Australian Integrated Ocean Observing System (AusIOOS) Working Group Final Report

6 May 2005

Prepared By

OPSAG AusIOOS Working Group

Executive Summary

This report presents (1) the rationale for an Australian Integrated Ocean Observing System (AusIOOS), (2) the conceptual design of such a System, (3) options for governance, (4) approaches for evaluating the performance and benefit of the System, and (5) a proposed way forward, including immediate high priority actions. The report is based on the deliberations of a Working Group established by the Oceans Policy Science Advisory Group (OPSAG) to consider options and needs for Australian ocean observations, and to prepare a proposal for an Australian Integrated Ocean Observing System (AusIOOS).

The oceans around Australia drive seasonal and interannual changes in Australian climate, play a key role in national security and as a lifeline for transport and commerce, contain unique ecosystems making significant contributions to global biodiversity and attracting millions of tourists to our shores, provide marine living resources worth several billion dollars and petroleum products worth tens of billions of export dollars.

In the 21st century, Australia's ocean ecosystems and marine environments are being subjected to unprecedented stresses. These stresses include (1) increasing intensity of use for commercial, industrial and social purposes, (2) expanding exploitation of marine living resources and coastal habitats, (3) ongoing impacts on coastal marine systems of past unwise land use in Australia's catchments and (4) global climate change. The result is a rapid escalation in pressures on, and demands of, our marine environments and ecosystems, which can be expected to result in major, rapid change.

Pressures on the oceans are now such that sustainable use and sensible management must be based on accurate information, assessment and prediction, if human use and ocean ecosystems are to be sustained. To date, marine information needs have largely been addressed on a sectoral or institutional basis, resulting in observations that are limited in scope, and fragmented in time and space. While there is effective national coordination of observations in some areas such as met-ocean and tidal observations, other observations

are generally not well-coordinated at national and regional levels. This means that critical gaps in some areas are not addressed, while there is a risk of duplication in other areas.

As envisaged here, an AusIOOS would enable the integrated design and implementation of systems to acquire and deliver marine data and derived products to meet the priority needs of diverse user groups, including policy makers, government agencies, industries, scientists, educators and the community, in a reliable and timely manner. An integrated AusIOOS will deliver cost-effectiveness by serving multiple applications with individual products, providing multiple products from individual data streams, and maintaining multiple sensors and data streams on individual platforms.

Following the international precedent established by GOOS and GCOS, it is proposed to design AusIOOS around two linked components: a global / climate component and a coastal component. With international collaboration, the global /climate component will provide assessment and forecasting of ocean circulation, sea state, weather and climate and other marine issues that have a global dimension. The coastal component would address the effects of weather, climate and anthropogenic pressures on marine ecosystems, living resources and human commercial and recreational activity in the Australian EEZ. It would consist of a federation of regional coastal observing systems, developed and implemented as a partnership across federal, state (and local) agencies, industry, and universities, linked through a national backbone.

Data management and communication are key issues for AusIOOS delivery and a strong foundation is being created by initiatives already underway, such as the Australian Ocean Data Centre Joint Facility (AODCJF), and the Ocean Portal under development by the National Oceans Office (NOO).

AusIOOS will be a user-driven system, designed to deliver triple-bottom line benefits to Australia. The economic benefits will come from

- improved efficiency and sustainability of maritime industries,
- mitigation and better management of risk,

- improved design of ocean infrastructure, and
- improved climate forecasting to the benefit of a wide range of primary and secondary industries.

Preliminary assessments of likely benefits to Australian primary industry through improved climate forecasting alone indicate benefits of hundreds of millions of dollars. International assessments indicate that benefits flowing from targeted investment in ocean observing systems can generally be expected to exceed costs by at least an order of magnitude.

The AusIOOS will deliver social benefit in terms of increased security, through mitigation of risks arising from hazards for coastal communities and infrastructure, recreational and commercial activity, and through support of defence operations. It will also deliver social benefit through contributions to education, and to improved community awareness and understanding of the marine environment. It will deliver environmental benefit through improved management of coastal environments, ecosystems, living resources, and the human activities impinging on them.

The approach advocated for development and management of AusIOOS is analogous to that adopted for planning and management of other major national infrastructure requirements such as for critical national transport. It will need sound governance and organisational arrangements. This report identifies a set of principles that the AusIOOS planning and coordinating structure and process should satisfy. These principles address coordination across agencies at national and regional scales, stakeholder input and user benefit, the need for a staged and adaptive approach, and integration with related national and international initiatives.

AusIOOS will emerge from a combination of enhanced existing capability and the phased introduction of short-term (do now) and long-term (start now, but grow over time) new components and functionality. The Working Group recommends the following priority actions:

Recommendation 1. Establish a national AusIOOS office, to provide Secretariat support and coordination of national activities.

Recommendation 2. Establish a national AusIOOS advisory / steering committee.

Five tasks have been identified as high priorities to be addressed by a national AusIOOS advisory / steering committee, supported by the AusIOOS office, in its first year:

Task 1. Develop an implementation plan for the global (ocean basin/climate) component to meet Australia's contribution to the ocean climate observing system, including Argo, GODAE and IOGOOS components.

Task 2. Coordinate and prepare a combined ocean observing research infrastructure bid to NCRIS for both global and coastal (national) AusIOOS components from OPSAG agencies and AusIOOS partners.

Task 3. Develop an implementation plan for a national backbone to support regional coastal observing systems.

Task 4. Facilitate the early establishment of pilot regional coastal observing systems through e.g. a national workshop on coastal observing systems.

Task 5. Work with NOO to consider how identification of national and regional information needs and priorities for AusIOOS might be incorporated into the Regional Marine Planning process.

If adopted and completed, these recommendations and tasks would constitute a scoping phase for AusIOOS, leading to sustained implementation.

Purpose

This report presents (1) the rationale for an Australian Integrated Ocean Observing System (IOOS), (2) the conceptual design of such a System, (3) options for governance, (4) approaches for evaluating the performance and benefit of the System, and (5) a proposed way forward, including immediate high priority actions.

The report is based on the deliberations of a Working Group[1] established by the Oceans Policy Science Advisory Group (OPSAG), responding both to national perceptions of need, and international initiatives in this area, such as the Global Ocean Observing System, and the US Integrated Ocean Observing System. The Working Group was tasked by OPSAG to consider options and needs for Australian ocean observations, and to prepare a proposal for an Australian Integrated Ocean Observing System (AusIOOS).

1 The Need for Ocean Information

The oceans around Australia drive seasonal and interannual changes in Australian climate, play a key role in national security and as a lifeline for transport and commerce, contain unique ecosystems making significant contributions to global biodiversity and attracting millions of tourists to our shores, provide marine living resources worth several billion dollars and petroleum products worth tens of billions of export dollars. They play a vital role in Australian culture and recreational life, and attract internationally recognized scientific research to the benefit of Australia. Through its EEZ and submission for areas of extended continental shelf to the United Nations Commission on the Limits of the Continental Shelf (CLCS), Australia is taking on responsibility for an

---

[1] Membership: Simon Allen (CSIRO), Crispian Ashby (FRDC), Rick Bailey (BoM), Doug Cato (DSTO), Peter Doherty (AIMS), Trevor Gilbert (AMSA), John Middleton (UNSW), Phil O'Brien (Geosciences Australia), John Parslow (CSIRO), Chari Pattiaratchi (UWA), Martin Rutherford (RAN), Neville Smith (BoM), Sally Troy (DEH).

area of ocean and seabed occupying more than 1.5 times the land area of continental Australia.

1.1 Oceans of Change

In the 21st century, Australia's ocean ecosystems and marine environments are being subjected to unprecedented stresses. These stresses include (1) increasing intensity of use for commercial, industrial and social purposes, (2) expanding exploitation of marine living resources and coastal habitats, (3) ongoing impacts on coastal marine systems of past unwise land use in Australia's catchments and (4) changes in climate, ocean circulation and chemistry resulting from anthropogenic increases in greenhouse gases. The result is a rapid escalation in pressures on, and demands of, our marine environments and ecosystems, and increased risk of major, rapid change.

Oceans are often referred to as the "last frontier", and in the past have been subjected to "frontier management", under the assumption that the oceans are so vast, and human impacts so small, that ocean ecosystems are protected by remoteness and ignorance, and the challenge is one of discovery rather than management. However, the consistent global picture now emerging from a range of major reviews and assessments (eg Millenium Assessment, US Pew Commission) is one of over-exploited fisheries, loss of coral reefs and seagrass beds, and the potential for major changes in climate, ocean circulation and biological productivity. It is now clear that human use of and impacts on the oceans are so substantial that management must be based on accurate information, assessment and prediction, if human use and ocean ecosystems are to be sustained.

Natural Hazards

Worldwide, the 20th century has seen a rapid increase in human (urban) populations on the coast. This trend is continuing and accelerating, both in Australia and in the nations surrounding our adjacent ocean basins. As the recent tsunami has tragically underscored, this has greatly increased vulnerability to natural hazards, including cyclone and storm surge, and coastal flooding, as well as rarer events such as major tsunamis. Hazard forecasts, based in part on ocean signal detection and processing, play a critical role in any effective hazard response strategy. Accuracy, reliability and dependability are critical, as unnecessary false warnings can have major adverse economic and social impacts and degrade responsiveness.

Coastal Development

Rapid growth in coastal development and population results in increased pressure on coastal marine ecosystems through habitat loss, pollutants from outfalls and urban catchments, recreational and commercial harvesting, and the growth of marine tourism and aquaculture. These local pressures are exacerbated by changing catchment flows and loads resulting from broadscale changes in land and water use, and increasingly by changes in ocean circulation, temperature and chemistry resulting from climate variability and global climate change. Many local decisions on coastal development and resource use are still made in isolation, without adequate information or understanding of the regional and historical context, or the likely interactions among local, regional and global processes. We further lack the ability to adequately monitor the cumulative impact of these local decisions.

Offshore Industries and Defence

Maritime transport underpins Australia's export economy, while naval operations maintain Australia's security, protect our infrastructure and resources, and ensure Australia's territorial integrity. There is a rapidly increasing investment in offshore infrastructure for oil and gas, and potential for increasing investment for offshore aquaculture. In all these sectors, there are major economic and security benefits in improving the quality of information and forecasting of the ocean's state and its uses. Relevant time scales range from hours to days for operational purposes, to seasonal, annual and decadal periods for resource management and policy development and up to hundred year return periods for engineering design.

Risk Management

Crisis management, from search and rescue to marine emergency response, is an important issue for Australia. Data and products are used as needed to mitigate or alleviate the impacts of crises, as in oil spill response and search and rescue. Improved information on the frequency and intensity of extreme events can be used to better manage risk associated with operations in the marine environment and to enhance efficiency and effectiveness, as in the design and construction of coastal and offshore structures.

Fisheries

Australia shares high-value migratory fish stocks in the Pacific, Indian and Southern Ocean basins with other nations. Ecologically sustainable management of these stocks, and those located entirely within the Australian EEZ, is critically dependent on accurate and timely information about the size and composition of the stocks. There is increasing awareness of the need for additional information on fisheries bycatch, and ecological interactions with other ecosystem components. There is also increasing evidence that changes in climate and ocean circulation drive changes in marine ecosystems and in the distribution, availability and recruitment of fish stocks.

Weather and Climate

The ocean plays a major role in the global weather and climate system, on time scales from days to decades. Accurate and timely knowledge of the ocean state plays a critical role in weather and climate forecasting on all these scales. Interannual climate variations such as El Nino, arising from ocean-atmosphere interactions, drive multi-billion dollar variations in Australia's agricultural output. Improved ocean observations are expected to improve both accuracy and lead times for seasonal climate forecasts, with potential economic benefits of hundreds of millions of dollars *per annum*.

The planet is currently in the midst of an unprecedented climate experiment resulting from anthropogenic increases in atmospheric carbon dioxide and other greenhouse gases. Climate change models suggest this will not only increase global temperatures, and change the frequency and intensity of regional rainfall and extreme weather events, but may also change ocean circulation patterns. There is also growing concern among marine scientists about the potential for very large and significant direct impacts of changes in ocean pH and carbonate chemistry on iconic coral reefs, and also on a broad range of other marine organisms with carbonate shells or skeletons .

Climate change impacts are expected to play out over decades. There is already evidence of marine impacts of global warming, such as coral bleaching. Implementation of effective adaptation strategies may require long lead-times, such as changes to urban development planning in the coastal zone and protection of existing infrastructure. Early detection, assessment and prediction of change will be critical if we are to successfully anticipate and adapt. Reliable detection of climate change impacts on marine systems will be complicated by high levels of natural climate variability, and by interactions between climate forcing and the other drivers referred to above.

Managing Change

We can confidently predict that marine systems will undergo significant changes on a wide range of time and space scales, in response to the drivers and pressures outlined above. Through targeted scientific research, some of these responses may be understood and anticipated. Others will come as a surprise. Carefully designed, long-term, sustained observations will be essential if we are to use the oceans safely and sustainably in a rapidly changing world.

1.2 Informing oceans policy and management

The need for sustained utilization and responsible management of Australia's marine environment and resources is well recognized in Australian policy and legislation. Australia's world-leading Oceans Policy requires integrated, ecosystem-based, multiple-use management of marine industries and resources on a regional basis. Under Australia's Oceans Policy, regional marine plans provide a mechanism for ongoing, integrated decision-making regarding management of these uses. Successful implementation will depend critically on our ability to evaluate the performance of management strategies and the outcomes for ocean ecosystems and ocean-dependent communities and industries.

Many other legislative instruments at state and federal levels require informed ocean use and demonstration that uses are sustainable. The Australian Environment Protection and Biodiversity Conservation Act requires that all Commonwealth approved activities in Australia be managed in an ecologically sustainable manner. Australian federal and state legislation governing coastal development, land and water use, fisheries, aquaculture and tourism similarly requires environmentally responsible and informed decision-making. Observational data of many types are needed to be able to meet these demands.

The Meteorology Act in 1955 provides the explicit legal basis and the basic charter for the operation of the Australian Bureau of Meteorology, including for the reduction of the social and economic impacts of natural hazards, improved national security and safety of life, and contributions to the efficient and effective operations of industry. The Act explicitly charges the Bureau with gathering the observations required for monitoring which, for the present purposes, can be interpreted as the identification and prediction of ocean, weather and climate. Marine meteorological and oceanographic data are an important contribution to these public good services.

Across all of these sectors and issues, effective management and sustainable use depend on our ability to detect and predict change in marine environments and ecosystems across a wide range of time and space scales. We are just beginning to develop an appreciation of our information needs and of the consequences of poor or ill-informed decision-making. An objective assessment both of the national information needs, and of the national capability to meet these needs, is timely and necessary. Examples of recently identified information needs and gaps include:

- Need for ocean observations for climate change prediction, adaptation (AGO, DFAT/AusAID, IPCC, UNFCCC);

- Need for ocean observations to improve seasonal and interannual climate forecasting (Indian Ocean Climate Initiative, Land & Water Australia, Indian Ocean GOOS Panel, NRM)
- Need for observations to underpin regional marine planning (NOO);
- Observations for understanding and mitigating coral reef bleaching (OPSAG, GBRMPA);
- Need for coastal and ocean sea-level monitoring for navigation, commercial operations, recreational boating, and to improve tsunami response (Prime Minister, DFAT, AAPMA, Navy Hydrographer);
- Need for improved ocean forecasting in region of Indonesian throughflow to assist operation and planning of offshore industries (WAGOOS, Pacific-Indian Throughflow Project).
- Ocean observations to support ocean prediction systems needed for defence, air-sea rescue, and marine pollution response (Navy, AMSA, SOLAS)

Section 4 discusses the potential economic and other benefits that could be expected to flow if these needs are successfully addressed. Even preliminary analyses suggest economic benefits are likely to reach hundreds of millions of dollars, and to exceed costs by one to two orders of magnitude.

1.3 Status of Existing Ocean Observations in Australia

The disparate nature of Australian marine science and management has meant that marine information needs have largely been addressed on a sectoral or institutional basis, despite the fact that sectors and institutions largely have overlapping and intersecting information needs. Because any individual sector or institution finds it impossible to support a comprehensive, sustained observing system, the result has been observations that are often limited in scope, and fragmented in time and space. Lack of coordination across sectors and institutions can result in duplication of effort, while serious gaps are neglected. The lack of a coordinated framework for managing and delivering information has meant that much of the historical information which is acquired is lost, or not delivered in a timely way, or not analyzed in a way that maximizes benefit. In combination, these weaknesses and limitations in existing observing strategies and systems mean that the information needs of policy, management and operational use are not being met.

The Working Group has undertaken an initial survey of existing ocean observations across participating OPSAG agencies. A summary of the findings is provided in Appendix A, and a more detailed account can be found in Attachment 1. While not comprehensive, the survey did identify a number of strengths and weaknesses in the existing activities.

The survey identified a number of examples where coordinated multi-agency approaches to ocean observations have been adopted on a national or regional basis. Tidal and sea level observations, conducted throughout Australia and the SW Pacific by port authorities, state and federal agencies, are coordinated and integrated through the Permanent Committee for Tides & Mean Sea Level (PCTMSL) and the National Tidal Centre (NTC) within the Bureau of Meteorology. The CSIRO/BMRC Joint Australian Facility for Ocean Observing Systems (JAFOOS), helps maintain a valuable though limited set of upper ocean temperature and salinity observations in oceans around Australia, through autonomous profiling Argo floats and expendable bathythermographs (XBTs) deployed from merchant shipping. The Joint Bureau/CSIRO/RAN BLUElink Project, which is due for completion by the end of 2006, is developing a national state-of-the-art data assimilating ocean forecasting capability.

Geoscience Australia hosts the national Ozestuaries online database, developed through the National Land and Water Audit Estuaries Theme. This was a partnership project across GA, CSIRO, universities and state agencies, coordinated by the Coastal Zone CRC, to assemble a national assessment of the health of Australian estuaries. Although non-operational, it could serve as the basis for a regularly-updated national estuarine information system. At a regional scale, long-term monitoring of the Great Barrier Reef conducted by AIMS, GBRMPA, universities, and the Reef CRC, has provided information to support regional multiple-use management.

The recent Commonwealth Agency initiative to address lack of coordination in marine data management and delivery through the establishment of the AODC Joint Facility also provides a precedent for a broader IOOS initiative.

The above examples illustrate the benefits of national and regional coordination and partnership, and provide positive models for development of an expanded IOOS. In some cases, these coordinated programs still lack sufficient long-term resources to meet operational goals. The survey identified many other examples of observing activities which lack coordination at regional or national levels, and are fragmented in space and time. The opportunity for enhanced coordination would likely be even more evident if the survey had extended beyond Commonwealth agencies to include state and local government agencies and universities. The challenge is to strengthen and build on existing examples of national and regional coordination, and to extend this approach to other regions and classes of observations, including benthic and pelagic ecosystems, fisheries, coastal water quality, and waves and currents.

Australia is a large, sparsely settled continent, with an even larger marine territory. It lacks the economic resource per kilometre of coastline of the USA or Europe (but is better positioned than many developing nations). It is therefore vital to ensure that our marine observational infrastructure is used as cost-effectively as possible. Traditional ship-based observations, whilst essential for process studies helping to advance our understanding of the ocean, are expensive and intrinsically limited in spatial and temporal coverage. New technologies (satellite remote sensing, robotic in situ platforms and sensors) offer orders of magnitude increases in coverage and equivalent reductions in cost per observation. Oceanographic researchers have justifiably described the combination of these new observing technologies with powerful, data-assimilating models, exemplified by the BlueLink project, as constituting a revolution in our ability to assess and predict the many facets of ocean state. This revolution, and the benefits it promises, will not be achieved without an investment in the observing technology.

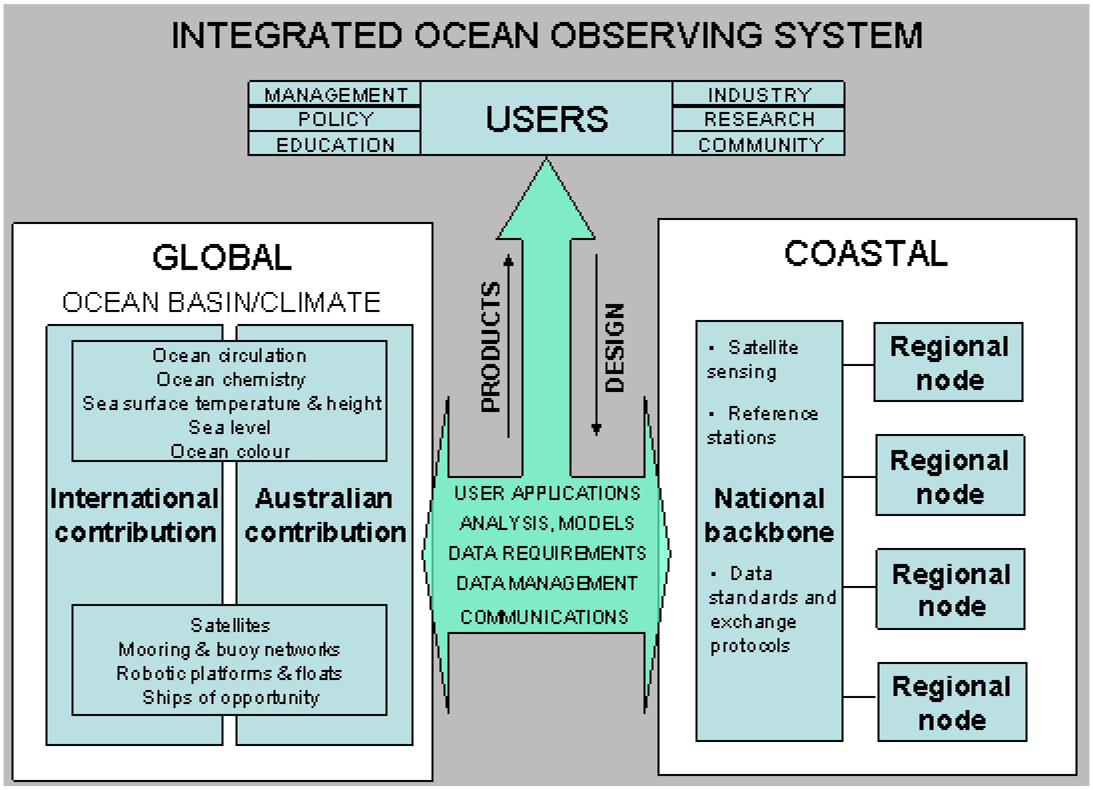
There is currently a convergence of the recognition of the societal importance of ocean information, the benefits of partnerships across sectors and institutions, and the development of the technology to make delivery of the necessary information both feasible and affordable. It is this convergence of need and opportunity which is driving the development of Integrated Ocean Observing Systems (IOOS) internationally and in Australia.

2 Meeting Information Needs – the IOOS vision

IOOS Vision

An IOOS is envisaged as a national and international system, which systematically acquires and delivers marine products to monitor and forecast the state of the ocean environment, to meet the needs of user groups, including policy makers, government agencies, industries, scientists, educators and the community. The system must be:

- End-to-end, incorporating subsystems for data acquisition, data communication and management, and data analysis, modelling and product generation.
- Responsive to user needs and able to deliver useful products in a reliable and timely manner.
- Deliver cost-effectiveness by serving multiple applications with individual products, providing multiple products from individual data streams, and maintaining multiple sensors and data streams on individual platforms.



One can think of meteorological agencies and services as a simple analogue of an IOOS. Weather forecasts are based on an extensive observational network, and assimilation of the resulting data into complex computer models. They are managed and provided through national organizations and international collaboration, subject to international exchange agreements, and deliver essential information to a wide variety of users through efficient and reliable distribution channels. One can imagine the inefficiency and lack of performance if each sector tried independently to produce its own weather forecasts. The observations and products required of an IOOS are more diverse, and the technical and institutional arrangements needed to deliver these products will be more complex. Nonetheless, the potential for gains in cost-effectiveness and performance through integration and coordination are immense.

International experience has found it useful to design an IOOS around two linked components: 1) global (ocean basin/climate) and 2) coastal. The ocean basin /climate component intrinsically depends on international collaboration, and is intended to support assessment and forecasting of ocean circulation, sea state, weather and climate, as well as addressing other marine issues that have a global dimension. The coastal component comprises a system of regional and national initiatives, addressing the effects of weather, climate and anthropogenic pressures on marine ecosystems, living resources and human commercial and recreational activity in the Australian EEZ. It must be developed and implemented as a partnership across federal, state (and local) agencies, industry, and universities. Both of these components need to link to national and regional systems for data management and integrated service delivery.

2.1 The Ocean Basin / Climate Component

Planning and design of the requirements for a global and basin scale observing system to detect and predict changes in the ocean-climate system are already well-advanced. Internationally, this has been led by communities involved in the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS). Australian scientists have been well-represented in this planning process, and are already actively involved in implementation and evaluation of the observing system and in pilot projects.

Key elements of the global strategy include:

a) ocean observing satellites for sea surface temperature, sea surface height (altimeter), surface winds (e.g., scatterometer), and ocean colour,
b) global observations of sea level,
c) long-term repeat surveys of the ocean circulation and carbon chemistry, and
d) fixed and automated *in situ* observations based on moorings and robotic platforms.

Critical elements currently being implemented include

a) the ship-of-opportunity program, to measure surface and subsurface ocean parameters, including temperature, salinity, pCO2, fluorescence,
b) the global array of drifting profiling floats (*Argo*) which provide high quality data on ocean structure in the upper two kilometers,

c) a global array of sea level stations,
d) arrays of fixed buoy networks and moorings mainly in the tropical ocean and at key locations of the ocean circulation, and
e) the Global Ocean Data Assimilation Experiment (GODAE), which is developing data-assimilating ocean circulation models assimilating data from satellites and in-situ platforms to provide high-quality nowcasts and forecasts of ocean state.

Australian scientists actively collaborate with the key space agencies and international groups involved in planning, gathering and using satellite data, and Australia maintains good access to satellite data sets as a result. Australian scientists are active participants in the *Argo* program, and in international planning and implementation of the other *in situ* networks. However, as a key developed nation at the intersection of three major, poorly sampled ocean basins (South Pacific, Indian and Southern Oceans), Australian scientists and operational agencies carry a heavy responsibility to contribute to planning, to deployment of *in situ* platforms and instruments, and to analysis and quality control of the resulting data. This responsibility is shared across a number of agencies, but support both for instruments and for staff to analyse the data is often *ad hoc* and inadequate. Despite successful efforts to attract investment by other nations in ocean basins near Australia, there remains a considerable risk that the information Australia needs will not be forthcoming or sustained, and that these basins will remain undersampled in global maps of observation networks. Moreover, the existing Australian contribution is largely based on short-term research funding: the commitment to convert this into a long-term sustained observing program is yet to be established.

In summary, planning and preliminary implementation of the global / climate component of the ocean observing system is well-advanced at international and, to some extent, national levels. The key challenges facing Australia are the development of a business case and work plan to complete the implementation, and the need for a commitment to sustain this activity beyond initial phase. Development of a business plan for implementation of this component should be a high priority for an Australian IOOS.

2.2 The Coastal Component

As described above, the coastal component of an IOOS is intended to meet a very wide range of user needs, involving a wide range of phenomena and time and space scales, in a complex biophysical and institutional domain. Designing the coastal component is consequently much more of a challenge and is less advanced internationally than the climate component. Nonetheless, there has been a very significant effort invested in the design of coastal ocean observing systems in the last 5 years, both through the GOOS coastal panel, and through planning processes in the USA and other nations. While we are just beginning to think about this in a systematic way in Australia, we are in a good position to build on the thought and effort invested internationally.

One of the key ideas adopted by US IOOS, which is eminently transferable to the Australian context, concerns the structure of the coastal component. US IOOS proposes that this be developed as a combination of a national "backbone", and a federation of regional observing systems. The national backbone would take responsibility for those activities which are most effectively carried out at national scale. Examples include satellite remote sensing, data standards and exchange protocols, links between the coastal and basin scale components, and a national network of reference sites. The proposal for a federation of regional observing systems recognizes that the users and stakeholders for coastal observations, the types of coastal ecosystems present, the observations and products required, and the institutional arrangements for coordination and implementation, will all vary from region to region and that efficiency and effectiveness will come from building regional alliances.

Within Australia, we can think of the Great Barrier Reef as providing a prototype for how a regional coastal observing system might function. The existence of the Great Barrier Reef Marine Park Authority has provided a formal mechanism for coordination and collaboration across federal, state and local government agencies, industries, and the research community (assisted recently by the Reef CRC). This has already led to the design and implementation of a regional ocean observing system which is arguably more integrated and comprehensive than elsewhere in Australia. This system is not yet complete, but building on what already exists, we could anticipate a system which provides the observations, products and applications shown in Table 1. Again, the reason to pursue an integrated regional system is that the various elements are mutually reinforcing, providing reduced cost and increased benefit.

While the exact composition and approach of the regional observing systems will vary, they will inevitably have many elements in common. To derive maximum benefit and cost-effectiveness, it will be important that we minimize unnecessary duplication of effort, maximize exchange of information and experience, and encourage adoption of common protocols, data management and analysis procedures across regions. Interoperability must be assured. This will be partly the role of the national backbone, but will also require strong communication and coordination across regions. Unlike the USA, Australia cannot tackle the comprehensive design and preliminary implementation of observing systems in many regions simultaneously. A staged implementation and testing of pilot regional observing systems around the continent will be necessary.

There has been considerable effort devoted by both the Coastal GOOS Panel and US IOOS to identifying and prioritizing a set of core variables for coastal observations. The criteria were based on feasibility, affordability and maximizing the number and importance of issues / user needs addressed by these variables. These variables are proposed not as a minimalist complete observing system, but as a common set across all observing systems, to be augmented based on need and capacity. An early action for an Australian IOOS would be identification of the relevant elements of this core set by reviewing the priority-setting process underpinning it and the relevance to Australian needs.

Table 1. Potential Elements in a Great Barrier Reef Regional Observing System

Observations (from a combination of remote sensing, autonomous moorings and AUVs, volunteer observing ships, research vessels, community programs)	**Products** (delivered by modelling and assessment tools)	**Applications**
• atmospheric forcing: winds, precipitation; • temperature, salinity, wave fields, currents, • river run-off, catchment loads, water and sediment quality, • reef and inter-reefal benthic ecosystem indicators, • commercial and recreational fishing effort, target and non-target fish stocks, • tourist activities.	• real-time forecasts of ocean circulation and temperature, coastal sea height and wave state, • fate and impact of catchment loads, • predictions of larval transport and recruitment, • assessments of fish stock, fishing bycatch and impacts, • state of the reef reports; and • forecasts and assessments of climate change impacts.	• regional marine planning, • assessment and review of MPAs, • fisheries management, • tourism planning and development, • catchment and land-use planning and management, • shipping and maritime safety, national security, and • planning and adaptation for climate change.

2.3 Data Management, Analysis and Delivery

Integrated data management, analysis and delivery are critical to the performance of IOOS as an end-to-end system. This requires processes and capability to ensure acquisition of data from a variety of observing platforms and sensors, quality control and preprocessing, archiving of data and derived products along with appropriate metadata, and data access and delivery to a variety of end users through networked distribution systems. The data delivered by an IOOS of the kind considered here will vary widely in spatial and temporal structure, in variable types, and in volume. Some data sets (eg satellite data) may involve gigabytes of data each day, and terabytes over years. For some time-critical purposes (eg short term ocean forecasting for transport, security, and hazard warning), acquisition, analysis and delivery must be accomplished in near real time, and reliability and dependability are essential. Other data sets (e.g. benthic habitat monitoring) may involve repeat times of years, with long delays between acquisition and application.

Given these diverse data types and requirements, some elements of the data acquisition, analysis and distribution system will need to be tailored to specific observations, and developed and managed by specific agencies. Nonetheless, it is important that data be available for multiple uses, and therefore accessible across agencies and institutions. Much attention is currently focused on identifying the technical and procedural requirements for achieving this interoperability across data management systems distributed across agencies and spatial locations.

Data management and communication are recognized as a key issue both internationally and nationally. Within Australia, there are already initiatives underway, through the Australian Ocean Data Centre Joint Facility (AODCJF), and the NOO Ocean Portal, to improve national marine data management and communication. The AODCJF is seeking a collaborative agreement, initially among the main Commonwealth agencies, to develop a comprehensive and distributed data management system, which is likely to cover the immediate needs of an Australian IOOS. The Ocean Portal project is developing key pieces of community software infrastructure and agreement on standards and protocols that will underpin these systems. Together, these initiatives provide a strong foundation for an Australian IOOS to build on.

2.4 The Operational, Research and Educational Partnership.

An IOOS is intended to create a long-term, sustained flow of observations and analysis products to meet user needs. The emphasis on a long-term, reliable and sustained user-driven system in effect defines the IOOS as operational. In practice, achieving an IOOS requires a partnership across policy setting, operational, research and educational agencies. In most cases, elements of an observing system (including the observing platforms / instruments and the analysis or modelling systems) will be developed and tested through pilot projects. GOOS defines 4 stages in the research to operational continuum: (i) research into relevant technologies and methods, (ii) research pilot experiments to trial elements with potential for implementation, (iii) pilot operational networks tested for relevance and benefit, (iv) sustained operational systems including evaluation and adjustment. In an IOOS implementation framework, these four elements will be surrounded by a process for priority setting, evaluation and review, with strong input from policy, users and stakeholders.

The policy pull is being provided by Australia's Ocean Policy and associated bodies such as OPSAG, and by policy development within the Natural Resource Management framework and its Marine and Coastal Committee (for example, integrated oceans management, and integrated coastal zone management framework). These bodies will play a critical role in developing a responsive and relevant system. The National Oceans Office provides a national focus for such policy development.

Operational capabilities are likely to come from those agencies that have missions with long-term goals and public-good services and capabilities that allow for sustained commitment. Several Australian agencies have such mandates and facilities. Operational agencies will mostly focus their attention in stages (iii) and (iv).

Research agencies will typically play a number of roles in IOOS. Research agencies will typically be involved in stages (i) to (iii). For some types of measurements, research agencies may be involved in the sustained operational systems, particularly where they have the unique skills required. Research contributions to IOOS development may range from the development and testing of new observing technologies (platforms and sensors) through development and testing of new analysis systems, to pilot implementation and evaluation of end-to-end systems to support user applications. At the same time, long-term sustained observations are essential to address many important research questions, especially those involving long-term change (e.g. ecosystem, fisheries and climate research). So research agencies are users as well as providers for IOOS product.

Similarly, universities are both an important research contributor to IOOS development and implementation, but also an important end-user for IOOS products. A well-designed functioning IOOS with effective networked delivery will represent an invaluable source of information and educational material, not only for higher education, but for secondary and primary schools, and for the general community.

3 IOOS Governance, Planning and Coordination

We are starting from a situation in which ocean observation efforts are largely fragmented in space and time, and across agencies, end-users and issues. We lack the national integrating framework and the strategic analyses and assessment needed to ensure adequate investment in observations, analysis and delivery. We presently lack ongoing mechanisms for user-driven priority-setting, feedback and coordination which would ensure effectiveness and relevance and justify any allocation of additional resources. A successful IOOS needs to be both sustained and able to adapt to changing capabilities and demands. This means that we require an ongoing mechanism for integrated planning and coordination, not a one-time or ad hoc fix.

The approach we advocate here is analogous to that adopted for planning and management of other major national infrastructure requirements such as for critical national transport. The multi-use and multi-purpose character of the system argues for a national approach, with benefits accruing across many different sectors and the Australian community as a whole. Such an approach needs sound governance and organisational arrangements and case studies demonstrating the socio-economic benefits. The national good must justify the investment.

3.1 IOOS Organisational Principles

Sustained and adaptive integrated planning and coordination will in themselves require ongoing IOOS structures, processes and resources. The structure and process need to be carefully designed to deliver IOOS goals and benefits, taking into account the Australian institutional and agency context.

Proposed AusIOOS Principles

An IOOS planning and coordinating structure and process should:

1. be consistent with and support the proposed broad IOOS component structure, including a global / climate component, and a coastal component incorporating both a national backbone, and a federation of regional / coastal observing systems.
2. allow development of a common strategy for implementation, and facilitate and encourage coordination and integration across the various agencies and institutions (operational, research, educational, industry) involved in implementation at local, state and national levels.
3. provide an interface to users and stakeholders, to support identification of needs, specification of products, priority setting, and evaluation of performance, benefits and costs.
4. support a staged, flexible and adaptive approach to developing required infrastructure according to priorities and providing for its evaluation, maintenance and upgrade or decommissioning as required
5. assess and where necessary test alternative approaches to meet priority needs, and recommend adoption of those which meet established criteria of feasibility, reliability, accuracy and cost-effectiveness.
6. allow development of an integrated strategy for IOOS funding, recognizing that this will likely involve multiple approaches to different funding sources for different and complementary components.
7. interface with marine data initiatives such as the AODCJF and Ocean Portal to ensure that IOOS data management and communication needs are met.
8. provide a national focus for interactions with the international Global Ocean Observing Systems (GOOS).

3.2 IOOS Organizational Elements

Based on these principles, it is possible to identify some likely elements of an Australian IOOS structure and process.

Overall Australian Integrated Ocean Observing System

An Australian IOOS Secretariat will be required to support coordination, planning and stakeholder engagement. The Secretariat should report to an overall AusIOOS Steering

Committee or Board, which will provide oversight and review. The Secretariat office would be small, and could most efficiently be located within a partner agency.

The initiative will need to be consistent with, and endorsed by, relevant government agencies and programs. At the Commonwealth level, the administrative arrangements for Australia's Oceans Policy are well-positioned to support planning of observing systems at national and regional scales. The Oceans Board of Management, OPSAG (and the National Oceans Advisory Group) provide cross-sectoral cross-agency interfaces for priority-setting, reporting and feedback. The Marine and Coastal Committee (MACC) of the Natural Resource Management Ministerial Council (NRMMC) provides an interface to state and federal governments.

Processes to support user-driven priority setting and evaluation, and technical design and implementation, will need to be established for the Global / Climate component, the national backbone of the Coastal Component, and for each of the regional Coastal nodes, as they evolve. It is likely that each of these components and nodes will ultimately require a technical advisory committee drawn from participating research and operational partners, and a stakeholder group drawn from users (government, business, educational, research). The panel responsible for the national backbone would work together with the AusIOOS office and the regional nodes to ensure coordination and integration of systems across national and regional levels.

Global Component & Coastal Component – National Backbone

An Australian IOOS office, coordinating national components and a federation of regional observing systems, would provide a natural focus for interaction between Australia and international GOOS, including the I-GOOS basin initiatives such as Indian Ocean GOOS, and SW Pacific GOOS. It is noteworthy that IOC, in collaboration with the State of WA and the Commonwealth, maintains a Regional Programme Office in Perth with a focus on Indian Ocean GOOS and Southwest Pacific GOOS activities. There are moves to establish a Southern Ocean GOOS initiative. The establishment of an

Australian IOOS Office would help position Australia to not only contribute to, but further benefit from international initiatives in our region, including increased access to international resources.

Coastal Component – Regional Nodes

At a regional scale, the National Oceans Office (NOO) is overseeing the development of Regional Marine Plans in a staged process around Australia. The regional marine planning process includes a wide variety of users and stakeholders, including state policy, management, research, industry and education interests, in addition to Federal interests. This process offers an opportunity to identify and engage with potential regional IOOS stakeholders, and could be modified to explicitly incorporate identification of stakeholder information needs, and design of pilot regional marine observing strategies, into the regional marine planning process.

Australia's Oceans Policy and the Australian Government's Regional Marine Plans do not currently cover state waters. The Integrated Coastal Zone Management Framework being developed for MACC could provide a complementary vehicle for coordinating national approaches to observations of inshore waters, estuaries and catchment inputs. The Framework recognizes the need to coordinate and improve acquisition of and access to coastal information and products.

In setting up regional observing systems, an Australian IOOS initiative should also take account of existing regional structures. For example, WAGOOS has already been established to coordinate design and implementation of ocean observations in Western Australia.

3.3 IOOS Resources

We have not attempted in this report to provide an estimate of the cost of a fully-implemented AusIOOS. The concept proposed here is of an observing system which is scalable and implemented in a staged manner, with components selected and designed to meet user-driven priority needs. We do note that, in scoping of comparable IOOS initiatives, other nations have argued that investments of tens to hundreds of millions of dollars per annum are justified. At the upper end of the scale, US IOOS has argued for an immediate investment of $138M p.a., ramping up to $500M p.a.

Avenues for resourcing IOOS initiatives include:

- Existing resources allocated by operational and research agencies to ocean observations;
- New proposals from individual operational agencies (e.g. New Policy Proposals);
- Proposals by research agencies and universities into existing research or infrastructure funds e.g. ARC, NCRIS;
- Industry contributions (in-kind or cash);
- Dedicated and direct funding of IOOS activities by federal or state governments.

It is likely that, in practice, some or all of the above will be involved. Regardless of the mix, it is critical that IOOS funding strategies are coordinated so that proposals take account of existing activities, and deliver complementary capabilities to meet agreed priorities.

4 Measuring Benefit

The argument for AusIOOS rests fundamentally on the cost-effective delivery of benefit to stakeholders and users. Experience shows that relying on individual users or sectors to commission ocean observations independently is neither efficient nor effective. We argue that, analogous to national weather services and the support of national infrastructure projects, some central coordination and implementation of ocean observations will deliver large net national and regional benefits. Demonstration of those benefits will be necessary to justify establishment and ongoing maintenance of IOOS.

An Integrated Ocean Observing System can be expected to deliver triple-bottom line benefit, across economic, social and environmental grounds. It will deliver economic benefit through improved efficiency and sustainability of maritime industries (fisheries, aquaculture, tourism, transport), through mitigation and better management of risk, through improved accuracy and reductions in overdesign of ocean infrastructure, and through improved climate forecasting to the benefit of a wide range of primary and secondary industries.

The IOOS will deliver social benefit in terms of increased security, through mitigation of risks arising from hazards for coastal communities and infrastructure, recreational and commercial activity, and through support of defence operations. The lack of observational networks and associated infrastructure was a major factor in the recent tsunami disaster in the Indian Ocean region. It will also deliver social benefit through contributions to education, and to improved community awareness and understanding of the marine environment. It will deliver environmental benefit through improved management of coastal environments, ecosystems, living resources, and the human activities impinging on them.

It may not be appropriate to measure all these benefits in dollar terms. Nonetheless, there is a need to quantify benefits, and to establish the links between information products and benefits, so as to allow a rigorous cost-benefit comparison for elements of the observing system, to justify resource allocation and help set priorities. Of course, implicit in the argument for a scalable, priority-driven AusIOOS is that not all of the potential benefits will be realized. Australia will need to make informed and deliberate decisions as to where the benefits justify the required investment in the observing system.

The estimation of benefits from the delivery of information can be a difficult and uncertain proposition, particularly where these involve mitigation of risk, or insertion of information into complex social and institutional decision-making processes. An IOOS ideally requires some relatively simple, transparent and agreed rules for estimating risk and benefit, allowing comparison across different proposed products and uses. It also requires an explicit user feedback / evaluation process for monitoring benefit from implemented components and products.

The Australian Academy of Technological Sciences and Engineering (AATSE) in partnership with WAGOOS, and with support from the NOO and WfO, among others, has initiated a study of the socio-economic benefits of GOOS for Australia. They have commissioned an assessment by ABARE on the likely economic benefits arising from the ocean observing system through improved climate and weather forecasts.

This assessment provides a fairly comprehensive analysis of the possible benefits that may accrue in the form of increased Gross Domestic Product from improved climate and weather forecasting. In one scenario, concerning the agricultural sector (wheat, sheep, beef, sugarcane and cotton), the macroeconomic effects of improved productivity/output, assumed to result from improved forecasts, were modeled, resulting in an estimated annual increase of about $170M. The Report notes the many assumptions explicit and implicit in such modeling but, overall, concludes that a significant benefit will accrue. The study does not link the observing system directly to the model but instead assumes that the scientific community will be able to attribute such effects; their basis is an assumed level of improvement due to forecast skill.

While there have been many studies of the economic benefits of climate prediction, this study is the first to place such benefits in the context of Australian ocean observations, *al beit* indirectly. The study comments on likely benefits from knowledge of the ocean state and marine conditions but defers detailed analysis to a later study. It also makes reference to the recent tsunami and the very obvious and tangible links between improved observational capabilities and effective warning and mitigation strategies, and consequent saving of life and property.

5 The Way Forward

We believe that there is a compelling case for an Australian Integrated Ocean Observing System., based on stakeholder need and identified benefit, and on the advantages and efficiencies arising from improved coordination and planning across sectors and agencies. To be effective, at least for the breadth of IOOS services envisaged here, a decision to implement an IOOS would need broad national advocacy and support and the IOOS would need to be national in scope and be jointly adopted by federal and state governments. Such a national mandate can be delivered through OPSAG, in consultation with MACC. For industry support and academic involvement, the IOOS will need backing from bodies such as AATSE and peak industry bodies.

An IOOS will emerge from a combination of enhanced existing capability and the phased introduction of short-term (do now) and long-term (start now, but grow over time) new components and functionality. The development of IOOS will also be staged regionally, with prototypes tested and demonstrated in pilot projects for one region before the technology is transferred and implemented in the system as a whole. It will also be important to engage with international earth observation initiatives such as GOOS, GCOS and IGOS, to implement the Australian system in a way that maximizes the benefit available from international investment in ocean observations, and to continue to participate in international priority setting processes to ensure Australia's interests are represented.

This report provides the rationale and strategy for the establishment of AusIOOS as a long-term, sustained and adaptive system. The recommendations below are designed to provide a firm foundation for staged, priority-driven implementation.

5.1 Recommended priority steps

The Section on IOOS governance described a set of potential organisational elements of IOOS which would meet proposed goals and criteria for planning and coordination. We now consider a set of concrete short term actions (to be undertaken within the next year) which would provide a path towards full IOOS implementation.

Recommendation 1. Establish a national IOOS office, to provide Secretariat support and coordination of national activities.

There will be a need for intense design, planning and coordination activity in developing and implementing AusIOOS, and an ongoing need for adaptive and responsive planning, coordination and reporting. A small executive / secretariat of at least two people will be essential to support these tasks. This should be a permanent office. However, it is possible that the office might be contributed by one of the participating agencies or resourced on a temporary basis, through contributions from partner agencies, for a start-up / demonstration phase of two to three years.

Recommendation 2. Establish a national AusIOOS advisory / steering committee.

The committee will draw on scientific, technical, user and policy expertise across the agencies represented at OPSAG, and include representatives of state interests. It will act as an interface between the AusIOOS Office and the participating agencies, and provide advice and guidance on capabilities, priorities, and opportunities to meet AusIOOS goals.

The Working Group considered a “minimal” option of continuing the OPSAG AusIOOS Working Group, without establishing an AusIOOS Office. Such a group might lead to incremental improvement in coordination across OPSAG agencies, but would lack the time and resources to engage more broadly with state agencies and other stakeholders, or to address current shortfalls in observational capacity and product delivery at national and regional scales.

The Working Group also considered options to move immediately to establish a more elaborate AusIOOS governance structure, including separate national panels for the climate and coastal backbone components, and for regional nodes. However, we feel that it is premature to establish a more elaborate structure, and that any such structure should emerge from the national secretariat and steering committee after careful consideration and initial experience.

The Working Group has identified a number of high priority tasks or outputs which the AusIOOS Office and Steering Committee should address immediately.

Task 1. Develop an implementation plan for the global (ocean basin/climate) component to meet Australia's contribution to the ocean climate observing system, including Argo, GODAE and IOGOOS components.

This is an urgent need, as some of the pilot programs are due to finish in the next few years, and there are still critical gaps, for example in meeting Australia's short-term contribution to Argo. In the longer term, the implementation plan needs to address the transition from pilot to sustained operational mode for such elements, including the design and resourcing of a sustained program.

Task 1 Milestone: Implementation plan and business plan by December 2005, with funding proposal to establish Australian pilot program starting July 2007.

Task 2. Coordinate and prepare a combined ocean observing research infrastructure bid to NCRIS for both global and coastal (national) AusIOOS components from OPSAG agencies and AusIOOS partners.

Australia's marine research agencies are currently significantly under-invested in key new observation technologies, especially autonomous platforms and sensor technologies (gliders, profilers, coastal radar) which offer order of magnitude reductions in cost per observation. This lack of infrastructure not only means that investments of research time are less productive than they should be, but also represents a considerable obstacle to the 4-stage transition from research through pilot operational to full operational, described earlier. NCRIS represents an opportunity to achieve a substantial improvement in this situation. AusIOOS will need to work with partners in an NCRIS bid to develop a joint strategy for maintaining and delivering access to the infrastructure. This might be done in a manner similar to that adopted for the National Research Vessel Facility.

Task 2 Milestone: NCRIS proposal submitted in response to NCRIS call for proposals expected around July 2005, with due date some months later.

Task 3. Develop an implementation plan for a national backbone to support regional coastal observing systems.

This would involve several key elements including:

- Integration and coordination of marine satellite-based remote sensing across Commonwealth and state agencies, addressing data acquisition, processing, product delivery and calibration/validation;
- Identify AusIOOS data management and delivery needs, and working with AODCJF and Oceans Portal to ensure that these needs are met;
- Review international approaches to identifying common core variables and establishing coastal reference sites, and assess their suitability for Australia.

Task 3 Milestone: Implementation plan for national backbone by December 2005, with proposal for priority components to start in July 2006.

Task 4. Facilitate the early establishment of pilot regional coastal observing systems through e.g. a national workshop on coastal observing systems.

As discussed earlier, Australia is unlikely to have the resources to establish full-scale pilot coastal observing systems in many regions simultaneously, and a staged approach will likely be required. There are some regions where early implementation seems likely to prove attractive, as a result of past investment in research and planning, and/or for reasons of national priority. Possible such regions include the Great Barrier Reef, North-west Shelf and Timor Sea, and South-west WA. One option might be to hold a national workshop on coastal observing systems for Australia, possibly in collaboration with NOO (see below) and the MACC ICZM Framework initiative.

Task 4 Milestone: Hold national workshop on coastal observing systems, and identify one or more regions for rapid establishment of pilot coastal observing systems by June 2006.

Task 5. Work with NOO to consider how identification of national and regional information needs and priorities for AusIOOS might be incorporated into the Regional Marine Planning process.

As noted above, the NOO Regional Marine Planning Process offers an interface to regional marine stakeholders, and an opportunity to identify information needs and observing system priorities as part of a regional adaptive management strategy. If this opportunity is to be realized in NOO's current planning process, AusIOOS will need to work with NOO to incorporate observing system priority setting and design in the NOO regional marine planning process.

Task 5 Milestone: Agreement with NOO to incorporate observing system design in regional marine planning process by June 2006.

5.2 Initial Resourcing of AusIOOS

If adopted, the recommendations and tasks in 5.1 would establish AusIOOS as a formal initiative, and constitute a multi-objective scoping project leading to costed proposals for subsequent implementation of priority components. The estimated cost of adopting these recommendations and tasks, over the initial 12 months period, is approximately $430k. This represents a total cost, including overheads, accommodation, etc. The cash cost could be lower, depending on the level of in-kind support contributed by supporting agencies.

Appendix A. Summary of a survey of existing ocean observing programs and activities across OPSAG agencies.

A1. Ocean Basin / Climate Component

A program of ocean met observations on volunteer merchant vessels and RAN vessels is coordinated by BoM. Measurements include air and sea temperature, barometric pressure, humidity, visibility, waves, ocean currents and sea ice. BoM also maintains a network of around 20 meteorological drifting buoys in the Southern and Indian Oceans, and a network of around 30 marine automated weather stations at coastal sites. These are operational programs – data are relayed in NRT and ingested into numerical weather forecasts. AIMS also maintains automatic weather satations on reefs and coastal locations, mostly on the Great Barrier Reef. BoM maintains two wave-rider buoys in southern Australian waters, and accesses wave data from instruments maintained by state agencies.

The CSIRO / BMRC Joint Australian Facility for Ocean Observing Systems (JAFOOS), with support from RAN and US NOAA, maintains a ship-of-opportunity program using XBTs to monitor upper ocean thermal structure. RAN vessels routinely launch XBTs. CSIRO is undertaking repeat high-precision hydrography sections are being obtained by to monitor long-term changes in ocean vertical structure and composition around Australia. Australia is participating in the international Argo pilot program to monitor changes in ocean structure through a global array of profiling floats, through Argo Australia, a joint collaborative program across CSIRO, BoM, AGO and ACE CRC.

Ocean current measurements are undertaken through deployment of moored current meters, and operation of ADCP on research vessels and RAN hydrographic vessels. Deployments are mostly undertaken as part of short-term research projects.

Monitoring of biogeochemical tracers and changes in the ocean carbon cycle is restricted to a small ship-of-opportunity program in the Southern Ocean and SW Pacific, and to observations from research vessels.

Australia has a major commitment to acquisition, analysis and validation of satellite data, including altimeter, SST and ocean colour, with involvement by CSIRO, BoM, AIMS, WASTAC and GA.

Geoscience Australia maintains national geospatial datasets, including jurisdictional boundaries, bathymetry, sediments and geological provinces.

Overall, the Basin / Climate component is most mature in terms of national (and international) planning and coordination, and subcomponents such as ocean met can already be classified as sustained routine operational. However, other key elements, particularly those related to observations of the ocean interior, are either in research or pilot mode, and in some cases severely resource limited. The challenge here is to translate a strong design base into effective implementation.

A2 Coastal Component – National Backbone

The SST and ocean colour satellite data sets referred to above are available at 1 km resolution for the Australian EEZ, and are suitable for many coastal applications. SST data are being used to monitor and forecast coral bleaching events, and to target fishing effort. The optics of coastal waters are more complicated, and the development of reliable coastal ocean colour products is still a research activity, with great promise for operational monitoring of coastal water quality, including river plumes, turbidity and algal blooms.

Tide and sea-level monitoring is well coordinated nationally through the Permanent Committee for Tides and Mean Sea Level, and the National Tidal Centre in BoM. The NTC maintains the high-precision Australian Baseline Sealevel Array, and additional stations in the SW Pacific. The PCTMSL coordinates these observations and many additional observations undertaken by state agencies and port authorities.

Geosciences Australia maintains the Ozestuaries online database, containing an assessment of over 700 Australian estuaries carried out by a multi-agency project under the National Land and Water Resources Audit. This could serve as the basis for a nationally coordinated estuarine observation, assessment and forecasting program.

Australia does not possess a national network of coastal reference stations. CSIRO with some state partners still maintains a long-term (50+ year) monitoring program at three sites off NSW, Tasmania and West Australia.

The elements described under this component offer a strong contrast in terms of coordination and maturity. The tide and sea-level program offers an excellent example of the benefits of national coordination across federal, state and local levels. In areas such as coastal remote sensing, it is arguable that greater national coordination will lead to more rapid progress and better delivery. In areas such as estuarine assessment and coastal reference stations, we are just starting, and the existing activities offer just a hint of what might be achieved through national coordination.

A3 Regional Coastal Observing Systems

The most comprehensive long-term regional monitoring program is arguably that established for the GBR, supported by AIMS, GBRMPA and other Reef CRC partners. This program has included monitoring of ocean temperatures, river inputs, water quality, and reef ecosystem health over two decades. This program is well positioned for development into a state-of-the-art, integrated, regional observing system.

Recent research initiatives in both SW and NW West Australia, undertaken by CSIRO and AIMS, in partnership with universities and state agencies, also offer opportunities for development into pilot regional observing programs. WAGOOS is also developing plans for regional observing systems to support oil and gas development in NW Australia.

Australian Commonwealth and state fisheries are subject to annual operational assessment and management. The data acquisition and analysis systems supporting fisheries management include routine collection of catch and effort data through logbooks, observers, and satellite vessel monitoring systems. A variety of additional fishery independent surveys are used to support stock assessment. There is increasing commitment to monitor bycatch, ecosystem impacts and interactions with the ocean environment, and a variety of new high-tech sensors (smart tags, acoustic receiver arrays) are being trialled. There is tremendous potential to integrate fishery observing systems into broader regional observing systems, with benefits the operations and management of fisheries and other sectors.

The NOO Regional Marine Planning process has seen a concerted effort to map Australia's deep benthic habitats, through partnerships across NOO, GA and CSIRO. There are also new initiatives to improve knowledge of shallow benthic habitats eg the AIMS-CSIRO-QDPIF-QMuseum GBR Seabed Biodiversity Project, and the Shallow Benthic Habitat Initiative from Coastal Zone CRC, involving multiple universities, GA, DSTO, CSIRO and state agencies. It is becoming increasingly feasible to incorporate habitat mapping into regional observing systems on the time and space scales needed to support regional planning.

None of these coastal regional observing activities meets the vision of a regional IOOS, although the combined activity on the GBR comes closest, and provides an exciting opportunity to move quickly towards a truly integrated regional system. The activities described here of course represent only a subset of the observations in Australian coastal waters, most of which are undertaken by state and federal agencies. The challenge here is to achieve integration across agencies, sectors and disciplines on a regional basis, while ensuring communication and adoption of common effective techniques and approaches across regions.