these residuals and it will immediately be appreciated that some, e.g, sewage, domestic garbage, inorganic solid wastes and oil among the wastes, and changes in shoreline configuration and beach conditions, may produce substantial alteration in seawater quality, coastal fauna and flora, sediment deposition and accretion, and aesthetic quality.

5. Most of the changes in the marine environment identified above as likely to occur following development of tourism, if not controlled, will result in a gradual deterioration of the area as a coastal resort. In addition it is necessary to consider, in advance, the probable inter-action of tourism and recreational development with other potential uses of a particular area. These can be identified by following through to Matrix 3 where the environmental effects produced are related not only back to tourism and recreation but also to a range of other (and, sometimes, competing) uses of the coast. From the matrix it is apparent not only that touristic development is very dependent upon the maintenance of ambient water quality and physical condition of the beaches but also that the development of fishing, and especially mariculture, could be seriously impeded if their essential requirements are not borne in mind. Where

Example 1 - 3

freshwater supply by desalination is important, or natural sea-salt production takes place, serious conflicts could also arise. On the other hand most industrial activities are not directly affected by the residuals of tourism, although the reverse is far from true. The wastes arising from industry may, indeed, seriously hinder or prevent development for tourism, and conflict can also arise between these two potential uses in other ways, e.g., competition for sites, labour and freshwater supplies. Touristic and industrial development of the same general coastal area must usually be well separated. The presence of commercial fishing activities within a predominantly tourist development may, however, prove to be a substantial attraction to visitors.

6. Although the matrix approach can be useful in evaluating the environmental acceptability of tourism and recreation activities, it is clearly only a guide. While the conflicts that may arise between tourism development and the exploitation of renewable living resources can be quickly identified, political and economic considerations may be the deciding factors in whether to proceed with a recreational development. As noted earlier, there are certain intangibles in a resort area, and even after all the quantifiable criteria are apparently adequately met, an area may still be unattractive for tourists. Other areas with apparently little to offer may always be crowded; this may be related in part to the proximity of large urban populations. Promotion and advertising by word of mouth or through the media, the deliberate provision of onshore facilities, and sheer convenience undoubtedly also play a big role.

Example 2: Pulp and Paper Mills - 1

Introduction

1. In addition to the raw materials and principal chemicals used in industrial processes, most industries make use of a large number of auxiliary chemical compounds for various purposes. Some of these compounds give rise to environmental problems and unless this is appreciated, measures to control only the major chemicals and spent raw materials allowable in the effluents would be inadequate to eliminate them.

2. The paper and pulp industry provides a good example of the problems which may be encountered. Chlorination is used to bleach the fibres leading to formation of a large number of chlorinated degradation products of lignin. Complexing agents, such EDTA/DTPA, released in the process have been shown to be very persistent in the environment. Slimicides, such as organomercury, organotin compounds and chlorinated phenols may accumulate in marine organisms after discharge.

3. The pulp and paper industry may be increasingly important in developing countries but two phases have environmental implications, in addition to the effects of construction: (1) logging and transport of logs to the mill; and (2) manufacture of pulp and paper. The main environmental impact of logging is on freshwater streams, but there may also be an effect on estuaries and on other coastal waters. This impact stems from poor logging and road building practices, which lead to erosion of large amounts of sedimentary materials into water courses and coastal waters. Another ecological impact in coastal waters which should not be ignored is the effect of log transport and storage. This aspect of the logging industry leads to deposition of bark and wood debris on the bottom, and such deposits have been found to alter significantly habitats for marine bottom fauna.

Preliminary site requirements

4. There are certain prerequisites for establishing a pulp and paper mill on the coast. First of all, there must be a demand (not necessarily local) for the products, i.e., wood pulp and paper products. Secondly, there must be raw materials relatively near at hand, with electrical power and fresh water, and other essential requirements for economically producing pulp and paper, readily available. Finally, transport facilities are needed to bring in the raw material to the plant and to ship out the finished product.

Example 2 - 2

5. These requirements mean that coastal pulp and paper mills will be located near a forested area to provide the essential wood for pulp, adjacent to a stream or lake for a supply of fresh water and preferably near a cheap source of electrical energy (often hydroelectric power from nearby steep-graded streams). Because it is desirable to have deep-sea transportation from a protected harbour, pulp and paper mills are often located in bays and inlets into which rivers discharge. This often leads to a conflict with renewable aquatic living resources, because these estuarine areas not only serve for passage of anadromous and catadromous fishes, but are also important rearing areas for other young fish and invertebrates.

6. Other important environmental characteristics to be considered in site selection for a pulp and paper mill are given in Table 1. These include shoreline type, flooding potential, water depth, circulation and mixing of adjacent waters, ambient water quality, residence time for pollutants, and atmospheric characteristics (prevailing winds, inversions and dispersion potential).

Effects of construction

7. Construction for a pulp and paper mill on the coast disturbs a substantial section (1 kilometre or more) of shoreline. Not only must buildings be constructed to house the pulp- and paper-making machinery, but ancillary facilities must also be installed, i.e., a wharf for deep-sea ships, a log pond for storage of logs before they are taken via jack ladder into the woodrooms, and a general log booming area. There will usually be some infilling and dredging along the water front. It is generally conceded that the section of the shoreline allocated to a pulp and paper mill must be sacrificed as far as further fisheries activities there are concerned.

8. The coastal siting of a pulp and paper mill can greatly influence the intensity of local pollution arising from disposal of waste from manufacture of pulp and paper. Ideally such sites should be chosen so that there is a maximum dilution and dispersion of not only the water-borne effluents but also of the atmospheric emissions. The odour problems of kraft (sulphate) pulp mills have not been fully solved, and mills improperly placed with respect to wind patterns can make such areas unattractive for human settlement.

Example 2 - 3

Preliminary environmental impact assessment

9. In Matrix 1, the important residuals arising from pulp and paper manufacture are given, namely industrial wastewaters, inorganic and organic solid wastes, floating wastes, scums, atmospheric contaminants and odours. Most of these residuals have a local impact and are largely transient or bio-degradable. However, certain persistent substances may be added in pulp and paper manufacture, such as mercurial slimicides, and certain persistent chemicals, e.g., PCBs, may inadvertently leak from the various facilities, such as electrical transformers, on the site.

10. Matrix 1 also shows the changes in physical conditions which can be caused by pulp and paper mills. Significant effects may occur on the shoreline configuration and profile and nearby bottom characteristics.

11. Pulp and paper manufacture traditionally requires a large amount of good quality fresh water. A full-bleach kraft (sulphate) pulp mill requires about 190,000 litres of water per ton of pulp produced. Depending on the type of process used, there may be partial recovery of materials from the spent cooking liquor or it may be released without recovery or treatment into receiving waters.

12. In Matrix 2, the marine environmental effects of the residuals are shown. The principal environmental effects arise from the discharge of industrial wastewaters. These include effects on salinity, turbidity, colour and transparency, dissolved oxygen, BOD, other dissolved substances, and fauna and flora. There may also be deposition and accretion on the bottom with effects on primary productivity and flora and fauna.

13. Other uses of the coastal area which may influence its use for a pulp and paper mill are shown in Matrix 3. There are relatively few environmental effects from other uses that impact on a pulp and paper mill operation. These, however, include erosion, deposition/accretion and circulation. The presence of many recreational vessels in the coastal waters could affect the use of these waters by a pulp and paper mill for log towing, booming and log sorting activities and for shipment of finished product. In general, however, pulp and paper mills deter any other uses of the adjacent waters, especially for recreation, because of the impairment of aesthetic qualities.

Example 2 - 4

Information needed for environmental assessment

14. What are the observations required to assess the effect that a pulp mill will have on the coastal environment? First of all, there is a need for general information on the living resources and their economic importance. Considerations include whether or not there are migrating salmonids; intertidal and shallow, sub-tidal, shellfish beds; resident birds which feed and breed in the are; or migratory waterfowl which use the nearby salt marshes and waters for roosting, feeding or as a staging ground.

15. The system of effluent disposal will depend a great deal on the living resources or the types of amenities that are to be protected. For example, in some fjord systems it has been found most satisfactory to release effluent in the surface, seaward-flowing brackish layer in order to obtain rapid flushing. However, this is not the best way to discharge the effluent if inter-tidal and shallow sub-tidal shellfish beds are to be protected, or if aesthetic considerations are important. Estuarine areas, important as nursery grounds for juvenile fishes, cannot tolerate high concentrations of pulpmill effluent or deposits of wood solids. In such circumstances, it is generally desirable to achieve effluent concentrations as low as possible in the surface layer and to settle out the wood solids before discharge. This is often done by installation of a deep-water discharge through a diffuser with multiple ports for rapid initial dilution and dispersion.

16. A first approach is to determine the environmental impact of a given daily volume of effluent discharge on the local body of water. For example, knowing the BOD of the effluent and its volume, one can estimate the daily oxygen demand. This information can be compared with a rough estimate of the oxygen availability in the coastal water based on either existing information or some quickly obtained oceanographic data, and an oxygen balance can be developed. The oxygen needs of living resources must be taken into account in the analysis. Sometimes, the type of basic environmental information needed for such a preliminary assessment can only be acquired in a series of oceanographic surveys, including current measurements. This initial assessment is often needed to determine what degree of treatment will be required, or indeed, whether it is environmentally feasible to establish the pulp and paper mill there at all.

Example 2 - 5

Oceanographic observations

17. The basic oceanographic observations required are those that will provide the information for dilution, dispersion and the ultimate characteristics of the receiving waters under steady-state discharge of effluent to be determined. Where discharge is through a deep diffuser, certain basic oceanographic information (salinity and temperature) is required to determine the initial dispersion and the behaviour of the effluent plume in its ascent from the diffuser. Then current information is necessary to determine the behaviour of the effluent field, at whatever depth it ultimately lies, in the 24 hours following release from the outfall. For surface discharge, surface current observations are most useful, and these can often be obtained with suitable drogues or floats whose movement can be mapped by a variety of techniques. Wind observations are needed simultaneously to give wind effects.

18. Oceanographic data from a number of stations, appropriately selected, where salinity, temperature and dissolved oxygen measurements are made with sampling bottles placed at discrete depths, or vertical profiles of these variables are obtained with appropriate sensors, provide the essential information on water structure, i.e., whether it is vertically mixed or stratified. This is useful information for the initial assessment of the behaviour of any effluent released into the waters. It will tell us whether the effluent would be transported away from the outfall in a discrete layer or whether it would become mixed into the water column and essentially diffused seaward through the full depth of the water. To obtain seasonal changes, it is recommended that monthly surveys of the foregoing type be conducted over the course of a year, but if this is considered too costly, at least four surveys should be made during the year to cover each of the seasons.

19. Current observations should be made at an anchor station over at least a 25-hour period at a number of depths to provide a vertical current profile of both tidal current and residual current over a tidal day. Ideally, current measurements should be made continuously at selected depths for at least a 30-day period to provide a more reliable picture of tidal and residual

currents. Recording current meters can be moored at a given depth to provide a continuous record of current over prolonged periods. Tidal elevations should be continuously recorded on a tide gauge, if possible, to relate current speed and direction to the tide. Wind data should also be recorded on recording anemometers with direction sensors during such continuous current observations, to provide some measure of wind effects on circulation.

Prediction of impact on resources

20. Combining the oceanographic data with bathymetric and tidal information provides a means of calculating exchange rates. Although such calculations are approximations at best, they do provide a basis for predicting the impact of a given effluent discharge. Knowing the toxicity and BOD of the effluent, one can determine whether unacceptable oxygen and toxicity conditions will arise with a steady-state discharge of effluent. Such information, coupled with biological data on the living resources, will be required to determine:

(a) whether a proposed pulp and paper mill site is environmentally acceptable;
(b) the degree of treatment required for the effluent from the operation; and
(c) the location and type of outfall required to minimize the pollution effects of effluent discharge.

Notes on specific pulp and paper industries

The following notes refer to the Canadian experience. It is recognized that other processes, such as that involving chlorine pulp, may present other problems:

Sulphite pulp

21. Sulphite pulp, produced by a chemical pulping process, with calcium bisulphite usually in the cooking solution, leads to recovery problems, and frequently the effluent, containing half of the weight of the wood pulped (lignin and other non-fibre constituents) plus the cooking chemicals, is discharged into an adjacent water course. Because of the large concentration of biodegradable organic constituents (wood sugars) in spent sulphite liquor , the BOD (biochemical oxygen demand) is high (1,000 ppm) and the dissolved oxygen in receiving waters can be rapidly depleted. Spent sulphite liquor is also known to be toxic to fish and invertebrates, especially the larvae.

Example 2 - 7

Groundwood pulp

22. For newsprint, groundwood pulp is largely required. This is produced by stone grinding of blocks of wood to mechanically abrade the short fibres. This groundwood pulp is treated with a brightening agent, such as zinc dithionite, to render it white enough for newsprint. Then a certain proportion (about 20%) of longer-fibred, chemically produced pulp is added to give it strength. The main pollutant from groundwood production is the wood fibre that escapes, which can be harmful to fish when present in high concentrations. However, the main problem with effluent from groundwood production, which also applies to the chemical pulping process, is that the fibres may accumulate on the bottom of receiving waters and destroy benthic habitats. Most mills now have a settling basin for their wastewaters, so that the wood fibres can be removed before discharge of the effluent.

Kraft (sulphate) pulp

23. In draft pulp production, the more popular chemical pulping process in North America, the recovery of salts and organic constituents from the spent cooking solution (black liquor) is economically part of the normal production sequence. Hence the BOD of draft mill effluent (ca. 100 ppm) is not as high as that of sulphite effluent. However, kraft mill effluent may be toxic as a result of some rather persistent constituents, such as fatty and resin acids, and sulphur-containing compounds. It is now a practice in new kraft pulp mills, especially when located on freshwater systems, to install biobasins for reduction of both the toxicity and BOD, as well as for settling out the wood solids. In coastal pulp mills, the tendency is to instal long outfalls with diffusers for rapid dilution and dispersion, without preliminary treatment. A local effect sometimes in evidence is the presence of foam and discoloured water, which is largely an amenity problem, but also has certain ecological implications, such as restricted light penetration and reduction of photosynthesis.

Example 3: Port and Harbour Development - 1

Introduction

1. With growing maritime trade, there is an increasing demand for ports and harbours. Moreover, it is more economical to ship with large carriers than with small ships. Therefore, the trend is towards larger freighters and tankers, having greater draught and requiring deeper harbours and approach channels and larger port facilities to handle them.

2. Port and harbour construction or enlargement almost invariably involves major disturbance and often restructuring of segments of the coast. When such a disturbance occurs in particularly productive coastal areas, e.g., estuaries, there can be both acute and long-term ecological impacts on populations of species, communities and ecosystems. Furthermore, operation of port facilities can be a continuing source of pollution and general disturbance of the local environment.

Preliminary site requirements

3. In Table 1 are given the important site characteristics to be considered for port and harbour development. These include bottom profile, currents, wave characteristics, winds, water depth, bottom type, approach geometry, tidal range, flushing rate, sub-bottom condition, soil mechanics and visibility.

4. Various activities connected with port and harbour development not only disrupt but may permanently destroy certain aquatic renewable resources and their habitats. This adverse effect may be very localized or could be rather extensive, depending on the scale of the development and the care used in design to minimize environmental damage.

Ship loading facilities

5. For loading ships, there must be a wharf or quay allowing deep-sea ships of reasonable draught to come alongside at all stages of the tide. A loading derrick or crane must be able to run along the wharf in order to load heavier items for shipment. With containerization now common for many commodities, heavy loading equipment is essential in most ports.

Example 3 - 2

6. A port normally requires road and/or rail access to bring in or carry away raw material or manufactured products. Suitable land must be available adjacent to the ship-loading facilities for handling and storage of commodities to be shipped.

Breakwaters and jetties

7. Breakwaters are often needed to protect ships tied up at exposed wharves. Because they modify the movement of nearshore water, they also alter the sedimentary regime and may substantially modify the nearshore ecosystem. A variety of breakwater types is now available from floating wharves and trains to tethered buoys to rows of pilings and huge concrete structures. However, jetties and breakwaters are still predominantly made of large boulders armoured with massive rock or concrete slabs or steelsheet piling for protection against wave action, and extending to elevations well above high tide levels.

8. Structures are frequently required as guides for sea traffic in river channels which are subject to modification by silting, e.g., in estuaries. They may also provide protection from wave action for vessels plying such channels. Training walls are sometimes used to prevent siltation from river-borne sediments in ship channels, and in some cases to enhance scouring by river flow. These coastal structures also affect the distribution of river water or sea water near shore, and hence the salinity and temperature patterns and sediment transport regime.

Preliminary environmental impact assessment

9. The residuals arising from port and harbour development and operation are given in Matrix 1. They include for a conventional on-shore terminal: sewage, ballast water, domestic garbage, inorganic solid wastes, dredge spoils, floating solid wastes, oil and oily wastes, and noise.

10. From Matrix 1, it can also be noted that the direct changes in the physical environment caused by on-shore ports and harbours include those on: shoreline configuration, shoreline profile, wave conditions, bottom character, circulation, littoral sand budget, and visual characteristics.

Example 3 - 3

11. In Matrix 2 are given the marine environmental effects of the residuals arising from port and harbour development and operation. As an example, dredge spoils are noted to affect turbidity, colour, dissolved oxygen, BOD, nutrients, metals and other dissolved substances in the water. There would also be primary effects on deposition and accretion, with consequences for the fauna and flora.

13. From Matrix 3 the interaction of port and harbour development and operation with other uses of the coastal marine environment can be deduced. While ports and harbours affect virtually all other activities, few activities interfere with port and harbour development. However, those activities which introduce floatables, increase flora and fauna, cause erosion and deposition/accretion or alter the circulatory pattern need to be carefully considered.

14. Estuaries present attractive sites for ports, but are often highly productive for living resources. They provide access to rivers for anadromous fishes returning to spawn, and for catadromous fishes coming to the rivers to feed. Access to the sea for the juveniles of the anadromous fish is also provided, and these species may feed intensively for several weeks or months in estuaries. Disruption of habitats for estuarine species can occur as a result of development, and spawning and larval rearing grounds for both inshore and pelagic species can be destroyed.

15. Breakwaters and jetties extend from the sea shore in some configuration either normal, oblique or parallel to the shoreline. They invariably alter the along-shore current patterns and modify the littoral drift of sediments. They may also modify the nearshore distribution of salinity by redirecting the movement of fresh water entering the coastal waters from streams. Such altered environmental conditions can affect plant and animal communities, and thus modify the nearshore ecosystem.

16. Some jetties in estuaries are associated with impoverished local biological productivity while others appear to have led to enhancement. Guidelines for jetty and breakwater construction in estuaries should stipulate that alteration of currents and salinity distribution by such structures must be minimized.

Example 3 - 4

Observations for an assessment of environmental effects

17. To assess an area as a potential site for a port, and to determine likely environmental effects of development, the living resources must be appraised carefully and the impact of any changes in the coastal environment examined in all important respects. It is necessary to evaluate not only the threat of the development to existing living resources, particularly as they contribute to commercial and recreational fisheries, but also to foresee the possibility of aesthetic impairment and reduction of amenities.

18. Ideally, an interdisciplinary study should be conducted to evaluate the impact of any port and harbour development. This would include studies of the fisheries resources, oceanographic characteristics, climatology, hydrology and marine sedimentary geology of the area. It should also involve the socio-economic aspects of the development, which may determine whether it is a viable project over the long term, when the benefits are weighed against reduction of renewable living resources and amenities in perpetuity.

Some guidelines in selection of sites for port and harbour development

19. There is no simple quantitative way of predicting the ecological and aesthetic impacts of a given port development, but certain guidelines can be laid down to minimize the harmful effects that such a development might produce. One major guideline which might be offered is that highly productive estuaries should be avoided for port development whenever possible. Well-flushed areas with a substantial flow of water and comparatively low biological productivity would be preferred sites from environmental considerations. While rocky shorelines are usually comparatively low in productivity, and might be recommended for port development, they pose problems of access and construction which usually limit their usefulness.

20. Breakwaters and jetties which allow an exchange of water through them are better suited to prevent major ecological changes than impermeable solid structures. Usually, provision for free flow of water through them does not impair their usefulness in dampening wave action. Structures on pilings, which allow water to flow through freely, alter nearshore current patterns less than those with solid foundations. Moreover, pilings can also provide a substrate for attachment of invertebrates which provide an additional source of food for species higher in the food chain.

Example 3 - 5

21. Although the main ecological impact of port and harbour development occurs during construction, it should be borne in mind that the operation of a port can lead to long-term chronic degradation. Either adequate preventive measures should be taken in the design of a port to avoid long-term effects, or a site should be chosen where such degradation would not have serious ecological consequences.

Example 4: Mining of Construction Materials - 1

Introduction

1. Construction materials from marine sources include sands and gravel for concrete buildings and structures, shell sands for the production of portland cement, and sand for beach replenishment or land fill. The selection of a site for mining is usually based on local need; that is, some development is being considered which will require construction materials. Exploration for a source of materials (described in GESAMP Reports and Studies No. 7) may result in the discovery of a number of minable deposits from which a selection may be made. Assuming the presence of adequate reserves, the selection would be influenced very strongly by the distance of the deposit from shore, the depth of water and characteristics of the bottom. Transportation costs for bulk materials usually represent a major portion of the product cost whether the material is transported by pipeline or in the hopper of the dredge, and the cost of the delivered product is very sensitive to changes in transport needs. Most standard dredges are limited in digging to about 100 feet, combined water depth and deposit thickness. Greater depths require commensurately greater capital expenditures or lease costs for the dredge.

2. Bottom characteristics assume prime importance in the consideration of the deposit itself as well as the pollution implications of its removal. In all cases, but particularly where the sources of materials are limited or there are compelling political or other reasons influencing site selection, it is important to examine the potential environmental conflicts and determine the options applicable to the operation. In discussing the implications it has been found convenient to use the following illustrative example: a sand and gravel deposit is being developed some two miles off the coast to supply the construction of a large port development in a West African state. The sand and gravel is delivered by hopper dredge to the construction site in a sheltered estuarine natural harbour. The material is pumped ashore to the plant where it is washed with fresh water, screened and graded, before being stockpiled for delivery to nearby sites by road.

Example 4 - 2

The development of the port is necessary for the outward shipment of ore from an extensive deposit in the hinterland. No previous development has been carried out in the area which is tropical with a low rainfall and situated at the mouth of a major river.

Preliminary environmental impact assessment

3. As indicated in Matrix 1, industrial waste waters, sludge and muds and dredge spoil may result from the mining operation in the plume of fine sediment created by the overflow of the dredge hopper during the pick-up operation. In the open sea, two miles from shore, the dispersion of the fines would be such that redeposition would be unlikely to result in a significant local buildup. This could, however, be measured, if it were close to nearby fish spawning or shellfish grounds, for example by simple bottom sampling techniques. On shore, the washing plant would result in accumulation of mud, fines and organic debris. The dried stock-piles would generate dust while the plant itself would be a source of noise.

4. Significant changes in the physical environment may also result as the operation at sea will alter the bottom characteristics by lowering the seabed several meters over an area of a few square miles. There is some likelihood of affecting wave conditions sufficiently to cause alteration in the equilibrium of adjacent beaches (shoreline) or nearshore bars (shore profile). Removal of the gravel substrate will alter the bottom characteristics of the mined area and locally change the habitat for benthic fauna. Because no sand is removed from or placed directly on the beach, the littoral sand budget may not be directly affected unless sand is moved shoreward on a seasonal or intermittent basis. Changes in circulation due to altered bottom characteristics could affect beach conditions indirectly as could changes in wave refraction. On shore, the construction of the unloading dock and plant will have changed the shoreline by the construction of bulkheads and the placement of fill. This will have a local effect on the circulation and possibly tidal zone life but, in order to determine this, preconstruction surveys and projections should be made, based on simple biological examinations.

Example 4 - 3

5. Effects on the environment of residuals and direct changes resulting from development may be varied (see Matrix 2) but in the case described here, the only potentially significant impacts which might require continued monitoring would be those connected with erosion and deposition resulting from changes in the shoreline and the discharge or spillage of effluents.

Multiple use conflicts

6. Marine mining is somewhat affected in a direct manner by changes in the environment due to conflicting uses (see Matrix 3). In certain cases, erosion or changes in circulation might alter the working conditions around the deposit but significant effects of this nature are highly unlikely in the situation described. More likely conflicts would be with commercial fishing and tourism, which could impose regulatory restrictions on mining operations thought to be destructive or undesirable according to some criteria. To avoid damage to fisheries the local distribution of living resources in the area to be exploited by marine mining would need to be carefully mapped (see Paras. 74-78).

Example 5: An Oil terminal - 1

Introduction

1. Because of increased prices for oil, there is a worldwide search for new reserves. The shallow seas and continental shelves are being examined everywhere and thoughts have even turned to the Antarctic. Consequently, the provision of additional oil terminals may become necessary in many countries. Such coastal development commands top priority so the importance of being aware of its possible pollution implications does not need to be stressed. These may arise from three main groups of causes:

(a) conveyance of oil to or from the terminal by tanker or pipeline or both;

(b) construction of offshore moorings, jetties, quays, tank farms and other installations; and

(c) development of refineries and ancillary industries, e.g., for the production and/or utilization of petrochemicals.

2. Because oil is such a convenient energy source, its presence may lead ultimately to the development of a multitude of industries and this possibility should be kept in mind at the planning level. By itself, an oil terminal does not employ many people - the processes of landing, storage and onward transportation can be largely automated - so that extensive housing development for operating a terminal alone is not usual.

Preliminary site requirements

Preliminary environmental impact assessment

3. The developments (a) and (b) above are associated with two main kinds of pollution arising from: (i) the spillage of oil; and (ii) interference with coastal current and sediment transport regimes through erection of massive structures on and near the shore. The effects of such structures will not differ from those associated with ports and harbours, described in Case Study 3 (see Matrix 1).

Example 5 - 2

4. Oil may be brought ashore by pipeline but this may constitute a substantial interference with fishing. Even if buried initially (a common requirement if the seabed traversed is suitable) such pipelines may emerge above the sea bottom due to erosion of sediment by current and wave action. For this reason alone, the banning of all trawling across the pipeline, and in a defined band alongside it, is highly desirable. Dredging of any kind and anchoring of any ship in this band should also be prohibited. For these reasons, the siting of a pipeline and terminal needs to be planned so as to minimize interference with existing shipping and fishing activities or any considered likely to develop on the basis of knowledge of unexploited resources, such as shellfish beds or mineral deposits.

5. In theory spillages may occur at any point along a pipeline but, in practice, facilities for isolation of particular sections are usually incorporated which restrict considerably the amount of oil that can be released. The regions of greatest vulnerability offshore are related to the character of the sea bottom and the degree of exposure to wave action during storms and to accidents arising from ships unaware of the pipeline's position. Spillages from pipelines occur only rarely but are most frequent at the ends, i.e., the connections with the production platform or its ancillary structures and with the shore terminal. Spillages at sea, generally speaking, present fewer hazards and are more readily dispersed than spillages in the coastal zone. Heavy oils are an exception to this. Contingency plans must be made in advance for dealing with offshore spills and the operators are usually required to have available both equipment (including ships) and trained personnel for this purpose as a condition of a lease. Spillage of oil in the coastal zone may be very damaging locally for both living resources and amenities. Matrix 2 gives an indication of how such damage may arise. Contingency plans should be prepared by the local authority for minimizing the effects of such spills but, even with the best will in the world, mechanical and electrical faults do occur, which occasionally result in oil spillages. It must also be admitted that human error of one kind or another is a frequent cause of oil release, even in the best managed installations.

Example 5 - 3

The inevitability of spillages must be kept in mind during initial planning and site selection.

6. The potential for damage differs considerably according to the type of crude oil being brough ashore, particularly according to its content of aromatic substances. For fuller information, see GESAMP Reports and Studies No. 6, 1977 - Impact of Oil on the Marine Environment.

7. If oil is brought ashore or distributed from the terminal by tankers, then the additional risks of pollution normally associated with such ships, e.g., tank cleaning, discharge of waste oil and sewage and garbage disposal, need to be considered. Suitable reception facilities for ships' wastes need to be provided ashore. As indicated in Matrix 3, oil terminals and refineries may produce environmental effects which have considerable impact on other uses of the coastal area but no other activity appreciably interferes with its operation.

8. Of possible industrial developments near an oil terminal, a refinery and the production of petrochemicals are the most likely to be favoured. Refineries may entail substantial levelling and infilling of coastal areas and will certainly produce effluents that are actually or potentially damaging, while adding materially to the risks of spillage of oil and oil products. In most cases, road, rail or ship access will need to be developed for the distribution of products. Additional urban development with increased sewage discharge will be inevitable. Well-run refineries release only small quantities of oil and refined oil products but many of the latter are toxic to marine life and liable to cause tainting of fish, shellfish and other seafood. The coastal area immediately adjacent to either a refinery or a petrochemical plant must in practice be regarded as sterilized so far as fishing is concerned.

9. No general guidance can be given as to the extent of marine pollution risks from petrochemical plants since, in theory at least, the list of possible products is extremely lengthy and contains many potentially harmful organic substances. Judgements as to the likely hazards can only be reached on the basis of knowledge of: (a) chemical substances to be

Example 5 - 4

produced and which may be discharged; (b) local water movements; and (c) distribution of harvestable resources. Each major group of chemical substances requires specialized production equipment and usually new plant will be constructed if new products are to be made and marketed. For this reason, unheralded changes of any magnitude in the character of effluents or the appearance of new substances in the effluents are unlikely. An initial appreciation of the potential for harm of particular substances in the marine environment can be obtained from GESAMP Reports and Studies No. 2, 1976 (Review of Harmful Substances) and from the hazard profiles produced by GESAMP in co-operation with the Intergovernmental Maritime Consultative Organization (IMCO).

Example 6: Municipal Sewage Disposal - 1

Introduction

1. Nearly all coastal development entails human activity and settlement, and water-borne waste (sewage) will be generated which must be removed (see Matrix 1).

(For the purpose of this note, municipal sewage is defined as domestic sewage together with small industrial waste flows from such commercial activities as laundries, restaurants, garages and so on as are normally sited within residential areas. Large flows of industrial waste should be considered individually whether discharged to the municipal system or not. Municipal sewage comprises mainly body wastes, kitchen wastes and sullage water diluted by the comparatively large volumes of waste water which arise from normal domestic use, and still further diluted in some circumstances by infiltration of subsoil water into the sewage system or by the ingress of surface water in wet weather. Compared with many industrial wastes, sewage has a low polluting load, the biochemical oxygen demand often averaging not much more than 200-300 mg/l. The concentration of toxic chemicals is also very low, but because of its origin and nature, sewage is objectionable in character and carries a large number of bacteria and viruses of intestinal origin, some of which may be pathogenic.)

Although land disposal of sewage may sometimes be possible, in most instances it will be necessary to dispose of the liquid fraction to rivers, lakes or to the sea, and in most coastal developments disposal to the sea is the only economically feasible solution. Whatever the method of disposal, sewage will need to be treated before discharge to the extent necessary to protect the receiving water from pollution.

Effects of Sewage Discharges

2. Matrix 2 shows that municipal sewage (with its associated odour, scum and floating wastes) affects nearly all aspects of the marine environment to a greater or lesser degree. The sea offers such large potential dilution that if the sewage outfall is carefully located to ensure rapid dispersion, the effects of sewage discharge on salinity, temperature and pH are not usually significant. However, care is required to avoid local damage to

Example 6 - 2

flora and fauna by the depletion of dissolved oxygen and pollution of molluscan shellfish beds must be prevented. Most concern is usually with human health, arising from the discharge of pathogenic organisms and other harmful matter; and with amenity, including the effects of turbidity, colour, smell, particulate solids and floating matter. It can be seen from Matrix 3 that these environmental effects may adversely effect a number of potential uses of the coastal area including the urban development which contributes the sewage and is necessary to support industrial or commercial enterprises. The satisfactory disposal of municipal sewage is thus nearly always of fundamental importance.

Outfall Investigation

3. The investigations necessary for the design of a satisfactory outfall must be carried out to satisfy set objectives and cannot be planned or executed without an appreciation of construction methods and costs. The extent of the investigation appropriate at each stage of the development planning will depend in part on the magnitude of the problem, and in part on the circumstances. It is clearly wasteful to deploy a full range of expensive techniques in the early stages of investigation of a small development, or where the circumstances are clearly favourable to the rapid dispersion and removal of sewage. Conversely, it would be foolish to embark on the design and construction of an outfall and of pretreatment facilities without adequate study. The acquisition of data should not be an end in itself but the means to an end and should be limited at each stage to what is necessary to identify and quantify those factors which will influence the design of a satisfactory outfall.

4. The assumption is made that the essential background of basic information, i.e., of coastal oceanography and living resources, is already available; if not it must be collected. The sequential steps in investigation will then be to identify the problem, specify the objectives, postulate possible solutions, and collect the further data needed to assess the effects of the discharge. Alternative schemes can then be outlined and evaluated and the preferred solution selected.

5. The location of the development determines the point at which the sewage originates, and good planning will take into account the difficulties and costs of sewerage and of the location of the development relative to possible disposal areas. There will often be a variety of possible sites and lengths of outfall but there is also a wide range of pretreatment possibilities ranging from the minimum of removing gross solids, e.g., by screening, to the

extreme of treatment to a standard appropriate to inland water discharges. It will not usually be possible to identify the optimum solution without evaluating the economics and other features such as the labour and energy requirements of alternative solutions.

Quantifying the problem

6. It is evident that the probable strength and quantity of the sewage has to be established before investigations can be planned. The nature of municipal sewage may vary with climate, living standards, habit and similar factors but only within quite narrow limits. The quantity is closely related to domestic water consumption except in circumstances where by design or otherwise surface or subsoil water is drained into the foul sewers. In the early stages, therefore, the knowledge of the probable contributory populati... is sufficient to enable a first assessment of polluting load to be made. At a later stage, the pollution contributions from industrial and commercial activity must be carefully assessed.

Objectives

7. To avoid wasting resources, disposal systems should be designed to satisfy defined environmental objectives, the nature of which are indicated in Matrix 2. This necessitates setting realistic quality standards which are appropriate to the intended use of the coast and coastal waters; higher standards will obviously be required for bathing beaches and recreational waters than for water in the vicinity of oil terminals, docks, harbours and similar industrial activities. Bacterial standards for health protection are frequently set and are more easily defined than amenity standards which are inherently subjective, but not less important.

Dispersion, Dilution and Self-Purification

8. The adverse effects of sewage discharges into the marine environment are minimised by dilution with large volumes of sea water and by natural processes of purification. Consequently, studies of sea outfalls are primarily concerned with the behaviour of sewage after discharge - the initial dilution that can be expected, the speed and direction of travel after initial dilution, the rate of dispersion during travel, and the rate of self-purification in the receiving waters. Such studies should cover the various conditions of tide, wind and season which may be experienced, and depend on an adequate understanding of the physical, chemical and biological processes involved and of

the quality and movement of coastal waters both at the outfall and for a wide area around it.

Feasibility of Construction

9. There would be little point in identifying suitable outfall sites if the construction of the outfall proved to be either physically or economically impracticable. Consequently, as well as acquiring data relevant to discharge behaviour, the investigation needs to take note of the various sewerage layouts possible on land and of the many factors affecting outfall construction costs. These include the nature and stability of the sea bed; the importance and influence of shipping and fishing requirements and of other uses of the sea which might be affected by outfall construction; meteorological conditions such as the frequency of storms, fog or high waves; and the availability and cost of suitable materials and equipment.

Pretreatment

10. The polluting load of sewage can be reduced as far as is necessary by treatment, using physical, biological or chemical methods as appropriate. Treatment before discharge to sea may be necessary to reduce the environmental impact, and may enable a shorter and cheaper outfall to be used. Treatment is however expensive, and there may be objections to siting treatment works on the coast, and problems of noise and smell from the works. Nearly all methods of sewage treatment result in residues of solids in the form of screenings or sewage sludge which may be difficult to dispose of on land. Consequently, if sewage is treated before disposal, account must be taken of the possible disposal of sludge by dumping at sea, and the consequential effects on the marine environment.

Surface Water Discharge

11. Although the main problems of urban drainage are related to the disposal of municipal sewage, it should not be overlooked that surface water drainage from paved areas and in some instances from open and agricultural land may carry appreciable pollution loads derived from accidental spillages, aire-borne contaminants, fertilisers and so on. Sometimes some or all of the surface water is drained by the same system of sewers as the foul drainage and in this event it is impracticable to convey, treat and discharge the full flows during heavy rainfall, and relief overflows are provided. The siting of such overflows and the disposal of storm sewage from them necessitates careful consideration.

Table 1. Site characteristics and their importance for particular coastal development activities

This table is intended to serve as a reminder of the more important site characteristics that need to be assessed when making a preliminary selection of possible areas to accommodate a particular type of development. In respect of all the development activities considered it is essential also to assess existing natural hazards at a very early planning stage, including seismic risk, occurrence of major storms and the flooding potential of any site being considered, i.e., the likelihood of the coastal area being flooded by extraordinary tides or storm surges. In the table below only characteristics of the marine environment are considered but certain non-marine factors must also be taken into account in site selection. Among the more important of these are soil conditions, freshwater availability and accessibility.

Activity	Site characteristics	Notes
Urban development	Shoreline energy regime - Waves - Slope - Longshore currents	These combined marine factors influence erosional and depositional processes, and may affect shoreline stability.
	Local weather and climate ...	Wind direction, wind speed, rainfall, visibility, etc. may affect the visibility of an urban community , e.g., by storm damage, interference with transport, maintenance of air quality, fresh water flooding, etc.
	Coastal water circulation	Influences the disposal of sewage and so affects the value of the shore for recreational purposes
Tourism and recreation	Ambient water quality...	Cleanliness, colour and water purity may influence use for bathing, boating, water skiing, recreational value of the shore, etc.
	Shoreline energy regime ... - Waves - Slope - Tide - Water level	The desirability of a shoreline for recreational purposes depends on the nature of the waves and currents because of potential danger to bathers or the need for a particular characteristic for a sport (e.g., surfing). The energy regime would also influence the stability of the shoreline and of artificially created beaches.
	Flora and fauna...	The presence of various species of plants and animals will affect the desirability of an area. Thus, game fish should be present for sport fishing; poisonous fish should be scarce or absent for bathing; slimes and heavy seaweed growth are undesirable.
	Bottom characteristics ... - Profile - Type	Boating and bathing can be affected by the profile of the bottom and type of material. For bathing, a steep profile can be dangerous; for boating the same characteristics may be desirable. Well-populated reefs (or other rich shore habitats) provide tourist attractions as well as recreational opportunity.
	Residence time of contaminating substances..	This will be influenced by wind, tides, currents, nature and movement of sediments (a large proportion of potential pollutants become bound to soft sediments), and other physical characteristics of the marine environment.
	Shoreline type ...	Certain forms of shoreline are more attractive for recreation and tourism than others, e.g., sand beaches for bathing, surf fishing or strolling; mangrove swamps for nature study, fishing; precipitous cliffs and rock-bound coasts for scenic views.

Activity	Site characteristics	Notes
	Local weather and climate	Winds, temperature, hours of sunshine, precipitation, visibility, etc.greatly influence recreational and touristic use.
	Upwelling ...	This may cause nutrient rich waters to appear close to shore thus encouraging sport fishing but may also bring colder water adjacent to beaches.
Port and harbours	Water depth ...	Adequate water depth is important and if dredging is required, it is expensive and has associated environmental effects.
	Approach geometry ...	It is usually necessary to approach ports and harbous through restricted waters and channels. The path to be followed will affect time of transit and safety.
	Coastal water circulation ...	Strong currents influence ship handling and vessel safety and have a major effect on pollution dispersion.
	Tidal range	Tidal range influences accessibility to the port or harbour and also cargo handling. Excessively large variations create safety hazards and higher costs.
	Seabed characteristics - Bottom profile - Bottom type - Seismicity	These factors affect design and ship operation, costs and safety, e.g., bottom profile relates to charnel width which, if inadequate, requires dredging and may affect navigational safety; bottom type affects the ability of anchors to hold; seismicity will affect design criteria and hence costs as well as safety.
	Local climate ... - Wind speed - Wind direction - Visibility	Ship handling may be adversely affected by winds and visibility.
	Shoreline energy regime .. - Longshore currents	Longshore currents may result in siltation around port and harbour structures requiring dredging.
	Wave conditions ... - Height - Period - Direction	These can adversely affect the movement of vessels when approaching and when alongside a dock or pier.
Primary Industry - Oil terminal with refinery - Paper and pulp mills - Metallurgical plants	Shoreline type ...	The susceptibility of the shore to erosion will greatly affect its suitability for the siting of industry. The presence of bluffs, nature of beaches, existence of adjacent wetlands, barrier islands, a coastal plain, etc., will all affect the suitability of a coastal site for the location of industry.
	Coastal water circulation ...	Conditions of water exchange off industrial sites may greatly influence the practicability and cost of waste disposal.
Fish processing industry	Ambient water quality..	If seawater is used in fish processing, it must be of a high quality.
	Coastal water circulation ...	Fish processing wastes are objectionable and good dispersal conditions are required off the selected site.
	Local climate ...	Wind characteristics should be such as to disperse stack emissions and odours effectively.

Activity	Site characteristics	Notes
Mining for construction material (e.g., sand and gravel)	Water depth ...	Mining depth greatly affects operating time, technological requirements and cost. Transport costs are critical in assessing economic feasibility.
	Distance from shore ...	The amount of overburden and the propation of unwanted fire material will affect mining costs. Released fire material may cause undesirable turbidity and local habitat destruction.
	Shoreline energy regime.. - wave height - wave period - wave direction - tidal range - littoral current -slope	These factors will influence mining efficiency, accessibility to a resource and the dispersion of sediment plumes with possible environmental and aesthetic consequences. Coastal protection problems may arise from mining for construction material offshore.
Power stations	Water depth ...	A factor to consider in relation to design and placing of discharge structures and when sea access is required, e.g. for supply of fuel.
	Coastal water circulation... - Currents	Currents will influence the sediment transport regime and may lead to erosion or deposition around physical structures. These will be important if seawater cooling is employed.
	- Residence time	If coastal water exchange is restricted due to presence of bars, reefs, islands, etc. then efficiency of seawater cooling may be greatly reduced.
	- Ambient water quality	The quality of water for cooling purposes is particularly related to its content of suspended and dissolved solids.
	- Marine life	The presence of fouling or clogging organisms in the seawater intake may interfere with the flow of cooling water. Antifouling measures will increase costs.
Mariculture	Ambient water quality...	The quality of water will influence the mortality and growth rates of animals in hatcheries, impoundments, embayments and other areas used for rearing fish and shelfish.
	Shoreline energy regime .. - waves - longshore currents	Facilities such as rafts, sea cages, or other impoundments are very susceptible to damage from waves and strong currents.
	Coastal morphology	Protected waters are usually more suitable for mariculture than more open coastal landforms.
	Bottom characteristics	Sand and mud bottoms are more generally suitable for mariculture than those of hard materials.
Intensive agriculture (halophytes)	Tidal range	The possibility of an area being irrigated by natural fluctuation of water level is an asset.
	Local weather and climate ...	Coastal climate may particularly favour certain crops. With respect to halophytes, excessive rain may dilute salinity below acceptable levels (during monsoon for example) thus requiring provision for salt water irrigation.
	Shoreline energy regime.. - waves - longshore currents	The need to protect growing areas and their embankments from erosion by wave action or longshore currents is an important siting factor.

Table 2: Summary of preliminary programme of oceanographic observations

Observation	Instruments	Minimum platform	Facilities/ calibration required	Data type and format	Sampling programme	Sample spacing
wind	hand anenometer	any	calibration at intervals	analog, speed and direction	at every station	
salinity and temperature	S/T bridge, (switch gear)	small boat	calibration and checking by standard water samples	analog, S o/ooo T°C	at every station at 0-1, 5, 10, 15, 20, 30m--bottom; closer above and below S or T transitions	sections at right angles to coast or depth contours at distance of 500 to 5000 m
current	current cross, window shade, compass	small boat at anchor	floats, weights, marked lines, stop watch	analog, speed and direction	1-2m, 10, 20, 30m depth or above and below transitions in S, T; at some stations time series over 12-24 hours	in estuary or inlet at sides and centre; along coast at 5m depth out to 50 or 100m; at beach to determine rip current spacing and width of nearshore cell (see GESAMP1, annex XI, app. II)
current profile	direct reading instrument, e.g., Braystoke or pendulum meter	small boat at anchor	hand winch; calibration meter wheel, stop watch	analog speed and direction	as above	as above
water level	marked staff	on jetty or pier	hourly readings	relative water level	at stations across inlet or estuary; along coast line on either side of and at planned site for development, on scales from 1 to tens of kilometers	
waves	marked staff, flout	small boat and/or jetty	team of two	analog, wave-period, height, height, length	in surf zone to determine height; off coast at 10 to 50m depth contours for different winds	
turbidity	Secchi disc, white diameter	small boat	marked line	analog in depth (m) of disappearance	at every other station	note cloud conditions and elevation (high/low)
morphology	may need compass, sextant, etc. but generally necessary only to establish the basic morphological features such as capes, bays, inlets				generate map of coastal area and hinterland, if possible with geological information	
bathymetry	portable echo-sounder, position fixing equipment	small boat	marked line	analog profile	sections across and along inlet, estuary or lagoon; at right angles to and along open coast line; at positions also where water level is observed	
sediments	suitable weight with grease	small boat		gives information on grain size, type of sediments e.g. sand or mud	at selected locations, including special topographical features; also note slope of beach	

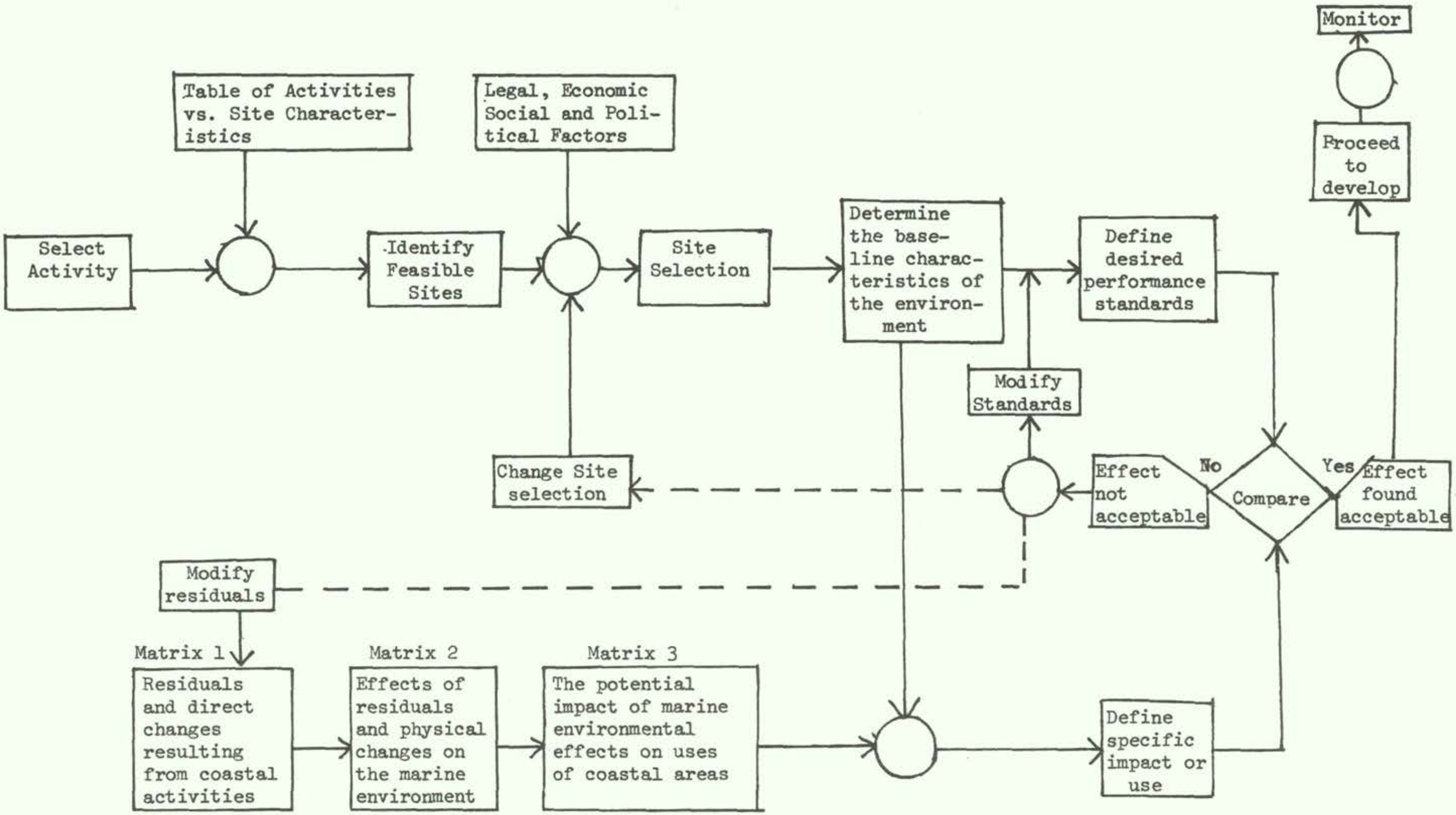
Note: In many coastal areas special dynamic features occur, such as fronts where temperature or salinity vary markedly, or other properties of the water, e.g., colour; these features can usually be located at a first survey and station positions should be adjusted so that they are included; a front can be topographically induced but it can also be due to the wind and can shift position; fronts are often areas of high biological activity and normally they will be known to local fishermen.

Table 3. Chemical observations to measure impact of coastal area development

Variable	Sampling Interval	Device	Derived information
Preliminary Determinations			
Salinity	0-1, 5, 10, 15, 20, 30, 50, 75, 100, 125, 150, 175, 200m in stratified waters. 0, 10, 20, 30, 50, 75, 100, 125, 150, 175, 200m in vertically-mixed waters.	Water sampling bottles, Salinometer (conductivity type) or Mohr titration wit with silver nitrate using Knudsen-type automatic pipette and burette	Salinity profiles Density (from salinity and temperature)
Dissolved oxygen	At discrete depths (as above) and near bottom	Water sampling bottles	Input of biodegradable matter. Flushing rate. Photosynthetic activity.
pH (hydrogen-ion concentration)	At discrete depths (as above) and near bottom	pH meter.	Acid or alkaline conditions from waste input. Decomposition of organic matter (low pH) and photosynthesis (high pH)
Alkalinity (total and carbonate)	At discrete depths, as above.	titration	Effects of alkaline and acidic wastes, biodegradable organic matter and freshwater input.
Nutrients (phosphate, silicate, nitrate and nitrite)	At discrete depths, as for salinity	Plastic or fibre-glass water sampling bottles, e.g. Van Dorn. Analysis with clorimeter, spectrophotometer or auto-analyzer	State of enrichment by nutrients from sewage and industrial wastes; potential for algal production; rate of flushing.
Chlorophyll-carotenoids	At discrete depths, as for salinity, but only to 50m depth	As above for sampling water. Filtration of samples through membrane filters.	Standing crop of phytoplankton; degree of enrichment from sewage and nutrients in industrial wastes
Additional Determinations			
Salinity	Continuous	STD (Salinity-Temperature-Depth system) or CTD (Conductivity-Temperature-Depth system)	Salinity and temperature (density) profiles. Water structure.
Dissolved oxygen	Continuous	Dissolved oxygen probe	Vertical profiles of dissolved oxygen
Metals	0-1, 5, 10, 20, 50, 100, 150, 200m and near bottom	Plastic or fibre glass water sampling bottles or vinyl-coated metallic sampling bottles. Atomic absorption spectrophotometer for analysis	Input of metals from sewage and industrial wastes; mobilization of metals from sediments; or without man-made source, natural concentration of metals
Persisten organic as above chemicals (DDT, PCBs and other halogenated organics)	Stainless steel or nickel-plated bottles. Gas chromatograph or coupled gas chromatograph/mass spectrometer for analysis	Stainless steel or nickel-plated bottles. Gas chromatograph or coupled gas chromatograph/mass spectrometer for analysis	Inputs from industrial wastes, agricultural runoff, streams and atmosphere

I L L U S T R A T I O N S

FIGURE 1. A SUMMARY OF THE STEPS TO BE TAKEN IN REACHING A DECISION TO SITE A PARTICULAR DEVELOPMENT ACTIVITY IN A COASTAL AREA



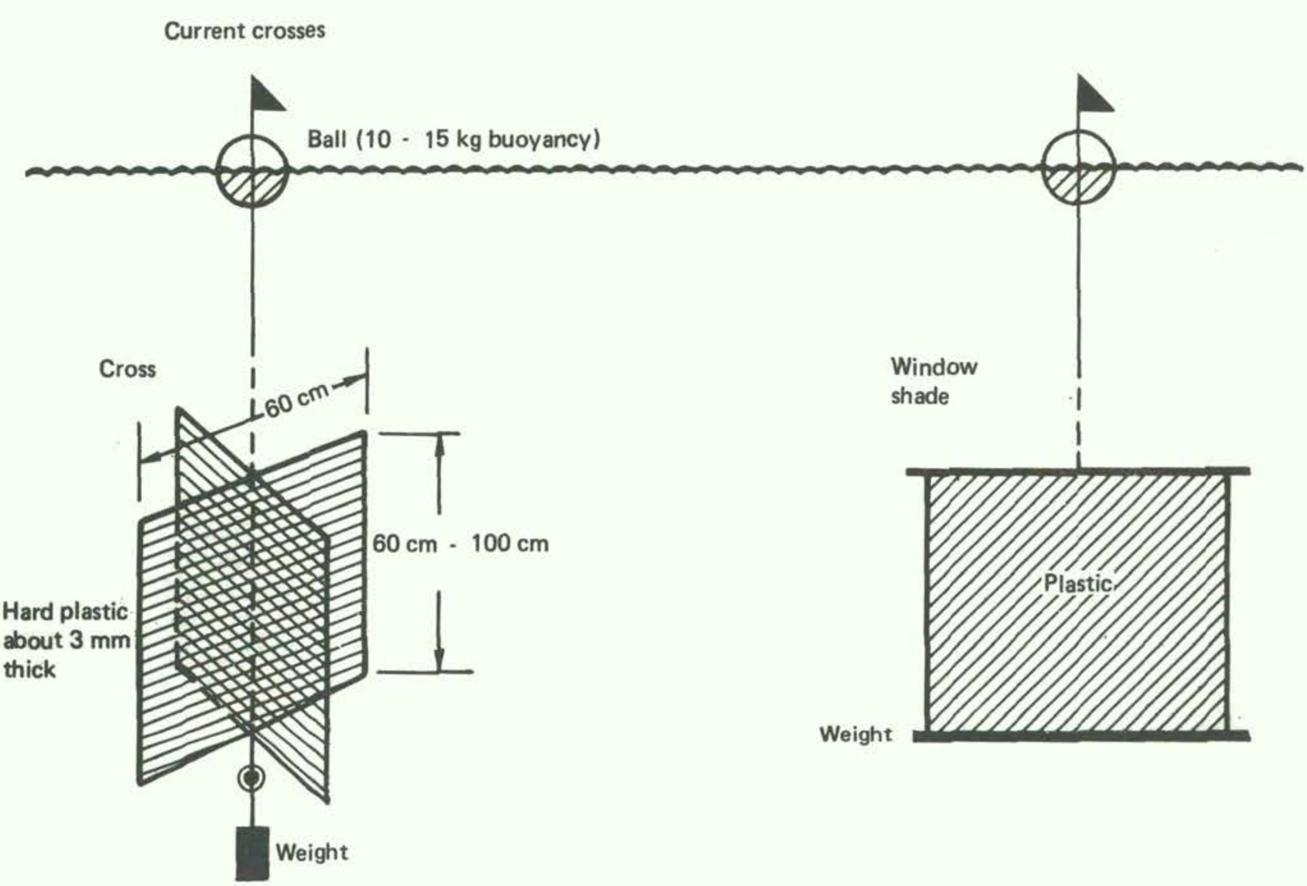
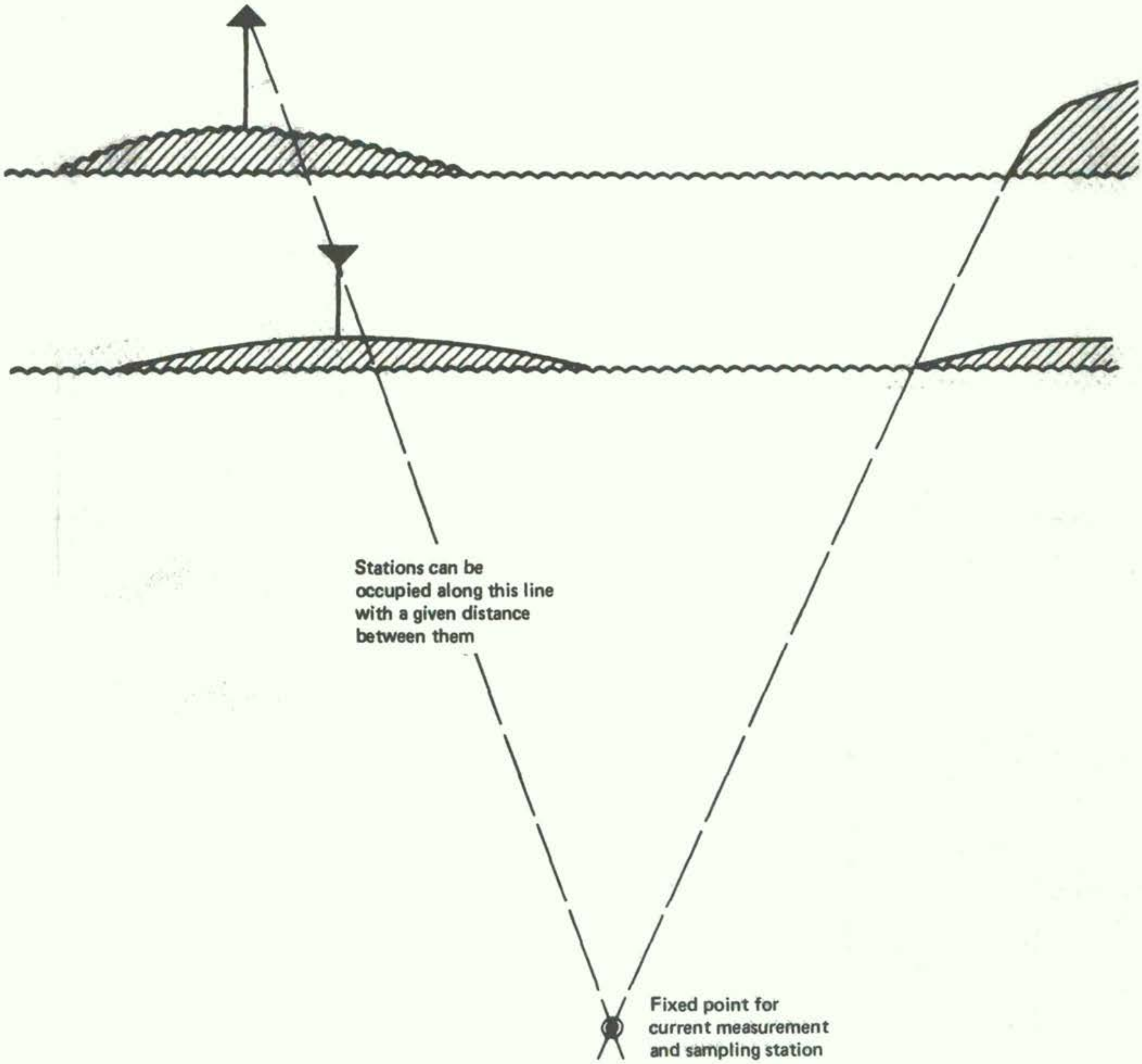

Current crosses
Ball (10 - 15 kg buoyancy)
Cross
60 cm
60 cm - 100 cm
Hard plastic
about 3 mm
thick
Weight
Window
shade
Plastic
Weight

FIGURE 2



Navigation illustration

FIGURE 3

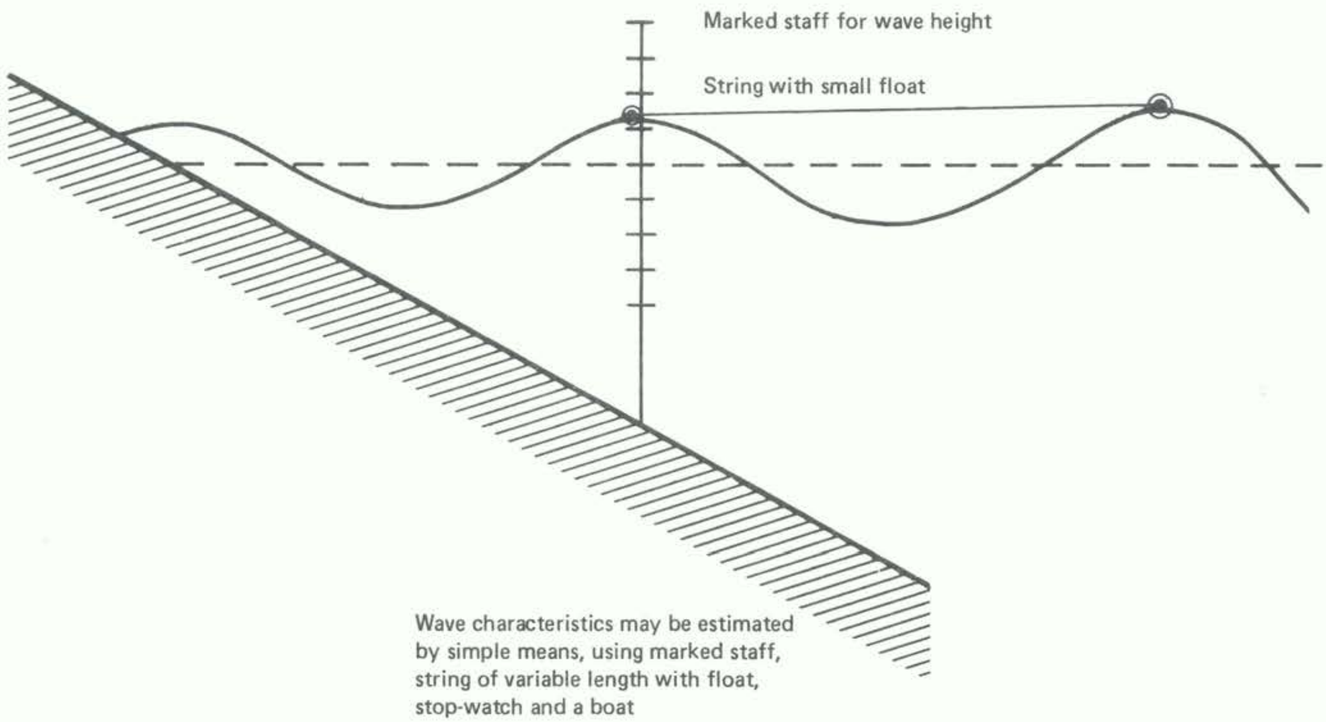

Marked staff for wave height
String with small float
Wave characteristics may be estimated by simple means, using marked staff, string of variable length with float, stop-watch and a boat

FIGURE 4

Water level observations

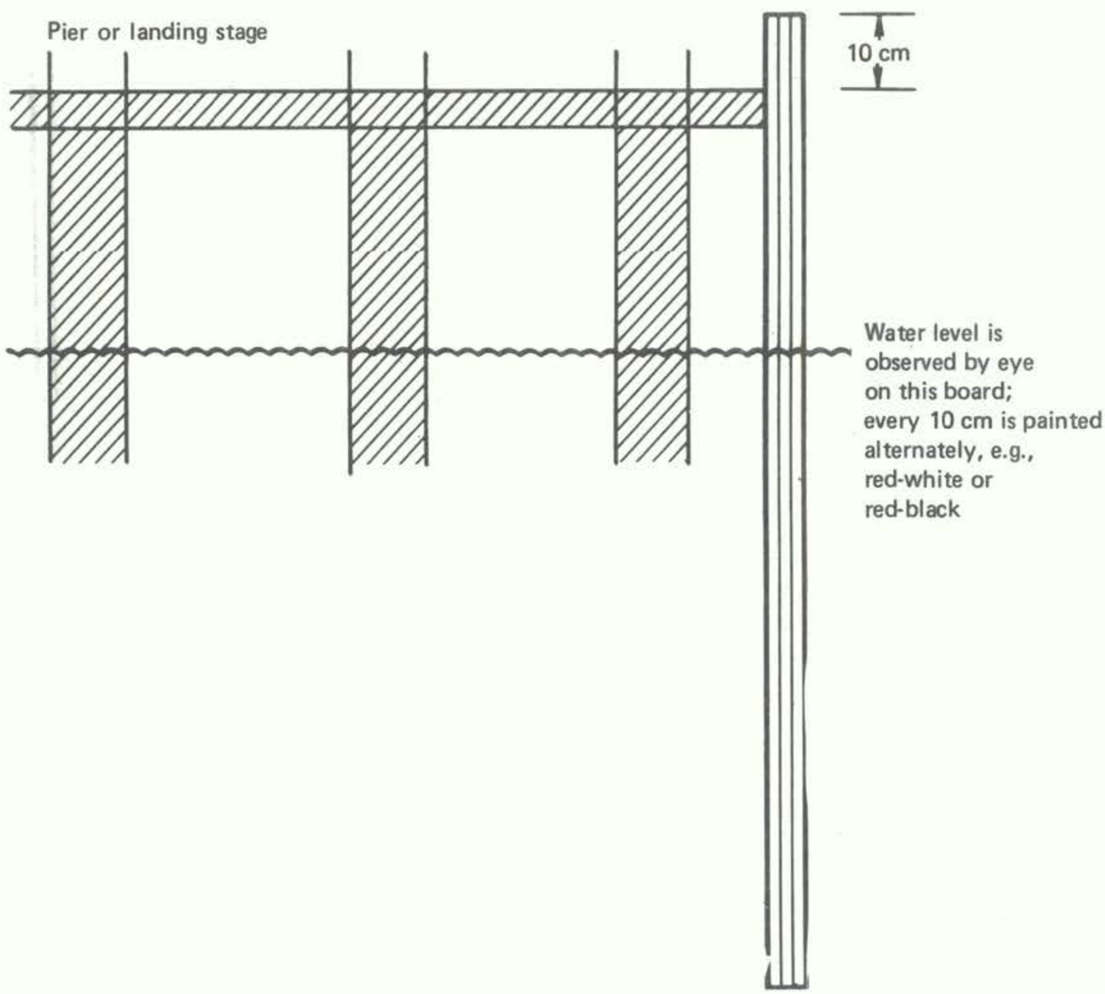
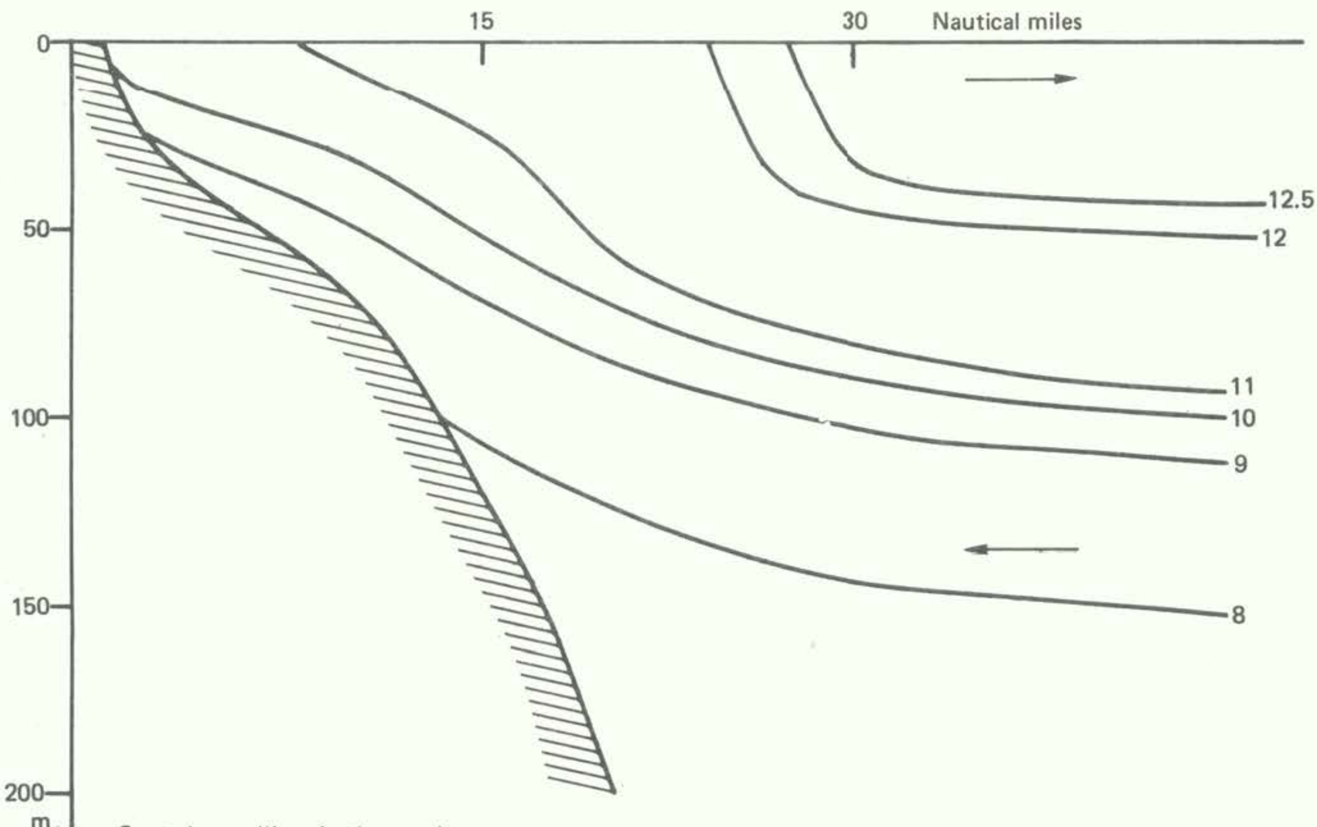


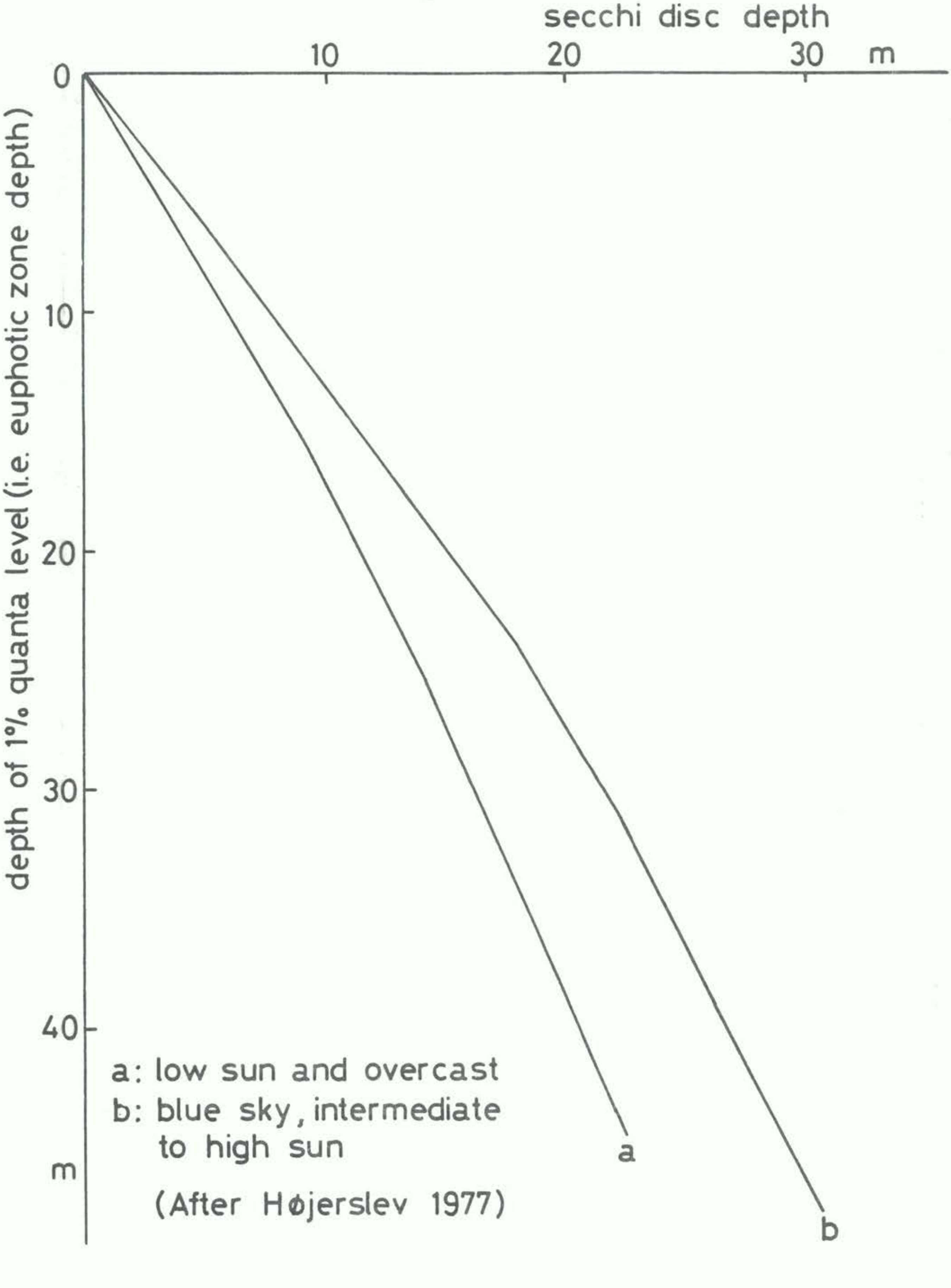
FIGURE 5



Coastal upwelling: isotherms slope upwards towards the shore from depths of 150 to 200 m, surface current offshore, subsurface current onshore. The upwelling is confined to narrow coastal zone

FIGURE 6

FIGURE 7


secchi disc depth
10
20
30
m
0
10
20
30
40
m
depth of 1% quanta level (i.e. euphotic zone depth)
a
b
a: low sun and overcast
b: blue sky, intermediate
to high sun
(After Højerslev 1977)

WASTES AND DIRECT CHANGES IN PHYSICAL CONDITIONS RESULTING FROM THE COASTAL ACTIVITIES / COASTAL ACTIVITY	SEWAGE	URBAN RUNOFF	GARBAGE	INDUSTRIAL WASTE WATERS	COOLING WATERS	ORGANIC SOLID WASTES	INORGANIC SOLID WASTES	SLUDGES	DREDGE SPOILS	DUSTS	FLOATING SOLID WASTES	SCUMS	OIL & OILY WASTES	PESTICIDES	ATMOSPHERIC CONTAMINANTS	ODOURS	NOISE	WATER CIRCULATION	SHORELINE PROFILE	WAVE CONDITIONS	BEACH CONDITIONS	SEABOTTOM CONDITIONS	SEDIMENT TRANSPORT
URBAN DEVELOPMENT	X	X	X				X		(X)		X	X	X	(X)	X	X	X		X		X		(X)
TOURISM AND RECREATION	X		X				X		(X)		X		X	(X)			X		X		X		(X)
PORTS AND HARBOURS	X		X				X		X		X		X				X	X	X	X	X	X	X
OIL TERMINAL WITH REFINERY	(X)		X	X	X		X	X	X			X	X		X	X	X		X		X	(X)	(X)
PAPER AND PULP MILL				X		X	X					X		(X)	X	X	(X)	X			X	X	
METALLURGICAL PLANT				X			X	X		X		X			X	X	X				X	(X)	
FISH PROCESSING				X		X					(X)	(X)				X	(X)				(X)		
MINING FOR CONSTRUCTION MATERIALS				X					X	X								(X)	X[1]		X	X	X
POWER STATIONS					X		X[2]			(X)					X			X			(X)	(X)	(X)
MARICULTURE																(X)					(X)	(X)	
INTENSIVE AGRICULTURE[a]						X		X				X											
CONSTRUCTION PHASE			X				X		X				X		X		X	X	X		X	(X)	(X)

MATRIX NO. 1

Wastes and direct changes in physical conditions resulting from coastal area developments

Notes

a. In immediate coastal zone, e.g., rice paddies, sugarcane, halophytes, stock farming, horticulture
1. If carried out on beach or in shallow coastal water
2. If using solid fuel, e.g., coal

(This matrix relates the selected coastal area activities in the column on the left to the wastes they produce and to direct changes in the physical environment resulting from these activities.)

EFFECTS / WASTES AND PHYSICAL CHANGES RESULTING FROM COASTAL ACTIVITIES (MATRIX 1)	SALINITY	TURBIDITY	COLOUR	TEMPERATURE	pH	DISSOLVED OXYGEN	BOD	NUTRIENTS	METALS	OTHER DISSOLVED SUBSTANCES	MICRO-ORGANISMS	FAUNA & FLORA	PRIMARY PRODUC-TIVITY	EROSION	DEPOSITION & ACCRETION	AESTHETIC VALUE
SEWAGE	X	X	X	(X)	(X)[1]	X	X	X	X	X	X	X	X		X	X
URBAN RUNOFF	X	X	X	(X)		(X)	(X)	(X)	X	X			(X)		X	
GARBAGE		X				X	X	(X)		(X)		(X)			X	X
INDUSTRIAL WASTE WATERS	X	X	X	(X)	(X)[1]	X	X	X	X	X		X	X		X	X
COOLING WATERS	X[2]			X		(X)			(X)	(X)[3]						
ORGANIC SOLID WASTES		X				X	X	X		X	X	X	X		X	X
INORGANIC SOLID WASTES		X							X			X			X	X
SLUDGES		X	X			X	X	(X)	X	(X)	X	X	(X)		X	(X)
DREDGE SPOILS		X	X			X	X	X	X	X		X	(X)		X	(X)
DUSTS		(X)	(X)						X			(X)	(X)		(X)	X
FLOATING SOLID WASTES										(X)		(X)				X
SCUMS			X						(X)	(X)		(X)	(X)			X
OIL & OILY WASTES		(X)	X			(X)	X		(X)	X	(X)	X				X
PESTICIDES							-			(X)		X				
ATMOSPHERIC CONTAMINANTS									X	X		(X)				X
ODOURS										(X)						X
NOISE												(X)				X
WATER CIRCULATION	X	X		X		X		X				X	X	X	X	
SHORELINE PROFILE		(X)		(X)[4]								X		X	X	X
WAVE CONDITIONS		X				X						X		X	X	X
BEACH CONDITIONS		X		(X)[4]								X		X	X	X
SEABOTTOM CONDITIONS		X				(X)		(X)	(X)			X	(X)	X	X	X
SEDIMENT TRANSPORT		X				(X)		(X)	X			X			X	X

MATRIX NO. 2

Effects of wastes and physical changes on the marine environment

Notes

1. In estuaries and semi-enclosed conditions
2. If freshwater is used for cooling
3. Substances introduced to combat fouling, corrosion, etc.
4. Close inshore

(This matrix relates the wastes and physical changes resulting from the selected coastal activities of matrix 1 to the resulting changes in marine environmental factors listed as effects.)

USES OF COASTAL AREA / MARINE ENVIRONMENTAL EFFECTS RESULTING FROM WASTES AND PHYSICAL CHANGES (MATRIX 2)	URBAN DEVELOPMENT	TOURISM & RECREATION	PORTS & HARBOURS	OIL TERMINAL & REFINERY	PAPER & PULP MILL	METALLURGICAL PLANT	FISH PROCESSING	MINING FOR CONSTRUCTION MATERIALS	POWER STATIONS	INTENSIVE AGRICULTURE	COMMERCIAL FISHING	MARICULTURE	NAVIGATION	DESALINATION	SEA-SALT PRODUCTION (SOLAR)
SALINITY			X						X	(X)[1]	X	X		X	X
TURBIDITY		X							X		X	X		X	X
COLOUR		X													(X)
TEMPERATURE		X	X						X		X	X		X	
pH										(X)[1]		(X)			
DISSOLVED OXYGEN											X	X			
BOD		X									X	X'		X	X
NUTRIENTS		X								X[1]	X	X		X	(X)
METALS		(X)					X			X[1]	X	X		X	X
OTHER DISSOLVED SUBSTANCES							X			X[1]	(X)	X		X	X
MICRO-ORGANISMS	X[2]	X[2]					X			X[1]	X	X		X	X
FAUNA & FLORA	(X)	X	X						X		X	X	X	X	X
PRIMARY PRODUCTIVITY		X									X	X		X	X
EROSION	X	X	X		X			X			X	X	X		
DEPOSITION ACCRETION		X	X		X			X			X	X	X		
AESTHETIC VALUE	X	X													

MATRIX No. 3 The potential impact of marine environmental effects on selected uses of a coastal area

Notes

1. Growth of halophytes
2. If sewage organisms are present in significant quantities

(The environmental factors in the column at the left have been changed by the wastes and physical changes resulting from the selected coastal activities (matrix 1). The impact of these changes on other uses are expressed by the entries in the matrix.)

COASTAL ACTIVITY	WATER CIRCULATION	OIL & OILY WASTES	DREDGE SPOILS	INORGANIC SOLID WASTES	INDUSTRIAL WASTE WATERS	SEWAGE
URBAN DEVELOPMENT		X	(X)	X		X
TOURISM & RECREATION		X	(X)	X		X
PORTS & HARBOURS	X	X	X	X		X
OIL TERMINAL & REFINERY		X	X	X	X	(X)
MINING FOR CONSTRUCTION MATERIALS	(X)		X		X	
POWER STATION	X			X[1]		

WASTES AND PHYSICAL CHANGES

EFFECTS	WATER CIRCULATION	OIL & OILY WASTES	DREDGE SPOILS	INORGANIC SOLID WASTES	INDUSTRIAL WASTE WATERS	SEWAGE	DESALINATION	HORTICULTURE	COMMERCIAL FISHERIES	POWER STATIONS	PORTS & HARBOURS	TOURISM & RECREATION
TURBIDITY	X	(X)	X	X	X	X	X	X	X	X		X
TEMPERATURE	X				(X)	(X)	X	X	X	X		X
METALS		(X)	X	X	X	X	X	X	X			(X)
FAUNA & FLORA	X	X	X	X	X	X	X	X	X	X	X	X
EROSION	X							X	X		X	X
AESTHETIC VALUE		X	(X)	X	X	X						X

OTHER USES OF COASTAL AREA

Matrix overview

The "other uses" shown are selected as examples

Notes

1. If using solid fuel

(This matrix overview selectively portrays the relation of the three matrices: <u>Coastal Activities</u> produce <u>Wastes and Physical Changes</u> causing <u>Marine Environmental Effects</u> affecting <u>other uses of the coastal area</u>.)

TECHNICAL APPENDIX A - 1

Treatment of Oceanographic Data

Observation	Calculation and information derived
Salinity, Temperature	Using density ρ, calculate $\sigma_t = (\rho - 1) \cdot 10^3$ from nomograms (e.g., the Kalle type). plot the fields of S, T and σ_t for each profile and along the sections; calculate the stratification parameter $N^2 = \frac{g}{\rho} \frac{\Delta \rho}{\Delta z} = \frac{g}{\rho} \frac{\Delta \sigma_t \cdot 10^{-3}}{\Delta z}$ where the stability seems to be marked (z = depth, g = acceleration and gravity). In this way information is obtained on the circulation by S, T differences horizontally and from the slope of the σ_t lines, and on the stratification and its variation in time and space.
Currents	Plotting speed and direction as function of time gives typical periods of oscillation such as tides, inertial. Plotting distribution of current vector horizontally (provided the observations are fairly synoptical) should give general agreement with the picture obtained from the S, T and σ_t plots in the different sections. Vertical current profiles give changes in direction and speed between layers and the mean vertical shear can be calculated, using an average profile, for the same vertical interval as N^2; combined with N^2 the shear dq/dz gives the Richardson number Ri which is directly related to the mixing conditions, so that for $Ri < 0.2$ well-mixed conditions prevail, $Ri > 1$ generally strongly stratified and often bad dispersion conditions exist, $0.2 < Ri < 1$ partially mixed, weakly stratified are indicated. $Ri = N^2/(dq/dz)^2$, q = horizontal current vector for the surface layer. Down to the first density layering, the vertical mixing can be related to the wind W_{10}, the shear and the stratification. The observed surface current, 0-1m depth, can be compared with wind speed and direction - in some cases the current will be proportional to the wind strengths.

APPENDIX A - 2

Water level Plotting observed relative levels vs. time gives periods of oscillation which in general should agree with information obtained from current data. By comparison with wind speed and direction any coupling can be seen. Prepare separate calculations for alongshore and offshore-onshore wind conditions.

Waves In surf zone, height of surf H_6, width of nearshore circulation cell B_b and rip current spacing L_b give estimate of dispersion volume $V \approx H_b L_b B_b$, which yields an estimate of nearshore concentration of contaminant released there (see GESAMP Reports and Studies No. 1, Annex IX, Appendix II, 1975). Relative wave height H/d (d = depth), and the parameter HL^2/d^3 (L = wave length) are informative in relation to erosion and sand transport.

Light penetration (Secchi disc) Observed depth of disappearance (D) and attenuation coefficient (c) have been found to be related through the semi-empirical relation $D.c = 6$, which gives a possibility to obtain c as a measure of the optical water quality. The time variation of c, depending upon the conditions (e.g., runoff, wind, waves), gives an indication of the influence of the various factors; and 1% quanta irradiance levels can be obtained from D using Tables 2 and 3 from Höjerslev 1977 (see Figure 7). Thus the depth of the euphotic zone and its time variation can be obtained.