DEVELOPING A SEAMLESS SDI MODEL ACROSS THE LAND-SEA INTERFACE

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ABSTRACT

A more integrated and holistic approach to management of spatial information relating to coastal and marine environments is needed and this can be facilitated by the creation of a Spatial Data Infrastructure (SDI) on a seamless platform. There is a growing and urgent need to create a seamless SDI model that bridges the gap between the terrestrial and marine environments, creating a spatially enabled land-sea interface to more effectively meet sustainable development objectives. This paper discusses the principles and concepts followed by introduction to issues and challenges that must be overcome in developing an overarching architecture for a seamless SDI that allows access to and interoperability of data from marine, coastal and terrestrial environments.

KEYWORDS: Spatial Data Infrastructure, Seamless SDI, Interoperability, Land-sea interface.

INTRODUCTION

The land-sea interface is one of the most complex areas of management in the world consisting of both the marine and terrestrial environments. The coastal zone is also home to an increasing number of activities, rights and interests. According to the UN Atlas of oceans about two-thirds of the world's population live within 60 kilometres of the coast, and almost half of the world's cities with more than one million people are sited in and around washed river mouths and estuaries (UN 2006). Many nations are economically, politically and socially dependant on the coastal zone. It is a resource provider and gateway to the worlds' oceans which humans rely on for food, raw materials, climate regulation, transportation, disposal of waste and recreation. Coastal economic potential includes shipping, oil and gas mining, fishing, aquaculture, and tourism. There are increasingly serious signs that these economic uses of our coast are undermining their long term sustainability. Overfishing is exhausting and deleting fisheries around the world and fears about offshore oil and gas development and its impact on beach and coastal environments are increasing. This has brought with it an increased need to more effectively and efficiently manage this area to meet the economic, environmental and social outcomes of sustainable development.

Clearly appropriate management of these areas is required. In this regard, improvement of models for sustainable coastal development has been the focus of many international governmental organisations over the last decade. Multiple reports internationally have highlighted the need for better coordination and integration between and within levels of government to improve coastal zone management (Hudson & Smith 2002, Middle 2004). In this respect, Coastal Zone Management (CZM) initiatives are turning to more integrated strategies worldwide, attempting to harmonise economic, social and environmental objectives, similar to the better-developed land use management frameworks of many urban areas. In coastal areas however, the diversity of interests,

some terrestrial and some marine, compounds the issue. Integrated Coastal Zone Management (ICZM) recognises that the coastal resources management situation is unique; that is, it differs greatly from management of either land or water resources, being a combination of both (Bartlett *et al*. 2004).

Worldwide countries are realising the need to balance development and exploitation of resources in the coastal zone with environmental and social needs. In the terrestrial domain, the need to share and integrate spatial data for more efficient resource information management has been recognised for over a decade, and has led to the development of Spatial Data Infrastructures (SDI) at all geographical levels from the purely local to the national and global. Until recently most, if not all spatial information management and administration tools have focussed on the terrestrial environment. The concepts of marine SDI, marine cadastre and marine spatial planning have all emerged recently in response to a global realisation of the need to improve management and administration of the marine environment. In the ocean environment, many elements of SDI for marine data exchange have been developed by the Intergovernmental Oceanographic Commission (Longhorn 2003).A more integrated and holistic approach to management of coastal and marine environments would be facilitated by the extension of the SDI on a seamless platform. There is a growing need to create a seamless SDI model that bridges the gap between the terrestrial and marine environments, creating a spatially enabled land-sea interface to more effectively meet sustainable development objectives. This would promote data sharing and communication between organisations, thus facilitating better decision-making involving marine and coastal spatial data. However, the differences in the marine and terrestrial environments in fundamental datasets, data collection and technology used in these environments will make interoperability and integratability between marine and terrestrial spatial data a challenge. Research and further works now needs to focus on combining these initiatives and developing a seamless platform.

With this in mind this paper discusses coastal zone management issues and the potential for adding a coastal dimension to an SDI to facilitate coastal zone management. It looks at the complexity and issues regarding management of the land-sea interface. Further it discusses the need to develop a seamless SDI as an enabling platform to increase the efficiency and effectiveness of management across regions and disciplines followed by an introduction to issues and challenges that must be overcome in developing an overarching architecture for a seamless SDI that allows access to and interoperability of data from marine, coastal and terrestrial environments.

COSTAL ZONE MANAGEMENT ISSUES AND CHALLENGES

As the interface between land and sea, the coast is a unique geologic, ecological and biological domain of vital importance to a vast array of terrestrial and aquatic life forms-including humankind. The importance and value of the coastal zone can not be underestimated. Since early settlement days the coastline has been used in a number of ways. Largely for transportation reasons, major industrial and commercial centres developed around port cities. Indeed, some two-thirds of the planet's population lives in a narrow 400-kilometer coastal band**.** Demographic trends suggest that coastal areas around the world are undergoing serious population growth pressures. Population growth is the driver behind many, if not most, coastal problems (Brower et al. 2002). The population and development pressures that coastal areas experience generate a number of critical problems and policy issues and raise serious and difficult challenges for coastal planners. Population density is another measure of the stresses placed on coastal areas; when more people are using a limited resource, the carrying capacity of the region can sometimes be exceeded.

Protecting the coastal environment while accommodating such growth pressures will be a major challenge.

The coastal environment is one of constant change, with many natural pressures such as wind, waves, currents, tides, etc. creating a change in topology. However, it is the effect of human induced pressures that can be far –reaching and long –lasting. Human activity can interfere with the natural processes of the coast and prevent the ecosystem from maintaining the equilibrium so necessary to its continued vitality. Human pressure exerted on the coastal region also involves the disposal of waste. Society is now using resources and producing wastes at rates that are not sustainable. Oceans and the coastal zone have been used as dumping grounds for many years. For instance population increases along Australia's shorelines and the corresponding industrial development has resulted in a rapid increase in sewage outflow into rivers, estuaries and oceans (Plunkett 2001a). It is important to consider land-based sources of marine pollution as around 80% of contamination in the marine environment (SOEAC 1996). Therefore protection of Coastal waters is a major goal of coastal management programs.

The coastal zone is also one of the most productive areas accessible to people. There are increasingly serious signs that economic uses of our coast are undermining their long term sustainability. Overfishing is exhausting and deleting fisheries around the world. As an example in Australia, according to the Bureau of Rural Sciences (BRS 2002) 11 target species in Commonwealth fisheries were classified as overfished, 11 as fully fished and a further 35 classified as ‘uncertain’, despite the highly regulated and generally regarded best-managed fisheries in the world. This overfishing came about partly due to lack of knowledge of the distribution, abundance and biology of the stocks, but also due to inadequate management arrangements resulting in unsustainable catches (NOO 2002). Additionally in recent decades production of offshore oil and gas has generally been declining due to the resource becoming depleted. Coastal storm mitigation, loss of biodiversity habitat and coastal wetlands, shore line erosion and sea level rise, lack of suitable sites for aquaculture, private property versus the public interest in coastal planning, protecting marine heritage and marine defense are other major issues and challenges which coastal stakeholders are struggling with. These issues and their potential impacts are forcing coastal states and localities to resolve how best to cope with.

As the interface between marine and terrestrial environments, coasts have diverse and ever increasing conflicting pressures and demands requiring effective administration and management. Most ocean and coastal management problems are of a spatial nature (Williamson *et al*. 2004) and hence it is now being recognised that the information required to balance competing interests over the coastal zone have an inherent spatial dimension (Rajabifard *et al*. 2005). Spatial information aids decision making by providing a spatial/geographic context to planning, management and resource allocation. It enables a better understanding of an area and thus better management (Binns *et al*. 2005). Many coastal management issues could be overcome if a spatial data platform that enables a holistic, integrated and coordinated approach to spatial information for decision-making existed. SDI provides an enabling platform enhancing decision-making and facilitating a holistic approach to management. However, the development of SDIs are generally confined top the landward or seaward sides of the coastal zone, with little or no thought given to the interaction between these two environments. The need for interoperable data between the three environments (land, coast, marine) requires a management system that incorporates them all. This is now being recognised through the development of a seamless SDI platform that takes into account the terrestrial, marine and coastal environments.

SEAMLESS SPATIAL DATA INFRASTRUCTURE

A more integrated and holistic approach to management of coastal and marine environments would be facilitated by the extension of the SDI on a seamless platform. This would promote data sharing and communication between organisations thus facilitating better decision-making involving marine and coastal spatial information.

Both the marine and terrestrial environments are tightly integrated systems in which all the parts are interrelated and dependent on one another. Destruction or degradation of one component can lead to impairment of other parts or the dysfunction of ecosystem as a whole. If two separate SDIs were created it would deepen the gap between these two administration systems and make coastal zone management more difficult. There is an opportunity for more research to be conducted into combining these initiatives and developing a seamless SDI that can include spatial data from all environments. This will recognise the interrelatedness of the marine and terrestrial environments and also improve management of activities or resources that occur across these boundaries (Strain 2006).

The complex physical and institutional relationships existing within the coastal zone make it impossible for development of a marine SDI to occur in isolation from land based initiatives. Furthermore a seamless infrastructure aids in 'facilitating more integrated and effective approaches to coastal zone management, dealing with problems such as marine pollution from land based sources' (Williamson *et al*. 2004). A seamless infrastructure was endorsed by the UN as part of the International Workshop on Administering the Marine Environment held in Kuala Lumpur, Malaysia, 2004 (Rajabifard *et al*. 2005). It was recommended that a marine cadastre act as a management tool within a marine SDI as an extension to NSDI's across Asia-Pacific. Recently, a recommendation of the 17th United Nations Regional Cartographic Conference for Asia and the Pacific (UNRCC-AP) in Bangkok further supported the inclusion and development of a marine administration component as part of a seamless SDI to "ensure a continuum across the coastal zone" (UNRCC-AP 2006).

A seamless SDI can be seen to have the following characteristics:
- Seamless, the digital spatial data is stored continuously throughout and across any jurisdictions
- Multi-purpose, the same data can be used for different purposes.
- Multi-users, the same data can be accessed by different users concurrently.
- Interoperable, the data stored in the database can be accessed using different GIS software and applications.

A seamless SDI platform would enable the utilisation of common boundaries across the coastal zone to ensure no ambiguity exists and no areas are unaccounted for over the coastal interface. This infrastructure will become a powerful information resource for managers in fields as varied as fisheries habitat management, pollution monitoring and control, shoreline erosion, weather forecasting and tourism development, etc. The information that can be derived from such a fully integrated information infrastructure will facilitate improved decision making at all levels.

The sharing and integration of coastal databases across regions and disciplines through SDI development would permit harmonised and universal access to datasets from oceanic, coastal and land-based spatial data providers so that complex issues affecting the coastal zone can be properly and efficiently addressed in many economic, environmental and policy areas (Bartlett *et al*. 2004). To improve management of the coastal zone, there needs to be access and interoperability of both marine and terrestrial spatial data. Interoperability is the capability to communicate, execute

programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units (OGC 2005).

On land, issues and challenges such as data interoperability and data integratability have been identified as major issues. However, there are more issues facing marine environment as it is highly dynamic with 4D boundaries and thus natural resources or features are more likely to move with time which leads to poor accuracy, precision, consistency and completeness of marine spatial data. These difficulties compound in the coastal zone, as it is both the on and offshore environments combined and interrelated. Figure 1 shows the conceptual demonstration of issues and challenges of the land, coast, and marine environments. It implies the need for an overarching spatial information framework to facilitate the management of the whole environment.

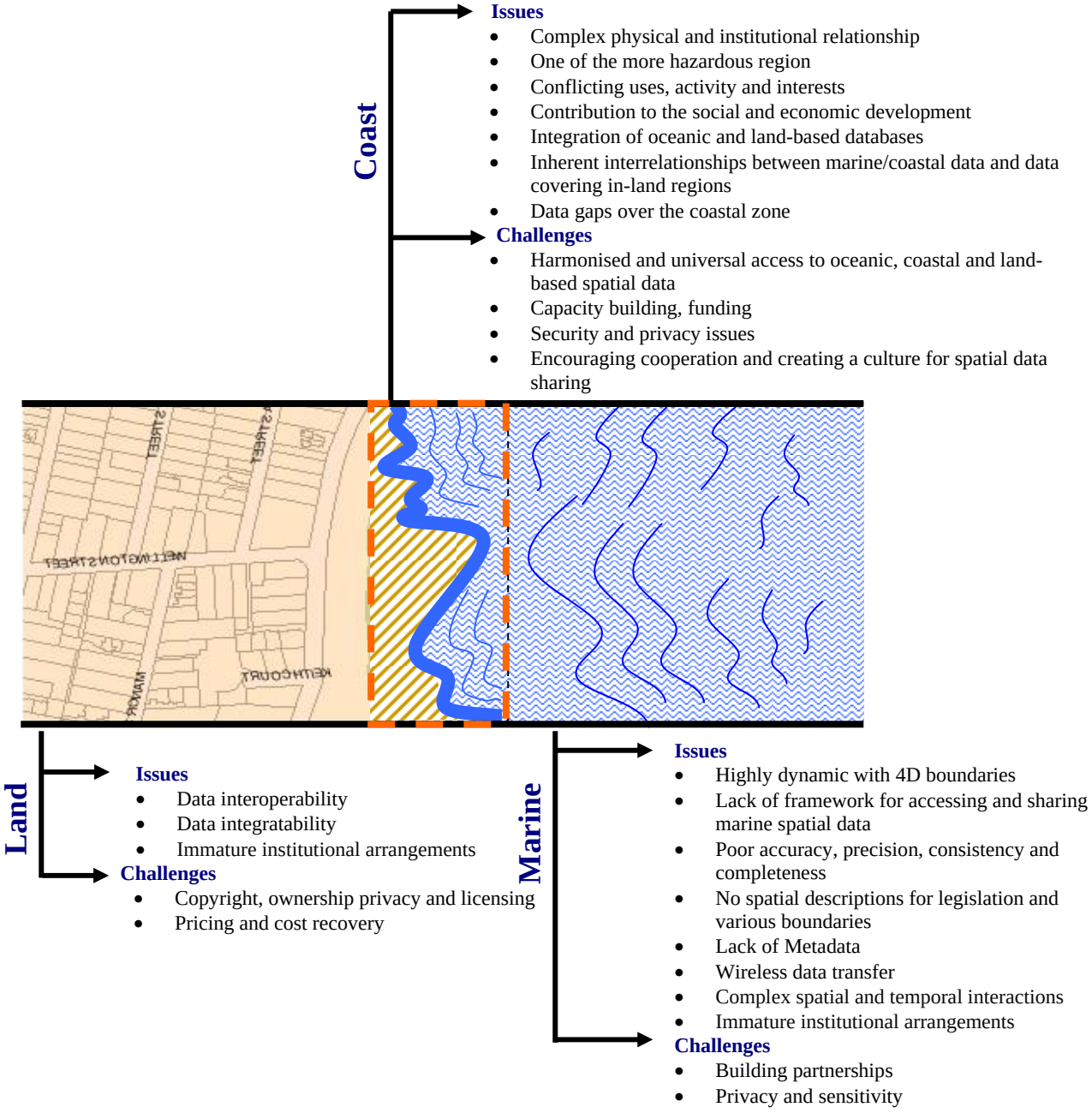

Figure 1: Issues and challenges of the land, coast and marine environments

The development of a framework such as a seamless SDI would aim to aid in facilitating decision making in order to respond to these technical, institutional and policy issues, in order to facilitate more effective management of the land sea interface.

ISSUES IN DEVELOPING A SEAMLESS SDI ARCHITECTURE

In order to create a seamless SDI across terrestrial and marine environments and jurisdictions, it is important to recognise and accept that building and maintaining an SDI is not an easy task even for well-developed states. It is a dynamic and complex process at different levels of government and requires research and collaboration with academia and private industry.

Research into the technical and institutional aspects of creating a seamless SDI in Australia is one of the major research priorities of a research project being undertaken in the Department of Geomatics at the University of Melbourne. The aim of this research project is to design an overarching architecture for developing a seamless SDI that allows access to and interoperability of data from marine, coastal and terrestrial environments.

The ability to access and integrate data has been identified as a problem by people involved in coastal zone management, as can be seen from the development of ICM initiatives. Incorporation of marine and coastal regions within global, national and regional SDIs will bring substantial additional benefits of integration, standardisation and interoperability of technologies, enabling better policy formulation, monitoring and enforcement, often reaching beyond the coastal zone itself (Bartlett et al. 2004). Seamless geospatial datasets across the land-sea interface are needed by almost all users struggling with issues of navigation, resource management, planning, hazard delineation and mitigation, environmental studies, and regulation issues.

The integration should be carried out for both land and marine spatial data to build a seamless spatial data management throughout any jurisdiction. Sustainable development also requires the availability of an integrated spatial information system which provides built and natural environmental dataset that is available to public access. As stated by Syafi'i (2006) the integration of spatial data at national level encounter several problems either technical or non-technical issues, however the non-technical issues are the most difficult problems to overcome.

Technical Issues

It is often difficult to find coastal geospatial data and/or derived products. Once located, it is often difficult to judge the quality of the data or to understand the limitations that apply to their use. With differences in scales, datums, projections, formats, or resolution, the data are often difficult to handle and even more difficult to integrate.

Spatial data may come from various sources or data providers. Each data provider has its policies and methods of managing spatial data. In many instances, land and marine data products are incompatible in terms of scale, projection, datum and format (Gillespie et al. 2000). The following are several technical issues that should be taken into consideration when integration spatial data from various data sources:

- Differences in spatial reference system (horizontal datum, vertical datum, coordinate system).
- Differences in storage format.
- Differences in scale of data source.
- Differences in feature or object definition.

• Differences in spatial data quality due to the differences of resolution or data acquisition method.
•Differences in spatial data modeling (geometry, features name, attributes, field type, topology, etc) (Syafi'i 2006)

The following table shows an example of the differences on several aspects of two main data sources (Topographic Map and Nautical Chart) of Australia that should be considered when integrating land and marine spatial data.

Table 1. Different aspects of land and marine spatial data integration

No	Item	Topographic Map	Nautical Chart
1	Coastline	-Taken from aerial photograph (the meeting line of land and water at time of exposure)	-Local Astronomic Tide (LAT)
2	Horizontal Datum	-GDA94 -WGS84	-GDA94 -WGS84 - AGD66
3	Vertical Datum	-AHD (Australian Height Datum or Mean Sea Level) for land elevations. - no depth information	-Mean Sea Level (MSL) for land elevations. - Chart Datum for depth information: LAT, ISLW
4	Projection system	-Universal Transverse Mercator (UTM).	-Mercator
5	Digital Storage Format	-Various format (DWG, ARC, SHP ,Hardcopy)	-Digital Nautical Charts: Raster(TIFF, ECW) -Electronic Navigation Chart: DIGITAL - S-57 Version 3.1 -Nautical Chart: Digital and Non digital - Raster HCRF V2 / GEOTIFF V1 (not to be used for navigation), Hardcopy Printed Charts -Bathymetric Map: Digital and Non digital-ASCII, Hardcopy - Printed maps
6	Scale	-Systematically (1 to 10K, 25K, 50K, 100K, 250K).	-Not Systematically (range from large scale to small scale)

From a technical point of view, the lack of spatial data standards that is implemented at national level is the main problem of the above differences. Each institution or organization creates spatial data for their own purposes using their own technical specification without considering that the

data may be shared or distributed to larger communities. There are concerns that a single set of standards may not be able to serve all applications and that those developing the standards may at times be too far removed from the user community, and/or that standards sometimes appear too complex for easy implementation and users are unaware of existing tools to simplify the implementation.

SDI must be based on 'interoperability' (seamless databases and systems). International standards organisations are addressing the development of standards for both land-based and marine-based spatial data and technologies. This includes the S-57 (Special Publication No. 57) cartographic standard developed and maintained by the International Hydrographic Organisation (IHO) International Hydrographic Bureau (IHB) in Monaco (IHO 1996) within the marine environment, and within the terrestrial environment, the International Standards Organisation's Technical Committee 211 (TC/211) on Geographic Information/Geomatics. This committee creates a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. For coastal zone users, a big issue is the difference in standards between land and ocean data products.

The implementation of spatial standards at national level will assure that every institution and organization creates spatial data in the same manner and it will ease spatial data sharing and exchange. These must be developed using the international procedures and practises in order to cover not only the national needs but also cooperation at an international level. In this respect the IHO has an important role to play in developing the appropriate standards needed for its hydrographic and cartographic applications, in close cooperation with appropriate organisations responsible for standardisation, such as ISO. As an example the IHO S-57 standard, although limited in scope and implementation, provides important compatibility for data sharing in the hydrographic information community. The next edition of the standard will not be a standard just for hydrography, but will have manageable flexibility that can accommodate change and facilitate interoperability with other GIS standards. It will also allow hydrographic offices to use other sources of geospatial data. The next edition of S-57 (which will become S-100), is being based on the ISO/TC211 base standard and will make provision for imagery and gridded data in addition to the existing vector data, defined in the present version. This will facilitate the development of additional products and services other than for navigation requirements (Maratos 2007).Therefore common standards and well documented metadata are essential for data discovery, management and compatibility within a SDI.

Another concern linked to the establishment of seamless SDI is the issue of a national shoreline. As the fundamental boundary for so many applications and studies, the lack of a consistently defined shoreline has frustrated coastal zone managers, planners, and scientists for many years. Since shoreline definitions typically relate to a water level, the shoreline is dynamic, changing over various temporal and spatial scales. Several different shoreline definitions are in use by various federal, state, and local authorities to meet non-navigational needs. The use of inconsistent shoreline definitions between maps, charts, GIS outputs, and other products leads to user confusion and ill-informed decision making. Additionally differences in shoreline definition can also lead to unnecessary duplication of data acquisition efforts (Ocean Studies Board 2004). Therefore different representations of the coastline in marine and land datasets leads to data overlaps while most of the application requires a single seamless layer of information with no duplication of common features. A single nationally accepted and consistent shoreline should be defined. The consistent definition of the shoreline would thus not only reduce legal and jurisdictional confusion but also would undoubtedly lead to increased data acquisition efficiency.

Another barrier to a seamless SDI is in different projections regarding land and sea data, which creates a problem in defining the parameters required for transformations. However, conversion from one projection to another could be easily done as long as the required conversion factors or corrections are well documented. Fortunately, the emerging GIS software and technology has most of the required tools to convert one projection to another. Although horizontal datum issues can be readily resolved with well-documented meta data and existing transformation tools, vertical datum issues present the most serious challenge to this effort. To resolve the vertical datum issues, NOAA, USGS have undertaken a pilot project in Tampa Bay, Florida for creating a seamless bathymetric/topographic dataset. The vertical datum transformation tool (Vdatum) that they developed allowed the transformation of all bathymetric data from the MLLW datum to the ellipsoid (Ocean Studies Board 2004).

There is a need for the establishment of national (and even international) standards for data collection, metadata creation, and tools for data transformation and integration. With these, the user community would be able to evaluate the accuracy of data, change scales and projections, and seamlessly integrate disparate datasets. Database and data integration tools must be easily accessible to all users, public and private, from a single digital portal accessible through the Internet .Once established, the national framework would need to be maintained and regularly updated.

Institutional Issues

Apart from the technical issues, there are several non-technical issues that should be overcome in order to develop a seamless SDI. The coastal zone is difficult to manage due to the fact that it is governed by a complex array of legislative and institutional arrangements from local to global scales. A coastal state may be a party to many international conventions (i.e. RAMSAR, MARPOL, and London Convention) in addition to developing its own national, and even state or local regulations. Activities and resources are usually managed in a sectoral and ad-hoc approach with legislations or policies created when the need arises and specific to only one area of interest (Strain et al. 2004). Furthermore, there is currently some confusion about the management of the land-sea interface, an example being in Australia where local governments manage land to High Water Mark (HWM), and state governments manage the marine environment from the Low Water Mark (LWM). This means that there are no overlapping arrangements in place to enable efficient coastal zone management. There is also a strip of land between the two boundaries which is not within a management jurisdiction at all (Binns & Williamson 2003).

There are also a large number of stakeholders with rights, interests, or responsibilities for management in the coastal zone. Binns (2004) states that there is often little cooperation or collaboration between these groups responsible for managing the same area offshore. To add to the complexity these rights and interests can often be overlapping and sometimes conflicting or competing for space.

Each institution or organization has different policies and rules on managing spatial data. Another exiting problem is that communication between different sectors is poor. There is little understanding of different organizational cultures and enormous administration fragmentation. As a result of this issue there are conflicts between sea users and pressures for services and facilities. Most conflicts have at least some relationship with the multi-objective nature of demand for coastal resources.

In any jurisdiction groups typically collect and maintain data to support their own specific disciplines or programs, with little or no consideration given to collecting, processing or managing data for use by other users. As such, available data are often inadequate for clear, rational decision making which is both environmentally and economically sound (Gillespie *et al*. 2000). The result is that organisations working in the same country or in the same discipline collect similar data in different ways, engage in much duplication of effort, suffer from insufficient or inappropriate standards, or are insufficiently aware of methods that should be used, or of the availability of existing data.

However, it is believed that the above non-technical problems can be overcome through coordination arrangements and existence of a single management authority or forum for collaborative planning, and deficient legislation. More information about NSDI are required to have a better understanding and knowledge about NSDI among different institutions and oragnisations and there should be proper regulation to enforce that all spatial data providers should involve in and contribute to the development of NSDI.

The ultimate aim will be a refined SDI model and implementation guidelines that seamlessly covers both land and sea that can be used by jurisdictions to create an enabling platform for the use and delivery of spatial information and services. This development aims to aid in meeting the sustainable development (economic, environmental and social) objectives of the region through the development of a seamless enabling platform to provide more efficient and effective decision making capabilities across both the marine environment and the land-sea interface.

CONCLUSION

The lack of accurate information that seamlessly cross the land-sea interface creates a serious obstacle for coastal zone managers. These managers need precise, accurate, and timely data and products that are easily accessible and usable for a wide variety of applications. In this regard a continuous up-to-date and high resolution terrain model extending from the land, through the littoral zone to the sea would be needed. Such a model will facilitate planning, management, conservation and administration of complex coastal region.

There is a growing need to develop the seamless SDI model as one platform instead of two to increase the efficiency and effectiveness of the management and administration of the land, marine and coastal environment. However, the differences in the marine and terrestrial environments in fundamental datasets, data collection and technology used in these environments will make interoperability and integratability between marine and terrestrial spatial data a big challenge.

In the terrestrial domain, the need to share and integrate spatial data for more efficient resource information management has been recognised for over a decade. There is now increasing recognition by the public at large of the need to support sustainable development of the coastal and marine environments as well. At the moment the practical implementation of a marine SDI is mainly occurring separately to the terrestrial SDI, using the same components but adapting them to suit the different environment. However the multidisciplinary interactions in the land–sea interface require sophisticated information infrastructures that not only do not yet exist, but which will not appear if disciplines continue to develop their SDIs in isolation from one another. Research now needs to focus on combining these initiatives and developing a seamless SDI. The development of a seamless SDI will ensure this data is interoperable and thus improve decision-making and administration in the coastal and marine environments.

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