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RESEARCH PRIORITIES FOR COASTAL AND OCEAN ENGINEERING IN AUSTRALIA

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Prepared by the

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EXECUTIVE SUMMARY

Australia's coasts and neighbouring oceans provide the most challenging regions for sustainable development in the country. The pressure of population, the vulnerability of the ecosystems, and the range of physical conditions mean that sound management decisions cannot be taken without a proper understanding of the processes at work in the coastal and ocean zones - a fact recognised by Australian governments for decades. Coastal and ocean engineers are in a unique position to play a major role in the necessary research because of their training in both technical and management issues, and the National Committee on Coastal and Ocean Engineering aims to provide guidance to ensure that this research is conducted strategically and efficiently. It is in this role that we have prepared this document setting out the following priorities for research.

Marine climate change and its effect on the coastal zone

Predicting the potential for sea level rise, changing wind, wave and current climates, to influence storm surge levels, wave setup and runup, the hydraulics and ecology of estuaries and many other coastal processes.

Capacity of receiving waters/integrated studies

The establishment of regional models for studying the interaction of pollutant input and ecological response.

Impacts of dredging

Understanding the processes causing siltation (particularly for cohesive sediments), impacts of turbid plumes, disposal of dredged material and researching potential for winning building material from offshore.

Beach processes

Wave studies, surf zone hydraulics, longshore and across-shore sand transport, effects of coastal structures, sand bypassing, and erosion.

Public safety and coastal hazards

Identification and classification of coastal hazards, development of means of assessing risk, standardisation of risk analysis. Improvement of disaster management.

Coastal protection

The development of sound guidelines for setting design recurrence intervals.

Coastal structures

As for coastal protection, the establishment of guidelines for design recurrence intervals.

Remote sensing and emerging technologies

The assessment of the efficacy of satellite techniques and shore-based remote data techniques for measuring ocean currents and determining wave statistics, providing input for ocean models, dune vegetation mapping, bathymetric survey and early warning systems for port operations.

Reef processes

Research in the following areas: mooring design for reef pontoons, storm tide levels for reef-protected beaches and structures, reef-top current systems, waste treatment and disposal for tourist resorts and facilities, impacts of estuarine discharge.

Knowledge codification

The development of a national code of practice in coastal zone management, and the publication of coastal zone manuals covering data/information standards, processes, environmental considerations and coastal management practices.

Fundamental underlying processes

Fundamental research into winds, waves, tides, currents, sediments and their interaction.

Data

Development of indicators and a monitoring program for state-of-environment reporting, establishment of baseline monitoring of waves, water levels and currents at several key sites, development of data management systems for satellite data to enable operational environmental reporting, execution of a national mapping project using satellite and other data sources. The development of a coordinated system for coastal information management.

Education

The provision of support at all levels of government for national forums, post-graduate positions, graduate programs for coastal managers, school study material, standards for coastal engineering professionals, planning, legal and scientific services, and specific programs to improve public awareness.

1. PURPOSE

The Australian coastal zone is diverse in its geology, geomorphology, oceanology and ecology. The human demands on the coastal zone are likewise diverse - it is highly prized by Australians and international visitors for its physical beauty and precious environmental attributes; it attracts residential and recreational development; it forms the gateways for trade; it supports fishing industries; it holds mineral resources; and it is a convenient (but contentious) site for returning wastewater to the hydrological cycle.

This zone is impacted by physical forces which range from the benign to the catastrophic. These, in turn, impact on people, natural ecosystems and developments. Coastal and ocean engineering aims to reconcile the forces of nature with the human demands. In the past, emphasis has been placed on 'man controlling nature', but modern management methods involve more working in harmony with nature, aiming always for a sustainable environment.

These methods will only succeed with a comprehensive under-standing of natural coastal processes and what happens when human actions interrupt them. Appropriately directed and funded research is required to provide this knowledge.

This document has been prepared by the National Committee on Coastal and Ocean Engineering (NCCOE) of the Institution of Engineers Australia. It lists priority areas for research activity in coastal and ocean engineering.

We intend this document to be the point of reference for researchers in project selection and for funding bodies when deciding which projects to support. The document should also be useful for industries as a check for where research effort is to be applied. Their input is encouraged in formulating priorities in the next edition.

2. IMPORTANCE OF THE COASTAL ZONE AND SURROUNDING OCEAN

It is a truism that the coastal zone is dominant in Australia's economy. The reason is geographical. As Gourlay (1996) points out, two thirds of the Australian continent lies in the arid zone and hence it is not surprising that 86% (and increasing) of Australians live within its relatively well-watered coastal zone. In addition to the water supply issue, early transport was dominated by shipping and with the absence of reliable inland waterways, settlement grew up around coastal trade.

The coastal zone is also an environmental focus. It contains a wide range of climatic, geological, and oceanographic regions which house a very rich store of biological diversity. Australia's coast includes the world's largest coral reef, the third largest mangrove area and globally significant populations of endangered species. (DEST, 1995).

It is a basic lesson of modern history that pressures on the coastal zone grow and intensify with time. Reasons for this include increased prosperity (resulting in increased demand for leisure, recreation and tourism), greater trade, improved technology (greater demand to exploit the resources of the coastal zone) and greater intensity of upland usage (higher levels of pollutants).

The influence of human activities on the coast stretches inland at least as far as the catchment boundaries and offshore to the Exclusive Economic Zone - an area 40% larger than the Australian mainland (MSTWG, 1999).

Australian governments have increasingly expressed the importance of the coast and ocean regions in terms of policies (DITC, 1989, DEST, 1995; and EA, 1999) and it behoves the coastal and ocean engineering communities to play their part in ensuring sustainable development via well considered research programs.

3. THE ROLE OF COASTAL AND OCEAN ENGINEERING

The short term exigencies of economic development in the coast and surrounding oceans often conflict with the demands of a sustainable environment. It is the coastal or ocean engineer who is in the best position to reconcile these conflicts. Nelson (1982) expands on this theme:

"Australia is an island continent with some 35,000 km of coastline, which is large by any national standard. The margins stretch from latitudes of 11° S to 44° S and experience the complete range of sea conditions possible, except ice. (The tides) vary (in range) from almost zero to some of the largest in the world... The strongest swell possible impinges on our southern margins ....The northern coast-lines in latitudes less than 25 degrees experience the ravages of tropical cyclones with their associated devastating storm surges. Most of our population lives in coastal cities and towns and we depend on shipping for export of our primary mineral and secondary products and import of petroleum, specialised materials and manufactured goods. The coastal (and ocean) waters provide fishing grounds, recreation areas, sought after residential sites, and are exploited for undersea gas oil and minerals. Conflicts of interest are numerous. The need to assist in the resolution of these conflicts, and to solve the numerous problems associated with coastal development gave birth to a new species of engineer in the mid to late 1960's, the coastal engineer."

The National Committee of Coast and Ocean Engineering (NCCOE, 1991) specifies the activities of a coastal engineer:

"Coastal Engineering is that branch of civil engineering which deals with the investigation, design, construction and maintenance of coastal projects and the control and/or management of natural processes in the near-shore zone. The coastal engineer must ensure that projects in these regions assimilate to the influence of prevailing wind, waves, tides, currents and sediment movements and optimise the consequent adverse and beneficial effects."

4. THE NEED FOR RESEARCH

In Australia's relatively short history of coastal engineering, a considerable number of major coastal engineering projects have been undertaken, and significant coastal engineering innovations made (several are documented in Gourlay, 1996).

"Coastal management in several Australian states was largely pioneered by engineers who in most cases initially had great difficulty in convincing politicians that coastal structures such as groynes would not by themselves solve the problems of eroding beaches. It took some time for the community to accept that the best management of the coast involved prevention rather than cure of erosion. Successful Australian coastal engineering projects have made significant contributions to the nation's economy in providing ports and harbours for exporting bulk commodities, in restoring beaches in major coastal tourist regions and in improving the quality of the natural environment in estuarine and coastal waters. Both in research and in practice Australian coastal engineering has been innovative and has produced significant new developments. Some of these initiatives have been widely published; others, particularly those originating from some government and consulting offices are not widely known. In many cases Australian coastal engineers also have been the leaders in establishing multidisciplinary teams to address the impacts of infrastructure and development upon coastal and estuarine environments." (Gourlay, 1996)

It is notable that, in many cases, the generation of new knowledge and techniques has come directly from the undertaking of projects, and the search for effective engineering solutions for the circumstances confronting those projects (rather than the engineer merely implementing a solution that had previously been developed by scientific research).

Indeed, it is still the case today that (too often!) when a coastal project is conceived or proceeding, it is discovered that there is less appropriate knowledge available than is required to effectively implement the project, thus requiring hasty (and sub-optimal) belated research.

In many ways, coastal engineering is a young field. Many problems have become tractable only with the advent of modern instrumentation and high-speed computing. And yet there is much that remains to be solved. The overriding factor that continues to confound research in this area is the extreme variability in the environmental factors. This provides the challenge to the researcher while the demands on the coastal zone justify the expenditure of effort.

Research in the coastal zone cannot be divorced from research in the oceans. Policy set out in Australia's Marine Science and Technology Plan (MSTPWG, 1999) included under 'A Vision for Australia's Marine Science and Technology' has as a theme: "*Strong and vigorous marine science, technology and engineering, informing national marine policy and decision-making and contributing fully to knowledge, to skills development, and to the health and wealth of the nation."* The plan goes on to set amongst its goals: "... *a strategy for integrated and innovative science and technology, … a key to better understanding of the marine environment."* showing that the current Australian Government clearly sees the need for research in the ocean and coastal environment.

5. THE ROLE OF NCCOE IN SETTING RESEARCH PRIORITIES

The National Committee on Coastal and Ocean Engineering is a standing technical committee of the Civil College of the Institution of Engineers, Australia. Its role is to promote best practice engineering in coastal and ocean engineering.

Since its inception in 1971, the NCCOE has sought to improve the understanding and practice of coastal engineering in Australia. It has identified priority research areas, and advocated to the responsible authorities that they support research in those areas.

It has provided input to a Coastal Zone Enquiry (RAC, 1993) and convened a workshop on Coastal Zone Management Research Needs (NCCOE, 1994). An outcome of the workshop was a formalising of priorities for research (an update of which is provided here) and several broader conclusions and recommendations:

The workshop concluded that there were four major needs in relation to coastal zone management research:

a. the need for a framework and coordination;
a. the need for long term funding;
b. the need for specific high priority studies; and
c. the need for professional management.

Further, it recommended work in the following priority areas:

a. setting of national priorities for coastal zone management needs;
b. a code of practice for engineering in coastal zone management;
c. design standards and manuals;
d. impacts of dredging;
e. coastal zone management mechanisms;
f. coastal resource inventories;
g. data collection / state of the coastal environment;
h. capacity of receiving waters / integrated studies;
i. coastal hazard management;
j. coastal impacts of climate change;
k. training and communication; and
l. support for community coast care programs.

6. THE RESEARCH PRIORITIES

The setting of priorities is based on the CSIRO's formal Priority Setting Process which is designed to allow an organisation to assess the overall returns from research and development by systematically considering both the likely benefits or *attractiveness* as well as the *feasibility* of achieving technical progress for a number of defined "Areas of Research Opportunity" or ARO's. The quantification of *attractiveness* and *feasibility* is derived as follows:

Attractiveness is the product of:

Potential Benefits - the maximum returns possible from technological improvements etc; and

Ability to Capture Benefits - the ability to transfer technological knowledge into practice.

Feasibility is the product of:

R & D Potential - the technical potential of the relevant research area: and

R & D Capacity - Australia's capacity to realise the R & D potential in a timely way.

Research areas were identified and ranked in this way at the workshop on Coastal Zone Management Research Needs (NCCOE, 1994). The following details represent an update on these priorities taking into account a shift of emphasis over the last five years.

6.1 Marine Climate Change and its Effect on the Coastal Zone

In the past, for the purposes of designing and undertaking projects in the coastal zone, the environment has usually been regarded as statistically static. It is assumed that probability distributions for environmental factors such as wind speed, wave height and sea levels are unchanging with time. The proven rise in atmospheric carbon dioxide levels and the possibility of the earth being subject to the "greenhouse effect" has brought this basis of environmental design into question. Extrapolation of assumed probability distributions to times much longer than the data base are invalid in a changing climate environment unless specific account is taken of those changes.

In addition to the long term trend is the fact of inter-annual variability which is also often ignored.

There is an extensive list of primary variables affecting the coastal zone which are sensitive to climate changes, e.g. sea level rise, wind and wave climate, currents and water and air temperatures. These variables, either alone, or in combination, lead to a train of secondary effects which have direct impact on coastal engineering design and management, e.g.:

- wave setup and runup on beaches and seawalls,
- hydraulics of estuaries,
- deepwater sediment movement,
- foreshore stability,
- river and inlet entrance stability,
- seawater penetration,
- quality of coastal waters,
- groundwater levels,
- storm surge,
- beach response,
- sand transport,
- coastal flooding,
- forces on structures,
- marine ecosystems.

The impact of these changes on commercial and recreational facilities as well as the protection of life and property is potentially enormous, both in Australia and overseas, if greenhouse scenarios eventuate. Major research efforts are needed to ensure future coastal and ocean engineering projects are adequate to withstand these changes and still remain cost effective to the community. Initially, the highest priority needs to be given to the determination of existing trends and the development and/or refinement of scenarios for the key variables.

The 1991 NCCOE Report, "Guide-lines For Responding To The Effects Of Climatic Change In Coastal Engineering Design", listed research priorities based on the paucity of information available on the key and secondary variables detailed above. It was recommended that initially the highest priority should be given to the determination of existing trends and the development and/or refinement of scenarios for the key variables. The priorities are given in the following table:

Climate Change Priorities		
Priority 1	Wind Climate Wave Climate Rainfall	regional trends and scenarios regional trends and scenarios regional trends and scenarios
Priority 2	Sea Level Rise Ocean Currents/ Temperatures	regional scenarios regional trends and scenarios
Priority 3	Air Temperatures	scenarios

While some work has been done in these areas since that time, these priorities remain valid.

A process of particular interest for sea level and wave climate change scenarios is cross-shore sediment transport.

6.2 Capacity of Receiving Waters/Integrated Studies

The understanding of coastal ecosystems requires an approach that considers the entire system.

It is strongly recommended that comprehensive physical/ecological studies of entire regional coastal systems be undertaken to enable impacts to be understood and predicted. For regional systems which are already substantially developed, a key concern is the capacity of receiving waters to accept present and future inputs from agricultural, industrial and urban runoff, as well as wastewater. Addressing this using a systemic approach rather than on a case by case basis avoids the effects of the tyranny of small decisions, and can aid the overall optimisation of input management. For regional systems which are not currently the subject of major development and inputs, integrated studies would enable the assessment of the overall system behaviour prior to key decisions regarding the location and type of development, leading to greater opportunities to locate and design such development to minimise impacts.

6.3 Impacts of Dredging

Australia's ports are vital gateways for exports and imports; their ongoing efficient operation requires significant dredging for development and maintenance purposes. Many of these ports are in the vicinity of valued environmental assets (including the World Heritage Great Barrier Reef), fishing grounds and/or highly developed areas with high levels of human use of waterways and beaches. Dredging must be carried out in an efficient manner compatible with environmental considerations. Australia also has international obligations under the London Dumping Convention (UN, 1972).

Siltation and maintenance dredging are major considerations in the planning and design of ports and harbours in sediment-active coastal areas, and can significantly affect the economic viability of such facilities. Safe navigation may be prejudiced in harbour entrance channels susceptible to extensive or unpredictable siltation. Many major ports, particularly in northern Australia, are susceptible to massive siltation during single short-term cyclone events. This may result in severe restrictions on shipping until the access channels are cleared.

Cost effective and environmentally sound maintenance dredging re-quires a good understanding of both the sedimentation processes causing siltation and the most appropriate dredging equipment. It is essential to properly take into account the inherent differences in the siltation processes and maintenance dredging requirements of non-cohesive sands found in the higher wave energy open coast and adjacent estuary areas, and the fine silts typical of lower energy coastal and estuarine environments. Sands and silts behave differently, and harbour siltation problems need to be assessed in terms of the unique transport, deposition, and consolidation characteristics of the sediments involved.

Many of the problems related to port dredging are associated with the impacts of turbid plumes of fine silts and clay material both from dredge hopper overflow and from spoil deposition. The behaviour of this material and the impacts on sensitive ecological areas are presently not well understood.

High levels of development in the coastal zone in a number of other nations have resulted in the reduction of land and river sources of fill and construction materials, leading to an emphasis on marine sources for these materials. This trend has already reached Australia, and imposes significant constraints in several states. As well, sands for beach replenishment (whether to counter present problems, or to combat future sea level rise) mostly depend on dredging offshore sand resources. Beach replenishment is required in many areas for the maintenance of beaches; this requirement would increase dramatically with rising sea levels.

Present research in these areas is not coordinated, is usually of limited duration related to specific projects, and is often directed to policing criteria rather than improving under-standing of processes and impacts.

Models exist for a more comprehensive approach. The United States has implemented a national dredging research program coordinated by the Corps of Engineers and the USA Environmental Protection Authority (McNair, 1997).
Of particular importance is the definition of appropriate environ-mental management strategies for dredging (including defining and justifying appropriate environmental windows).

It is recommended that a national dredging research program be established to assess the impacts of dredging and placement of dredged sands and fine silts. The aim being to produce dredging processes which are more effective and have acceptable (and understood) environmental impacts, and which minimise duplication of expensive site-specific studies.

Understanding of the transport and deposition behaviour of sands is improving, but nevertheless requires ongoing research. However, of utmost priority is the need for greater knowledge of processes involving fine silts and clays. It is recommended that high priority be given to research particularly in the following areas:

a. The behaviour of cohesive silt/mud under influence of currents, waves, etc., under various weather conditions, including the physics of resuspension transport and deposition processes.
b. Dumping or disposal of dredged material at sea. Determination of the most efficient methods of dumping

including how silt moves between release and deposition on the bottom under various weather conditions.

c. Effects of dredging processes upon the marine environment and ecology and the control/minimisation of silt plumes during dredging operations.

6.4 Beach Processes

Australia's beaches and coastal areas are important resources for the tourism industry and as a recreational outlet for the community. They provide a unique focus to attract international visitors. Long term protection of our coastal environment is recognised as vital.

The coastal zone is utilised for a variety of purposes which are essential in other ways to Australia's industry and economy. These include ports and harbours, residential and resort development, extractive industries, provision of roads/bridges, etc. Careful planning, design and construction procedures are required to achieve sustainable development of these uses with protection of our coast.

Achieving sustainable development in the coastal zone requires a highly developed understanding of coastal processes which may be affected by works and impacts involved in our use of the coast. In particular, sediment movement by waves and currents and both the local and broad-scale effects of natural and man-induced changes on such movement must be better understood.

A high priority must be given to research in this field. A number of specific areas in which research should be directed include:

- wave studies (wave grouping, tropical cyclone waves, shoaling/refraction/diffraction of wave spectra),
- surf zone hydraulics including wave breaking and wave-generated current systems,
- longshore sand transport,
- beach profile development/ cross-shore sand movements,
- effects of coastal structures on sand transport patterns and coastline stability,
- sand bypassing at tidal inlets (natural and artificial),
- long and short term erosion processes affecting beaches and other areas of coastline.

6.5 Public Safety and Coastal Hazards

Coastal hazards constitute a serious threat to human life and health, developments in the coastal zone and the coastal environment itself. These coastal hazards include storm surge, coastal flooding and storm wave attack (which in tropical and sub tropical Australia is principally due to cyclones), and tsunamis. Historically, storm surge is amongst the largest killers of all natural disasters worldwide. In some locations geotechnical hazards arising from instability of coastal cliffs may pose threats to human life and structures. The increasing concentration of population and development in the coastal zone (in Australia, and in many other countries) means that vulnerability is increasing. It is often too late to effectively improve coastal safety after development has been committed to a site.

It other fields involving public safety and asset management (e.g. dam safety, airline safety), standard methods of risk assessment exist, and risk management is incorporated into design standards and legislation.

It is recommended that a national coastal hazards project be undertaken. This project should:

a. identify and classify coastal hazards and the risks arising from them;
b. develop means of assessing the vulnerability of coastal zone resources and assets to hazards, the consequences of the hazard, and the costs of damage; and
c. develop a standard approach to risk analysis in the coastal zone to lead to standard design risk criteria, and optimised management.

It is proposed that this project deals initially with physical hazards, and incorporates disaster management. The project would be capable of extension to include specific environmental risks (e.g. pollutant, effluent and oil spills). Another hazard type is the hazard to those enjoying or using the coastal zone as swimmers, surfers and anglers. The safety of these recreational users of the coastal zone warrants specific study related to user characteristics.

Improved design, accounting for coastal hazards, would improve public safety, and would lead to better design for risk, thus reducing the overall cost of damage from coastal hazards, which is usually borne by the community and government.

6.6 Coastal Protection

General methods for calculating erosion rates, setback and storm surge levels are given in the Shore Protection Manual (SPM, 1984) and other similar publications. However, a shortcoming of such guidelines is the absence of any advice on a choice for the design recurrence interval. In Western Australia the practice has been to use a 100 year recurrence interval for foreshore stability, flood levels and beach erosion. However there is no documented rationalisation for that choice. Some authorities have guidelines for design risk level and/or design conditions, but these are not comprehensive. The 1992 NCCOE Report “Australian States’ Coastal Flooding and Erosion Policies” summarised the variety of regulatory provisions existing at that time.

In a management and regulatory environment where it is increasingly common for local authority personnel (who may not be expert in coastal engineering) to have to authorise or accept designs for coastal protection structures (or non-structural measures), it is essential that specific guidelines be produced.

6.7 Coastal Structures

No comprehensive guidelines or codes exist for the design of coastal structures such as breakwaters. The Shore Protection Manual provides no guidelines on recurrence intervals to be used. Nor do a British Standard (BS 6439, 1991), or a recent PIANC publication (PIANC, 1992), provide guidance on specific design recurrence intervals, al-though tools are provided to determine risk and balance construction and maintenance costs. Verification of designs by physical scale modelling is also worthwhile for any reasonable sized project.

In Western Australia, the history of breakwater construction and performance has lead to a wide variety of recurrence intervals being used in the designs. In essence this reflects the trade-offs between available construction materials, and capital and maintenance costs.

It is certainly desirable to have a “Unified Code” for the design of various coastal engineering projects, that could be adopted for use in Australia and elsewhere. How-ever variations in requirements from State to State produce various adaptations. The approvals processes for major projects are such that conformance to a guideline or code is only a first step to approvals, and the uniqueness of all coastal projects makes prescribed design criteria and conditions difficult. A guide to what may work can be found in the NSW Government publications “Estuary Management Manual, Coastal Management Manual, and Subdivision Guidelines and Design Guidelines for Wharves and Jetties”. These publications vary from providing comprehensive typical layout details to general descriptions of management principles.

6.8 Remote Sensing and Emerging Technologies

The cost of gathering marine-based information is extremely expensive, logistically difficult and often prone to failure in this harsh environment. In recent years, the availability of, and access to, satellite-derived information has had a dramatic impact on many areas of science and engineering. The advantages of wide areal coverage, reasonable repetition and low relative cost have contributed to a substantial growth of both interest in, and application of, technology of this type. Other examples include shore based mi-crowave radar for the determination of local wave height and direction, HF radar (over-the-horizon) which can measure wave height and direction, wind direction and current speed and direction at ranges up to several hundred kilometres, and aerial-borne lasers capable of shallow water surveys. The implications of this technology are the vast increase in information available at low cost and the added potential of further insight into existing physical processes and knowledge.

One of the critical questions for all new technology is the degree of accuracy and reliability which can be attained relative to existing conventional/direct measurement systems. This is an area which needs research effort to marry the technical/theoretical perspective and the practical/engineering application so that the promise of this new technology can be fulfilled and generally made available to the engineering community.

Particular areas of immediate benefit include:

- ocean current climatology for dispersion of effluents,
- wave height climatology for the protection of structures,
- input to numerical ocean models for engineering design,
- dune vegetation mapping for beach stability,
- offshore bathymetry mapping for shipping,
- early warning systems for critical port operations.

In the particular case of satellite derived data there is also a need to ensure an adequate coverage of receiving stations is established in Australia, otherwise much potentially useful information will not be collected. If data are not immediately collected by groundstations in the vicinity they will be lost, and this would seriously delay the effectiveness of such technology in the short term.

6.9 Reef Processes

Australia's fringing reefs, particularly the coral reefs in the tropics and subtropics are potentially threatened by increasing sea temperatures, river discharge of silt and nutrients, oil spills and the pressures of the tourist industry. These valuable assets (much of which are world-heritage listed) are, because of their extent, unable to be wholly quarantined from human impact. These areas are extensively studied by marine scientists, but the coastal or ocean engineer can also contribute because of the engineering nature of many sources of impact. Examples of areas which would profit from research effort include:

- mooring design for reef pontoons,
- storm tide levels for reef-protected beaches and structures,
- reef-top current systems and associated flushing and sediment transport,
- waste treatment and disposal for tourist resorts,
- impacts of estuarine discharge.

6.10 Knowledge Codification

There are no official codes or standards for coastal or ocean engineering. A strong case can be put for filling this void. Reasons include the increasing demands for non-expert practitioners to make decisions, the increasing demand for “best practice” (and hence the implicit requirement to know what best practice may entail) and the tendency to increasing litigation.

Coastal zone managers, including those in local authorities, have expressed uncertainty regarding their management responsibilities and particular concern regarding their legal responsibilities for public health and safety and towards owners of assets in the coastal zone. Potential litigation arising from actions or inaction is seen as a serious threat to the organisations and to the decision-making individuals in those organisations.

These factors indicate that a Code of Practice for Engineering in CZM needs to be developed.

The Duty of Care which local authorities have in their CZM dealings would be fulfilled when those engineering dealings were carried out in accordance with the Code of Practice. The Code of Practice would enable local authority engineers whose duties and responsibilities are often diverse and onerous to operate with the backing of learned professional advice. Such a code may become a model for defining the responsibilities of others groups with responsibilities in the coastal zone.

Much current information about processes and practices is not widely known because it is not well explained, codified or disseminated.

It is recommended that the development of coastal management manuals and standards be continued, and provided to local coastal zone managers, practitioners, and the community. These manuals should include in general (details are given in various sections of these recommendations):

a. data/information standards;
b. processes;
c. environmental variables and their behaviour;
d. coastal management practices and standards

NCCOE has produced draft Coastal Engineering Guidelines which outline general principles and procedures for working with the Australian coast in an ecologically sustainable way (NCCOE, 1998). They also include technical supplements dealing with specific areas of coastal engineering practice. The final version of these guidelines should meet many of the needs of coastal zone managers as to when to seek coastal engineering advice.

6.11 Fundamental Underlying Processes

The priority areas listed above have been developed (and are described) from the point of view of application or implementation. Thus the fields of recommended priority areas consider the application first, then the contributing processes.

It is worth remembering that certain fundamental processes underlie most of these fields of activity. These processes are those related to winds, waves, tides, currents, sediments and their interaction. The complexity of these processes cannot be overstated. They include turbulence at scales from micro to macro, fluids of varying densities, chemical composition, aeration, and sediment concentration, mobile boundaries, sediments of varying sizes, densities and compositions, all interacting non-linearly and varying in time and space (at scales from small to large).

Fundamental research is required to understand these processes, and to provide means whereby they can be calculated and predicted.

6.12 Data

There is a lack of consistent, widespread, long-term data that will allow the assessment of the condition of the coastal environment, and the variability and changes due to natural and artificial causes. The role traditionally taken by government agencies in this area is under threat with the dismantling of many such agencies.

Short-term, project-specific data will rarely suffice given the wide variability in key environmental parameters. When impacts of developments must be predicted, the time frame available usually is not long enough to collect data over several seasons, and data collection over several years is usually impossible. Assessments of impacts must then be made using data collected over a short term at the site, plus whatever data may be available from other sources, aided by analyses, modelling and prediction. The result is that assessed impacts are generally not able to be determined with the same degree of reliability that would be possible if a longer quality data set were available. Thus effort and expense devoted to reducing impacts is unlikely to achieve the optimum outcome.

It is strongly recommended that a strategic national approach be taken to coastal data collection to improve our understanding of the state of the coastal environment, and the ability to predict impacts on the coastal environment. This should include:

a. development of appropriate indicators for state of the environment reporting (the State of the Environment National Environment Indicators Task Force may be a mechanism to produce coastal indicators);
b. development and funding of a monitoring program suitable for state of the environment reporting;
c. a coastal driving forces project to measure and define the key physical driving forces for the coastal environment. This would involve assessing the currents for the Australian coastal zone, and providing a mechanism for their prediction that could be used as the boundary condition inputs to site-specific analyses of projects; the project would involve data collection, analysis, research and modelling, and should be carried out as a national initiative. (For

tides, the National Tidal Facility at Flinders University provides such a role);

d. baseline monitoring of waves, water levels, and currents at sufficient key sites on a long-term basis to assess key driving forces, their long-term variability, and extreme events. An item needing particular attention is the analysis of global wind fields to calculate wave directions;
e. a strategic approach to satellite data acquisition to develop links so that satellite data will be available for key requirements including state of the environment reporting, currents, and waves, and key technologies to exploit satellite data be encouraged; and
f. a national mapping project from satellites and other data be developed so that regular coast-al resource data/maps can be obtained/produced as a national resource, with the capacity to obtain additional data for key events, including extreme events.

The publication “At What Price Data?” (NCCOE, 1993) provides a discussion of the value of data collection as an investment for responsible environmental management, for risk management, and for economic management, as well as a discussion of some of the benefits of data collection, and the costs of a lack of data.

Coastal zone data are held in a diversity of forms (eg data, research, investigation, impact assessment and management reports, and as raw or analysed data, or in photographic or graphical form, and may be in paper or digital form). There are few consistent general standards for the collection and storage of coastal resource information.

This means that information accessibility is often difficult, and the existence of relevant data may not be known, particularly between different organisations. Coordination between organisations should be improved.

It is recommended that coordinated system for coastal resource information be enhanced. This would include:

a. the development of standards for coastal data/information;
b. the development of standards for coastal information storage systems/databases;
c. the development of protocols and the coordination of these databases so that information will be stored and maintained in appropriate locations, with inventories available at several locations, and access gateways/contact points defined;
d. the Coastal Atlas of Environment Australia be further developed in coordination with Australian Oceanographic Data Centre's Blue Pages directory as a mechanism to summarise and index available data ;and
e. a system for accessing the information on the resource inventories be developed.

It is recommended that financial support be provided for the enhancement of existing resource inventories. It is recommended that it be a requirement of nationally funded coastal research, investigation and monitoring that the data and information be collected and analysed to defined and agreed standards, and that this data/information be promptly placed on the appropriate database, or at least that its existence be registered on the appropriate database.

6.13 Education

In the field of coastal management, education is an important process to develop the skills and the appropriate philosophy required in those who manage the coast. It is important that at the ground level, particularly coastal councils, that skilled professionals are employed in the field of coastal engineering, science and environmental management.

All levels of government need to appreciate and facilitate this through a range of mechanisms such as:

- support of national forums for coastal management,
- post-graduate studies to develop expertise,
- primary and secondary school coastal studies courses,
- establishment of standards for professionals providing coastal engineering,

- planning, legal, and scientific services (possibly through learned institutions),
- specific programs to improve public awareness of coastal management issues.

7. CONCLUSIONS AND RECOMMENDATIONS

The list of prioritised issues is long as is to be expected given the national importance of the coastal and ocean zones and given the range of environment on Australia's coasts. The list encompasses climate change, dredging, beach processes, public safety/coastal hazards, coastal protection, coastal structures, receiving water capacity, remote sensing, reefs, codes/manuals, fundamental processes, data, and education.

If there is a single theme running through the recommendations it is the need for national coordination. Because of their legislative responsibility it is the state agencies that have dominated the applied research and development of management strategies. However the principles are often applicable to any coast and the problems can sometimes transgress borders as exemplified by the Queensland/NSW experience of the Tweed River Entrance.

The specific recommendations as listed on the previous pages target a greater effort and more national coordination for research to understand the processes that dominate the coastal and ocean zones (climate change, beach processes, remote sensing and fundamental underlying processes. There are also recommendations regarding human impact (dredging, protection, structures, capacity of receiving waters, and reef processes); while some recommendations target management (public safety/coastal hazards, knowledge codification). The need to establish and maintain long term data systems is highlighted as is the need to address education at various levels.

The consequence of not supporting research in the prioritised areas is that Australia will fall behind other countries in its expertise in coastal and ocean engineering. A more immediate impact will be that improper decisions will be taken and the coastal amenity will be damaged if not destroyed.

The National Committee of Coastal and Ocean Engineering commends this report to the government agencies responsible for allocating research funds. The report is also intended to be of use to researchers as an aid to research topic choice. We welcome feedback from any interested parties especially prime stakeholders such as industry, environmental groups, and recreational users of the coasts.

8. REFERENCES

BS 6439, 1991, Part 7, "Guide to the Design and Construction of Breakwaters", British Standards.

DEST, 1995, “Living on the Coast - the Commonwealth Coastal Policy,” Department of Environment, Sport and Territories, Australia, 70p. ISBN 0 642 22772 1.

DITC, 1989, "Oceans of Wealth?", Report by Review Committee on Marine Industries, Science and Technology, Dept Industry, Technology and Commerce, Aust Gov. Pub. Service, Canberra, 188p, ISBN 0 644 096179.

EA, 1998, "Australia's Ocean Policy", Oceans Policy Marine Group, Environment Australia, 2 Vols, ISBN 0 642 54580 4 and ISBN 0 642 54592 8.

Gourlay, M.R., 1996, “History of Coastal Engineering in Australia”, in Kraus, N.C. (ed.) “History and Heritage of Coastal Engineering”, ASCE, New York., p 1-88, ISBN 0 7844 01969.

MSTPWG, 1999, "Australia's Marine Science and Technology Plan", Marine Science and Technology Plan Working Group, Dept of Industry Science and Resources, Australia, 146p, ISBN 0 642 72043 6.

McNair, C., 1997, "Dredging Operations and Environmental Research (DOER) Program", US Corps Engineers CERCular, http://bigfoot.wes.army.mil/c313.html

Nelson, R.C., 1982, “Coastal Engineering - An Overview,” Paper presented to the Civil/ Structural Branch, Inst. Eng. Aust., Canberra Division, 14 Sept., 1982.

NCCOE, 1991, “Guidelines for Responding to the Effects of Climatic Change in Coastal Engineering Design,” IEAust, Barton, ACT. ISBN 85825 564 2.

NCCOE, 1992, “Australian States' Coastal Flooding and Erosion Policies,” IEAust, Barton, ACT.

NCCOE, 1993, “At What Price Data?,” IEAust, Barton, ACT. ISBN 85825 596 0.

NCCOE, 1994, “Coastal Zone Management Research Needs,” Report on the Outcomes, Priority Setting Workshop for the Department of Environment, Sport, and Territories, 11-12 Oct. 1994, Sydney, NSW.

NCCOE, 1998, "Coastal Engineering Guidelines for working with the Australian coast in an ecologically sustainable way" IEAust/ Environment Australia, Barton ACT, ISBN 0 642 545472.

NSWG, 1990(1), "Coastal Management Manual", New South Wales Government, Sydney, ISBN 0 7305 7606 3.

NSWG, 1990(2), "Design Guidelines for Wharves and Jetties", New South Wales Department of Public Works, Sydney, ISBN 0 7305 5189 X.

NSWG, 1992(1), "Estuary Management Manual", New South Wales Government, Sydney, ISBN 0 7310 0933 9.

NSWG, 1992(2), "Canal Subdivisions: conditions and guidelines", New South Wales Department of Public Works, Sydney, ISBN 0 7305 7534 9.

PIANC, 1992, "Analysis of Rubble Mound Breakwaters", Supplement to PIANC Bulletin No. 78/79.

RAC, 1993, "Coastal Zone Enquiry Final Report", Resource Assessment Commission, Canberra, Australia, 116p, ISBN 0 644 29495 7.

SPM, 1984, "Shore Protection Manual", 4th ed., US Corps of Eng, Coastal Engineering Res Council, 1200p, 2 vols (being replaced by Coastal Engineering Manual http://bigfoot.wes.army.mil/)

UN, 1992, "Convention on the prevention of marine pollution by dumping of wastes and other matter" (London Dumping Convention) http://sedac.ciesin.org/pidb/texts/marine.pollution.dumping.of.wastes.1972.html