Building a Seamless SDI Model for Land and Marine Environments

By

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DECLARATION

This is to certify that the thesis has not been submitted for a higher degree to any other university or institution. The text does not exceed 100,000 words.

Parts of this work were published in books, journals and refereed conference proceedings as listed in Appendix 1.

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ABSTRACT

With climate change, rising sea levels pressing harder year on year and the need to manage our resources more carefully in this dynamic environment, the inability to integrate marine and land based spatial information is an increasing problem in many countries. Without spatial data, sustainable development of the coastal zone is difficult, if not impossible. The absence of a seamless spatial information framework prevents the execution of standard practice of locating and referencing spatial information across the land – marine interface where so much pressure and development is taking place. This also inhibits the access and sharing of spatial information leading to data duplication often resulting in a proliferation of discrete data collection projects with the consequences of substantial investments.

Currently, Spatial Data Infrastructure (SDI) design is focused mainly on access to and use of land related datasets or marine related datasets, with most SDI initiatives stopping at the land-ward or marine-ward boundary of the coastline, institutionally and/or spatially. Consequently, there is a lack of harmonised and universal access to seamless datasets from marine, coastal and land based spatial data providers. This leads to the creation of inconsistencies in spatial information policies, data creation, data access, and data integration across the coastal zone.

The extension of a National SDI covering the land and marine environments on a seamless platform would facilitate greater access to more interoperable spatial data and information across the land – marine interface enabling a more integrated and holistic approach to management of the coastal zone. A Seamless SDI leads to the promotion of data sharing and communication between organisations thus facilitating better decision-making involving marine and coastal spatial information.

The research strategy is designed in such a way as to meet the objectives of the research, namely:

- Justifying the need for seamless information across the land – marine interface;
- Identification of the characteristics and components for the design of a Seamless SDI model;
- Developing and proposing a Seamless SDI model and associated guidelines using current SDI theory to incorporate identified characteristics and components; and
- Testing of the limitations and problems for combining the marine and terrestrial components in the coastal zone with a particular focus on Australia's marine jurisdictions.

To establish the theoretical background of the research, an extensive literature review has been undertaken. The literature review covers a comprehensive study of drivers for integrating land and marine environments, SDI concepts, components and the salient properties of current SDI initiatives (both land based and marine based and/or straddling

the land – marine interface) within Australia and internationally. This leads to the identification of the commonalities and differences between land and marine based SDI initiatives along with influential treaties and conventions driving the development of the Seamless SDI. The literature review has also informed the research strategy and has been utilised in the case study investigation. In order to achieve a better understanding of the marine and coastal management issues and identifying current impediments to the creation of a Seamless SDI, a case study of Port Phillip Bay which is located in Victoria, Australia has been conducted.

The development of a Seamless SDI model and implementation guidelines has built on the investigation of real life experiences, discussion with practitioners and current theory and practice in regards to SDI developments throughout the world. Defined actions were utilised within each of the SDI components of people, data, access network, standards and policies in order to overcome identified barriers to the creation of a Seamless SDI. By using Hierarchical Spatial Reasoning, the conceptual model of Seamless SDI has been developed and the Seamless SDI class and its inherited characteristics and properties have been discussed. The model proposed addresses the objectives of the research and responds to the problems discussed earlier. Furthermore, the Use Case Diagram and Object Diagram of Seamless SDI have been designed. These diagrams describe the Seamless SDI systematically and its context, users, providers, services and so on, necessary to establish them. These models could be seen as a contribution towards the overall model of the Seamless SDI and its technical characteristics. To test the limitations of this model, the research strategy uses a case study to assist in validating the results.

The case study demonstrated the difficulties of integrating terrestrial, coastal and marine data and the need for a seamless platform across the land – marine interface within the case study area of Port Phillip Bay. The ability of marine and coastal stakeholders in accessing and sharing spatial information relating to all areas especially the coastal zone has been examined. The case study examined the SDI concept at the state and local jurisdictional level, drawing out the current problems and opportunities from the perspective of the main stakeholders responsible for managing Port Phillip Bay.

The results are a SDI model and implementation guidelines that seamlessly covers both land and marine environments and 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 initial needs of stakeholders in the coastal zone. It is particularly in line with the sustainable development (economic, environmental and social) goals 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 land – marine interface.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AFMA	Australian Fisheries Management Authority
AHD	Australian Height Datum
AHS	Australian Hydrographic Service
AMBIS	Australian Marine Boundary Information System
AMSIS	Australian Marine Spatial Information System
ANZLIC	Australia and New Zealand Land Information Council
AODC	Australian Oceanographic Data Centre
AODC JF	Australian Ocean Data Centre Joint Facility
APSDI	Asia-Pacific Spatial Data Infrastructure
ARC	Australian Research Council
ASDD	Australian Spatial Data Directory
ASDI	Australian Spatial Data Infrastructure
CGDI	Canadian Geospatial Data Infrastructure
CHRIS	Committee on Hydrographic Requirements for Information Systems
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CZM	Coastal Zone Management
DFO	Department of Fisheries and Oceans
DoI	Department of Infrastructure
DSE	Department of Sustainability and Environment
EA	Environment Australia
EC	European Commission
ECC	Environment Conservation Council
ECDIS	Electronic Chart Display and Information Systems
EEZ	Exclusive Economic Zone
ENC	Electronic Nautical Chart
EPA	Environment Protection Authority
EU	European Union
EUROGI	European Umbrella Organisation for Geographic Information
ESD	Ecologically Sustainable Development
FAO	United Nations Food and Agriculture Organisation
FGDC	Federal Geographic Data Committee
GA	Geoscience Australia
GSDI	Global Spatial Data Infrastructure
HO	Hydrographic Offices
HWM	High Water Mark
ICT	Information and Communication Technology
ICZM	Integrated Coastal Zone Management
IHB	International Hydrographic Bureau
IHO	International Hydrographic Organisation
INSPIRE	INfrastructure for SPatial InfoRmation in Europe
IOC- IODE	Intergovernmental Oceanographic Commission's Committee on International Oceanographic Data and Information Exchange
IPCC	Intergovernmental Panel on Climate Change
LAT	Local Astronomical Tide
LAS	Land Administration Systems
LWM	Low Water Mark

MLLW	Mean Lower Low Water
MPAs	Marine Protected Areas
MSDI	Marine Spatial Data Infrastructure
MSDIWG	Marine Spatial Data Infrastructure Working Group
MSL	Mean Sea Level
NII	National Information Infrastructure
NOAA	National Oceanic and Atmospheric Administration
NOO	National Oceans Office
NRE	Natural Resources and Environment
NSDI	National Spatial Data Infrastructure
PCGIAP	Permanent Committee on GIS Infrastructure for Asia and the Pacific
PPB	Port Phillip Bay
RRRs	Rights, Restrictions, and Responsibilities
SDI	Spatial Data Infrastructure
SDS-SEA	Sustainable Development Strategy for the Seas of East Asia
SFR	Statutory Fishing Rights
SOA	Service Oriented Architecture
SOLAS	Safety of Life At Sea
TSB	Territorial Sea Baseline
UML	Unified Modelling Language
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNRCC-AP	United Nations Regional Cartographic Conference for Asia and the Pacific
VCC	Victorian Coastal Council
VSDD	Victorian Spatial Data Directory
WFD	Water Framework Directive
WWW	World Wide Web
XML	Extensible Markup Language

CHAPTER 1

INTRODUCTION

1.1 Research Background

The land – marine interface is one of the most complex areas of management in the world consisting of both the land and marine environments. Humanity is increasingly gravitating towards the coasts. The population along the coastline is continuously increasing and has done so dramatically in the past decade. Coastal zones are now the most important area in terms of human population growth and sustainable development, and their significance will only increase. According to the UN Atlas of Oceans almost half of the world's cities with more than one million people are sited in and around washed river mouths and estuaries (United Nations 2004). The more people that crowd into coastal areas, the more pressure they impose both on land and sea.

Many nations are economically, politically and socially dependant on the coastal zone. Coasts are used by millions of people for recreation. Major transport hubs are situated in or near the coastal zone where ports and harbours are vital to commerce and trade. This narrow band of land and sea occupies only 20% of the world's land area. Half the world's population, some three billion people, lives within 200 km. of the coast, and it is estimated that by 2025, this figure may double (FIG 2006). Our cities use some 75% of the world's resources and discharge similar amounts of waste (Greenland and Van der

Molen 2006). It is hardly surprising then that these marine and coastal spaces are under serious threat from a myriad of overlapping and conflicting interests. There is a complex relationship and interaction between overlapping, and sometimes competing rights, restrictions and responsibilities of various stakeholders, both in the marine environment and at the land – marine interface. This is made more complicated by a deficiency in the availability of reliable and accurate spatial data for the marine and coastal environments and a lack of coordination in management of their resources (Binns 2004; Strain et al. 2006). There are increasingly serious signs that the economic uses of our coastal resources are undermining their long term sustainability. The evidence of change is compelling and manifest. This has brought with it an increased need to more effectively and efficiently manage marine and coastal environments to meet the economic, environmental, and social goals of sustainable development. This idea is reflected in the number of global and regional initiatives that aim to improve marine and coastal management such as the Sustainable Development Strategy for the Seas of East Asia (SDS-SEA), Integrated Coastal Zone Management (ICZM) and the 3rd United Nations Convention on the Law of the Sea (UNCLOS). In this respect, Coastal Zone Management (CZM) initiatives are turning to more integrated strategies worldwide, attempting to harmonise economic, environmental, and social 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. ICZM recognises that the coastal resources management situation is unique; that is, it differs greatly from management of either land or marine resources, being a combination of both (Bartlett et al. 2004).

In spite of this situation, current marine and coastal zone management systems are neither effective nor sustainable (Thia-Eng et al. 2003; Neely et al. 1998; Binns 2004). It is now being recognised that the information required to balance competing interests over the coastal zone have an inherent spatial dimension (Williamson et al. 2004; Rajabifard et al. 2005a). Effective governance and administration is underpinned by the need for access to spatial information (Ting and Williamson 2000; Barry et al. 2003). The importance of the spatial dimension in administering marine environments was recognised by International Federation of Surveyors (FIG) Commissions 4 and 7 (FIG 2006). Spatial information aids decision making by providing a spatial/geographic context to planning, management and resource allocation and is increasingly recognised as essential to emergency response. It enables a better understanding of an area and thus better management (Binns et al. 2005).

In response to the need for integrated spatial information 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, regional and global. SDI creates an environment that will enable users to access and retrieve complete and consistent spatial datasets in an easy and secure way. A similar facility is needed for marine management. The concepts of Marine SDI (MSDI), 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 (Strain et al. 2006). Tools such as marine cadastre can provide a means for delineating, managing and administering legally definable off-shore boundaries. It can manage ownership and work activities (Binns 2004). Nevertheless, the marine environment requires an overarching spatial information platform that facilitates coordinated use and administration of these tools.

Most current SDI initiatives direct their attention land-ward or marine-ward with limited or no consideration of coastal SDI. 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 (Longhorn 2003; Gillespie et al. 2000). To achieve the required sharing and integration of coastal databases across regions and disciplines, and with marine and land based spatial data, there is a growing and urgent need for the extension of existing SDIs to fully encompass the information needs of all coastal zone stakeholders. This SDI should deliver a seamless model that creates a spatially enabled land – marine interface and bridges the gap between the marine and terrestrial environments to more effectively meet sustainable development goals. Ideally, this would result in harmonised and universal access, sharing, and integration of marine, coastal and land based spatial datasets across regions and disciplines.

To improve management of the coastal zone, there needs to be access and interoperability of both marine and land based spatial data (Longhorn 2003; Bartlett et al. 2004). However, the differences in the marine and terrestrial environments in terms of fundamental datasets; data collection and technology used in these environments will make interoperability and integration between marine and land based spatial data a challenge. Research and further work now needs to focus on combining these initiatives and developing a seamless platform to be able to model, monitor and manage both marine and land environments, particularly the land – marine interface. A seamless infrastructure was recognised at the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP) Workshop for Administering the Marine Environment held in Malaysia in 2004. It has been endorsed by the United Nations (UN) through a resolution passed at the 17th United Nations Regional Cartographic Conference for Asia and the Pacific (UNRCC-AP) meeting in Bangkok in 2006. A resolution that aimed to define the spatial dimension of the marine environment was passed, defining the terms marine cadastre and MSDI within the context of marine administration. It was recommended that a marine cadastre operate as a management tool within a MSDI as an extension to National SDIs across Asia and the Pacific. The UN meeting recommended that countries with an extensive marine jurisdiction and administrative responsibilities be encouraged to develop a marine administration component as part of a Seamless SDI covering both land and marine jurisdictions to ensure a continuum across the coastal zone (UNRCC-AP 2006). International organisations, including the International Hydrographic Organisation (IHO) are becoming increasingly involved. IHO is working on a strategy to implement a Marine SDI to better manage global marine activities. In November 2005, IHO organised and conducted a seminar on "The Role of Hydrographic Services with regard to Geospatial Data and Planning Infrastructure". This seminar formally recognised an option for Hydrographic Offices (HO) to become responsible or partner in National MSDI and the possible connection of MSDI to the National SDI (IHO 2005). With this in mind the aim of this research 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.

1.2 Research Problem

With climate change, rising sea levels and the need to manage our resources more carefully in this dynamic environment, the inability to integrate marine and land based spatial information is a problem in many countries. Without spatial data, sustainable development of the coastal zone is difficult, if not impossible. The absence of a seamless spatial information framework prevents the execution of standard practice of locating and referencing spatial information across the land – marine interface where so much pressure and development is taking place. This also inhibits the access and sharing of spatial information. It leads to data duplication which often results in a proliferation of discrete data collection projects, which can lead to substantial investments (EuroSDR and IHO 2007).

The research problem is that current SDI design is focused mainly on access to and use of land related datasets or marine related datasets, with most SDI initiatives stopping at the land-ward or marine-ward boundary of the coastline, institutionally and/or spatially. Consequently, there is a lack of harmonised and universal access to seamless datasets across the land – marine interface from marine, coastal and land based spatial data providers. This leads to the creation of inconsistencies in spatial information policies, data creation, data access, and data integration across the coastal zone that limits sustainable management and development of the coastal zone.

1.3 Hypothesis

The development of a seamless platform covering the land and marine environments as part of the National SDI would facilitate greater access to more interoperable spatial data and information across the land – marine interface enabling a more integrated and holistic approach to management of the coastal zone.

1.4 Research Aim

The aim of this research is to design, develop and test a Seamless SDI model that integrates marine, coastal and land based spatial information.

1.5 Research Objective

As a result of the identified research problem and the aim of the research, the research objectives are:

1) Investigate and justify the need for seamless information across the land – marine interface in support of better management of the coastal zone;
2) Investigate and understand current land and marine SDI initiatives and concepts at both national and international levels;
3) Investigate the characteristics and components for the design of a Seamless SDI model;

4) Develop and propose a Seamless SDI model and associated guidelines using current SDI theory and models to incorporate identified characteristics and components; and
5) Test the limitations of developing a Seamless SDI with a particular focus on Australia's marine jurisdictions.

1.6 Research Approach

The proposed research design and stages to investigate the problem and hypothesis proposed in this research are incorporated into four major steps of: literature review; Seamless SDI design; model development and implementation guidelines; and testing and analysis of the Seamless SDI by using case study investigations. The research design is illustrated in Figure 1.1.

To establish the theoretical background of the research, an extensive literature review has been undertaken. Initial investigations of the first four objectives required a comprehensive study of drivers for integrating land and marine environments, SDI concepts, components and the salient properties of current SDI initiatives (both land based and marine based and/or straddling the land – marine interface) within Australia and internationally. This leads to the identification of the commonalities and differences between land and marine based SDI initiatives along with influential treaties and conventions driving the development of Seamless SDI. Books, journals, organisation reports, conference proceedings, visits and information published over the World Wide Web (WWW) were used to collate a range of information for literature reviews. The literature reviews provide the basis for the development of the research strategy and highlight the significant issues that must be taken into consideration through developing the model.

The literature reviews highlight marine and coastal management issues together with current inefficiencies in the ability to create and access spatial data relating to the marine and coastal environments. An investigation into the concepts and components of marine and coastal SDIs at both national and international levels has also been undertaken, within the context of identifying barriers/challenges to the creation of a Seamless SDI. This includes an assessment of the attributes and underlying infrastructure of various extensions of off-shore initiatives, their comparative strengths and weaknesses, their success or failure or even how the approaches taken in each project or initiative compare or differ from the others in terms of contents and effectiveness. This led to the identification of opportunities and barriers for combining land and marine components of SDIs.

During literature investigations a reconnaissance trip to Tasmania and Monte Carlo in order to visit a number of hydrographic, mapping and research agencies such as IHO, Land Information System of Tasmania (LIST) and Commonwealth Scientific and Industrial Research Organisation (CSIRO) substantiated and highlighted issues uncovered in the reviews. This provided real issues faced by both hydrographic and national mapping agencies in respect to create, access, sharing, and integration of marine, coastal and land based spatial datasets. The literature reviews and reconnaissance visits provided a background for defining the issues and challenges associated with developing an overarching architecture for a Seamless SDI which allows access to and interoperability of data from marine, coastal and land environments. These included the technical, institutional and policy issues such as the use of differing standards in the two environments, governance arrangements, institutional considerations, technical specifications (2D, 3D and 4D nature of data), reference datums, interoperability etc.

The development of a Seamless SDI model and implementation guidelines have been built on the investigation of real life experiences, discussion with practitioners and current theory and practice in regards to SDI developments throughout the world. Defined actions created within each of the SDI components which are people, data, access network, standards and policies were utilised in order to overcome identified barriers regarding the creation of a Seamless SDI. Based on the Hierarchical Spatial Reasoning and Object Oriented Modelling method, the Seamless SDI conceptual model has been proposed. It uses the Unified Modelling Language (UML) approach. The model proposed addresses the objectives of the research and responds to the problems discussed earlier in this chapter.

Using the theoretical background from the literature review and reconnaissance visits, a case study of Port Phillip Bay was designed. This is located in Victoria and is one of the busiest ports in south - eastern of Australia. Most SDI research to this point has been conducted at a national level, with small scale data; however the coastal and near-shore environments, which are usually under state or local government management, are more complex with more intense data use and conflicting activities. The ability of marine and coastal stakeholders in accessing and sharing spatial information relating to all areas especially the coastal zone has been examined. The common limitations and problems facing each of the stakeholders in the development of Seamless SDI have been tested. This testing supports the findings regarding barriers against implementation of the Seamless SDI model.

The thesis hypothesis and designed Seamless SDI model were also tested and revised through conference presentations and discussions with experts and also related research which had previously been conducted in the Department of Geomatics at The University of Melbourne.

The result is a SDI model and implementation guidelines that seamlessly covers both land and marine environments and 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 initial needs of stakeholders in the coastal zone in particular in line with the sustainable development (economic, environmental and social) goals of the region. The development of a seamless enabling platform provides more efficient and effective decision-making capabilities across both the marine environment and land – marine interface.

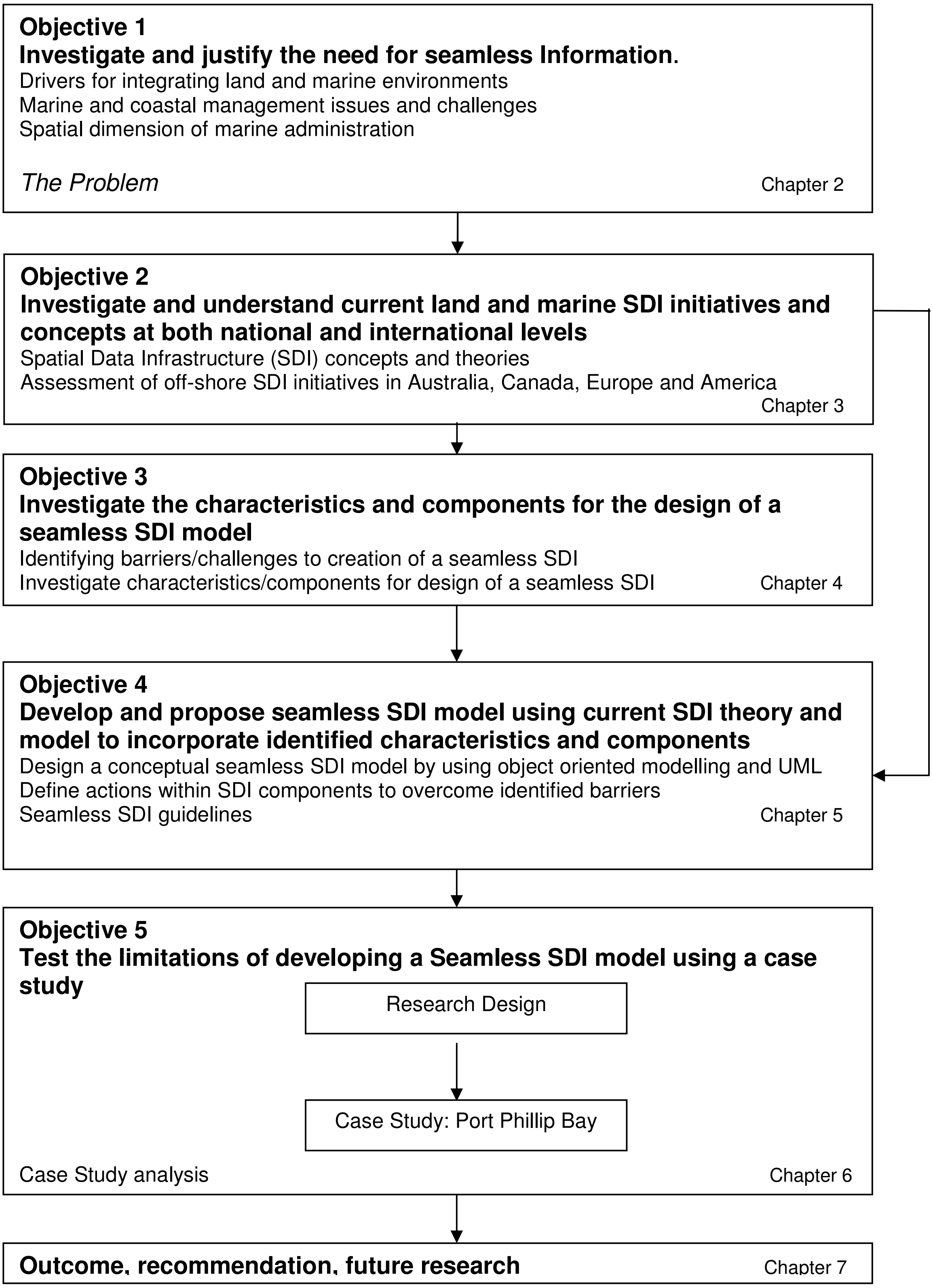

Figure 1.1 Research design relative to objectives

1.7 Case Study of Port Phillip Bay

The research design is described in Section 6.2 in detail. The scientific method is used to design experiments to answer the research objectives. The answers to each of the research objectives are presented in Chapters 2, 3, 4 and 5. However, the answer to objective 5 is tested and checked through the case study analysis. The implementation of a case study as part of the overall project enables theoretical ideas and concepts to be tested and evaluated.

The selection of the case study area was based upon a number of criteria. Firstly, the jurisdiction needed to have a coastal and marine environment. Secondly, the jurisdiction needed to have a defined management framework. Thirdly, it needed to represent a heavily used and heavily populated coastal and marine environment. Finally, the jurisdiction needed to be accessible to the researcher.

Most SDI research to this point has been conducted at a National level, with small scale data, however the coastal and near-shore environments, which are under state government management, are more complex with more intense data use and conflicting activities. Therefore, this research used a larger scale case study area of Port Phillip Bay (PPB), which is located in Victoria, and is one of the busiest ports in Australia.

This case study was used to complete the assessment of the limitations of developing a Seamless SDI with a particular focus on Australia's marine jurisdictions through examining Marine SDI as a state/ local level. The case study relies on knowledge of who is responsible for managing PPB, and collecting all available spatial data from these organisations for PPB.

In the context of this thesis, the major objectives of the case study are:

1) Identification of governing bodies and relevant legislation operating over the PPB case study area;

2) Investigation of the current management framework of PPB including manager, regulator, planner, stakeholders and users of spatial data over the area;

3) Examining availability, accessibility and interoperability of spatial data within PPB through collecting all available data;

4) Justification of the need for seamless information across the land – marine interface by integrating all available datasets.

5) Identification of the current use, access and sharing of spatial data in PPB from the perspective of the selected stakeholders responsible for managing this area; and

6) Examining common problems and limitations in use, access and sharing of spatial data from the interviewed stakeholders' point of view.

In order to meet these objectives the case study involved three parts. These were:

Part 1 – Assessing Port Phillip Bay management and planning framework;
Part 2 – Analysing/ examining available spatial data about PPB;
Part 3 – Interviewing relevant stakeholders of PPB about sharing and use of spatial data;

The first part of the case study demonstrated the complexity of the management framework and the stakeholders' involvement from the land, coastal and marine environments. Further, the second part investigated availability, accessibility and interoperability of spatial data within PPB through collecting all available data. Lastly, the third part of the case study examined the current use, access and sharing of spatial data from the perspective of the selected stakeholders responsible for managing this area. The interview questions covered the use, management and sharing of spatial data. The results were verified using related research that had previously been conducted in the Department of Geomatics at The University of Melbourne. This research is used as it also targeted responses from a similar range of stakeholders in Victoria and also at a National level and thus can confirm the reliability of the case study results.

1.8 Thesis Structure and Summary

Chapter 2, *Marine and Coastal Management – The need for Seamless Information,* starts with justification of the need for seamless information across the land – marine interface.

It describes marine and coastal management issues with the primary focus of this chapter being Australia's coastal and marine jurisdiction. It follows the societal, commercial and technological drivers for integrating land and marine environments. It reveals the need for spatial information to support marine and coastal administration through the presentation of integrated coastal zone management initiatives.

Chapter 3, *Spatial Data Infrastructures*, gives a background introduction into SDI. The concept, nature, and components of SDI are discussed in general and specifically within the Australian SDI (ASDI). This chapter also reviews current developments and implementation of Marine SDIs in Australia, Canada, Europe and US. It uses examples of various off-shore SDI initiatives at both national and international levels, to explore the concept.

Chapter 4, *Seamless SDI – The Characteristics and Components*, Seamless SDI initially highlights the issues raised from the case study area and literature review to justify the objectives and hypothesis proposed for this research. It starts with a Seamless SDI definition and concept and then addresses treaties and resolutions worldwide which influence the development of Seamless SDI. Further to this, barriers/challenges to the creation of a Seamless SDI are identified. Chapter 4 concludes by describing the characteristics and components for design of a Seamless SDI. This helps to develop a Seamless SDI model along with the introduction of its critical issues and components.

Chapter 5, *Design Seamless SDI Model*, develops a Seamless SDI conceptual model and implementation guidelines to address the hypothesis stated earlier in this chapter. It uses Chapters 3 and 4 to present a pathway through the research. The barriers identified in Chapter 4 are overcome with the solutions offered in Chapter 5 within the context of Seamless SDI guidelines. It starts with the introduction of UML and object oriented modelling followed by presenting a Seamless SDI conceptual model, Use Case Diagram, Object Diagram and governance model. To test and improve the proposed model, the research strategy uses a case study approach to assist in refining and validating the results.

Chapter 6, *Research Design and Case Study*, focuses on the case study area of Port Phillip Bay, and examines the applicability of a Seamless SDI within this environment. This chapter includes the methodology for analysis and strategy development for the case study site. Chapter 6 examines the Seamless SDI concept at the state and local jurisdictional level, drawing out the current problems and opportunities from the perspective of the main stakeholders responsible for managing Port Phillip Bay.

Chapter 7, *Conclusion and Recommendations*, discusses and summarises the overall research findings and development of the final model based on the analysis of case study. Possible future research and key recommendations are then discussed in Chapter 7.

This chapter has laid the foundations for the research and introduced the problem, aim and objectives of the research. The problem statement shows current SDI design is focused mainly on access to and use of land related datasets or marine related datasets, with most SDI initiatives stopping at the land-ward or marine-ward boundary of the coastline, institutionally and/or spatially. However, the interests of a nation do not stop at the land – marine interface. They continue into the marine environment. It then argued that this leads to the creation of inconsistencies in spatial information policies, data creation, data access, and data integration across the coastal zone. Therefore, the responsibilities and opportunities of governments to provide infrastructure for land and resource management extend to marine areas. This has brought with it an increased need to more effectively and efficiently manage marine resources to meet the economic, environmental, and social goals of sustainable development.

To respond to the problem statement, the research set out five objectives: firstly, justification of the need for seamless information; secondly, learning from global land and marine SDI initiatives; thirdly, investigating characteristics of Seamless SDI model and associated components; fourthly, proposing an answer to the research problem by developing a Seamless SDI model; and finally, testing the barriers against implementation of this model. The research approach was designed and described based on the five objectives. The research was presented using the thesis structure in seven chapters (Figure 1.2).

The next chapter provides a background to marine and coastal management issues and challenges within the context of justification of the need for seamless information across the land – marine interface.

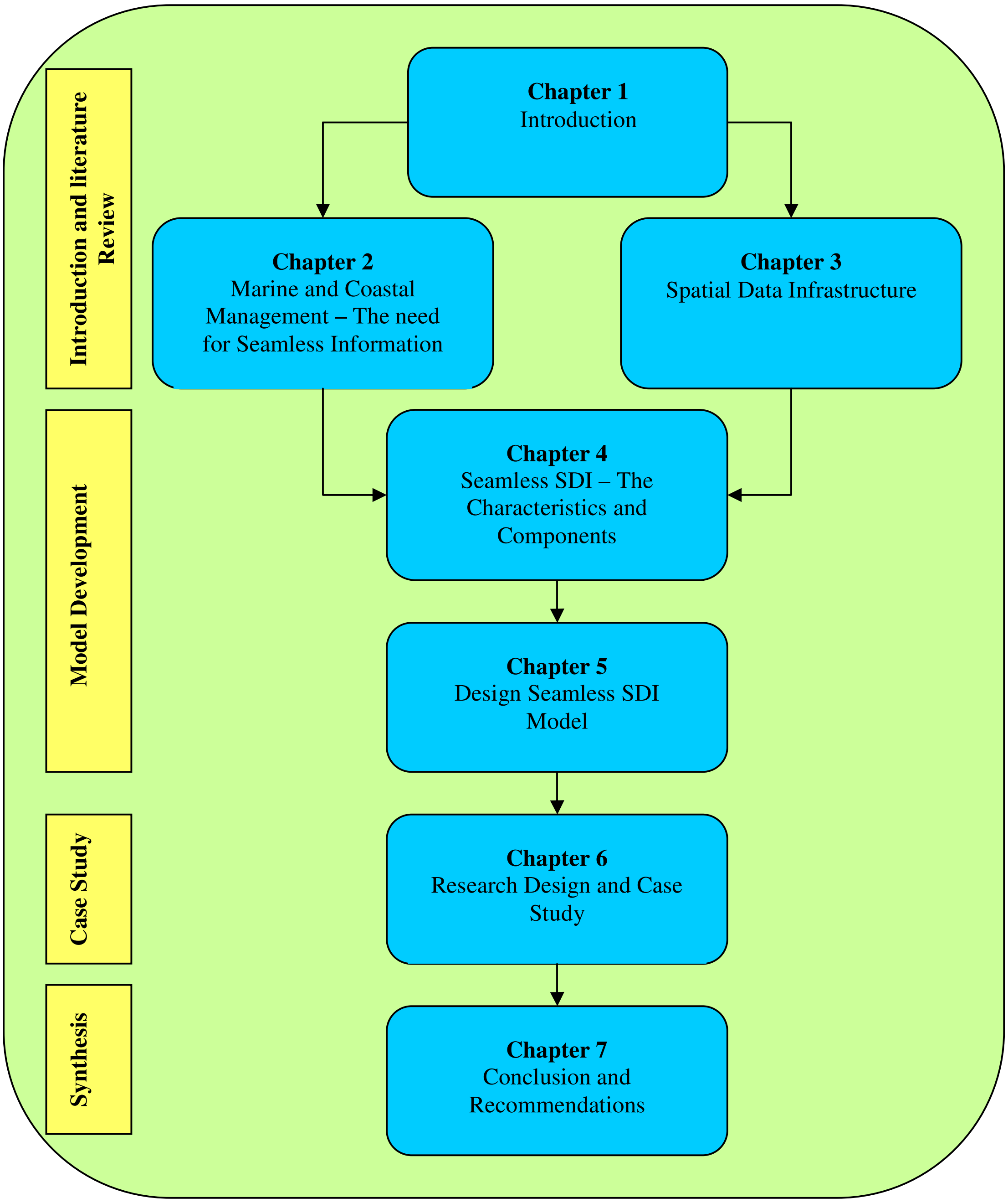

Figure 1.2 Thesis structure

CHAPTER 2

MARINE AND COASTAL MANAGEMENT - THE NEED FOR SEAMLESS INFORMATION

2.1 Introduction

This chapter aims to identify and clarify current marine and coastal management issues and their potential impacts which currently coastal and marine stakeholders are struggling with at the global level. However, the primary focus of this chapter is Australia's coastal and marine jurisdiction. It examines the management and administration of rights, restrictions and responsibilities in Australia's coastal and marine environments and discusses how the ability to map and spatially define such issues would be an essential component for a more efficient and effective management regime, balancing the rights and responsibilities of multiple users. These lead to the justification of the need for seamless information across land – marine interface. It then discusses marine administration systems and highlights the fact that diversity of marine environments requires effective economic, social, and environmental management that is just as comprehensive as land management. It is followed by an introduction to Integrated Coastal Zone Management (ICZM) initiatives to improve marine and coastal zone management similar to the better developed land use management frameworks of many urban areas attempting to harmonise economic, environmental, and social goals of sustainable development. Lastly this chapter discusses drivers for integration of land and marine environments and categorises them to societal, commercial and technological drivers.

2.2 Marine and Coastal Management Issues

Humanity has always had a close relationship with marine and coastal environments. The coastal zone is a complex area, consisting of both the marine and terrestrial environments. It is also home to an increasing number of activities, rights and interests. Many nations are economically, politically and socially dependant on the coastal zone. It is a resource provider and gateway to the worlds' oceans upon which humans rely for food, raw materials, climate regulation, transportation, disposal of waste and recreation. The coastal environment is one of constant change, with many natural pressures such as wind, waves, currents, tides, etc. creating a change in topography. 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 necessary to its continued vitality. It has been suggested that "the coastal zone is not a narrow band. It is the whole country" (U.S. Commission on Ocean Policy 2002).

Despite its overwhelming importance to society, the coastal zone is a difficult geographical area to manage due to temporal issues (tides and seasons) and the overlapping of off-shore, near-shore, shoreline and in-shore physical geography, hydrography and bathymetry, as well as jurisdictional and organisational overlaps with many competing and overlapping rights, restrictions and responsibilities (Longhorn 2004). Typically, many different local, national and regional government agencies are responsible for different aspects of the same physical areas and different uses of the coastal zone, e.g. fisheries, environment, agriculture, transport (inland and marine), urban planning and cadastre, national mapping and hydrography.

However, there is still a lack of understanding of the coastal environment. While land management systems deal with an environment that changes with timescales of thousands of years, in comparison, the marine environment is highly dynamic with processes such as tides, shoreline erosion and accretion needing much smaller timescales. The marine environment is also fluid and thus natural resources or features are more likely to move with time. These difficulties compound in the coastal zone as it is both the on and off-shore environments combined and interrelated.

Based on literature reviews, major marine and coastal management issues which marine and coastal stakeholders are struggling with have been identified. Examples of such issues are listed below:

- Rapid coastal population growth;
- Global warming;
- Shoreline erosion, accretion and sea-level rise;
- Overfishing (commercial and recreational);
- Extensive extraction of oil, gas and minerals;
- Loss of habitat and coastal wetlands;
- Lack of suitable sites for aquaculture;
- Protecting marine species;
- Indigenous resource management issues;
- Protecting marine heritage; and
- Marine defence and security.

Of major concern in these issues is global warming and the resulting sea-level rise and shoreline movement during this century. The following subsections focus on the issues listed with the particular focus on Australia's marine and coastal management regimes. These issues and their potential impacts (Figure 2.1) are forcing coastal states and localities to resolve how best to cope with them.

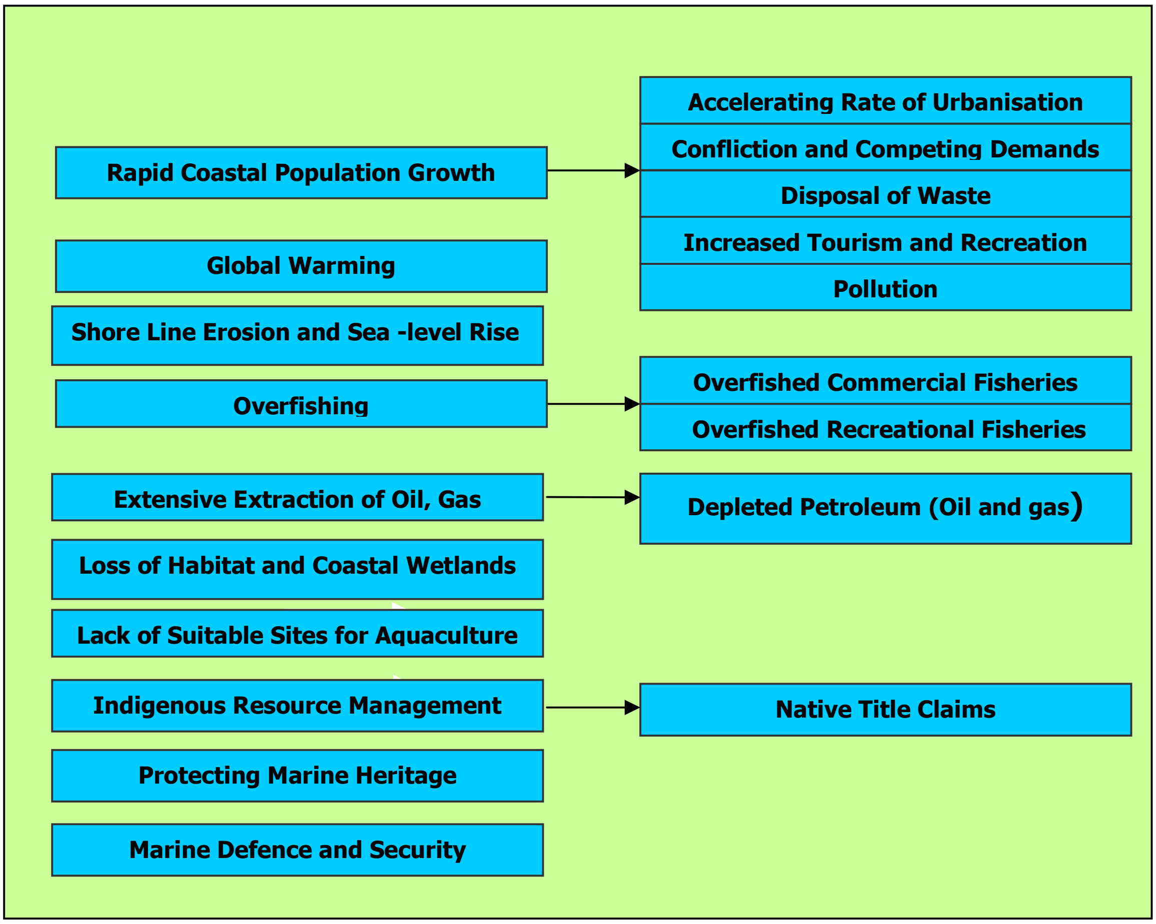

Figure 2.1 Marine and coastal management issues and some of their potential impacts

2.2.1 Rapid coastal population growth

Coastal regions are the most attractive places to live, both in terms of economics and aesthetics. Historically, cities have been located on coastlines because there are many transport, recreation, food and ecological benefits. Largely for transportation reasons, major industrial and commercial centres developed around port cities. The resources of the coastal zone provide numerous job opportunities, and many people come to the coast for recreation. This has set a precedence for populations to naturally migrate towards coastal areas. Eight of the top ten largest cities in the world (Tokyo, Mumbai, New York City, Shanghai, Lagos, Los Angeles, Calcutta and Buenos Aires) are located by the coast (United Nations 2006).

Humanity is increasingly gravitating towards the coasts. While this narrow band of land and sea occupies only 20% of the world's land area, half the world's population, some three billion people, lives within 200 km. of it, and it is estimated that by 2025, this figure may double (Greenland and Van der Molen 2006). According to the map showing projected population change for the year 2025 and developed by scientists at the Center for Climate Systems Research (CCSR) of the Earth Institute at the Columbia University, and Population Action International, the number of people living within 100 km. of coastlines is expected to increase by about 35% over 1995 population levels (Population Action International 2006). It is exposing 2.75 billion people to coastal threats from global warming such as sea-level rise and stronger hurricanes in addition to other natural disasters like tsunamis (Figure 2.2).

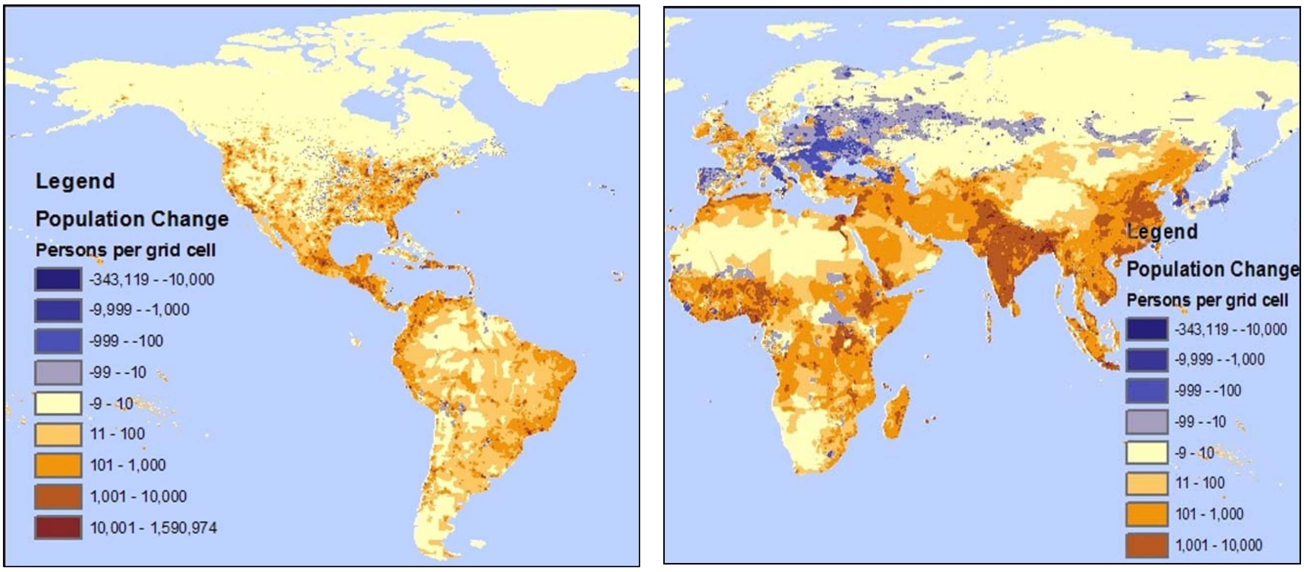

Figure 2.2 Map shows an increasing population in coastal areas, which will expose 2.75 billion people worldwide to the effects of sea-level rise and other coastal threats posed by global warming (Population Action International 2006).

One example of this incredible population growth could be Australia. Australia's population is projected to reach 35 million by 2049 (Swan 2009). Around, 85% of Australians live within 50 km. of the coast, and all state capitals are on the coast and they experienced population growth in 2008. The greatest growth occurred in Queensland, followed by Victoria, then New South Wales (Commonwealth of Australia 2009). Since European settlement, most Australians have congregated along the thin strip of the coastline. Only a small proportion have inhabited the sparse inland. The proportion of the population living in the country has declined since World War II and will probably continue to do so (Salt 2003). Outside capital cities, the largest population growth in 2007–08 generally occurred along the Australian coast (ABS 2008). 75% of Australia's non-metropolitan population is living in coastal areas (Berwick 2008). Australia has become a coastal society. In the United States, around 53% of the population lives near the coast and since 1970 there have been 2000 homes per day erected in coastal areas. In China alone, where the urban population is expected to increase by over 125% in the next twenty five years, over 400 million live on the coast (United Nations 2006). The rate of population growth in coastal areas is accelerating and increasing tourism adds to the pressure on the environment.

Demographic trends suggest that coastal areas around the world are undergoing serious population growth pressures. The more people that crowd into coastal areas, the more pressure they impose both on land and sea. Natural land-scapes and habitats are altered, overwhelmed and destroyed to accommodate them. Lagoons and coastal waters are reclaimed, wetlands are drained and covered with rubbish, the floodplains around estuaries are built over and reduced, and mangroves and other forests are cut down. Ecosystems are damaged, frequently lost forever. Fish stocks, fresh water, soils , the great wealth of coastal areas, whether in terms of fishing, tourism, international trade, or natural resources, is what attracts these abundant populations, making them the seeds of its own destruction.

Population growth is the driver behind many, if not most, coastal problems. 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. The following subsections look into the potential impacts resulting from coastal population growth. These are accelerating rate of urbanisation, conflict and competing demands, disposal of waste, increased tourism and recreational activities and pollution.

a) Accelerating rate of urbanisation

The clearest result of population growth in the coastal zone is the accelerating rate of urbanisation. By the year 2025 more people are projected to live in cities than occupied the whole world in 1985. Results from the Pilot Analysis of Global Ecosystems (PAGE) show that urbanisation have extensively altered coastal ecosystems worldwide. Nearly 30% of the land area in the world's coastal ecosystems had already been extensively altered or destroyed by growing demand for housing, industry, and recreation. 19% of all lands within 100 km. of the coast (excluding Antarctica and water bodies) are classified as altered, meaning they are in agricultural or urban uses; 10 % are semialtered, involving a mosaic of natural and altered vegetation; and 71% fall within the least modified category. A large percentage of this least modified category includes many uninhabited areas in northern latitudes (PAGE 2000). High population density correlates with urban areas, which is classified as altered lands. The most uninhabited areas, as is expected, are in northern latitudes, where much of the natural land cover remains. As human population increases in coastal areas, so does pressure on coastal ecosystems through habitat conversion, increased pollution, and demand for coastal resources.

Many specific resource allocation and planning issues are raised by the urbanisation debate: urban residential densities, the development of high rise buildings and public versus private access to beaches and foreshores are among the more prominent. More of the narrow strip of land along the world's coasts and its habitats has been ruined by poorly planned and badly regulated activities, from the explosive growth of coastal cities and towns to the increase in tourism and from industrialisation to the expansion of fish farming. The pressures are particularly exacerbated along the coasts of many developing countries, where rapid population growth combines with persistent poverty, and there is little capacity to manage the situation. But developed countries' coastlines are often overdeveloped too, as people and businesses demand foreshores properties (GESAMP 2001).

There is a need for effective planning controls to be put in place in urban and coastal regions, so that the effect of urbanisation can be managed. The ability of coastal planners to map and spatially define such issues would be an essential component for more efficient and effective management regime. They need to know:

- Where sensitive ecosystems spatially are;
- Statistical information relating to population movement so that they can predict where to regulate;
- Planning control information (both actual information on what planning controls there are, and also spatially where the controls are in place);

- Jurisdictional information on who controls what areas so that effective controls can be put in place – e.g. who controls the foreshore, local council boundaries, etc.

b) Conflict and competing demands

As the interface between marine and terrestrial environments, coasts have diverse and ever increasing conflicting pressures and demands requiring effective administration and management. If population and development continues to increase at current alarming rate, conflict and competing demands will enhance. Larger populations tend to have proportionally higher demands on their surrounding environment than smaller settlements. When more people are using a limited resource, the carrying capacity of the region can sometimes be exceeded. This in turn impacts on the visual land-scape, and creates increased pressure on coastal resources and the use of facilities such as transport, landfill and sewerage (Lockie and Rockloff 2005).

There is a complex relationship and interaction among overlapping and sometimes competing Rights, Restrictions, and Responsibilities (RRRs) across various activities, both in the marine environment and at the land – marine interface. There are also a large number of stakeholders with rights, interests, or responsibilities for management in the coastal zone. The complex and dynamic nature of these rights which regularly overlap, creating the need for interaction between a wide range of stakeholders and activities. The task of efficiently and effectively managing all stakeholders is complicated by the fact that their rights can often overlap, creating competing RRRs. This gives rise to the need for cooperation between agencies, something which can be difficult to achieve.

As a result of investigation and assessment of marine and coastal spatial data in case study of Port Phillip Bay (PPB) which is located in south – eastern of Australia, one of the highlighted coastal management issues is overlapping coastal interests. Many different activities take place within the bay, for example: shipping, fishing, aquaculture, conservation, recreation and tourism. The PPB's coastal zone has spatially overlapping rights, restrictions, and responsibilities for many stakeholders. As shown in Figure 2.3 exploitation of off-shore oil and gas near Point Wilson could detrimentally impact Ramsar Wetlands or bioregions. Therefore, the complex regime of geographically overlapping interests and activities, which are managed in a task-specific manner, results in redundant effort, inefficiency, ineffectiveness and a lack of coordination amongst different agencies responsible for managing the land – marine interface.

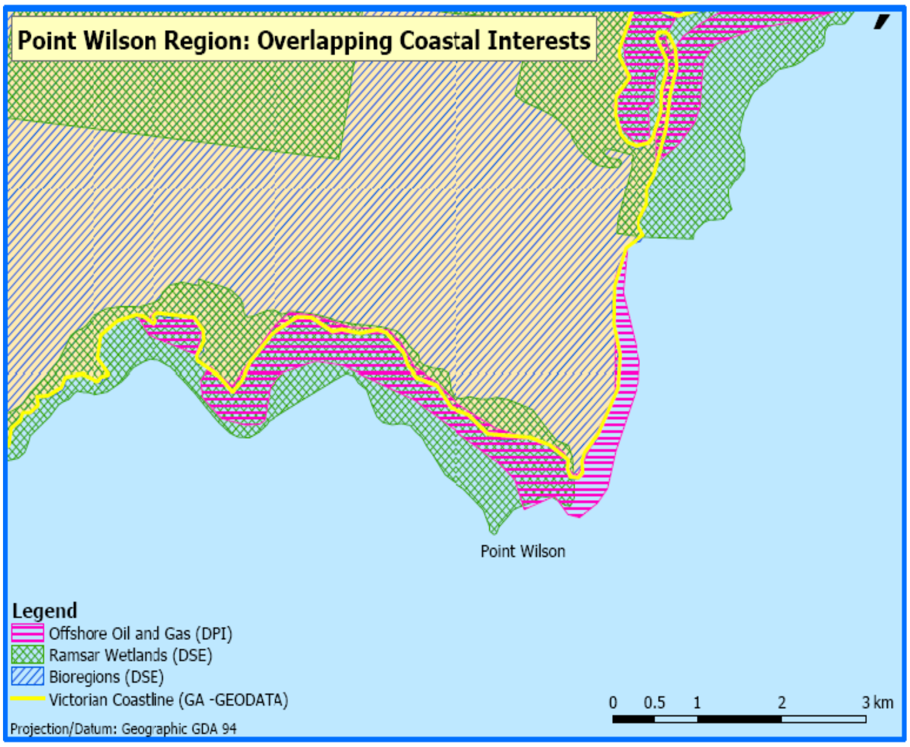

Figure 2.3 Overlapping coastal interests in Point Wilson region

In coastal areas, 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. This is made more complicated by a deficiency in the availability of reliable and accurate spatial data for the marine and coastal environments and a lack of coordination in management of their resources (Binns 2004; Strain et al. 2006). There is a need for a common platform to enable the different stakeholders involved in the administration of overlapping interests' concurrent access to seamless spatial information including land and marine information and to demonstrate the effect; decisions may have on other interests.

c) Disposal of waste

Dumping at sea has been a common practice as it was perceived to minimise the impacts of land-based waste disposal on population centres in a time when there was not much awareness of potential environmental impacts. Additionally, waste disposal at sea may have also been a cheaper and less regulated alternative to land-based waste management. Humans have been using the oceans and the coastal zone as dumping grounds for years, hoping the capacity of the ecosystem will take care of the problem (Beatley et al. 1994). Population growth pressure exerted on the coastal region also involves the disposal of waste. Human society is now using resources and producing wastes at rates that are not sustainable.

Ocean waste disposal is considered to derive from two main sources: land-based sources and dumping at sea. The waste itself is increasingly getting into the sea, either by accident or design. Garbage is often dumped on important habitats, like wetlands and mangroves; they are destroyed, and contaminants leach from the rubbish into coastal waters. It can cause eutrophication and endanger public health. Ocean disposal encompasses the dumping of a myriad of society's waste at sea. For an instance, types of materials dumped in Australia's waters include (EA 2001a):

- Ammunition;
- Dredge spoils;
- Chemical and industrial waste;
- Obsolete equipment including boats;
- Materials for artificial reefs;
- Food scraps; and
- Treated water.

In the case of Australia, 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. At least 41 waste disposal facilities are located within 200 metres of the coastline (Commonwealth of Australia 2009). Land use and storm water systems influence the nutrient load of rivers as well as the turbidity and sedimentation in coastal environments (Plunkett 2001). Australia currently regulates the deliberate loading, dumping and incineration of waste at sea under the *Environment Protection (Sea Dumping) Act 1981* and the *Environment Protection (Sea Dumping)*

Amendment Act 1986. A permit must be granted from Environment Australia (EA) for all sea dumping, with about 30 permits a year currently being issued for dumping in Australian Commonwealth waters (EA 2003). State governments have permitted an unknown number of disposals within coastal waters of state jurisdiction. Under the Acts, Australian waters include those waters from the low water mark out to the 200 nautical mile limit of the Exclusive Economic Zone (EEZ), excluding seas within the limits of a State or the Northern Territory (e.g. gulfs in South Australia, Port Phillip Bay, Darwin Harbour and Sydney Harbour). States can legislate to control sea dumping in their adjacent three nautical miles of sea if the legislation conforms to Federal law and the London Convention 1972. This is a consequence of the 1979 Offshore Constitutional Settlement, an agreement between the Federal Government and State Governments allowing the States full sovereignty over the first three nautical miles from their coast. The Commonwealth Act does not apply to dumping in waters within the limits of a State such as bays, gulfs and rivers (NOO 2002a).

Unlike the past, however, current sea disposal is highly regulated, especially with respect to potential environmental impacts. The ability to successfully manage waste and dump sites needs careful spatial planning in order to avoid unnecessary disturbance or disruption of waste within the marine environment. Such management also needs spatial location of other activities such as shipping routes and the location of marine parks, enabling permits to be granted for the most appropriate areas. This will minimise disturbance to other marine stakeholders as well as the marine ecosystem as a whole. There is still the need for seamless spatial information to facilitate the management of the whole environment. As an example Figure 2.4 illustrates numerous sea dumping sites within Port Phillip Bay case study area.

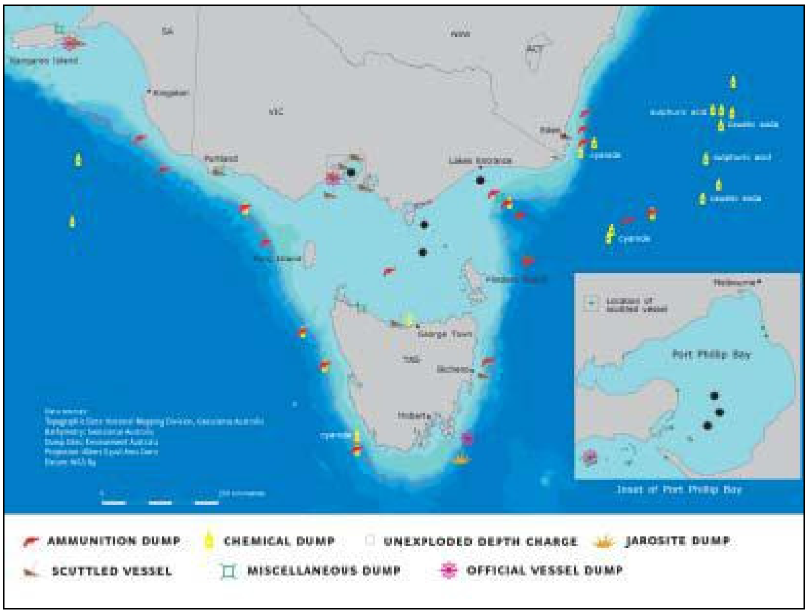

Figure 2.4 Sea dumping sites within Port Phillip Bay - Victoria, Australia (NOO 2002d)

d) Increased tourism and recreational activities

In more recent decades uses of the coastline have shifted to include more recreational and conservation uses. The recreational use of beaches and other coastal environments will continue to increase in line with population growth and the movements to coastal areas. Proximity to the coast plays a major role in promoting tourism, which in turn, promotes higher employment in areas within the coastal zone. People undertaking popular activities such as recreational fishing, boating, surfing, swimming, snorkeling and diving, will be seeking continuing access to these areas and a clean and healthy environment in which to enjoy the recreational experience. Accompanying the increased tourism and recreational appeal of coastal areas has been a dramatic development and building boom. Yet, as coastal growth and development continue, public access to the coastline or the beach may itself become difficult.

Recreational and resort development have increased rapidly. With these development pressures comes a host of environmental and land use conflicts and issues. Substantial conflicts arise between the desires of coastal developers, resort owners, and private property owners to secure and protect shoreline locations, and the goal of ensuring public access to, and enjoyment of, coastal areas. Such developments often lead to impacts such as soil erosion, increased pollution, waste discharges into the sea, natural habitat loss and associated loss in biodiversity and increased pressure on endangered species. This is particularly true for some of the world's most ecologically fragile areas such as wetlands, mangroves, coral reefs and sea grass beds (UNEP 2000). Therefore, the human uses of the coastline have caused considerable damage to the coastal environment in a number of ways. These damages will arise when the level of tourist use is greater than the environment's ability to cope with this use.

In Australia, tourism and construction, which are related economic activities, are major contributors to coastal centres. Population growth along the coast has fostered local and regional booms in the construction of tourist facilities and housing. The social benefits of the coastline and individual beaches are valued highly by Australians. The beach is an important part of Australian culture and identity. Beaches are public places for all to enjoy and for many Australians beaches provide a sense of place and offer opportunities to participate in activities that stimulate and enhance wellbeing. Since the early 1900s, there has been a growing recognition that coastal living offered many recreational and aesthetic advantages for city dwellers. It is perhaps no coincidence that the second national park in the world after Yellowstone was the Royal National Park on the coast south of Sydney. The interest in coastal living has given rise to the "sea change" phenomenon, which since the 1970s has driven the demographic and economic revival of non-metropolitan coastal communities. There has been growth in coastal cities such as the Gold Coast and Cairns. In many cases the rate of population growth in such coastal local government areas has been about double the national average (Commonwealth of Australia 2009). This rate of growth has entailed persistent challenges for land use, infrastructure and planning. The "sea change" phenomenon is expected to continue especially as a result of further baby boomer retirement.

Tourism is mainly a natural resource based industry and, as such, affects air, land and water and can damage natural systems as a whole if its planning, development and operation are not properly managed. However, tourism is usually not managed well from an environmental perspective (GESAMP 2001). Uncontrolled coastal tourism development poses potential threats to many natural areas around the world as it can put enormous pressure on a very narrow area. In order to address the potential threats and pressures caused by tourism and recreational activities, access to seamless spatial data and information across the land – marine interface enables a more integrated and holistic approach to management of the coastal zone. If tourism is well planned, and is appropriate to local circumstances, it can do much for the sustainable development of coastal areas and be a positive force for conservation and environmental protection.

e) Pollution

As coastal and inland populations continue to grow, their impacts in terms of pollutant loads into the marine environment can be expected to grow as well. Marine pollution as defined by the Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP), which is part of the basic framework of the UNCLOS 1982 (Article 1.4) is:

> " The introduction of man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water, and reduction of amenities."

Bays and estuaries and other coastal waters are subject to a variety of pollutants, both point and non point sources. Controlling non point pollution is a major policy issue in most coastal areas, and in recent years there has been a considerable reemphasis on non point sources (Beatley et al. 1994). Under the framework of international law, sources of marine pollution are the following:

- Land-based sources and activities;
- Shipping and other sea-based activities such as fishing and aquaculture;
- Dumping;
- Seabed activities, both near and off-shore; and
- Atmospheric sources (IMO 2000).

Land-based activities constitute the largest sources of pollution as around 80% of contamination in the marine environment (SOEAC 1996). Contaminates come from a number of sources including sediment runoff, sewage, solid waste, pipes and drains, high nutrient loads, synthetic organic chemicals, rivers and urban catchments, oil, and the atmosphere. These result in eutrophication, and deteriorating of water quality, which have adverse effects on coastal ecosystems and their living resources (NOO 2002a). Therefore, pollutants from as far away as thousands of kilometres in land can impose a pollutant load into marine environment.

Protection of coastal waters is a major goal of coastal management programs. A number of cooperative and collaborative mechanisms to address, manage and mitigate pollution and degradation of the environment at the global and regional levels have been developed in partnership with governments, industries, scientific institutions, international organisations, NGOs and the public at large. In line with this is the MARPOL Convention which is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It was adopted on 2 November 1973 and covered pollution by oil, chemicals, harmful substances in packaged from, sewage and garbage. The Convention includes regulations aimed at preventing and minimising pollution from ships - both accidental pollution and that from routine operations (IMO 2000).

Unlike air pollution, water pollution has to be studied in the spatial perspective to understand the causes. Spatial-based management and marine spatial planning can provide a far more promising approach to implementing marine pollution management. However, current regulatory methods for the management of the coastal zone separate it into land and sea, with the use of spatial information for this area also remaining separated. This separation hinders the development of solutions to issues which straddle the land – marine interface, such as the pollution of the marine environment from land based sources. For this to come about, the integration of management techniques and spatial data within the coastal zone needs to occur.

2.2.2 Global warming

Global warming which has been identified as one of the greatest threats facing the living systems of the planet is the increase in the average temperature of the Earth's near-surface air and oceans since the mid-20th century and its projected continuation. Increases in greenhouse gases in the atmosphere since the industrial revolution, largely from human activity, have contributed to a warming of the atmosphere and the oceans. That warming is driving a range of other changes, some of which are not yet well understood, in the climate system and to coastal processes. Global surface temperature increased 0.74 ± 0.18 °C (1.33 ± 0.32 °F) during the last century. Climate projections summarised in the latest Intergovernmental Panel on Climate Change (IPCC) report indicate that the global surface temperature will probably rise a further 1.1 to 6.4 °C (2.0 to 11.5 °F) during the twenty-first century (IPCC 2007). Most studies focus on the period up to the year 2100. However, warming is expected to continue beyond 2100 even if emissions stop, because of the large heat capacity of the oceans and the long lifetime of carbon dioxide in the atmosphere (Solomon et al. 2009; Archer 2005). Of particular concern are recent scientific conclusions that climate change could occur more rapidly than previously thought and that the magnitude of change and resulting impacts could be larger (Commonwealth of Australia 2009). Moreover anthropogenic global warming will undoubtedly cause substantial sea-level rise and shoreline movement during this century and beyond.

Broader effects of global warming are glacial and sea ice retreat, Arctic shrinkage, worldwide sea-level rise and increasingly intense (but less frequent) hurricanes and extreme weather events. Additional anticipated effects include species extinctions, reductions in the ozone layer, changes in agriculture yields and ocean oxygen depletion (IPCC 2001). Social and economic effects of global warming may be exacerbated by growing population densities in affected areas. Some effects on both the natural environment and human life are, at least in part, already being attributed to global warming.

Furthermore, increased atmospheric carbon dioxide increases the amount of carbon dioxide dissolved in the oceans and resulting in ocean acidification. Heat and carbon dioxide trapped in the oceans may still take hundreds years to be re-emitted, even after greenhouse gas emissions are eventually reduced (Solomon et al. 2009). This raises extinction concerns and disruptions in organisms and ecosystems. One study predicts 18% to 35% of a sample of 1,103 animals and plant species would be extinct by 2050, based on future climate projections (Thomas et al. 2004). Climate change will drive changes in many of the processes associated with inundation or erosion of the coastline and will increase the frequency of individual high water level events. With increasing frequency the likelihood of events occurring simultaneously increases and what were once seen as rare and independent events will increasingly become more common.

As it is shown in Figure 2.5 the atmosphere, land and oceans are greatly interconnected and interrelated. Our climate is actually very complex and intimately connected to life on Earth. Because the atmosphere interacts with the underlying surface-land and oceans on many different scales in both space and time, causing the climate to have a large natural variability; and human influences such as greenhouse gas emissions add further complexity.

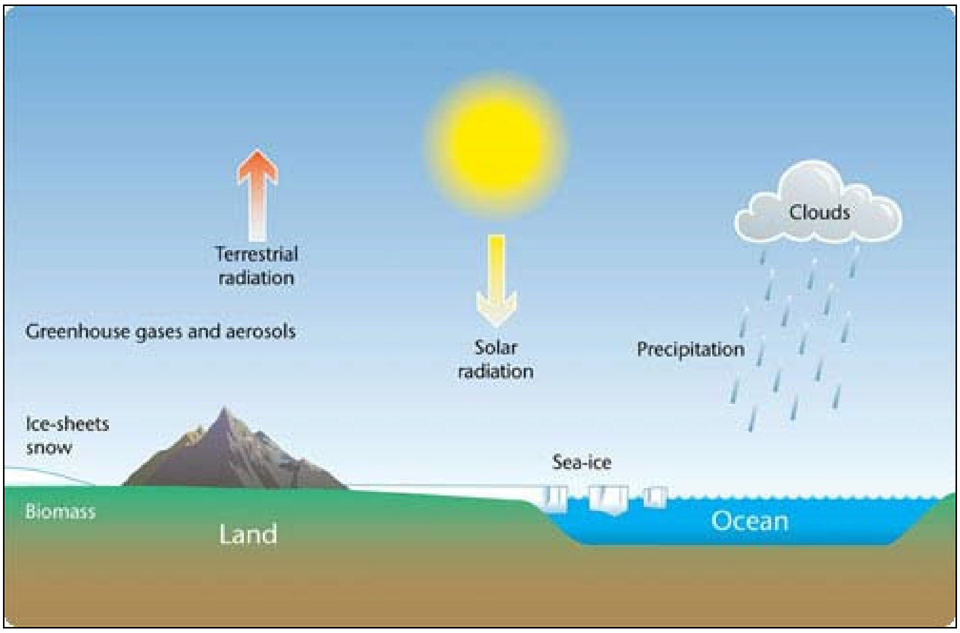

Figure 2.5 Components of climate system (http://www.metoffice.gov.uk/)

Figure 2.6 further supports the complexity of interactions in the coastal zone and suggests that the impacts of climate change could manifest in many ways. Risks of inundation in low-lying areas and accelerated coastal erosion are particular concerns. Changes in sea surface temperatures and ocean acidity can also have large impacts on estuary and marine life.

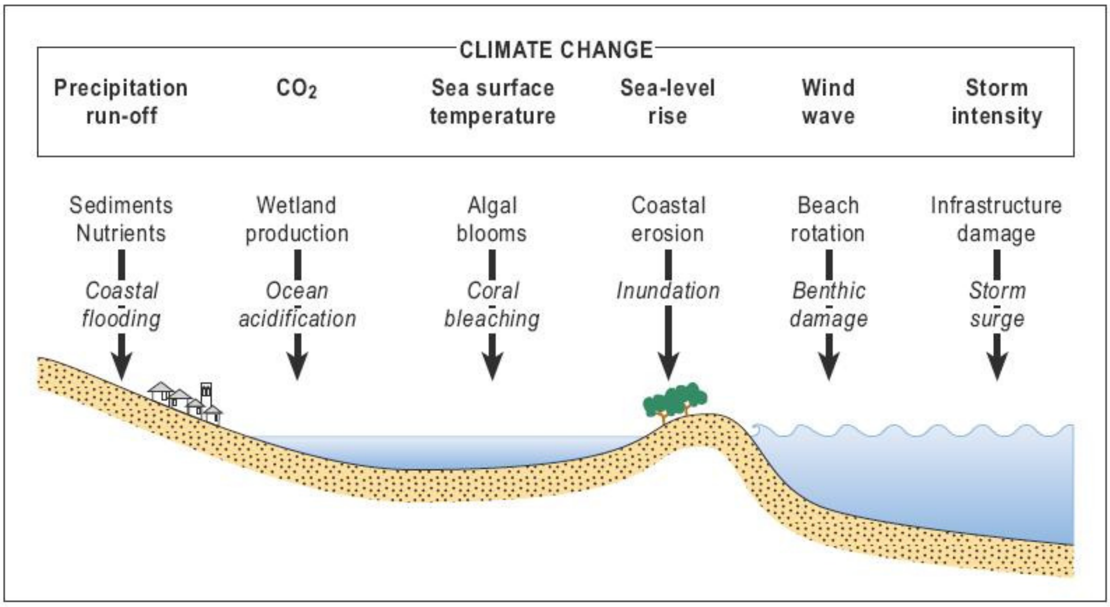

Figure 2.6 Climate change drivers and impacts on the coast (Short and Woodroffe 2009)

The climate and the sea have always been major forces shaping the Australia's coast, and over time the position of shoreline has shifted large distances. Now climate change is driving the evolution of a new coastline for Australia, but the location of that coastline is not yet clear. With much of Australia's infrastructure concentrated in the coastal zone around centres of population, climate change will bring a number of risks to built environment assets which could have consequences for the delivery of community and essential services, regional economies and possibly the national economy. The risk of damage to settlements from a climate event and climate change is also due to the number of buildings exposed to that event. Over the past few decades there has been rapid growth in many Australian coastal settlements including the emergence of the Gold Coast and other new coastal cities and towns (Salt 2004). As noted by the Parliamentary Committee Report *Managing our coastal zone in a changing climate: the time to act is now* of October 2009, there are 711,000 addresses sited within three km. and in areas below 6 metres, with more than 60% of those addresses located in Queensland and New South Wales (Chen and McAneney 2006). Difficult decisions will need to be made in the future on what assets need to be protected and how this should be done. Spatial information provides clear identification of the individual land parcels and land rights attached to these parcels. The information on the people to land relationship is crucial and plays a key role in adaptation to climate change and in prevention and management of natural disasters. Seamless spatial information is needed to ensure that trade-offs and consequences of decisions are understood.

According to the Millennium Development Goals 2009, the continued growth of global emissions confirms that combating climate change must remain a priority for the world community (United Nations 2009). Achieving a substantive breakthrough in the UN Framework Convention on Climate Change negotiations, held in December 2009 in Copenhagen, was extremely important in that regard and is likely to be the biggest trade off issue at the global agenda at this early stage of the new millennium. Consequently climate change and global warming would be a serious crisis which would require greater attention to coastal protection and change management. Political and public debate continues regarding climate change, and what actions to take in response. The available options are mitigation to reduce further emissions; adaptation to reduce the damage caused by warming; and, more speculatively, geoengineering to reverse global warming. Align with that most national governments have signed and ratified the Kyoto Protocol aimed at reducing greenhouse gas emissions.

More generally, seamless spatial information platform can serve as a basis for climate change adaptation and mitigation. The management of natural disasters resulting from climate change can also be enhanced through integration of land and marine environments. This would enable control of access to land and marine environments as well as control of the use of these environments. The integrated administration system can include the perspective of possible future climate change and any consequent natural disasters. The system identify all prone areas subject to sea-level rise, drought, flooding, fires, etc. spatially and measures and regulations to prevent the impact of predicted climate change as well as natural disasters and provide preparedness for managing any disaster events.

Engagement of all stakeholders – governments, individuals, and the private sector – is essential to develop and implement a comprehensive, well considered and carefully staged coastal planning. All parties will have a role to play. This also relates to the fact that climate change is not a geographical local problem that can be solved by local or regional efforts alone. To address climate change, international efforts must integrate with local, national, and regional abilities (Chiu 2009). An effective spatial infrastructure will need to include national standards and benchmarks, information and tools for decision-makers, better understanding of risks to critical infrastructure, and enhanced local capacity to manage on-ground impacts. Leadership from governments will be required in a national partnership to maintain the public good assets in the coastal zone for future generations.

2.2.3 Shore line erosion, accretion and sea-level rise

Sea levels are rising at a significant rate because of global warming, melting of glaciers, the heating and expansion of oceans and the melting of the Antarctic ice caps particularly in the past ten years. Recent sea-level rise has increasingly been driven by human-induced climate change. It is now understood that global warming, or the so-called "green house effect" thermal expansion is responsible for about one-third of the global sea-level rise that occurred in the century to about 1990 (Commonwealth of Australia 2009). Global mean sea-level has risen about 20 centimetres since pre-industrial times, at an average rate of 1.7 millimetres per year during the 20th century (Church and White 2006). Since 1993, high-quality satellite observations of sea levels have enabled more accurate modelling of global and regional sea-level change. From 1993 to 2003, global sea-level rose by about 3.1 millimetres per year, compared to 1.8 millimetres per year from 1961 to 2003. These rates of increase are an order of magnitude greater than the average rate of sea-level rise over the previous several thousand years.

The IPCC provides the most authoritative projections of sea-level rise. Conclusions about future sea-level rise in the IPCC's Third Assessment Report (IPCC 2001) and Fourth Assessment Report (IPCC 2007) were broadly similar. The IPCC AR4 projections estimated global sea-level rise of up to 79 centimetres by 2100, noting the risk that the contribution of ice sheets to sea-level this century could be higher. More recent analysis finds that sea-level rise of up to a metre or more this century is plausible (Steffen 2009). Estimates of total sea-level rise remain uncertain. Further, nearly all of the uncertainties in sea-level rise projections operate to increase rather than lower estimates of sea-level rise. However, there is growing consensus in the science community that sea-level rise at the upper end of the IPCC estimates is plausible by the end of this century, and that a rise of more than 1.0 metre and as high as 1.5 metres cannot be ruled out (Steffen 2009). Sea-level rise projections presented to the March 2009 Climate Change Science Congress in Copenhagen ranged from 0.75 to 1.9 metres by 2100 relative to 1990, with 1.1–1.2 metres the mid-range of the projection (Rahmstorf 2009).

This rise will have drastic effects on coastlines. Submergence is an obvious effect but increased shoreline erosion and accretion rates are also consequences. Estuaries could migrate landwards at rates of around 10 metre/year. This will greatly affect the rights, restrictions and responsibilities of both governments and individuals who own or manage land along the coastal strip. This is especially problematic in some small pacific island nations as, unlike deltas and other coastal areas, they have no hinterland to move to in the case of coastal land loss or they may be wholly inundated with the sea-level rise. Small island nations contribute just 0.6 percent of the global greenhouse gas emissions yet will be the first to suffer the consequences of sea-level rise due to global warming.

Many coastal areas are facing long term shoreline erosion and accretion problems. Coastal erosion is and will continue to be one of the most severe impacts of sea-level rise. The IPCC reported in 1998 that 1 centimetre rise in sea-level results in the erosion of a sandy beach by 1 metre horizontally. Sea-level rise contributes to coastal erosion by influencing and exacerbating on-going coastal processes, making coastal areas more vulnerable to extreme events. For example, higher sea-level will provide a higher base for storm surge. A 1 metre rise in sea-level would enable a 15-year storm to flood areas that today are only flooded by 100-year storms (IPCC 1998). Shoreline erosion is not restricted to marine-based influences like waves and surge, but can also be effected by the adjacent land use. Property owners on high bluff shorelines can contribute to their shoreline erosion problem. A variety of other human alterations can affect shoreline erosion and accretion patterns as well. The construction of jetties and groins can serve to interrupt normal littoral drift, depriving down-coast areas of sand sediment and causing erosion. The damming and diverting of rivers has also caused erosion by depriving coastal area of important fluvial sediment (Beatley et al. 1994).

In recent times several natural disasters as a result of sea-level rise and storm surges hit some part of the coastal areas around the world in particular small islands and archipelagic countries causing hundreds thousands of people lost their lives, while those who survived had lost their properties. As these storm surges reach shore, they may resemble tsunamis; inundating vast areas of land as such a storm surge inundated Burma (Myanmar) in May 2008. Tsunamis are not rare, with at least 25 tsunamis occurring in the last century. Of these, many were recorded in the Asia–Pacific region particularly Japan. Due to the immense volumes of water and energy involved, tsunamis can devastate coastal regions. The 2004 Indian Ocean tsunami killed over 300,000 people with many bodies either being lost to the sea or unidentified. Some unofficial estimates have claimed that approximately 1 million people may have died directly or indirectly solely as a result of the tsunami. According to an article in *Geographical* magazine (April 2008), the Indian Ocean tsunami of December 26, 2004 was not the worst that the region could expect. Professor Costas Synolakis of the Tsunami Research Center at the University of Southern California co-authored a paper in *Geophysical Journal International* which suggests that a future tsunami in the Indian Ocean basin could affect locations such as Madagascar, Singapore, Somalia, Western Australia, and many others. Figure 2.7 clearly demonstrates devastating situation on coastlines of Kalutara Beach, Sri Lanka after 2004 Indian Ocean tsunami.

Figure 2.7 Before and after tsunami in Kalutara Beach – Sri Lanka

The Australian coast is a dynamic place and since initial occupation over 50,000 years ago humans have witnessed major changes in sea-level, in habitats and in the shape of the shoreline from great storm events. Sea-level around Australia rose by about 17 centimetres between 1842 and 2002 – a rise in relative sea-level of about 1.2 millimetres per year (Church et al. 2008). The rise in sea-level has been very variable from decade to decade. The rate of increase was low between the 1970s and early 1990s. Recent rates of sea-level rise in eastern and southern Australia are similar to the global rate. In western and north-western Australia, the current rates are more than double the global rate. These trends are most likely a combination of climate change and shorter term variability (Commonwealth of Australia 2009).

While there is a lack of national information on social vulnerability to climate change, remote indigenous communities in the north of Australia and communities living on the low-lying Torres Strait Islands are particularly vulnerable to sea-level rise. Some Torres Strait communities are affected under current king tide conditions and even very small levels of sea-level rise are likely to have a major impact on these communities. Coastal communities outside of capital cities generally have less adaptive capacity than capital city communities and may therefore be more adversely affected by climate change impacts. Rising sea levels will bring significant change to Australia's coastal zone in coming decades. Many coastal environments such as beaches, estuaries, coral reefs, wetlands and low-lying islands are closely linked to sea-level. There is a lack of knowledge in many cases as to how these environments will respond to sea-level rise, but the risk of beach loss, salinitation of wetlands and inundation of low-lying areas and reefs beyond their capacity to keep pace must be considered in regional decision-making. Long term shoreline erosion and sea-level rise represent major future challenges for coastal states and localities to deal with.

The development of seamless spatial data bases across land – marine interface covering coastal landforms, digital elevation models and tidal/storm surge will serve to mitigate sea-level rise risk and, ultimately, to making informed, cost-effective decisions to adapt to climate change. The management of natural disasters resulting from sea-level rise can also be enhanced through integration of land and marine spatial data.

2.2.4 Overfishing

Coastal zone is one of the most productive areas accessible to people. Fish and other sea foods fulfil a significant portion of the dietary needs for millions of people around the world, while the industries of fisheries and aquaculture are commercial for thousands of coastal communities. There are increasingly serious signs that these economic uses of our coast are undermining their long term sustainability. As individual overfishing is exhausting and deleting fisheries around the world. The United Nations Food and Agriculture Organisation (FAO), which monitors the state of world fisheries, has estimated that since 1990 approximately one-quarter of fish stocks have been overexploited, depleted, or are recovering from depletion (17%, 7%, and 1%, respectively) (FAO 2005), with the north–east and north–west Atlantic, the Mediterranean, and the Black Sea being the areas with the largest number of depleted stocks (Garcia and Grainger 2005). Many authors have elaborated on these conclusions, documenting the poor state of fisheries worldwide (Pauly et al. 2003). The analysis of the situation in 2003, indicates that approximately half the world's stocks are exploited at or close to their maximum and ca. 25% of them are exploited either below of above such maximum (Figure 2.8). Globally, most know capture fisheries are at or near full exploitation (Productivity Commission 2004).

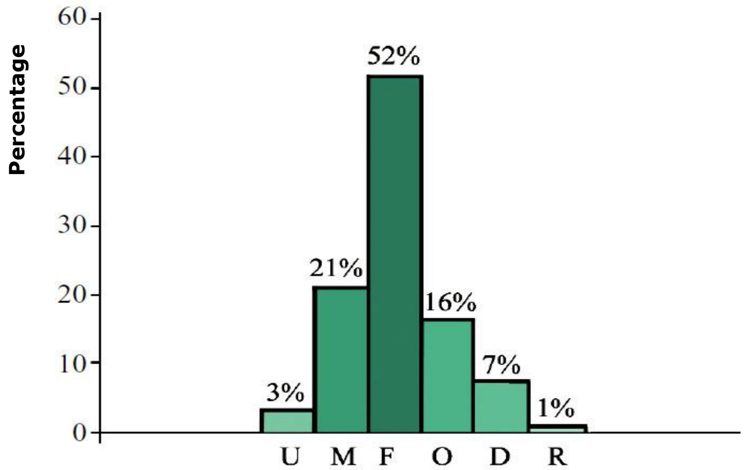

Figure 2.8 State of world fish stock items in 2003. U, underexploited; M, moderately exploited; F, fully exploited; O, overfished; D, depleted; R, recovering (Garcia and Grainger 2005)

Humanity faces a challenge to ensure sustainable use of fisheries resources when the level of demand has increased beyond what marine environments are able to supply. This pressure, moreover, appears to continue increasing as a result of population growth. This overfishing encompasses both commercial fisheries and recreational fisheries.

a) Overfished commercial fisheries

Commercial wild-catch fishing involves commercial fishing operators catching and removing fish from non-private waters, including oceans, estuaries, rivers and lakes (ACIL Tasman 2004). Commercial use of fish stocks is consumptive and rival in supply.

Only if managed are fish stocks renewable. A system of quotas tied to vessels in a particular jurisdiction is the principal means of control of the amount of catch. It is generally failing. Consistent information about deep sea fishing indicates not only that fish stocks are being depleted but than large sea mammals are being destroyed, a classic third party effect (Productivity Commission 2004).

In case of Australia the fishing zone covers nine million square kilometres, and extends 200 nautical miles from shore. The zone takes in tropical to sub Antarctic waters and reaches one quarter of the globe – from the Indian Ocean in the west to the Pacific Ocean in the east. A federal system, in which national power is limited, as in Australia, requires a dual approach to off-shore activities, with the states managing interests and activities related to resources up to the three nautical mile limit and the national government managing the area between the limit and the outer limit of the national marine jurisdiction. Therefore, fisheries managed by the Commonwealth are those that exist within Commonwealth waters (beyond three nautical miles from the coast or territorial baseline), with the states responsible for fisheries within coastal and internal waters (NOO 2002a). The spatial extent to which fishing occurs within the Commonwealth jurisdiction - within Australia's EEZ - is illustrated in Figure 2.9 and is important information for all users of the marine environment. The ability to map and spatially define fishing zones would be an essential component for more efficient and effective management regime, balancing the rights and responsibilities of multiple users.

The future of many commercial fisheries in Australia and, indeed around the world, is highly dependent on ensuring the sustainable harvest of those fisheries from all sectors. Bureau of Rural Sciences in Australia (BRS 2002) found that 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.

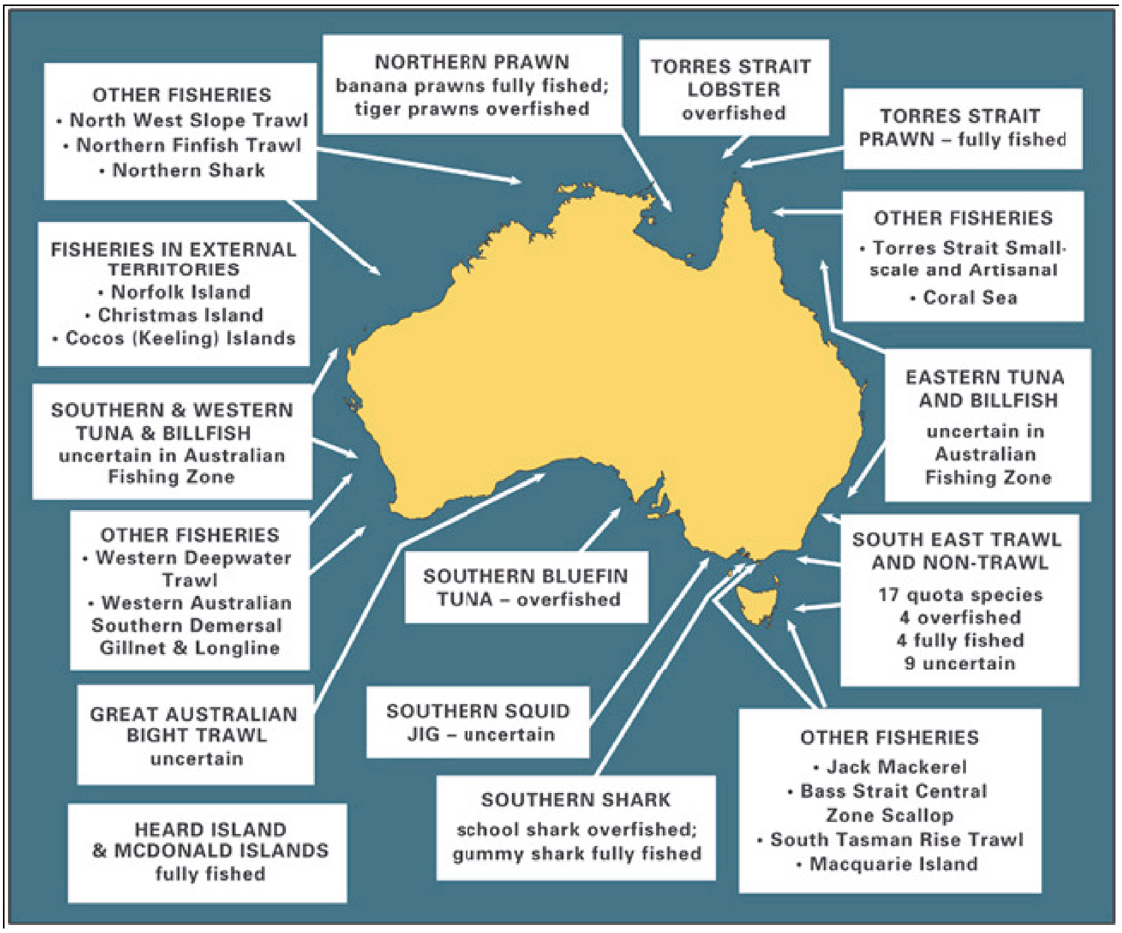

Figure 2.9 Status and location of Commonwealth-managed fisheries (Caton 2001)

In practice fisheries management arrangements are more complex. In Australia the principal legislation for the management of Commonwealth fisheries are the *Fisheries Management Act 1991(FMA)* and the *Fisheries Administration Act 1991(FAA)*. Under the *Fisheries Management Act 1991*, there are two main forms of access rights to fish that can be granted, including Statutory Fishing Rights (SFR) and fishing permits. SFRs are only provided under a management plan and are granted for the period of the plan, enabling SFR boundaries to be spatially defined. The granting of an SFR gives the right to fish for a resource and permits maximum allowable catches to be changed. Unlike SFRs, fishing permits do not formally convey the right to fish; they only specify conditions which must be met in order for the permit holder to retain their permit. Such permits also specify the area of operation for the permit, and are usually granted and renewed on a yearly basis (NOO 2002a). The Commonwealth fisheries are managed solely by the Australian Fisheries Management Authority (AFMA) or through joint authorities with State/Territory governments, or bilateral international agreements. The Australian Government is party to a number of international conventions or agreements for the management of fish stocks including those which range beyond the Australian fishing zone. There are different state agencies responsible for administering the Act as in Tasmania, the Department of Primary Industries, Water and Environment (DPIWE) manages and regulates the extraction of wild fish under the *Living Marine Resources Act 1995(*TAS*)*. In South Australia, the Department of Primary Industries and Resources – South Australia (PIRSA) is responsible for the *Fisheries Act 1982 (*SA). In Victoria, the Department of Natural Resources and the Environment (DNRE) is responsible for administering the *Fisheries Act 1995(*VIC*)* and NSW Fisheries manages fisheries in that State under the *Fisheries Management Act 1994* (NSW). Fisheries in each state are managed under separate management arrangements, and there is usually little cooperation across the states where species resources are shared. Figure 2.10 illustrates the catch information for all Commonwealth-managed fisheries for most stocks to the end of 2008.

The identification of legal and institutional aspects of the commercial fishing occurring within Australia's marine environment along with the key institutions and agencies responsible for implementing such legislation demonstrates the complex inter-jurisdictional relationship between users and stakeholders of the marine environment. The complex regime of geographically overlapping commercial fishing catchments, which managed under separate management arrangements results in redundant effort, inefficiency, ineffectiveness and a lack of coordination amongst state agencies. The seamless management framework across states and different stakeholders would be required.

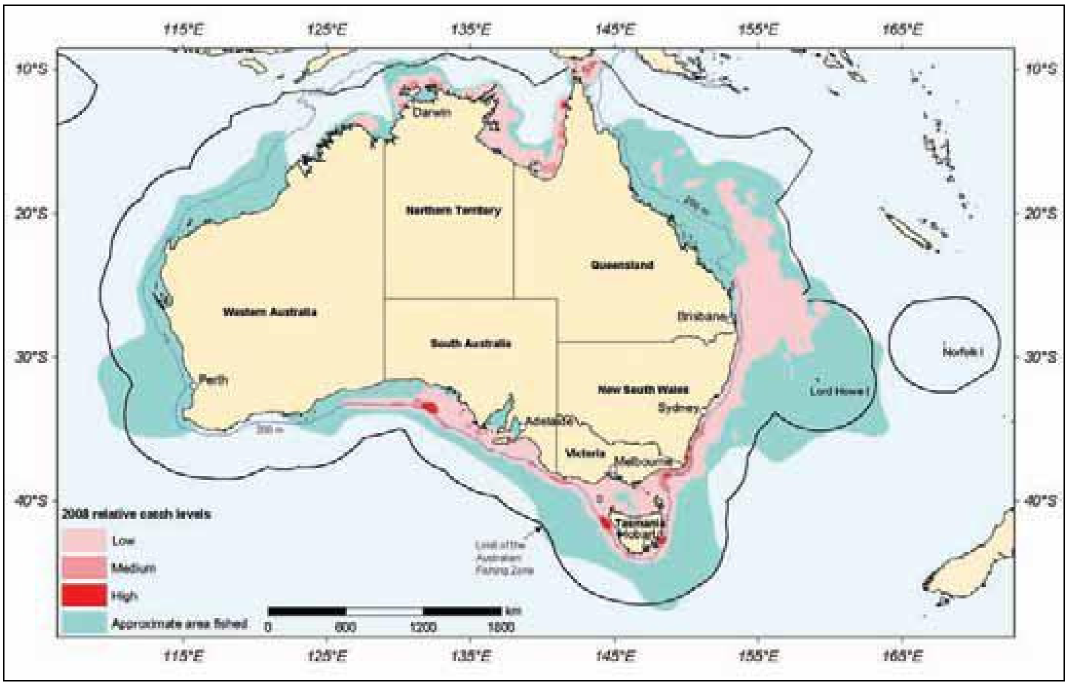

Figure 2.10 Relative catch levels of all Commonwealth-managed fisheries in 2008 (Commonwealth of Australia 2009)

Inadequate management arrangements results high and unsustainable catches. To achieve sustainable use of fisheries resources requires the establishment of management systems that limit the harvesting of fish to match the optimal capacity of nature to recreate or reproduce the resource. This has led to the recognition of the central importance of introducing explicit and secure fisheries access rights (or recognising rights where these already informally exist). This means that rights should clearly defined which in turn means that it should be know who holds the rights, what the precise limits of the rights are, and how rights are enforced. For example commercial fishermen can generally operate in any of the waters covered by the fishery in which they have a right. There may however be areas of exclusion such as near petroleum platforms or in marine protected areas. In some cases a geographic source of fish might be involved, say within a range of coastline, a bay, or a mileage limit. Management systems should create incentives that eliminate overcapacity, limit investment in capacity to what is commensurate with long term optimal harvesting of fish stocks, and encourage the interest of the fishers in resource rebuilding and conservation (FAO 2007). Therefore there is a need for a more integrated and ecosystem-based approach for the management of major fisheries. The nature of fisheries management should change to more fully address ecologically sustainable management, a prerequisite to achieve sustainable development goals.

b) Overfished recreational fishing

As the numbers of recreational fishers increases with the overall population increase, increased leisure time and the move to coastal areas, the pressure from this sector on some species will continue to increase. The challenge for governments is to limit the recreational sector's overall take of such species to ensure the long term sustainability of the species while still providing the recreational experience. The management of recreational fishing primarily seeks to ensure that the resource is harvested sustainably so that harvesting can continue. It is also important for managers to be able to help maximise the fishing experience and to manage cultural and social imperatives.

In case of Australia, historically, the Commonwealth has limited its jurisdiction to commercial fishing with states assuming responsibility for all recreational fishing. However, managing recreation and charter fishing in Commonwealth waters is presently under review and the Commonwealth may move towards taking more of a stewardship role while the States and Territories take effective responsibility for day-to-day management. The Commonwealth has also released the National Recreational Fishing Policy which outlines 16 key principles relating to all aspects of recreational fishing ranging from ecosystem protection, stewardship, recreational experience, access and funding (NOO 2002a). Figure 2.11 illustrates Australia national recreational catch based on the national recreational and indigenous fishing survey.

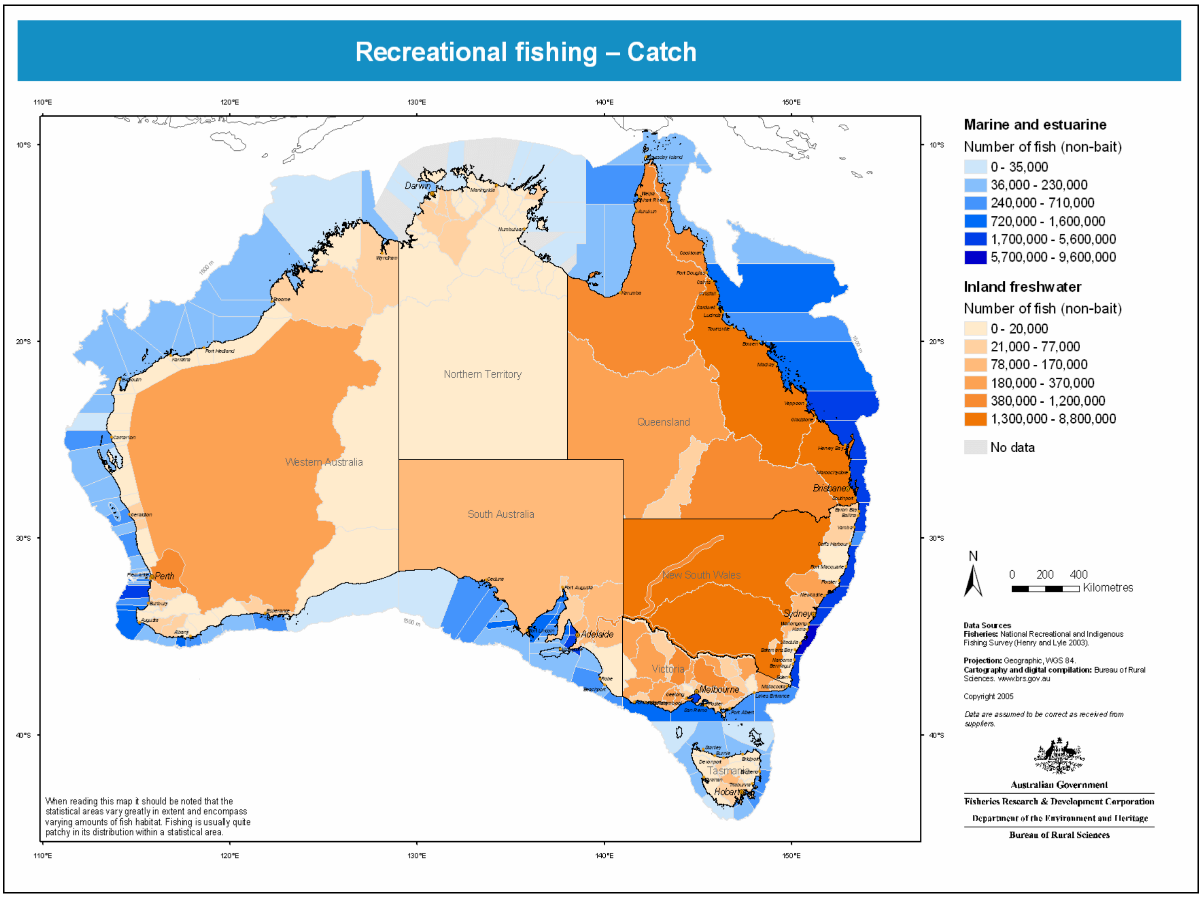

Figure 2.11 National recreational fishing catches - Australia (BRS 2005)

Countries have been tackling the problem of overfishing and, thus, the impacts that overfishing can have on the environment for a long time although with limited success in many instances. However, under the International Plan of Action (IPOA) for the Management of Fishing Capacity (IPOA-Capacity) that was adopted at FAO in 1999, countries are currently working to address overcapacity and its many associated problems, including overfishing. In addition, under the 2001 FAO IPOA on Illegal, Unreported and Unregulated Fishing (IPOA - IUU), there are many efforts currently underway around the globe to address illegal, unreported, and otherwise unregulated fishing activities and, thus, also helping to counteract overfishing zoning strategies, including Marine Protected Areas (MPAs) has been used to keep trawlers away from vulnerable habitats, although with little success in areas where there is ineffective enforcement. Programmes for the development of integrated and more sustainable livelihoods are being implemented (e.g. by FAO in Western and Central Africa). Some countries (USA, Ireland) require the elaboration of an Environmental Impact Assessment

(EIA) and Environmental Impact Statement (EIS) for their fisheries, whilst in other countries such as Australia; the fishing industry is voluntarily adopting and implementing environmental management systems (FAO 2005).

The fisheries sector is particularly susceptible to the impact of other land-based and sea-based activities on the marine environment, its quality and productivity. If fisheries are to make an optimal contribution to economic and social welfare, these interactions must be taken into account, by integrating fisheries management into broader-based coastal area management framework. The problem regarding the overfishing can be solved spatially, as the location and the map of overfished areas is available and accessible, administering of this issue will be facilitated. Seamless spatial data platform enables a holistic, integrated and coordinated approach to spatial information for decision-making.

2.2.5 Extensive extraction of oil, gas and minerals

Fears about off-shore oil, gas and minerals development and its impact on beach and coastal environment reflect serious concerns. Some 50,000 oil and gas fields have been identified worldwide, however about half of the known reserves were originally concentrated in less than 40 super giant oil fields (United Nations 2000a). Most of these fields are found in the Middle East, where they are located both below ground and below the shallow waters of the Persian Gulf. Other major oil fields are located in Russia, Mexico, the USA, China, Libya, Venezuela and Algeria. Methods of oil and gas extraction vary considerably depending on the form and depth of deposits and the local environmental conditions. There is some leakage at the point of extraction, and so marine-based extraction causes some immediate issues of pollution. The major source of crude and partially refined oil loss to the environment, however, comes from accidental spillage in the form of leakage from pipelines, tanker spillage and damage to drilling platforms. In addition there is considerable loss of hydrocarbons to the environment subsequent to their refinement. This may come from release from ships (deliberate or accidental) or from various forms of terrestrial runoff. Despite the considerable input from marine spillage it is considered likely that land-based sources of oil pollution are of greater significance. Even in the Black Sea where there is some oil extraction and considerable tanker traffic, an analysis showed that 48% of the total input of 110,000 tonnes came from the Danube River, with a further 30,000 tonnes from domestic sources and 15,400 from industrial sources (United Nations 2000a). Environmental concerns have a considerable impact on the future course and scale of off-shore oil, gas and mining activity. However, there are other socio-economic factors to consider, particularly the projected rise in world population and the overall rise in living standards. Either of these trends will inevitably result in greater minerals resource use that is unlikely to be balanced by increased recycling or material substitution (NOO 2002a).

Petroleum discoveries have been reported in Australia since early settlement. However, significant commercial discoveries have only been made in the last 30 years as 85% of Australia's oil and gas is found in the oceans that surround this continent. The overwhelming majority of discovered reserves are found in Commonwealth waters (i.e. three nautical miles from the Territorial Sea baseline to 200 nautical miles – the Australia's EEZ). The areas of highest production are the north–west Shelf adjacent to Western Australia, the Timor Sea adjacent to the Northern Territory, and Bass Strait adjacent to Victoria and Tasmania. Nevertheless, in recent decades production has generally been declining due to the resource becoming depleted.

Following the 1979 Offshore Constitutional Settlement (OCS), responsibility for off-shore petroleum mining is shared between the States, the Northern Territory and Commonwealth governments. The principal legislation governing off-shore petroleum mining is Commonwealth's *Petroleum (Submerged Lands) Act 1967* for Commonwealth waters and the relevant State or Territory *Petroleum (Submerged Lands) Act* for State or Territory waters. The *Petroleum (Submerged Lands) Act 1967* sets out subordinate legislation that extends the State and Northern Territory legal systems off-shore, in so far as they do not conflict with Commonwealth legislation. This ensures that there is a seamless transition from land to sea. An example of this is in the conveying of petroleum from an oil field in the contiguous zone to land in the state of Victoria. The pipeline is firstly administered under the Commonwealth's *Petroleum (Submerged Lands) Act 1967*, until it reaches coastal waters, where the Victorian *Petroleum (Submerged Lands) Act 1982 (*Vic*)* takes over administration. To ensure administrative consistency between State, Territory and Commonwealth jurisdictions, State and Territory Ministers or "Designated Authority" (i.e. the State/Territory Minister responsible for petroleum matters) have the power to administer the Commonwealth Act on a day-to-day basis. This is done through the approval of a "Joint Authority", made up of a Commonwealth and State minister (DPI 2003).

The economic uses of our coast are losing their long term sustainability. The question of whether or not an off-shore petroleum or minerals deposit can be commercially exploited is subject to a range of issues including location (distance from shore/port, depth etc), grade, price, environmental impact, extraction technology and government policy. The exploration for both petroleum and minerals, and as such new discoveries, can only occur within exploration permit areas. So further discoveries will only take place within the areas of current permits, plus other areas opened up for bidding in the acreage release program. However, unlike the controlled exploration lease program for petroleum where areas are planned in advance and put out to bidding, the location of the future minerals exploration leases is likely to be less planned and will probably be highly dependent upon the interests and expertise of the individual companies and the changing world demand for minerals resources. The petroleum permits and petroleum acreage release in Australia is shown in Figure 2.12.

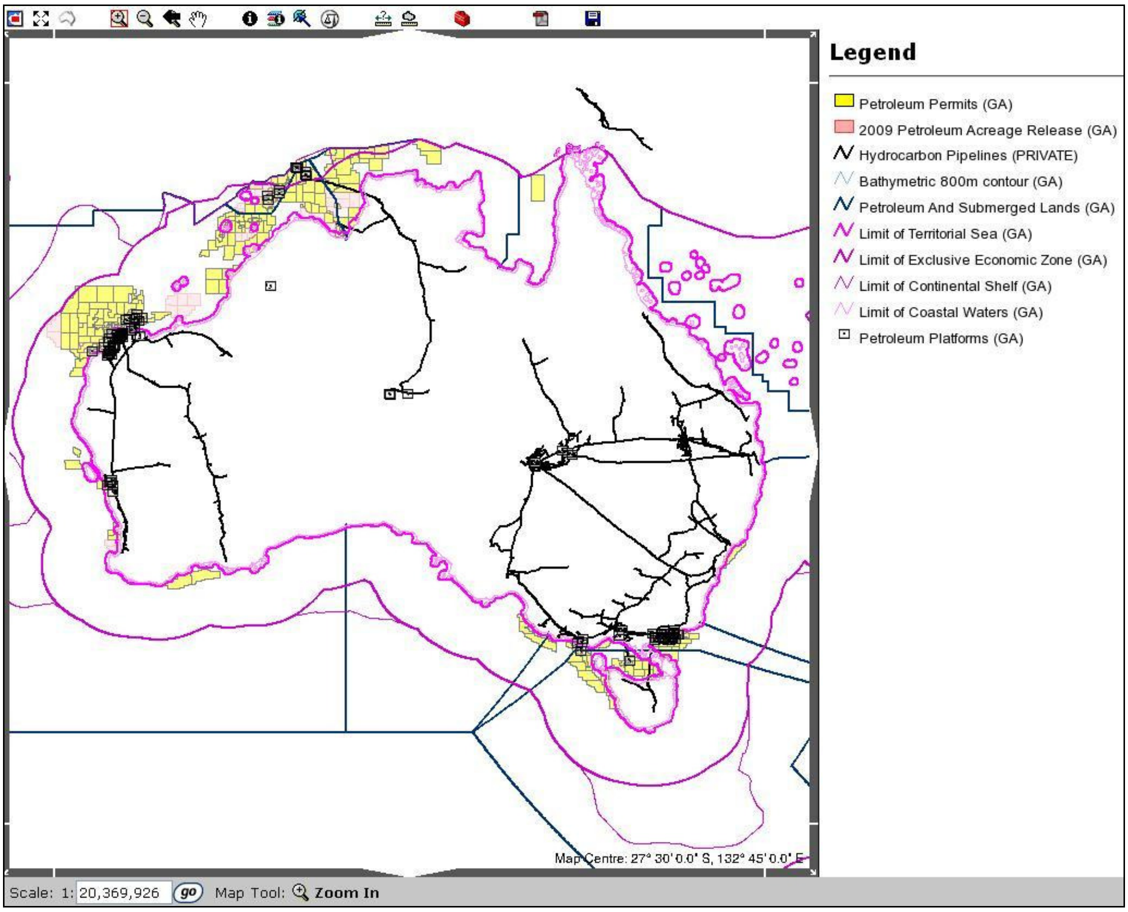

Figure 2.12 Petroleum permits and petroleum acreage release 2009 - Australia

The oil and gas industry currently has its own spatial management system to administer permits and lease areas. The system is based on parcels with relevant data such as permit holders and permit numbers attached to each parcel. This means that the rights, restrictions and responsibilities of those with exploration licenses are well documented. Within the lease and exploration areas of the oil and gas sector however, there are also other rights that occur which are also of concern (Binns 2004). At the Melbourne ARC Marine Cadastre Workshop, it was recognised that oil and gas companies need information concerning almost every major activity in the marine environment in order to effectively address their own needs. This includes shipping, native title areas, waste sites, heritage areas, fisheries etc. Such data needs to be found and integrated with existing oil and gas data before it can be used to maximum capacity (Yardley 2002).

The ability to map and spatially define oil, gas and minerals fields would be an essential component for a more efficient and effective management regime, balancing the rights and responsibilities of multiple users of seabed and subsoil areas, and ensuring that other activities that are permitted under relevant legislation can take place. The integration of land and marine environments aims to extend this management philosophy to all activities in the marine environment, to ensure that marine and coastal environments are utilised effectively.

2.2.6 Loss of biodiversity, habitat and coastal wetlands

The coastal areas are some of the most productive and biologically diverse on the planet. It provides a unique habitat for thousands of plant and animal species. Of the 13,200 known species of marine fish, almost 80% are in coastal areas (UN 2000b). The coastal ecosystem is made up of myriad interconnected subsystems whose functions can not be duplicated elsewhere. Coastal jurisdictions contain a disproportionate number of rare and endangered species. Moreover, coastlines represent important habitat for numerous species that may not be endangered. As development of coastal areas continues, habitat loss remains as a significant problem. There are numerous examples of direct conflicts between demands for resort development and other development proposals, and the habitat needs of endangered species. These result in disturbances of coastal ecosystems. On the other hand loss of coastal wetlands has been a significant problem in the past. Threats to wetlands have included draining and filling for agriculture, road construction, and urban and recreational development.

Australia's coastal waters and oceans contain one of the greatest arrays of marine biodiversity in the world. The area includes more than 4000 fish varieties and tens of thousands of species of invertebrates, plants and micro-organisms, with around 80% of southern marine species occurring nowhere else in the world (DSE 2003). Such diversity needs to be protected and conserved, with both the Commonwealth and state governments implementing Marine Protected Areas (MPAs) for just such a purpose. These areas are dedicated to the protection and maintenance of biodiversity and cultural resources, and are managed through legal means. They have been recognised nationally and internationally as being important for marine conservation and management since the early 1960's (Kriwoken and Côté 1996), but according to Cresswell and Thomas (1997) have not been used widely enough:

While the oceans comprise 70% of the earth's surface, less than 1% of the marine environment is within protected areas, compared with 9% of the land surface. Cresswell and Thomas (1997) claim that this worldwide lack of marine protected areas is reflected in Australia, with approximately 7.6% of terrestrial area protected and only about 3.5% of the marine environment.

Through Australian's ocean policy the Commonwealth government is committed to accelerate the declaration and management of MPAs in Commonwealth waters. The world's largest highly protected zone is contained within the 16.2 million hectare Macquarie island marine park in Australia. Each MPAs is managed by both Commonwealth and state government as key players. Within some jurisdictions, local government may be involved in MPA planning and management as well. Australia aims to adopt an integrated approach to the conservation of marine diversity within a multiple use planning framework for Australian marine waters.

The significant principle affecting management of the marine environment and marine living resources is Ecologically Sustainable Development (ESD) which is defined as: using, conserving and enhancing the communities' resources so that ecological processes, on which life depends, are maintained and total quality of life, now and in the future, can be increased (EA 1992).

Australia has ratified several international conventions and is committed to the protection of marine biodiversity, ecological integrity and the sustainable use of marine and coastal resources. At a national level, the principle Commonwealth legislation relating to environmental matters is the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)*. The Act consolidates much of Australia's environmental law and gives direct effect to Australia's international environmental obligations. The Act identifies six matters of environmental importance including:

1. World Heritage Sites;
2. Wetlands of international importance (RAMSAR);
3. National threatened species and ecological communities;
4. Listed migratory species;
5. Commonwealth marine areas; and
6. Nuclear projects, including uranium mining.

All of these have relevance to the marine environment with the public needing spatial information of areas such as world heritage sites, RAMSAR and marine protected areas in order for legislation governing these areas to work effectively. Users cannot adhere to spatially defined rights in legislation if the area concerned is not clearly delineated and publicised. Therefore, the ability to map and spatially define conservation areas such MPAs is of great importance in aiding the protection of biodiversity within the areas. There are also conditions on the use of marine parks that need to be attached to their spatial extent. These conditions are described in legislation and prohibit acts which affect native species and heritage, ban commercial activity, and in some cases allow almost no human activity, including recreational fishing. There can also be seasonal adjustments to shipping routes to reduce the impact on marine species such as migrating whales. In some cases, there are adjoining marine and land parks which, when managed together, can reduce the effects of land-based pollution in the marine environment. The ability to join up marine and land based spatial information aids decision-making by providing a spatial/geographic context to planning, management and protection of habitats and protected areas across land – marine interface. This leads to effective and efficient management of marine resources and meet the economic, environmental, and social goals of sustainable development.

2.2.7 Lack of suitable sites for aquaculture

The vast majority of aquaculture concerns are small to medium operations located outside major population centers. As aquaculture and associated service and support industries develop, coastal and rural communities tend to benefit both socially and economically. Aquaculture production is spread throughout the in-shore waters as well. There are also a number of significant aquacultural products including oysters, abalone, oyster, scallops, mussel and freshwater trout. Australia's Oceans Policy identifies aquaculture as having great potential to develop further export markets for high value products and contribute to regional development opportunities (EA 1998).

The aquaculture industry is the fastest growing primary industry in Australia and is its management rests with the States and Northern Territory, which generally put in place aquaculture and coastal development plans. These are designed to take into account the needs of both aquacultural developments and other user groups. Under such plans, licences for marine farms are granted with the inclusion of environmental standards and conditions. New South Wales, South Australia and Tasmania use aquaculture leases. Western Australia uses annual aquaculture licences, but has capacity to use dedicated marine aquaculture lease arrangements. Victoria and Queensland have no specific arrangements but rely on licences for use of marine areas for aquaculture purposes (Wallace and Williamson 2006). The areas of such licences are spatially defined on maps and those wholly within the marine environment could be easily integrated within a marine cadastre. Particular classes of aquaculture license apply dependent upon the species cultivated. Licences authorise the holder to conduct aquaculture activities on crown waters, such as lakes, rivers and marine areas. Aquaculture farms have been established primarily in sheltered bays and estuaries. However, the scope for further development of aquaculture in these areas is finite due to the lack of suitable sites and resource use pressures. For example, the Environment Conservation Council (ECC) in Victoria identified that increased access to marine waters has been difficult to obtain and this is perceived as a major impediment to further development of aquaculture in the marine environment (ECC 2000).

The spatial locations of licences within the south east marine region of Australia are shown in Figure 2.13. The development of such zones is giving rise to the need for accurately defined maritime boundaries. There are some aquaculture leases that straddle the land – marine boundary and unless there is a link between the marine and terrestrial environments, these areas would be hard to spatially define and manage effectively. On the other hand, the processing of aquaculture is based on the land. Currently the management of the coastal zone separates into land and sea, with the use of spatial information for this area also remaining separated. This separation hinders the development of solutions to issues which straddle the land – marine interface, such as the aquaculture leases across coastal zone. For this to come about, the integration of management techniques and spatial data within the coastal zone needs to occur.

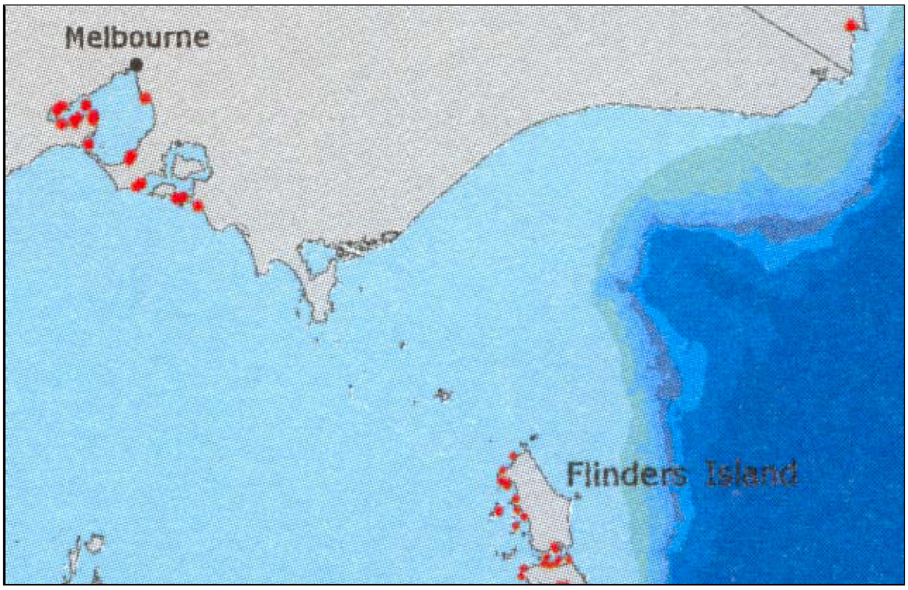

Figure 2.13 Major aquaculture sites within the case study area (NOO 2002b)

In summary the message is that existing regulatory structures create significant difficulties for management of aquaculture. The confliction of marine and coastal management, environmental management, land use policy, land tenure and quarantine and translocation together impede both business activities and regulatory arrangements. Diverse policies and implementation in aquaculture and fisheries legislation create an uncertain legal and regulatory environment. In many cases of actual operations, the industry needs dual access to land and water: the hybrid nature of mussel and oyster production where land access is required, for instance, provides an excellent example of the need for consistent management of both land and marine environments.

2.2.8 Indigenous resource management

In recent times there has been growing pressure to recognise the rights of indigenous people throughout the world. Conventions such as the International Covenant on Civil and Political Rights (entered into force in 1976) and the World Council of Indigenous Peoples in 1975 were some of the first key initiatives, along with the Working Group on Indigenous Peoples, which in 1991 drafted a Universal Declaration on the Rights of Indigenous Peoples to be tabled before the UN General Assembly. An important aspect of this draft, as described by Robinson and Mercer (2000), is the opening of Part III:

> "Indigenous peoples have the right to maintain their distinctive and profound relationship with their lands, territories and resources, which include the total environment of the land, waters, air and sea, which they have traditionally occupied or otherwise used."

International initiatives and court rulings have also given increased focus to the indigenous people's movement, with "global and domestic attention is focusing increasingly on the recognition of indigenous people's rights and interests in coastal and marine areas" (Robinson and Mercer 2000). This increased pressure has forced governments, including the Australian federal government, to change the way in which land and ocean territories are governed.

Coast and ocean are of continuing cultural and spiritual significance to indigenous communities. However there are only a limited number of coastal zone and waterways initiatives involving indigenous people and communities. In fact, in most parts of coastal Australia, Aboriginal people engage in subsistence hunting, fishing and gathering especially fishing which is an important part of Aboriginal culture. In the past decade, Australian courts have attempted to address indigenous or native title rights in marine areas, culminating in the High Court's decision in the Croker Island Case. This decision established the existence of native title in the territorial sea (Binns 2004). However, still there are some issues regarding the indigenous native title claims and their management with the region.

The main issues raised by indigenous people in relation to coastal resource management included:

• Deficiencies in representation and participation;
• Lack of certainty in government processes;
• Lack of recognition of cultural laws and protocols;
• Determination of indigenous cultural and land rights;
• Protection of indigenous cultural heritage; and
• The lack of resourcing for proactive engagement by indigenous people.

However, there are issues and problems raised by non-indigenous people such as restricting areas, pollution of the environment and taking protected species.

In order for indigenous Australians to claim native title to the marine environment, the areas concerned must be spatially defined. Such boundaries then become legally binding, determining areas that are of cultural, spiritual or recreational (hunting and fishing) significance. The availability of such spatial information to the wider community will aid in the management of native title areas, encouraging co-existence. This is also the case when dealing with declarations over maritime zones for the protection of aboriginal areas and objects of significance. Current legislation also enables emergency declarations to be made if an area is under serious and immediate threat of desecration, highlighting the need for spatial information to be accurate as well as up-to-date. The seamless spatial information and associated rights, restrictions and responsibilities enables a platform for rational and non political decision-making.

2.2.9 Protecting marine heritage

Natural, cultural and maritime heritage sites contribute to the share heritage of a nation. Marine heritage takes into account both places and objects of cultural and natural significance and can include coastlines, islands, reefs, shipwrecks, lighthouses and coastal fortifications amongst other things (NOO 2002a). Underwater cultural heritage includes any historic relic or structure that lies beneath the sea or inland waters such as shipwrecks, port facilities, submerged remains of jetties, deposits of bottles or other artifacts. Conservation and interpretation of these heritages is important as they help us to understand and appreciate our culture and history. However, there are some issues regarding the finding, protecting and managing the marine heritages.

In Australia such archaeological and historical objects are regulated through both Commonwealth and state legislation, which is guided by international treaties and United

Nations Convention of Law of the Sea (UNCLOS). All shipwrecks are protected under the *Historic Shipwrecks Act 1976* and in complementary state legislation. More than 6500 shipwrecks lie just beyond Australia's shores (EA 2001b). Over 1000 of these wrecks are located in the south-east marine region of Australia (Larcombe et al. 2002). While each state has legislation complementary to the Commonwealth to protect historic shipwrecks in its waters, the day-to-day management of most shipwrecks is the responsibility of the relevant state government.

Marine heritage is under constant threat from accidental damage from boat anchors, theft, vandalism, pressure from development (e.g. gas pipelines) and environmental factors such as erosion. Protecting natural heritage places relies primarily on a variety of environment protection, nature conservation, land-use and planning laws. State and Territory governments have their own legislation to protect heritage, usually covering only historic places and sites, and there are generally separate arrangements for identifying and protecting natural places and those important to Aboriginal and Torres Strait Islanders (AHC 2001). These threats need to be managed and mitigated with spatial information being one of the best tools for the job.

The major technique used to protect shipwrecks from damage is the proclaiming of a protected zone of up to 800 meters in radius around shipwrecks more than 75 years old (Binns 2004). This is in line with Australia's obligations under the Convention on the Protection of Underwater Cultural Heritage, adopted in November 2001. Such zones prohibit all entry in the absence of a permit, which includes no diving, trawling or mooring of ships. There is also the option of proclaiming protected zones around shipwrecks younger than 75 years if they are of national or cultural significance. There are currently 13 protected zones within Australian waters, with seven such zones located in Port Phillip Bay. The locations of such wrecks are kept in a national shipwrecks database, which includes nodes from each state of Australia.

The ability to map and spatially define marine protected zones would be an essential component for more efficient and effective management regime, in order to regulate and protect marine heritages. Seamless spatial data framework enables a holistic, integrated and coordinated approach to spatial information for decision-making. This leads to considerable saving of time, cost and managing risks.

2.2.10 Marine defence and security

National security deals with threats that have the potential to undermine security of the state or society. It represents the preservation of the nation's people, resources, and culture. As a subset of national security, marine security is a nation's ability to address successfully the security issues facing it that reside in the marine environment.

Nowadays, the issues on national security and defence are areas which need more attention. Issues such as maritime terrorism and piracy have emerged as formidable threats in the world, targeting both civilian and naval vessels. In this regard, Australia faces significant security issues due to its vast coastline, large maritime jurisdictional area and distance from maritime allies. Australia shares maritime borders with Indonesia, East Timor, Papua New Guinea, New Zealand, the French Territories and the Solomon Islands. With island territories extending from the tropics to the hazardous Antarctic waters of the Southern Ocean, the Australia Defence Force responsibilities cover an area of some 16 million square kilometres (NOO 2002a).

The primary objective of Australia's Defence Force is to prevent or defeat attacks on Australia. Its geography and reliance on the sea for trade are reflected in the Government's adoption of a maritime strategy as a cornerstone of the nation's defence. Australia's Maritime Strategy combines the capabilities of the three services to maximize combat power – the Army, the Navy and the Air Force. Such a strategy must also deal with increasing responsibilities of ensuring safety within claimed maritime zones in order to keep a county secure from the risk of terrorism.

Furthermore, under the UNCLOS, Australia has sovereignty out to 12 nautical miles from the territorial sea baseline. This means that international defence forces passing through the beyond 12 nautical miles of the territorial sea baseline are free to conduct exercises without Australia's knowledge or permission.

Different countries face a myriad of both national and international laws, treaties and conventions relating to and assessing their relationship and rights to the sea. Not only is this web of legislation complex, but there is also an increasingly diverse range of actors and authorities active in the marine environment, multiple and unclear jurisdictional limits, various co-management arrangements, and no single agency managing off-shore rights and boundaries creating overlapping and competing interests. All of these facets of management need to be considered.

Hence, there is a need to build a seamless platform that underpins off-shore rights and responsibilities and sensibly matches its on-shore counterpart. Its development can be aggregated flexibly and incrementally in a spatial framework underpinning the administrative infrastructure.

2.3 Marine and Coastal Management – The Spatial Dimension

The marine and coastal management issues previously discussed in this chapter identified the need for accurate and up-to-date spatial information to support a holistic and integrated approach to management and decision-making. Furthermore, the link between the terrestrial and marine environments was recognised as marine and land spatial data cannot be treated separately. The need to administer the spatial dimension of the marine and coastal environments is increasing, being driven mainly by the need to address environmental, economic and social issues of sustainable development, along with the need to break down data silos, creating easier access to current spatial data.

A common theme from many of the worldwide initiatives aiming to improve coastal and oceans management is the desire for access to appropriate and reliable spatial information to support these initiatives. The importance of the spatial dimension in administering marine environments was recognised by the International Federation of Surveyors Commissions 4 and 7 as well (FIG 2006). Spatial information aids decision-making by providing a spatial/geographic context to planning, management and resource allocation and is increasingly recognised as essential to emergency response. 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. To improve management of the coastal zone there needs to be access and interoperability of both marine and terrestrial spatial data (Strain et al. 2004).

The different activities and supporting processes that form marine administration rely on spatial data and information to make decisions. Each of these requires spatial data and information such as tide charts, bathymetry, climate, sea surface temperatures and currents, living and non-living resources, property rights in the area, legislation and international conventions in order to be managed successfully. However problems with accessing, sharing and using spatial data related to these areas is often reported. This can be seen in a proposed marine data policy by the CSIRO (1998) which stated that “present users of ocean and data are faced with a confusing array of datasets and data formats”. This has resulted in the increasing need for the development of an enabling platform to underpin decision making, and better manage and share spatial data assets.

Administering the spatial dimension of the marine environment is very important as decision-makers in both land and marine related areas of the coastal zone need to access marine related datasets. Currently, the ability to provide consistent and accurate spatial information on the wide range of rights and spatial boundaries in the marine environment is hampered by the fact that interests overlap and information is held in silos by various agencies. Therefore, the challenge is managing the complex interactions between the competing rights of stakeholders within the coastal and marine environments.

2.4 Marine Administration Systems

Marine and coastal spaces are complex environments, subject to conflicting pressures and demands, including economic development, social interaction and the need to protect ecosystems and ocean habitats. The marine environment also contains a wealth of actual and potential resources, with demand for exploitation increasing rapidly. In order to balance conflicting ocean uses, resource and coastal management and marine development, a governance framework is required which must be sustainable, holistic and informed (Figure 2.14).

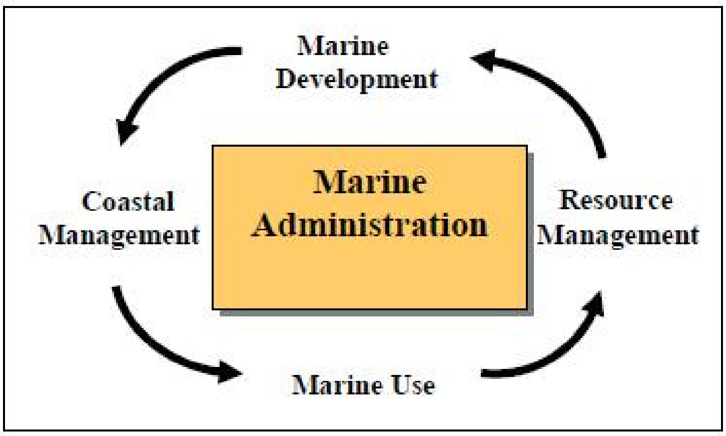

Figure 2.14 Features of marine administration (Rajabifard et al. 2005a)

Underpinning this governance framework is the complex interaction between overlapping and sometimes competing rights, restrictions and responsibilities of various activities within the marine environment and at the coastal zone. It is now being accepted that much of the required information needed to balance these competing interests has an inherent spatial dimension, which offers both potential and challenges for proper analysis and management (PCGIAP-WG3 2004).

The current systems in place to manage and administer marine boundaries and rights need to be assessed, in order to identify technical, legal and institutional issues and arrangements that are hindering the coordination and effective management of the marine environment. Common problems, issues, similarities and differences in institutional arrangements and in the administration of rights, restrictions and responsibilities need to be documented, in order for best practice to be established. There are also technological and human resource and capacity building issues affecting the establishment of effective marine administration systems that need to be taken into consideration. Perhaps the most important in creating an effective system however is investigating and solving socio-economic (institutional), policy and cultural issues that often hinder development long after technical problems have been solved, as seen in the terrestrial environment (Rajabifard et al. 2005a).

While Land Administration Systems (LAS) traditionally stop at the coastline, many countries apply land-based tenures, measurement and identification systems, and registration systems as initial solutions to marine management problems. Indeed, some countries even extend existing organisational structures beyond their traditional terrestrial boundaries (Williamson et al. 2009). Alongside these extrapolations of systems from the land to marine environment, the unique marine activities of fishing, navigation, aquaculture farming, and many others, including pollution cleanup, tend to be separately managed.

As a result, nations tend to produce diverse, silo-based, and generally unsatisfactory marine management and, consequently, insufficient, uncoordinated marine information. Concerted international efforts over the past decade have sought to introduce coherence and capacity in marine management by identifying the unique features of a marine administrative system, such as a lack of markers and changing boundaries, and integrating marine and land management wherever possible, particularly in coastal zones.

To be successful in this broad context, a marine system must be subsumed into a national approach to management of land, coastal, and marine environments. This then will enhance sustainable development.

The coastal zone, the overriding feature of the marine environment, is of vital importance, forming the glue that joins land and marine areas together. It is the centerpiece of the marine management system of every nation that enjoys sea boundaries, and it is ever changing. In short, if a nation fails to manage its coastal zones effectively, neither its land management nor its marine management will work. This is especially true for nations formed by archipelagoes or whose coastlines are extensive comparative to their land mass. Thus, states with extensive coastlines (Vietnam, Mozambique, Canada, Chile, Australia, and Costa Rica), island states (such as New Zealand and Madagascar), and many archipelagic nations (Indonesia, the Philippines, and Japan) need specially designed administration system that incorporate the marine environment. The international trend in modern marine management is to build a holistic approach to jurisdictional management and simultaneously create systems that improve regional management as well.

2.5 Integrated Coastal Zone Management Initiatives

Multiple reports internationally have highlighted the need for better coordination and integration between and within levels of government to improve coastal zone management (Hudson and 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) is an initiative that aims to "improve the quality of life of coastal inhabitants" (Thia-Eng et al. 2004). It has become the standard approach to coastal planning and management (Wescott 2004) with nearly 700 ICZM initiatives occurring at international, national and sub-national levels (Chuenpagdee 2004). ICZM has been slowly accepted over the last decade as a unifying approach for coastal planning and management through the world (Wescott 2004). ICZM has been described as a process for decision-making: it should be continuous, iterative, and should recognise the contributions of stakeholders and the natural dynamism, both physical and ecological, of the coastal environment. A primary goal of ICZM is to overcome the compartmentalised approach to managing coastal resources by harmonising the decisions of diverse jurisdiction between management of the land and of the sea. ICZM, therefore, is also about building institutions that facilitate this integration. It is founded on principles of sustainable development, recognising that the coastline is the fount of resources of great value to human communities and that these resources should be managed in ways that conserve their value for future generations (Cicin-Sain and Knecht 1998).

ICZM recognises that the coastal resources management situation is unique, that is, it differs greatly from management of either land or marine resources, being a combination of both. Therefore management needs to consider the multiple activities and interests in the area and provide an integrated approach, horizontally across different jurisdictions and vertically between different organisations and levels of government. The key is unitary management of the zone, treating the shorelands and coastal waters as a single interacting unit (Clark 1997). In the USA, both the Pew Ocean Commission (2003) and the U.S. Commission on Ocean Policy (2002) recognised that land-use practices carried out hundreds or even thousands of kilometres inland from a coastline have direct and often detrimental impact on environmental, social and economic health and value of coastal areas connected to the hinterland by major inland watersheds.

Therefore, the geographical coverage of ICZM programmes has widened from a strict focus on the coastal fringe, defined according to administrative (land-ward) and jurisdictional (marine-ward) criteria, to a wider area defined according to administrative and ecological criteria. The seawards extent of this definition covers a much-extended jurisdictional zone, while in the landwards direction it can, and frequently does, cover entire river basins. It has even been suggested that “the coastal zone is not a narrow band. It’s the whole country” (U.S. Commission on Ocean Policy 2002).

ICZM has been adopted by the state governments in Australia as the accepted approach to coastal management (VCC 2002). Data is seen as an important element in the ICZM process as shown by Bartlett et al. (2004) “if goals such as sustainable development of coastal zones are to be reached, then coastal researchers from different disciplinary backgrounds require access to a wide variety of marine and coastal databases". ICZM recognises the need to integrate planning and management over the land – marine interface and so there is a need for data and information that covers both these areas.

2.6 Drivers for Integrating Land and Marine Environments

As shown in this chapter, current regulatory methods for the management of the coastal zone separate it into land and sea, with the use of spatial information for this area also remaining separated. This separation hinders the development of solutions to identified marine and coastal management issues which straddle the land – marine interface, such as the pollution of the marine environment from land-based sources. For this to come about, the integration of land and marine spatial data within the coastal zone needs to occur.

The integration of land and marine base information is an increasing problem in many countries. Indeed, many development plans have failed due to the lack of necessary integration of information. This especially applies to archipelagos where seawater is the "bridge" connecting islands. While most of the countries are aware the problem of disconnected land and marine information, few have committed to resolving the problem (Murray 2007). This is partly due to complexity as it requires two or more organisations and users to identify and address the key issues. The ability to access and integrate data has been identified as a problem by people involved in coastal zone management. Also the development of ICZM initiatives has encountered similar problems (Strain et al. 2006). However, the primary drivers for land and marine integration can be categorised into

- Societal drivers;
- Commercial drivers; and
- Technological drivers.

Primary drivers are defined as motivators for integration of land and marine environments (Figure 2.15).

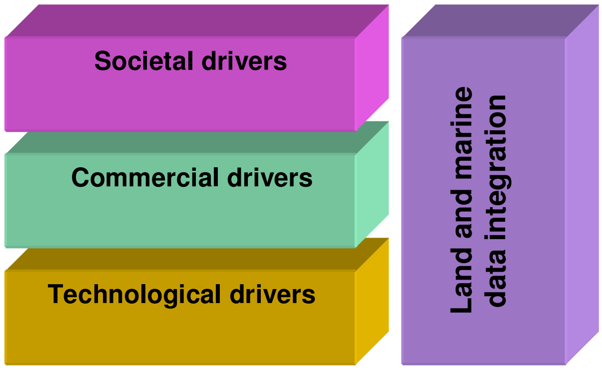

Figure 2.15 Drivers for integrating land and marine environments

2.6.1 Societal drivers

The coast as the interface between the land and marine 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 many ways. Largely for transportation reasons, major industrial and commercial centres developed around port cities. Some two-thirds of the planet's population lives in a narrow 400 km. 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). This puts more pressure on the land – marine environment through greater demand for development and the resulting increase in effluent and pollution. These problems can no longer be viewed in isolation. There is a need for connectivity and replacing a fragmentation with a collaborative, integrated approach (Toth 2007).

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 2001). Land-based sources of marine pollution account for around 80% of contamination in the marine environment (SOEAC 1996). Environmental problems have to be addressed globally.

Consequently climate change and global warming are a serious threat to coastal areas requiring greater attention to coastal protection and change management. Other drivers are cost and time efficiencies, public expectations coupled with greater awareness and focus on temporal issues and policy drivers such as the European Union Water Framework Directive (2000/60/EC) or other legislation concerned with limiting adverse impact of natural forces and processes.

2.6.2 Commercial drivers

The coastal zone is one of the most productive areas accessible to people. However, there are increasingly serious signs that economic uses of our coast are undermining their long term sustainability. For example, overfishing is exhausting and depleting fisheries around the world. 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 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 2002a). Additionally, production of off-shore oil and gas is declining due to depleting resources. The protection of marine ecosystems and fishery resources can not be tackled by individual eco-systems. There is an economic and social need to manage, explore and exploit the nation’s ocean territories in a way that will maximise benefit, while protecting the ocean environment.

2.6.3 Technological drivers

Seamless discovery and seamless use are two main user aspirations. The user would like to be able to search widely, at different levels and access all that exists. This entails the needs for agreements in terms of data descriptions, metadata definitions, protocols, data access and sharing policy. Also the user would like to identify easily the data available and to find easily what fits the purpose and download it directly to their analysis software.

2.7 Chapter Summary

This chapter examined examples of marine and coastal management issues with the focus of Australia's coastal and marine jurisdictions and particularly the south-east marine region of Australia which is the area for the case study. These issues are including but not limited to rapid coastal population growth, global warming, shoreline erosion, accretion and sea-level rise, overfishing (commercial and recreational), oil, gas and minerals extraction, loss of habitat and coastal wetlands, lack of suitable sites for aquaculture, indigenous resource management issues, protecting marine heritage and marine defence and security. Investigation and examination of these issues led to the need for seamless spatial data across the land – marine interface in order to increase the efficiency and effectiveness of management across the land – marine interface. Therefore, the first objective of this thesis which is the investigation and justification of seamless information by including real examples of marine and coastal issues that need seamless spatial information has been met in Section 2.2.

Section 2.3 further discovered the ability to map and spatially define marine and coastal areas as an essential component for a more efficient and effective management regime, balancing the rights and responsibilities of multiple users, and ensuring that other activities that are permitted under relevant legislation can take place. Moreover, Section 2.4 discussed marine administration systems and highlighted the fact that diversity of marine environments requires effective economic, social, and environmental management that is just as comprehensive as land management.

This chapter then introduced and generally highlighted ICZM initiatives in Section 2.5 in response to the need to integrate planning and management over the land – marine interface and also spatial data and information that covers both these areas. Therefore the drivers for integration of land and marine environments have been identified in Section 2.6 as societal, commercial and technological drivers.

The next chapter discusses SDI – an initiative that aims to facilitate and coordinate the exchange and sharing of spatial information. It will provide an insight into SDI concepts and definitions in land and marine environments. It also highlights the role of SDI to improve management and administration of coastal and marine environments through better availability and applicability of spatial data.

CHAPTER 3

SPATIAL DATA INFRASTRUCTURES

3.1 Introduction

This chapter aims to present the concept of Spatial Data Infrastructures (SDIs) as an enabling platform to facilitate sharing and access to up-to-date spatial data for all potential users. Chapter 2 examined the development of marine administration systems and highlighted the need for these to be underpinned by access to reliable and applicable spatial information. This chapter discusses what it is about spatial information that makes it so useful in management and administration, and also the difference between spatial and other types of information. It is followed by the diverse definitions of SDIs and SDI components within different communities and its hierarchical nature.

Furthermore this chapter discusses the emergence of the Marine SDI initiatives in response to a global realisation of the need to improve management and administration of the marine environment and help to overcome some of the coastal and marine management issues and challenges discussed in Chapter 2. It looks at the various initiatives in several countries and also at regional and global levels at different stages of developing a spatial dimension to marine administration systems. However they all have similar aims to improve marine and coastal zone administration and management through better availability and applicability of spatial data. Finally the need for a seamless platform is discussed as the next chapter (Chapter 4) looks at the development of the Seamless SDI and its characteristics and components.

3.2 Spatial Data Infrastructure Theory

Spatial information is a crucial and useful resource in many marine management and administration initiatives as demonstrated in Chapter 2. Spatial information is often described as special or essential as it describes the location of resources in a way that gives understanding and relativity to other objects or resources. This ability to visualise the location of resources enables planning and management of the exploitation of these resources, allocation of the rights to them, and creation of restrictions and responsibilities for the protection of these resources. Therefore, the utilisation of spatial information and spatial services is a suitable means to optimise the sustainable management of our resources (Muggenhuber 2003).

Spatial information plays a significant role in many social, economic and political decisions. Governments, business and the general public rely heavily on spatial information for their daily decision-making (Onsrud and Rushton 1995). They consider spatial information as a resource and also a part of fundamental infrastructure that needs to be coordinated and managed effectively (Ryttersgaard 2001). In response to this situation, over the last few years spatial data infrastructure (SDI) has been emerged at different levels, which is driven by business needs and technological developments to support both the government and the rapidly expanding spatial information industry (Williamson et al. 1998). Use of spatial data and spatial information in any field or discipline, particularly marine administration, requires a SDI to link data producers, providers, and value adders to data users. The SDI provides ready access to spatial information to support decision making at different scales for multiple purposes. Initially, the infrastructure links data users and providers on the basis of the common goal of data sharing. Potentially, it enables sharing of business goals, strategies, processes, operations, and value-added products.

SDIs encompass the policy, access networks and data-handling facilities (based on available technologies), standards, and human resources necessary for the effective collection, management, access, delivery, and utilisation of spatial data for a specific jurisdiction or community. It facilitates the sharing of data, by avoiding duplication associated with generation and maintenance of data and integration with other data sets. Sharing spatial data would allow users access to more and potentially better quality data, and better maintenance and integration of datasets (Rajabifard and Williamson 2001). The complex relationships among the technological, institutional, organisational, human, and economic processes need to be reflected in SDI design.

SDI as an enabling platform links services across jurisdictions, organisations, and disciplines. This cross-jurisdictional approach aims to provide users with access to and use of information related to both the land and marine environments in real time. This information is then used to enhance decision making and in turn supports the achievement of the economic, environmental, social, and governance objectives of sustainable development. An effective SDI can save resources, time, and effort for users who need to acquire new datasets by eliminating the duplication and expenses associated with the generation and maintenance of disparate data and then integrating that data with other datasets.

3.2.1 Spatial information

Spatial information is used in many disciplines, by many different people, for many different reasons. Some of the oldest disciplines, land surveying and geography, are built on the spatial paradigm (Lees and Williamson 2004). As a country develops most industry and activities are reliant on topological and other spatial information, including (Butler et al. 1987, p. 48): road and railway development, improvement in regional agriculture, development of water supplies and hydro-electric power from dam construction, large-scale cultivation of new crops, tourism planning and development, census studies, forestry management, industrial plant location, land ownership, land usage, environmental hazards, ecological studies, transportation, archaeological and anthropological studies, investigation, control and use of water resources, cadastral surveys, urban studies, sea defences, soil surveys, economic assessments, health investigations, irrigation systems, land reclamation; mosquito control in marshes, airport sitting, housing developments and vegetation classification.

By investigating the above list it can be seen that all of these activities will need access to all different kinds of information. Most of these will be spatial information. About 80 % of all information utilised by decision-makers is spatial information (Ryttersgaard 2001;

Klinkenberg 2003; Masser 1999). Spatial information is any information that can be geographically referenced (WALIS 2008), i.e. describing a location or any information that can be linked to a location (ANZLIC 2008). According to Rajabifard (2002), people need spatial data and its derived information to establish the position of identified features on the surface of the Earth. The ability to locate the position of an activity or feature allows it to be linked to other types of information, whilst also allowing "distances to be calculated, maps to be made, directions given and decisions to be made about complex, inter-related issues" (Mapping Science Committee 1995). Spatial information plays an important role in promoting economic development, improving stewardship of natural resources and helping to protect the environment.

The term spatial information is used almost interchangeably with spatial data, geospatial information or data and geographic information (Warnest 2005). By organising data, it is turned into information, so that we can easily draw conclusions. Having information available is necessary to promote a good understanding and knowledge for a particular discipline as described by Doody (2003):

Data + Context = Information
Information + Analysis = Understanding
Understanding + Management = Possibility of sustainable action.

Therefore, information has context. Data can also be turned into information by "presenting", such as making it visual or auditory (Cleveland 1982). Spatial information can now be stored and coordinated in databases, but the specific characteristics of spatial information make it a different form of information. Spatial information is scale-dependent. Spatial queries are inherently complex; all spatial queries, analysis and modelling are dependent on data models that are diverse and have many dimensions (Williamson 2006). The size of spatial information and the need for management of spatial and attribute information require a specific set of tools and arrangements (Egenhofer 1993). Hence, understanding the collection, management, manipulation, integration, use, presentation and querying of spatial information requires special skill sets.

The value of spatial information has increased with the emergence of improved Information and Communication Technology (ICT). This is supported by the evolution of measuring technology with satellite positioning, allowing much greater accuracy and range of ability to collect digital spatial data.

One of the characteristics of modern societies is the focus on publicising digital data and building information infrastructures. The information infrastructure helps the maximum use of information by more users and also facilitates the trade of digital data as a commodity (Warnest 2005). Building an information infrastructure does not just facilitate the availability of information (searchability, discoverability and accessibility) but it also provides links as a bridge from existing knowledge to new information. The publicity of information causes the diversity and heterogeneity among multi-source information; hence the effectiveness of information infrastructures greatly depends on integrated systems and information. This wave requires the ability of organisations and systems to cooperate and liaise, which means information becomes interrelated (Muggenhuber 2003).

In September 1993, the US President's Administration announced the construction of a National Information Infrastructure (NII). NII aimed at some critical principles and objectives (Executive Office of the President 1993), including:

- To ensure that information resources are available to all at affordable prices
- Promote seamless, interactive, user-driven operation of the NII
- Ensure information security and network reliability
- Protect intellectual property rights
- Coordinate with other levels of government and with other nations
- Provide access to government information and improve government procurement.

Former American Vice President, Al Gore (1998), insisted on georeferenced information as the building block of a NII. The Australian Government also pushed spatial information infrastructure to the force, initiating spatially enabled government (Williamson 2006).

3.2.2 SDI's emergence

The concept of SDI was first introduced in the mid 1980s around the need for cooperation and sharing of spatially related information across a nation. In the US, discussion about the National SDI initiative initially began primarily in the academic communities around 1989 and soon after in the government. These discussions progressed especially rapidly when in the early 1990s, the National Research Council's (NRC) Mapping Science Committee articulated the way that spatial information needed to be handled from an institutional perspective (Onsrud et al. 2004) and after the executive order from the President's office was issued in 1994 (Executive Office US President 2002).

The recognition of the importance of SDI for the governments was accompanied by the formation of the Federal Geographic Data Committee (FGDC) in 1990 (McDougall 2006). Since then, the FGDC attempted to develop a coordination framework, standards and the documentation of best practices in accordance with the National SDI objectives in building a national digital spatial data resource. In Australia, national land-related information initiatives commenced with a government conference in 1984, which eventually led to the formation of a committee responsible for SDI development (Williamson et al. 2003a). In the early 1990s, a number of state government agencies promoted the proposition that land and spatial information should be considered as an infrastructure (Davies and Lyons 1991; Kelly 1993). Australian efforts towards a National Spatial Data Infrastructure were promoted by ANZLIC in 1996, through a position paper on "Spatial Data Infrastructure for Australia and New Zealand" (ANZLIC 1996). Coordination efforts by ANZLIC activated this vision through the development of policy, standards and metadata toolkits.

These initiatives, then followed by a number of other initiatives, characterised the first wave of SDI development. From 1999 to 2005, the Canadian Federal Government put $60 million in funding towards a national partnership initiative to make Canada's geospatial information accessible on the internet, while provincial and territorial governments and the private sector are investing over $50 million in funding (GeoConnections 2008). In 2005, the minister announced that the government of Canada has allocated $60 million in its 2005 budget for a second, five-year phase of GeoConnections. A GeoConnections developed the policies, standards, technologies, and partnerships needed to build the Canadian Geospatial Data Infrastructure (CGDI).

In Europe, the European Umbrella Organisation for Geographic Information (EUROGI) was set up in November 1993, as a result of a study commissioned by the Directorate-

General, Information Society and Media of the European Commission to develop a unified European approach to the use of geographic technologies (EUROGI 2005). The activities of EUROGI are financed by the member countries which contribute to the total budget for the annual work plan in a challenging organisational, political, legal and technological environment. In 2002, the Commission began preparing an initiative to stimulate the availability of geographic information, INSPIRE (INfrastructure for SPatial InfoRmation in Europe). The initiative aimed to make interoperable spatial information readily available in support of both national and community policy and to enable the public to access to this information. This was a major milestone for the use of spatial information in Europe as a contribution to environmental policy and sustainable development. It was the first step in a co-decision procedure that led to the formal adoption of the pan-European SDI (INSPIRE 2007).

In Asia-Pacific region, through the efforts of the United Nations Regional Cartographic Conference for Asia and the Pacific region in May 1994, the national mapping agencies in Asia and the Pacific region formed the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP) in 1995 to develop a Regional SDI for Asia and the Pacific region (PCGIAP 1995). The aims of the PCGIAP were to maximise the economic, social and environmental benefits of geographic information in accordance with Agenda 21 by providing a forum for nations across the region to cooperate in the development of the Asia-Pacific Spatial Data Infrastructure (APSDI) and contribute to the development of the global infrastructure.

In the mid 1990s at the global level, Global SDI (GSDI) initiative was formed with a special focus on promoting international cooperation and collaboration in support of local, national and international spatial data infrastructure developments that will allow nations to better address social, economic, and environmental issues of pressing importance. GSDI aims at providing a point of contact and an effective voice for jurisdictions in the global community involved in developing, implementing and advancing spatial data infrastructure concepts to foster spatial data infrastructures that support sustainable social, economic, and environmental systems integrated from local to global scales, and to promote the informed and responsible use of geographic information and spatial technologies for the benefit of society (GSDI 2008).

Also, many of the countries around the world are developing SDI at different jurisdictional levels. Each jurisdiction has its own definition of SDI that springs from jurisdictional backgrounds and requirements.

3.2.3 SDI concepts and definitions

SDI is developing in many different countries and at different levels within each of these countries, and so there are a multitude of definitions for SDI. Within the SDI community there are differences in the understanding of SDI and its potential benefits (Grus et al. 2007), therefore SDI is viewed, defined and interpreted differently by different practitioners. The European Commission (2006) highlights this as one of the most challenging obstacles for SDI assessment and development. It also argues that there is much confusion resulting from the lack of an agreed definition of SDI, its components and the relationships between them. Table 3.1 shows a number of SDI definitions and perspectives.

Table 3.1 SDI definitions by different communities (Mohammadi 2009)

Source	Definition
Executive Office of the President (1994)	SDI means the technology, policies, standards and human resources necessary to acquire process, store, distribute, and improve the utilisation of geospatial data.
Brand (1998)	A Global Spatial Data Infrastructure is one that encompasses the policies, organisational remits, data technologies, standards, delivery mechanisms and financial and human resources necessary to ensure that those working at the global or regional scale are not impeded in meeting their objectives.
Coleman and McLaughlin (1998)	SDI encompasses the policies, technologies, standards and human resources necessary for the effective collection, management, access, delivery and utilisation of geospatial data in a global community.
ANZLIC (2003a)	SDI is a framework for linking users with providers of spatial information. SDI comprises the people, policies and technologies necessary to enable the use of spatially referenced data through all levels of government, the private sector, non-profit organisations and academia.
Groot and McLaughlin (2000)	SDI encompasses the networked geospatial databases and data handling facilities, the complex of institutional, organisational, technological, human and economic resources which interact with one another and underpin the design,

	implementation and maintenance of mechanisms facilitating the sharing, access to, and responsible use of geospatial data at an affordable cost for a specific application domain or enterprise.
Rajabifard et al. (2002a)	SDI is fundamentally about facilitating and coordinating the exchange and sharing of spatial data between stakeholders in the spatial community.
Nebert (2004)	SDI is a collection of technologies, policies and institutional arrangements that facilitates the availability of and access to spatial data.
GSDI (2005)	SDI supports effective access to geographic information. This is achieved through the coordinated actions of nations and organisations that promote awareness and implementation of complementary policies, common standards and effective mechanisms for the development and availability of interoperable digital geographic data and technologies to support decision making at all scales for multiple purposes.
Wikipedia (2008)	An SDI is a framework of spatial data, metadata, users and tools that are interactively connected in order to use spatial data in an efficient and flexible way. Another definition is the technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data.

The above table encompasses most of the SDI definitions. These different SDI definitions show the change in attitude and focus of the SDI movement. The early views of SDI were about producing, accessing and having spatial data. Other views, which have evolved recently, recognise that while obviously the data is important, developing a SDI needs to concentrate on the infrastructure, in providing the enabling technology and cooperation between stakeholders to allow and promote data sharing.

While there are many different definitions resulting from the different country context or discipline the SDI is intended for, they all have the same overall goal: to improve access and use of spatial data through enabling different people to share their spatial data products. These definitions mainly emphasise the facilitation of data access, sharing and use. They also urge on the interaction between spatial data stakeholders and spatial data through a number of technical and non-technical components including people, fundamental data, technology, metadata, standards, policies, institutional arrangements and financial resources. The next section will articulate the components of SDI within different SDI communities

3.2.4 SDI components

The core elements that comprise a SDI have been defined differently by different communities. Although there are many different definitions and models for SDI, researchers in SDI have identified some components common to most SDI initiatives (Coleman and McLaughlin 1998).

Rajabifard and Williamson (2001) have proposed the core components of SDI are as policy, access networks, technical standards, people (including partnerships) and spatial data. This model proposes that the fundamental interaction between spatial data and the stakeholders (people) is governed by the dynamic technological components of SDI including access networks, policies and standards as shown in Figure 3.1.

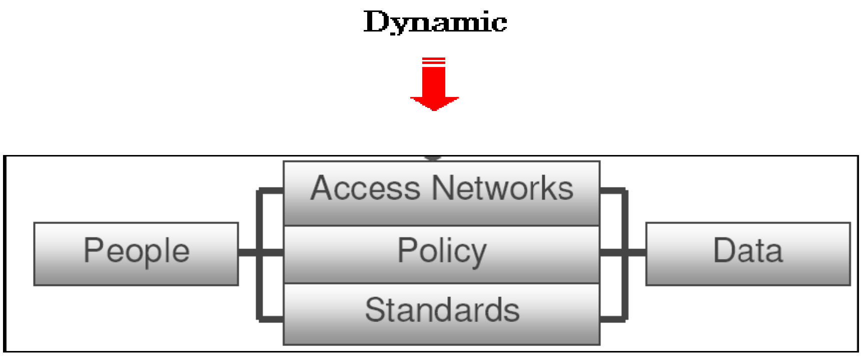

Figure 3.1 The SDI model (Rajabifard and Williamson 2001)

It is important to note that the SDI concept is dynamic in that it can be updated or expanded with changing technology or user needs, or to include a new environment. These components will be discussed in greater detail as they apply to the marine environment in Chapter 4.

The Executive Office of the President of the United States (2002) has introduced five components for US National SDI. The components of the SDI as can be seen in Figure 3.2 are fundamental data themes, metadata, the National spatial data clearinghouse, standards, and partnerships.

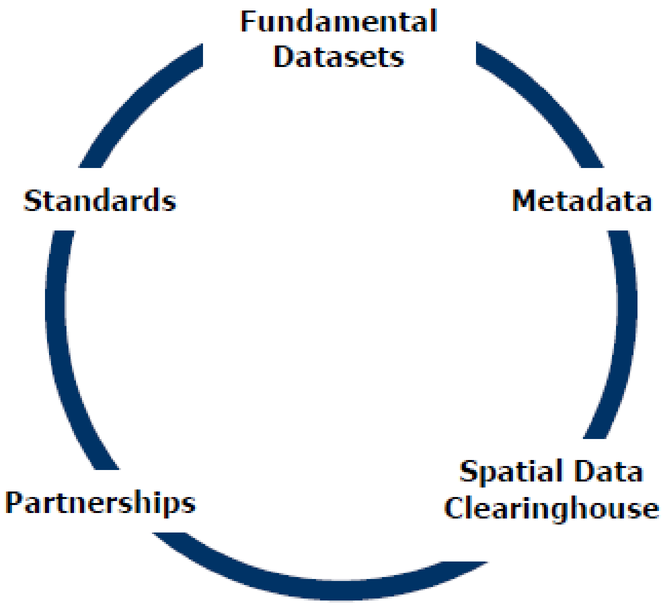

Figure 3.2 SDI components (Executive Office US President 2002)

In Canada, the CGDI has identified five main components for Canadian SDI, including technology, policy, framework, standards and access network as illustrated in Figure 3.3 (GeoConnections 2008).

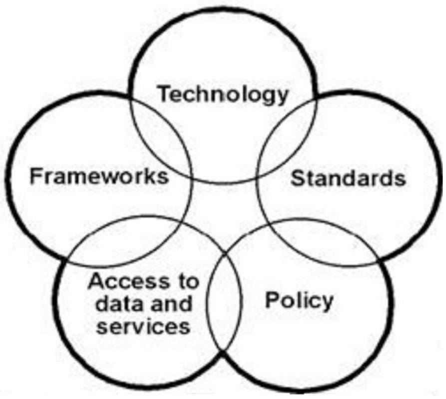

Figure 3.3 SDI components identified by GeoConnections (2008)

In UK, National Spatial Data Infrastructure has been defined as shown in Figure 3.4. SDI covers the processes that integrate technology, policies, criteria, standards and people necessary to promote geospatial data sharing throughout all levels of Government. It covers the base or structure of practices and relationships among data producers and users that facilitates data sharing and use. It covers the set of actions and new ways of accessing, sharing and using geographic data that enable far more comprehensive analysis at all levels of government, the commercial and not-for-profit sectors and academia. It also describes the hardware, software and system components necessary to support these processes (UK GI Panel 2006).

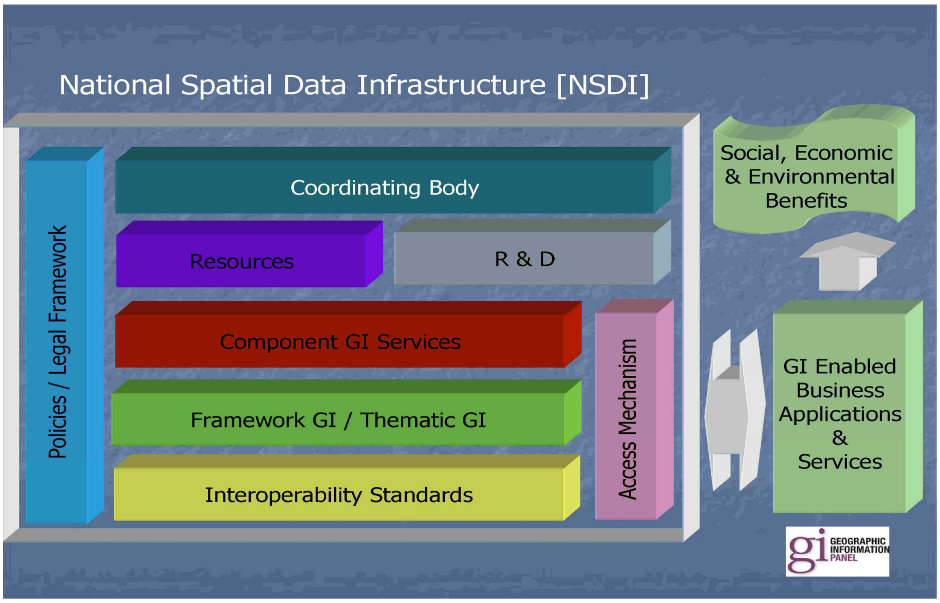

Figure 3.4 Components of the UK NSDI (UK GI Panel 2006)

As these examples show, different components have been identified for SDIs. In general these include spatial information, people, institutional arrangements, standards, metadata, access network, partnerships, governance and capacity building. These components are seen to be the tools which enable users and producers of spatial data to interact and cooperate with each other (Chan et al. 2001), reducing costs, both in terms of time and money, associated with the management and compilation of spatial data. In recent years, as the concept and the development of the SDI framework have matured, the role of some other elements has been greatly realised. In particular, capacity building, spatial data sharing, partnership and governance have been recognised to have a great impact on the effectiveness and success of SDIs.

While there are many different definitions resulting from the different country contexts or disciplines, the SDI model defined by Rajabifard and Williamson (2001) (Figure 3.1) will be adopted for SDI throughout this thesis.

3.2.5 Hierarchical nature of SDI and current developments

Early discussion of the SDI concept focused on nations as an entity. Now, more attention is given to understanding the SDI hierarchy, which is made up of interconnected SDIs at the various levels as illustrated in Figure 3.5 (Rajabifard et al. 2000). SDI initiatives are developing at various political or administrative levels from local through state, national, regional to global. SDI is developed at each particular level or within each discipline to promote better decision-making and therefore better social, economic and environmental outcomes for that particular level (Rajabifard et al. 2002b). The way in which data is collected, stored, maintained and used reflects the institutional and technical background of that particular level or discipline. SDIs at different levels have different drivers that reflect the issues at each particular level and each level of development supports the higher level of development. In general, the various levels are a function of scale. Local government and state-level SDIs manage large- and medium-scale data, leaving national SDIs to manage medium- to small-scale data, with regional and global SDIs adopting a small scale for their activities. The improved understanding of the SDI hierarchy has challenged different jurisdictions to improve the relationships among the different levels and to coordinate spatial data initiatives.

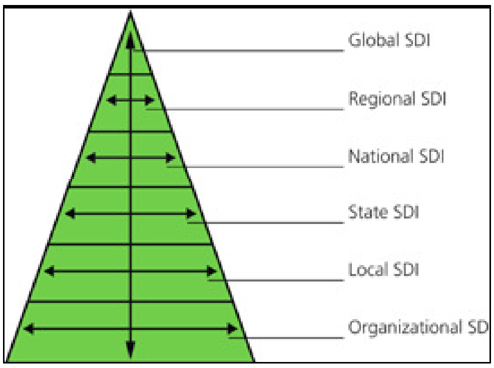

Figure 3.5 The SDI hierarchy has both horizontal and vertical relationships among its jurisdictional levels (Rajabifard et al. 2000)

Figure 3.5 also shows the complex and dynamic inter-and intra-jurisdictional nature of SDIs. In addition to the vertical relationships between different jurisdictional levels, complex horizontal relationships within each political or administrative level need to be analysed. The vertical and horizontal relationships within a SDI hierarchy are very complex because of their dynamic inter- and intra-jurisdictional nature (Rajabifard et al. 2002b). Users of a SDI thus need to understand all the relationships involved in the dynamic partnerships it supports.

Most successful SDIs are built through mutually beneficial partnerships that build inter- and intra-jurisdictional relationships within the hierarchy. These partnerships adopt a focused approach to SDI development, creating business consortiums to develop specific data products or services for strategic users. Thus, early identification of the human and community issues involved in these partnerships is essential.

Rajabifard and Williamson (2001) have proposed two SDI models that examine the nature of the SDI hierarchy (Figure 3.6).The umbrella view describes SDI as an umbrella, where the SDI at the higher level (such as the Global and Regional levels) encompasses all the components of the SDI at the lower levels (e.g. State or Local). In this view SDI have the necessary standards, policies and technology in place at the Global level to support and promote spatial data sharing at all the lower levels from Regional to Organisational. Another view of SDI hierarchy is the building block view. According to this view, any level of SDI, for example the State level, serves as the building blocks supporting the provision of spatial data needed by SDIs at higher levels in the hierarchy, such as National or Regional levels

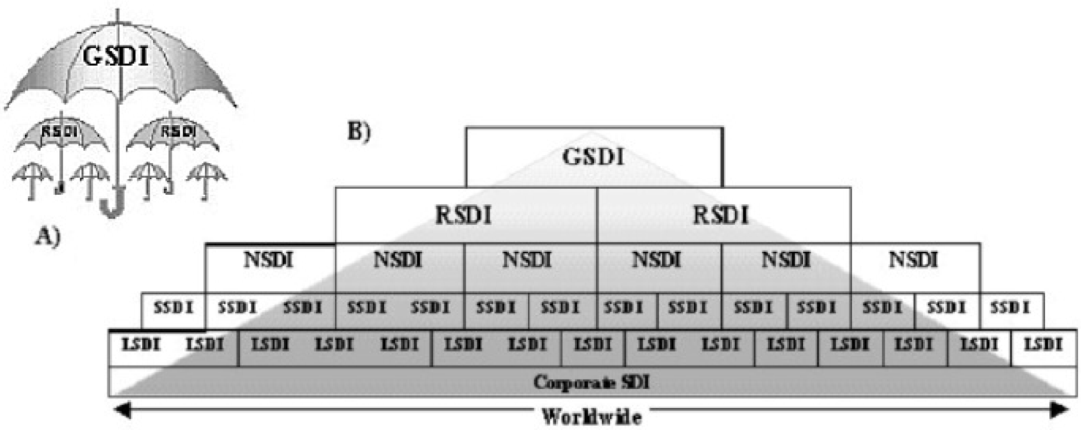

Figure 3.6 Two views of SDI: A) The umbrella view, B) The building block view (Williamson et al. 2003)

This would mean that a Global SDI is made up of the all the Regional SDIs and a State SDI is made from all the Local SDIs within the state. This is more of a bottom up approach, where the people and spatial data from the local and organisational levels drive the development of SDI up the SDI chain to the regional and global levels (Williamson et al. 2003a). An understanding of both of these models of SDI hierarchy can help to better design and implement a successful SDI.

However, Masser (2005) believes that although the properties and characteristics of the hierarchical system might be essential for the development of a consistent data structure, the absence of a strict hierarchical structure does not necessarily inhibit the implementation of SDI initiatives. For example, in the case of the US, the FGDC work directly with local governments without reference to the state level. This kind of structure is already operational to some extent in some countries including Australia and is implicit in the proposals for a 50-state initiative in the US (Masser 2006).

SDI has been in the spatial community for less than two decades and there are still many gaps in SDI advancement, which should be filled through conducting research and study. Onsrud (2004) highlights social and institutional issues as the most outstanding issues to focus on in future developments of SDI. He also recommends a number of specific projects that might be undertaken within the context of SDIs including:

- Real-time case studies to measure the effects of different legal, economic, and information policy choices on the development of spatial information infrastructures;
- Evaluate the costs, benefits, effectiveness, and efficiencies of current government information policies;
- Explore and develop a range of institutional and legal arrangements for accessing geographic resources;
- Capacity building in spatial information resource management through the development of curricula, educational programs, and professional training;
- Strategy development for increasing public access to government information;
- Examine the role that pricing and cost recovery practices play in public access and commercial uses of data;

- Compare local, state, and national government dissemination policies for allocating public and private funds to sustain government investments in a SDI;
- Develop guidelines for increasing public participation in the identification, creation, use, and exchange of spatial information resources to inform community decision making;
- Experiment with collaborative projects that are based on local knowledge and incorporate information to support public awareness and enhance decision making processes;
- Model the components and dimensions of an expanded view of the SDI focusing on technology and institutional developments and how they are embedded in other processes and media.

Masser et al. (2007) believe that the next significant step in SDI development is the spatial enablement of the government. They also urge that the future of SDIs is reliant on the ever-increasing involvement of the government in SDI development. There are many parallels between concepts based on which SDIs are developed and the vision of spatially enabling the governments.

One of the major achievements that move governments and societies towards spatially enablement is the concept of virtual jurisdictions (Rajabifard et al. 2005b). Virtual jurisdictions represent an entity (such as a government) representing a defined territory (such as the State of Victoria) operating in an electronic medium, principally the internet (Robertson 2004). The development of such a virtual system requires a set of concepts and principles to enable the design of an enabling platform. This platform facilitates interoperability and interaction of functional entities within a heterogeneous environment and SDI has taken a lead role to meet these objectives. It also provides a foundation for identifying best practice and key performance indicators of SDIs in terms of their policy, technology and institutional frameworks.

Spatial data integration and harmonisation have been identified as a major challenge for next generation of SDIs (Rajabifard et al. 2005c; Muggenhuber 2003). Among current challenges of next generation of SDI, the integration of land and marine spatial data and building a seamless and integrated SDI that covers land and marine environments is within the scope of this thesis.

3.3 SDI in Marine Environment

As discussed, in response to the need for integrated land information, a SDI was developed to create a secure environment that enables users to easily access and retrieve complete and consistent spatial datasets. Until recently most, if not all spatial information management and administration tools have focused 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. Management of the various Rights, Restrictions and Responsibilities (RRRs) is ideally achieved through the cadastre. In marine environment, a marine cadastre delineates, manages, and administers legally definable off-shore boundaries. It delivers the fundamental datasets that are especially vital to marine and coastal zone management. Nevertheless, the marine environment requires an overarching spatial information platform that facilitates coordinated use and administration of these tools.

SDIs enable a uniform approach for maximum integration and security of data, effective resource use, and development of comprehensive information systems. However, most current SDI initiatives direct their attention landward with limited consideration of Marine and Coastal SDIs. Yet there is a growing and urgent need to create a Marine SDI to facilitate marine administration.

The functionality of a cadastre in supporting the SDI is now recognised after a protracted debate about how to use and adapt land-based tools to service marine needs. The cadastral component and the SDI are fundamental to the way marine information is developed and shared, and ultimately for competent marine administration (Figure 3.7). The need for a marine cadastre was recognised at the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP) Workshop for Administering the Marine Environment held in Malaysia in 2004 and endorsed by the United Nations through a resolution passed at the 17th United Nations Regional Cartographic Conference for Asia and the Pacific (UNRCC-AP) meeting in Bangkok in 2006. A resolution that aimed to define the spatial dimension of the marine environment was passed, defining the terms marine cadastre and Marine SDI within the context of marine administration. The marine cadastre was seen as a management tool that spatially describes, visualises, and realises formally and informally defined boundaries along with their associated RRRs in the marine environment. This tool, in turn, is central to the Marine SDI, facilitating the use of interoperable spatial information relevant to the sustainable development of marine environments.

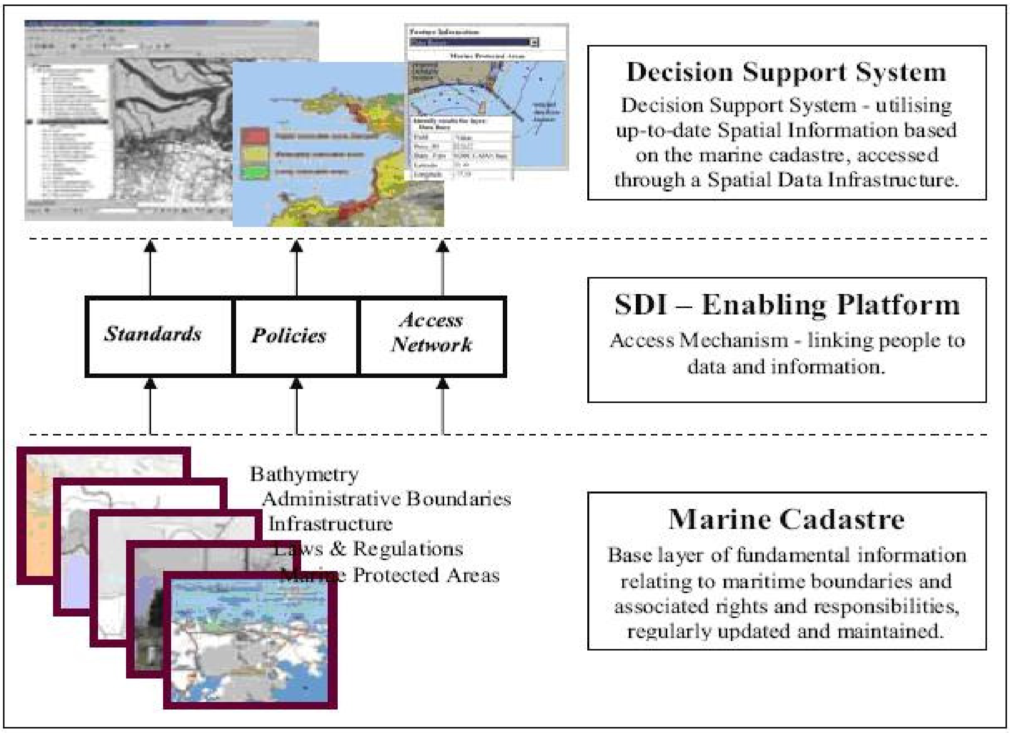

Figure 3.7 A marine cadastre and SDI are essential component of effective marine administration. (Rajabifard et al. 2006)

The concept of a Marine SDI to support the spatial dimension of marine administration has been evolving since the late 1990s, in conjunction with the International Year of the Ocean (Strain 2006). While the data interchange collaboration work of IOC's IODE (Intergovernmental Oceanographic Commission Committee on International Oceanographic Data and Information Exchange) has been ongoing for several decades, specification of Marine SDI at national level only started at the beginning of the new millennium (Longhorn 2004). Marine SDI is the component of National SDI that encompasses marine geographic and business information in its broadest sense covering sea areas, inland navigable and non-navigable waters. This would typically include seabed topography, geology, marine infrastructure (e.g. bathymetry, wrecks, off-shore installations, pipelines and cables etc); administrative and legal boundaries, areas of conservation, marine habitats and oceanography (Ozborne and Pepper 2007).

While the concept of Marine SDI is relatively new, the idea of supporting marine and coastal management through better access to spatial data or information is more established. Several countries and different jurisdictions are trying to improve their marine management through improving the accessibility and availability of spatial data. Often while these initiatives are not labelled “SDI” they share some of the objectives and concepts of SDI. Some countries are beginning to consider marine administration and are using spatial data management to improve decision-making and management in their off-shore environments. Each of these countries is approaching this idea with its own perspective and has developed slightly different methods to improve their marine management using spatial data management tools. Table 3.2 shows different perceptions and definitions of spatial information management initiatives in the marine environment in Canada, Europe, Australia, United States and Asia-Pacific. However, there are many other initiatives around the world in countries like New Zealand, Indonesia, etc. These different definitions of SDI can be expected due to the dynamic concept of SDI which can include a broad variety of information, can be updated with changing technology, human attitudes, or to include new environments.

Table 3.2 Different perceptions and definitions of spatial information management initiatives in the marine environment

Jurisdiction	Title	Definitions/Understandings
Canada	Marine Governance	The governance of marine spaces is the management of stakeholder activities in these spaces. To optimise this management and to address stakeholder issues requires that effective governance frameworks be in place. Collaborative, cooperative, and integrative governance are improved frameworks for dealing with stakeholder issues (Sutherland and Nichols 2002).
	Marine Cadastre	Marine Cadastre is an information system that not only records the interests but also facilitates the visualisation of the associated rights, restrictions and responsibilities in the marine environment (Ng’ang’a et al. 2002)
	Marine Geospatial Data Infrastructure	A Marine Geospatial Data Infrastructure (MGDI) is being developed within the framework of the CGDI, “to enable simple, third party access to data and information that will facilitate more effective decision making” for anyone involved in coastal zone management. MGDI is described as spatial and temporal data infrastructure comprising data and information products, enabling technologies as well as network linkages, standards and institutional policies (Gillespie et al. 2000) and is critical to sustainable development, management and control of national marine,

		coastal and freshwater areas (DFO 2001).
Europe	Marine Geospatial Data Infrastructure	The MGDI should provide a "thematic hub with information about water depths, currents, tides, channel widths, seabed texture, sediment characteristics, temperature, wrecks, pipelines, cables, seabed obstructions, fish stocks, coastal terrestrial data etc.; allow people to make better decisions (such as planning and protecting vital resources); (and) allow extraction of data from diverse sources, blend it and come up with original perspectives and innovative solutions." (Pepper 2003).
	Marine Spatial Planning	Marine Spatial Planning is a strategic plan for regulating, managing, and protecting the marine environment that addresses the multiple, cumulative and potentially conflicting uses of the sea (Tyldesley 2004).
	Marine SDI	Marine SDI is the component of National SDI that encompasses marine geographic and business information in its broadest sense covering sea areas, inland navigable and non-navigable waters. This would typically include seabed topography, geology, marine infrastructure (e.g. bathymetry, wrecks, off-shore installations, pipelines and cables etc); administrative and legal boundaries, areas of conservation, marine habitats and oceanography (Ozborne and Pepper 2007).
Australia	Marine Cadastre	Marine Cadastre is a management tool that spatially describes, visualises, and realises formally and informally defined boundaries as associated rights, restrictions, and responsibilities in the marine environment (Binns 2004)
	Marine Administration	Marine administration is management and administration of rights restrictions and responsibilities in the marine and coastal environments. Marine administration encompasses different activities such as marine industries, resource management, marine protected areas and conflict resolution. There is a need to create a framework for marine administration in order to provide a foundation from which management issues, including the global focus on sustainable development, can be addressed (Rajabifard et al. 2005a).
	Marine SDI	Marine SDI is an internet-based, customer focused view into data and information of interest to users of the marine environment (Finney and Mobauer 2003). Marine SDI has emerged to facilitate marine administration. Its components are: a marine portal, a marine catalogue and a network of interoperable service and content providers (Strain et al. 2006).
	Marine Cadastre	Marine cadastre is being examined within the FGDC Marine Boundary Working Group (MBWG), in order to address issues relating to the legal and technical aspects of marine boundaries, with the goal to alleviate cross-agency

United States		problems concerning marine boundaries, plus provide outreach, standards development, partnerships, and other data development critical to the NSDI (FGDC 1998).
	Coastal SDI	Coastal SDI is technologies to facilitate discovery, collection, description, access and preservation of spatial data that should be widely available to the coastal zone management community. The mission of Marine and Coastal NSDI is current and accurate geospatial coastal and ocean data will be readily available to contribute locally, nationally, and globally to economic grow the environmental quality and stability, and social progress (NOAA 2003).
Asia-pacific Region	Marine Cadastre	Marine cadastre is defined as a management tool which spatially describes, visualises and realises formally and informally defined boundaries and associated rights, restrictions and responsibilities in the marine environment as a data layer in a Marine SDI, allowing them to be more effectively identified, administered and accessed (PCGIAP-WG3 2004).

Global, regional and national effort to improve access and sharing of marine spatial data is occurring, there is now need for cooperation and collaboration between these efforts in order to create an overarching seamless spatial information platform that facilitates coordinated use and administration of these tools in a more integrated and holistic fashion. The next subsections look at the various initiatives in Australia, Canada, US, Europe and also at global scale that are developing a spatial dimension to marine administration systems.

3.3.1 Australia

In Australia the entity notionally overseeing the development of the National SDI is the Australia, New Zealand Land Information Council (ANZLIC). ANZLIC is Australia peak spatial information council, responsible for developing “best practice” guidelines for the use and sharing of spatial information in Australia and New Zealand. The Australian SDI (ASDI) was defined by ANZLIC in November 1996. It then comprised four components:

Institutional Framework: defining the policy and administrative arrangement for building, maintaining, accessing and applying the standards and datasets;

Technical standards: defining the technical characteristics of the fundamental datasets;

Fundamental Datasets: spatial data produced within the institutional framework and fully complying with the technical standards; and

Clearinghouse network: the means by which the fundamental datasets are made accessible to the community, in accordance with policy determined within the institutional framework, and to the agreed technical standards.

ANZLIC defined and developed the technical architecture of the ASDI to facilitate access to and use of fundamental spatial data produced by the various agencies. Initial schedule identified more than 80 separate fundamental datasets produced by 11 Commonwealth agencies; it includes digital topographic, hydrographic, resource and environment data, and the boundaries used for statistical mapping. The policy is overseen by the Spatial Data Policy Executive (SDPE) and operationally managed by the Spatial Data Management Group (SDMG) (Homes 2005).

National SDI aims for a national coverage of data through a distributed network of databases with datasets listed in a data directory and complying with standards and policies. In this regard, the Australian Spatial Data Directory (ASDD) is an essential component of ASDI. The gateway to the ASDD is maintained by Geoscience Australia on behalf of ANZLIC, as part of its broader Australian Government responsibility for the ASDI. The individual ASDD nodes are implemented by State/Territory jurisdictions, Australian Government agencies, and commercial organisations. It is the responsibility of individual nodes to maintain their own metadata and nodes in accordance with the ANZLIC Metadata Guidelines and the ASDD Requirements and Standards. For an instance, Australian Hydrographic Service (AHS) maintains it own node for the ASDD (http://asdd.ga.gov.au/asdd/tech/node/aho-1.html or www.hydro.gov.au/asdd). Metadata records for source and product data are updated by the AHS and are accessible through the ASDD internet search page. Also 4985 metadata records for Royal Australian Navy (RAN) source data are available through the ASDD. These are RAN hand-drawn and computer generated fair sheets that were digitally converted during the SEA1430 project. TIFF images of the manuscripts and HTF headers, paper charts, Raster Navigational Charts (RNC), Electronic Navigational Charts (ENC), Geotiff products and in some cases, digitised soundings may be found using the ASDD search facility and available by contact through the AHS web site.

In 2003, ANZLIC published its SDI Distribution Network roadmap (ANZLIC 2003b) in which a Service Oriented Architecture (SOA) was nominated to underpin SDI development. Since the publication of this roadmap, several initiatives have emerged from the bottom up which embrace the SOA concept, significant amongst these is the Australian marine community's effort to build a marine-themed SDI, which began in 2004 led by the Australian Ocean Data Centre Joint Facility (AODC JF), whole of government approach to ocean data management.

The AODC JF comprises Australian federal government agencies (Australian Institute of Marine Science, CSIRO, Geosciences Australia, Australian Antarctic Division, Bureau of Meteorology, National Oceans Office (NOO), and Royal Australian Navy) that have an interest in the marine domain. In 2004 the NOO was incorporated into the new Marine Division of the Department of the Environment, Water, Heritage and the Arts and continues to have lead responsibility for regional marine planning. These partners formed an alliance using a non-legally binding Heads of Agreement which provided for the instantiation of a governing Board and a Technical Committee to manage day-to-day facility operational activities. The aim of this consortium is to establish an infrastructure with re-usable patterns for publishing marine related data from multiple agencies and to keep the SDI essentially technology neutral.

This project will contribute to Oceans Portal project. The idea of the Oceans Portal which was aimed to develop by NOO is to provide "an Internet-based, customer focused view into data and information of interest to users of the marine environment (Finney and Mosbauer 2003)" through three different components.

- a demonstration Portal (Figure 3.8) hosted by the Department of Environment and Heritage's NOO,
- a marine catalogue (services registry) hosted by CSIRO's Marine and Atmosphere Division, and
- a variety of distributed content and service providers (mostly State and Federal government contributors).

The Oceans Portal is still under development identifying the main obstacles to its development to be both technological and institutional. NOO aims to comply with standards set by ANZLIC for the ASDI, so that the portal could be included in the ASDD (Finney and Mosbauer 2003). However there are some deficiencies for ANZLIC's standards to be applicable for marine spatial data. Regarding policy issues, there is still a level of institutional unwillingness to share spatial data both for 'not with my data' and capacity and ability reasons. This is also a challenge because the Oceans Portal, and the standards and policy that go with it, are not compulsory for data providers and there is no funding to encourage them (Strain 2006).

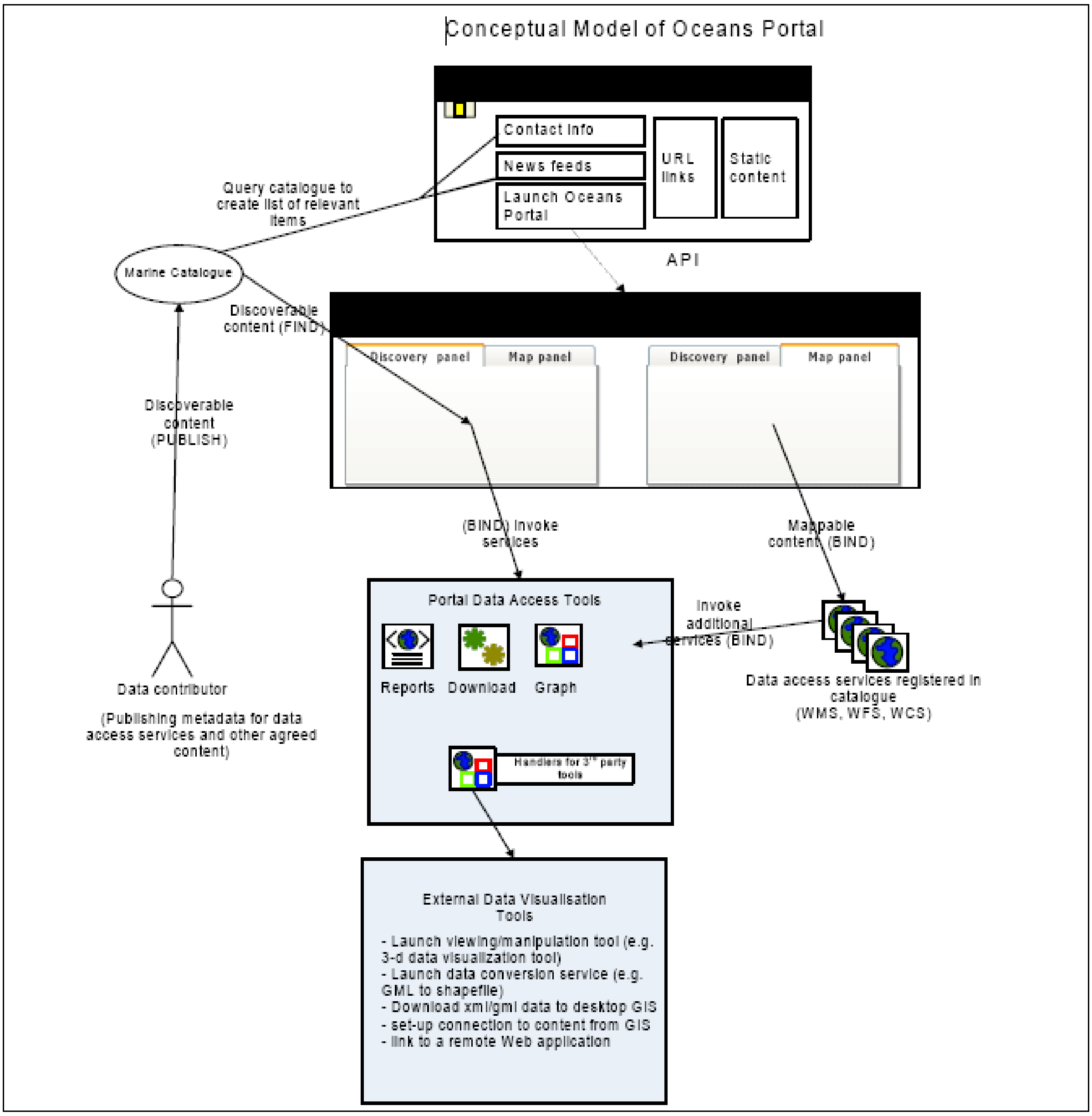

Figure 3.8 Oceans Portal Conceptual Model (SCO 2006)

Australia's Marine SDI is still in the closed, gestation phase but must soon transition into an open development if it is to grow successfully as a viable resource for Australia's marine community because there are insufficient resources available within the core initiating agencies to carry the infrastructure much beyond the kick-start phase (Finney 2007). Several obstacles, which must be overcome, currently stand in the way of the AODC JF infrastructure project making a successful transition to the Australian Ocean Data Network -the name assigned to the Marine SDI (Finney 2007) (Figure 3.8). This figure illustrates the serviced oriented architecture, publish find and bind paradigm.

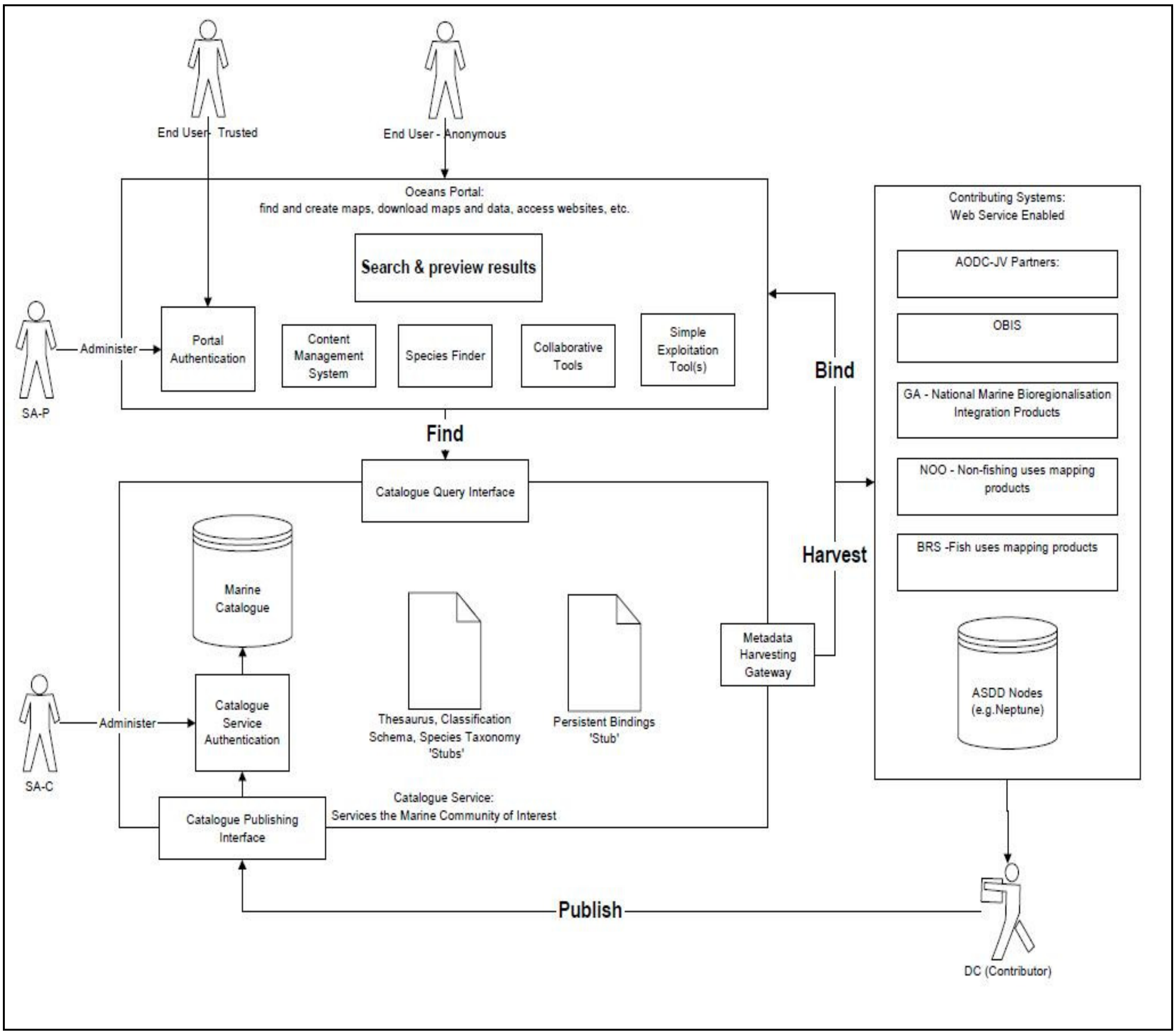

Figure 3.9 Australian Ocean Data Network (Finney 2007)

In line with Australian Marine SDI, similar initiatives are currently underway. These are an Australian Marine Spatial Information System (AMSIS) and an Australian Marine Boundary Information System (AMBIS) developed by Geoscience Australia (GA). AMSIS has similar aims to the Oceans Portal in that it will provide access to consistent spatial data and information and conform to current spatial standards, policies and technologies. It aims to provide current, integrated marine information and applications to support planning, industry development, policy development and operational requirements. AMBIS would form one of the datasets to be contained in AMSIS. AMBIS is a dataset that delimits the marine jurisdictional boundaries out from Australia's coastline. This includes the coastal waters, the territorial sea, and boundaries shared with other countries. It also includes the Territorial Sea Baseline (TSB), an approximation of the coastline that defines all the other boundaries. The data, which this representation is based on, is dated at 2001. As the coastline is dynamic these boundaries need to be re-computed every couple of years to adjust for the changing baseline. AMBIS has a metadata layer that lists this currency, as well as the completeness, standards, spatial extent and other attributes of the dataset.

GA believes that ocean management and planning is hindered by the current lack of information, especially related to boundaries, administrative areas, rights and interests and marine features. The database will firstly contain data that GA is the custodian of, which is sediment characterisation of the seabed, biophysical information on Australia's estuaries, and maritime boundaries. It also includes AHS data such as maritime boundary data, historic shipwrecks and nomenclature. GA envisages that other data custodians will also be able to contribute data and information to AMSIS, providing they can conform to the standards and policies. In developing these systems, GA has considered the following issues: data standards, dictionaries, format, structure, quality and datum, data maintenance, metadata and data gaps.

It is believed that the above issues represent current major impediments to an Australian Marine SDI. The end result of this research would facilitate the development of a Marine SDI in Australia. The next section looks to the marine cadastre as a means for defining, managing and administering legally definable Australian off-shore boundaries and in this context will form a fundamental component of marine spatial data and a layer in a future ASDI that covers both the terrestrial and marine environments.

Australian Marine Cadastre Project

National marine cadastres are being built because of an increasing awareness of the importance of spatial data to management of the marine environment and the need for a structured and consistent approach to the definition, maintenance, and management of off-shore legal and administrative boundaries. A marine cadastre has many definitions. Robertson et al. (1999) describe the marine cadastre as

> "A system to enable the boundaries of maritime rights and interests to be recorded, spatially managed, and physically defined in relationship to the boundaries of other neighboring or underlying rights and interests."

Nichols et al. (2000) highlight the value of information, introducing concepts of ownership and the need to record rights and responsibilities in addition to the recording of boundaries.

> "A marine cadastre is a marine information system, encompassing both the nature and spatial extent of the interests and property rights, with respect to ownership and various rights and responsibilities in the marine jurisdiction."

These ideas were the starting point for the development of an Australian marine cadastral concept. Initial support for marine cadastre research in Australia came in late 2001 with the awarding of an Australian Research Council (ARC) Linkage-Projects grant to a team comprising the University of Melbourne, GeoFix Pty Ltd, Geoscience Australia, the Queensland Department of Natural Resources and Mines, and Land Victoria and it aimed to define the issues relevant to the development of a coordinated spatial management system, or "marine cadastre" for Australia's ocean territory. Whilst there were methods in place in Australia to manage the wide range of spatial rights, restrictions and responsibilities in the marine environment, they were "task-specific" and lacking in coordination.

The ARC marine cadastre project formally commenced in June 2002. Since that time, a considerable amount of interest and discussion has been generated about the marine cadastre concept, the definition of the marine cadastre and the benefits and applications of a future marine cadastre for Australia. Results from the marine cadastre questionnaire highlighted the importance of spatial information to the majority of individuals and organisations with responsibilities and interests in the marine environment (Binns 2004). The first aim of this project was to define the concept of a marine cadastre through an investigation into institutional and legal aspects of Australia's current marine management regimes. The second aim was to analyse the applicability of current land based spatial management arrangements, including ASDI and cadastre, to the administration of current spatial rights, restrictions and responsibilities in the marine environment. The key terrestrial cadastral and Spatial Data Infrastructure (SDI) principles that may aid in the implementation of a marine cadastre have been identified. The key principles focus on policy, tenure, legal, institutional and technical aspects of Australia's terrestrial cadastral systems. The utilisation of the ASDI within the context of a marine cadastre focuses on issues of fundamental datasets, custodianship, accuracy, metadata and access to spatial data. This was being achieved through the running of workshops, the conducting of a broadly based national questionnaire and the execution of detailed industry consultation.

Following the success of the first ARC Marine Cadastre project, another application for funding to the ARC was submitted under the Linkage- Projects scheme, to allow marine cadastre research to continue in July 2004 to run until July 2007 with industry partners including Department of Land Administration Western Australia, Department of Lands New South Wales, Department of Sustainability and Environment Victoria and Land Information New Zealand. The objective of this application was to allow independent collaborative research in this area to continue, by building on the findings of previous research and by supporting strategic industry-academic research partnerships. The new proposal thus draws on the body of knowledge and expertise flowing from the previous ARC project and aims at providing solutions to four fundamental research problems that have emerged. This is not to say that these four research problems were the only ones that demand attention, but taken together they represent a major impediment to the development of a future marine cadastre for Australia. The four key areas were:

- Resolving issues in the definition of the tidal interface;
- The use of natural rather than artificial boundaries in a marine cadastre;
- Extension and application of the ASDI to support a marine cadastre; and
- Marine policy, legal and security issues and the marine cadastre.

The third stream of the ARC-linkage project focus was to extend, modify and test the principles that underlie the current SDI in order to support the implementation of an Australian marine cadastre. Through the first two years of this project a Master's degree thesis was successfully completed in this area entitled "A SDI Model to Include the Marine Environment". The thesis used a case study approach to examine the applicability of the SDI concept and components to the marine environment. The Marine SDI concept was examined at local, state, national and international levels to evaluate the ability of the SDI model in this environment. The end result was an extended SDI model that will facilitate the development of a "seamless" land – marine infrastructure (Strain 2006). Further to this progress, for the remaining part of the project and beyond that ,current research was commenced on August 2007 to continue the effort and research by undertaking a further examination of the "Seamless SDI model". The end result of the project will be to facilitate the development of a Marine SDI and a marine cadastre in Australia.

The outcome of the marine cadastre is the ability of users and stakeholders to "describe, visualise, and realise" spatial information in the marine environment (Todd 2001). Ideally, the cadastre describes the location and spatial extent of RRRs in the marine environment, including management boundaries, coastal planning guidelines, ocean parcel boundaries, and legally defined areas. These spatial extents should then be visualised through the continual updating of accurate digital spatial data in a maintenance environment. This then leads to an integrated and practical approach to a jurisdiction's management of its maritime extent.

A marine cadastre has been recognised in Australia as a fundamental off-shore dataset and an important layer in ASDI. The diagram below (Figure 3.9) outlines the design concept for an Australian marine cadastre, as being developed within the Victorian section of the ARC marine cadastre project. ASDI would provide the platform for data access within the development of a marine cadastre. The utilisation of the ASDI within the context of a marine cadastre will aid in forming partnerships and providing standards from which issues of data interoperability can be addressed.

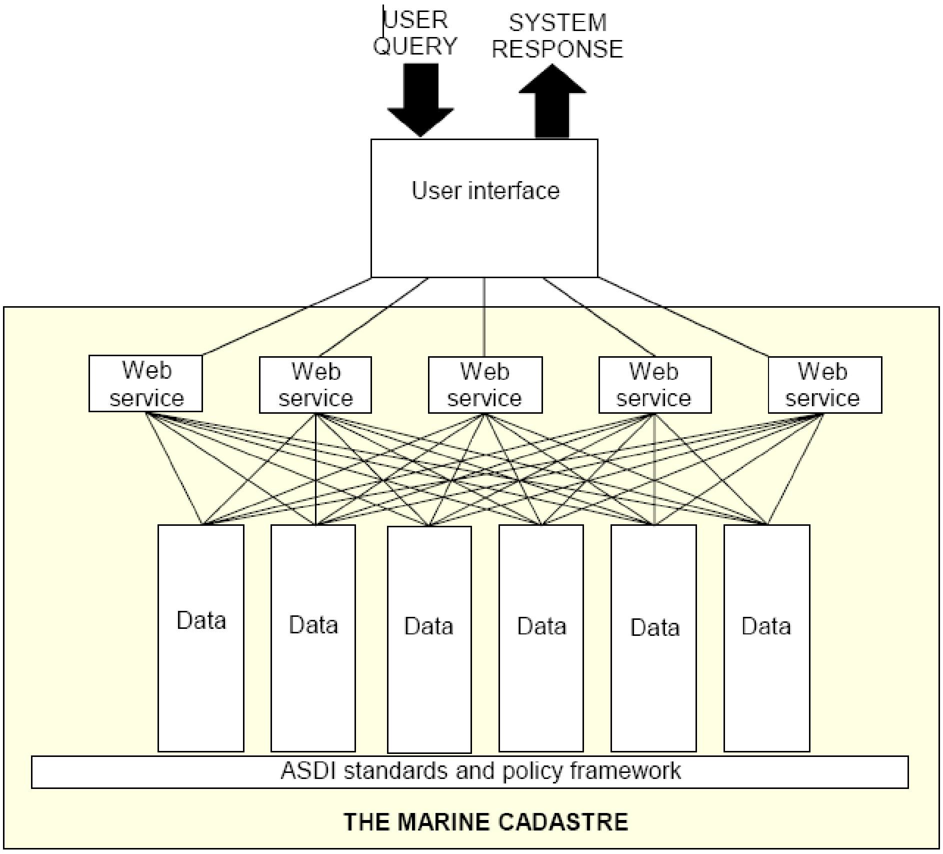

Figure 3.10 Marine cadastre concepts utilising the ASDI (Binns 2004)

3.3.2 Canada

In Canada, the Canadian Geospatial Data Infrastructure (CGDI) also known by its more market-oriented title "GeoConnections" is the National SDI. The CGDI vision is "to enable timely access to geospatial data holdings and services in support of policy, decision-making and economic development through a co-operative interconnected infrastructure of government, private sector and academia participants". CGDI planners realised from the start that "institutional issues will likely eclipse technology as an impediment to CGDI development and implementation" (Labonte et al. 1998). Marine navigation and charting for pollution control, coastal zone management and environmental monitoring are important applications for the CGDI.

The Marine Geospatial Data Infrastructure (MGDI) is the sub component of CGDI. It is seen as an extension to the CGDI to respond to the need for a comprehensive, integrated and common infrastructure of marine data and information accessible to all stakeholders. The primary goal of the MGDI is to enable simple, third party access to data and information that will facilitate more effective decision-making (Gillespie et al. 2000) for anyone involved in coastal zone management. Canadian MGDI components include data and information products, enabling technologies as well as network linkages, standards and institutional policies.

The concept for an MGDI-like information network was first proposed in 1988 as the "Inland waters, Coastal and Ocean Information Network (ICOIN)" (Gillespie et al. 2000), a project to develop an integrated marine-based information infrastructure. The ICOIN was planned to be built upon common standards and networking allowing simple third party access. The current MGDI has been built upon this idea, and has the same basic underlying principles. Under the auspices of GeoConnections (the CGDI), a Marine Advisory Committee was created in 1999 at the time of publication of a draft concept report for the MGDI (CCMC 1999). The committee's remit is to ensure the full functionality of the CGDI in providing service to all marine stakeholders. To help achieve this goal, a Marine Advisory Network has been set up to act as the physical focal point for stakeholder outreach and consultation (GeoConnections 2003). The proposed Canadian MGDI architecture includes:

- a common spatial data model,
- an integrated process and data modelling environment,
- a common spatial language and data exchange format,
- methods for managing, querying and delivering data with integrity, and
- open source productivity tools ensuring access for all.

The MGDI recognises the need for common standards so that data can be used seamlessly across disciplines and systems. Because the focus of most National SDI developments is predominantly land-based data and issues, MGDI also recognises that standards that apply perfectly well to land-based applications and data may be incompatible with the marine world. MGDI confronts data pricing and related policy issues dealing with intellectual copyright as crucial to the success of both CGDI and

MDGI and these potential barriers may be more difficult to remove than are technical issues such as standards and interoperability of data (Bartlett et al. 2004).

The Department of Fisheries and Oceans (DFO) is building on this previous work to develop a marine node in CGDI. The DFO defines the MGDI as “a spatial and temporal data infrastructure comprising a system of data and enabling technologies that are critical to sustainable development, management and control of national marine, coastal and freshwater areas”. The DFO recognised that in order to be successful the MGDI would have to respond to the needs of the potential stakeholders. Therefore they conducted eight workshops all over Canada in 2001, with representatives from all marine sectors, at which the potential users were briefed on the CGDI and MGDI, and were asked for their feedback (DFO 2001). The results suggest that user recommendations are:

- most users want information not data, however some want both,
- single portal where all information/ data is available,
- two-way infrastructure where they can contribute or update data,
- MGDI to be part of global Marine SDI,
- access to more and better quality data,
- interoperability of datasets,
- metadata that particularly lists currency and accuracy, and
- seamless land and water digital elevation model.

The workshops also highlighted that there are framework datasets that the majority of users want access to, such as bathymetry, boundaries, and shoreline. From these workshops the DFO also noted that compared to terrestrial data there was a greater focus from users on the currency of the data, as the marine environment is more dynamic and older data is less likely to represent the real world.

Progress in implementing the MGDI as a coherent system has been slower than anticipated. The challenges that have been noted in moving forward with the MGDI are:

- different users wanted slightly different needs from MGDI,
- copyright, ownership, privacy and licensing,
- diversity levels in currently collected and available data, interoperability,
- pricing, cost recovery,

- capacity building, funding,
- building partnerships, and
- adoption of common standards.

The Hydrographic Information Network (HIN) is another initiative developed by the Canadian Hydrographic Service (CHS) which is the official provider of national hydrographic information. The CHS is realigning its activities towards data accessibility and the integration of marine information in support of the safe and efficient use of waterways, the sustainable development of Canada's oceans and inland waters, and national sovereignty and security (Journault 2005). The Hydrographic Information Network has three primary components: metadata management system, source data management system and product data management system (Figure 3.10).

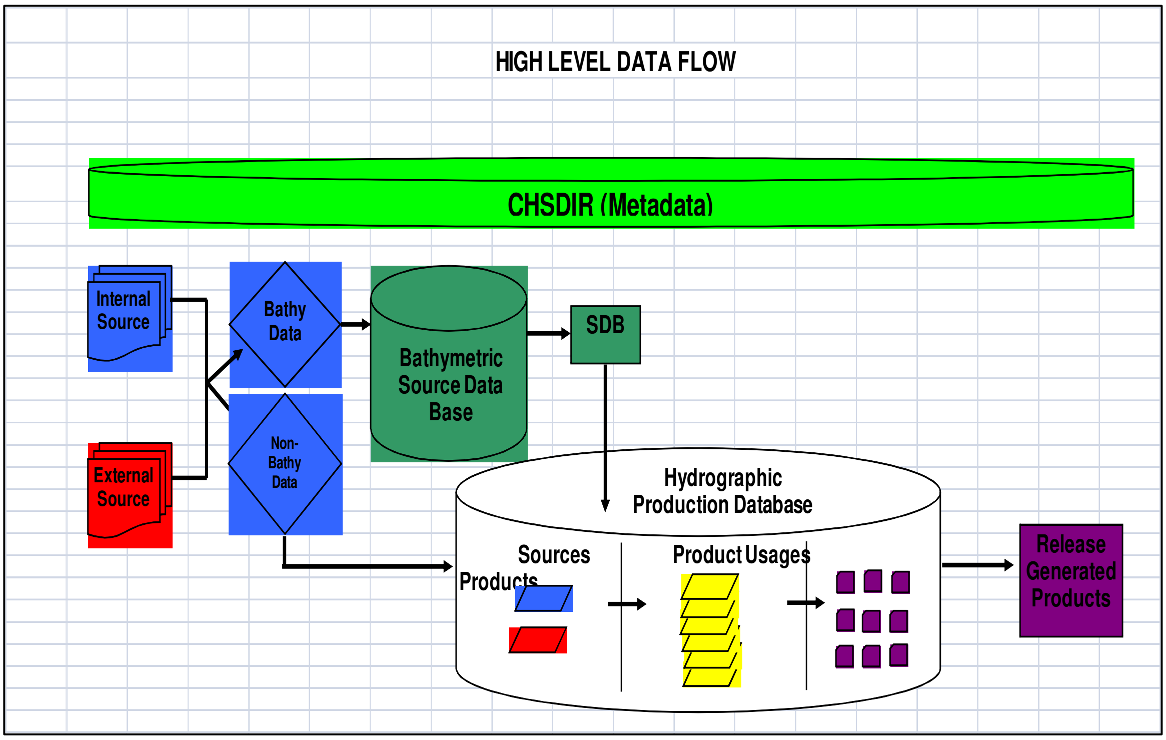

Figure 3.11 Hydrographic Information Network Architecture (Nicholson 2007)

CHS concentrates its efforts on source data management for very specific data domains: bathymetric data; seabed information; tides, currents and water level information (Journault 2005). CHS is a focal point that facilitates access to this information. It is not necessary for CHS to be the data holder; instead data should be organisations with knowledge of the existence and access to all these source datasets, information that will meet the needs of a wide spectrum of clients and not only navigators (Nicholson 2007).

In summary, as highlighted in this section, in the case of MGDI, and the need for a comprehensive, integrated and common infrastructure of marine data and information accessible to all stakeholders led to the development of MGDI as the sub component of CGDI. Further, the need for seamless data across the coastal zone and different disciplines has been recognised in the development of the Canadian marine spatial initiatives and is one of the basic user requirements.

3.3.3 United States

In the United States, the concept of a National SDI initially began in the academic communities around 1989 (Tosta 1999), and soon after in government with the formation of the Federal Geographic Data Committee (FGDC) in 1990 by the Office of Management and Budget. During the early 1990s, the FGDC developed coordination strategies, standards and best practice with the objective of building "a national digital spatial data resource" (Reichardt and Moeller 2000). A major study by the National Research Council in early 1990 further supported the development of a National SDI (National Research Council 1993). The National Information Infrastructure (NII) agenda proposed by the Clinton/Gore administered in 1993 was followed by the issuing of Executive Order 12096 in April 1994, which called for:

- the establishment of a National SDI as a key component of the NII;
- the development and use of a National Geospatial Data Clearinghouse;
- use of a national distributed framework of data for registering and referencing other themes of geospatial data; and
- FGDC-endorsed standards for data content, classification and management for use by Federal government and available to all other geospatial data producers and users (Reichardt and Moeller 2000).

An executive order in 1994 had paved the way for the creation of a National SDI. Initially the marine sector was omitted but a sub-committee to address this was created. The FGDC is responsible for the USA National SDI and involved in the National SDI as there are three data centres for oceanographic, climate and geospatial data. The FGDC Marine and Coastal Spatial Data Subcommittee came into existence in 1996. Its mission was to develop and promote the marine and coastal components of the National SDI so that "current and accurate geospatial coastal and ocean data will be readily available to contribute locally, nationally, and globally to economic growth, environmental quality and stability, and social progress" (NOAA 2003). It works to develop strategic partnerships, relevant standards, and to provide outreach that will enhance access to and utility of coastal and ocean framework data. In 2000-2001, a Coastal SDI vision was developed based on four goals that relate to the US National SDI (NOAA 2001). These goals are

- The coastal management community understands and embraces the vision, concepts, and benefits of the National SDI.
- Geospatial coastal and marine framework data are readily available for use by the coastal management community.
- Innovative practices and technologies that facilitate the discovery, collection, description, access, and preservation of geospatial data are widely available to the coastal zone management community.
- Foster, develop, and implement geospatial data applications in response to the needs of the coastal and marine communities.

The Coastal SDI initiative in the USA is led by the Coastal Services Centre of NOAA (National Oceanic and Atmospheric Administration), supported at implementation level by the Federal Geographic Data Committee's Marine and Coastal Spatial Data Subcommittee (FGDC 2002). Yet a recent report from the US Commission on Ocean Policy (U.S. Commission on Ocean Policy 2002) led one commissioner to observe that one of the most shocking findings of the Commission was the tight connection between inland systems like development and agriculture to what have traditionally been designated as coastal areas. The coastal zone is not a narrow band. It's the whole country.

Practical implementation work relating to metadata standards and creation, and geoportals, is undertaken by the NOAA and the FGDC. The most recent strategy for the US Coastal SDI is the Digital Coast initiative. The NOAA Coastal Services Center launched the site in 2008 and continues to lead the Digital Coast effort. The Digital Coast was envisioned as an information delivery system that could serve not only data, but also the training, tools, and examples needed to turn data into useful information. In this way, the Digital Coast is designed to play a pivotal role in ensuring the wise use and management of coastal resources (http://www.csc.noaa.gov/digitalcoast/index.html).

The main elements of Coastal SDI promoted by NOAA are bathymetry, shoreline identification and marine cadastre, hydrography, coastal imagery, marine navigation, tidal benchmarks and benthic habitats (Longhorn 2009). Bathymetric data are treated as a sub-layer of the Elevation layer data in the National SDI Framework. Marine cadastre is being examined within the FGDC Marine Boundary Working Group (MBWG), which includes members of the FGDC Cadastral Subcommittee. The MBWG was formed in 2001 to address issues relating to the legal and technical aspects of marine boundaries, with the goal to alleviate cross-agency problems concerning marine boundaries, plus provide outreach, standards development, partnerships, and other data development critical to the National SDI. A major product of the MBWG work to date is the FGDC's Shoreline Metadata Profile (FGDC 1998). Two further standards for the SDI are the National Hydrography Data Content Standard for Inland and Coastal Waterways (FGDC 2000) and Accuracy Standards for Nautical Charting Hydrographic Surveys (FGDC 2000). The FGDC listed the steps to a Coastal SDI as establishing standards, defining fundamental datasets, and policies that cover collection, publication, licensing and privacy. As the coastal zone is made up of the marine and terrestrial areas combined, the end aim is for a seamless marine and coastal spatial data clearinghouse.

In regards to data collection and sharing, the US Ocean Policy report further found that "there is no marine equivalent to the networks of meteorological observation stations distributed on land on all continents. Ocean observation efforts are limited temporally and spatially." This leads to the conclusion that "there is a need for a better and more comprehensive way to link the work of different disciplines in a manner that offers a more integrated understanding of the marine environment and the processes that control it. There is a need for standardised practices and procedures" (US Commission on Ocean Policy 2002). These findings reinforce the premise that Coastal SDI cannot and should not be developed in isolation from the broader National SDI of a nation or region.

However, it is believed that there is a need for a better and more comprehensive way to link different off-shore initiatives offering a more integrated understanding of the marine and coastal environments as there is a tight connection between inland, marine and coastal areas. These findings further support the premise that Coastal SDI cannot and should not be developed in isolation from the broader National SDI of any jurisdiction.

3.3.4 Europe

The SDI for Europe (INSPIRE - Infrastructure for Spatial Information in Europe), the Water Framework Directive (European Commission 2000) and Marine Strategy Directive which underpin the need for such regional Infrastructure, are more fully discussed here. They have legal mandates from a recognised regional body – the European Commission – and have developed detailed descriptions of spatial data requirements, including marine and coastal zone data.

During the early years of European SDI consultations (1995 - 2000), reference to particular themes for spatial data content in the proposed SDI specification was initially resisted. After much debate, the hydrographic component (including coastal zones) was included, along with only two other "topographic themes" – transport and height. Hydrography is defined as "surface water features such as lakes and ponds, streams and rivers, canal, oceans and shorelines". The "height" topographic theme includes "contour data showing heights by isolines, and including with the same data set spot heights, high and low water lines, breaklines and bathymetry" (INSPIRE 2002a). At the end of the consultation period, in an extended impact assessment report for INSPIRE, the recommended data remit was extended to cover a wide range of coastal and marine data components, including bathymetry, coastline, hydrography, surface water bodies, water catchments, oceans and seas, oceanographic spatial features, sea regions, fishery resources, aquaculture facilities, polluted areas and more (Craglia 2003). This recommendation reinforced the information needs developed earlier in the INSPIRE initiative by the Environmental Thematic Coordination Group, noted throughout its initial position paper (Lillethun 2002).

A separate strand of European spatial information management policy-making, the European Union (EU) Water Framework Directive (WFD), which came into effect in December 2003, provides both a testing ground and a justification for European SDI research and development (European Commission 2000). The WFD represents the culmination of five years of consultation and negotiations for implementing a harmonised and integrated water policy for all EU Member States, and imposes detailed monitoring and reporting requirements for the status of surface water in four regimes: rivers, lakes, coastal waters and transitional waters (estuaries and similar bodies of water which are partly saline but strongly influenced by freshwater flows).

Aligned with that is the European Union's Marine Strategy Framework Directive adopted in June 2008 to protect the marine environment more effectively across Europe. It aimed to achieve good environmental status of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend. The Marine Strategy Directive constitutes the vital environmental component of the Union's future maritime policy, designed to achieve the full economic potential of oceans and seas in harmony with the marine environment. It establishes European marine regions on the basis of geographical and environmental criteria. Each Member State – cooperating with other Member States and non-EU countries within a marine region - are required to develop strategies for their marine waters. The goal of the Marine Strategy Framework Directive is in line with the objectives of the Water Framework Directive 2000 which requires surface freshwater and ground water bodies - such as lakes, streams, rivers, estuaries, and coastal waters - to be ecologically sound by 2015 and that the first review of the River Basin Management Plans should take place in 2020 (Europa 2010).

Due to the fact that most of the data is to be presented in its spatial context, the WFD explicitly calls for the reporting of most of the information in a Geographic Information System (GIS) compatible format. For this reason, a very detailed GIS specification has been created (European Commission 2002). The GIS requirements of the WFD are in line with current efforts under the INSPIRE initiative. Moreover, the WFD has been used by various Directorates General at the European Commission (EC) to justify the INSPIRE initiative on the basis that much harmonised, integrated and interoperable basic reference data will be required if WFD reporting requirements are to be met at least cost. Thus, while the WFD does not in itself constitute development of a regional SDI, work associated with its implementation highlights the many common areas of interest and overlap between the objectives of the WFD and those of any proposed Marine or Coastal SDI.

The data relating to coastal and transitional waters, required by the WFD in order for the EU Member States to report adequately to the EC on water conditions, include: boundary information, various biological data for aquatic and benthic flora and fauna, hydromorphological data including depth variations, tidal regimes, transparency, thermal conditions, oxygenation conditions, salinity, nutrient conditions and pollution. The requested information about coastal and transitional waters will be in the form of GIS layers, and are included as categories within the "surface water bodies" entity. In particular, for coastal waters, the data to be captured includes shape, name, various identifying codes, type of water body, status of the water body (artificial, heavily modified), salinity typology, depth typology, tidal typology, and mode.

The debate on what coastal and marine data to include in the EU's regional SDI initiative was taking place in conjunction with the EU Integrated Coastal Zone Management Recommendation (European Commission 2000), adopted in May 2002. This recommendation, although one level removed from being a legally enforceable EU Directive, urges that all EU Member States should establish national ICZM strategies, preferably in law, by February 2006. The Recommendation provides a set of common agreed principles and strategic elements to ensure coherence of strategies throughout Europe. It also identifies the basic steps of the implementation process and the main components that national strategies should address. The recommendation focuses more on organisational, institutional and resource allocation issues than on data content, standards, and related technical implementation issues common to most SDI initiatives.

To confuse matters for coastal zone managers and government marine science agencies responsible for implementing both the EU Water Framework Directive and the ICZM Recommendation, the actual data requirements of the two initiatives are different and reporting is required at different geographic scales, i.e. 1:250,000 for the WFD and 1:100,000 for the ICZM Recommendation. This is a good example of the result of the absence of a single overarching coordinating body for pan-European coastal zone initiatives and problems. If properly defined coastal and marine spatial data infrastructure already existed throughout the European Union, the reporting requirements of the WFD and ICZM Recommendation could be much more easily met than is the case today. Both initiatives stress the inherent interrelationships between marine and coastal data and data covering inland regions which directly impact the coast and near-shore waters (Bartlett et al. 2004).This provides yet further evidence that coastal SDI should be an integral part of National and Regional SDI specifications

Sea–Search is another European initiative aiming to improve Pan-European infrastructure for ocean and marine data management. It is a gateway to oceanographic and marine data and information in Europe. The primary goal of Sea–Search (2002 – 2005) is to provide users with a central overview of ocean and marine data and information, collected and managed by research institutes, monitoring agencies and data holding centres in the countries bordering the European seas. Sea–Search focused on metadata and has established and populated an array of directories and overviews of ocean and marine data and information resources from 30 countries in Pan-Europe. The aims of Sea–Search activities are:

- To develop and operate a Pan-European infrastructure for ocean and marine data management ;

- To develop, maintain and electronically publish jointly metadata products/directories ;
- To explore data access methods and to develop a strong overall foundation for online data access;
- To improve the exchange, availability and accessibility of ocean and marine data and information within Europe and including non-European Union maritime countries sharing seas with EU countries;
- To exchange experience and to cooperate in development, promotion and implementation of data and information management practices and methods;
- To develop and organise an overall capability for handling, processing, quality controlling and archiving a variety of oceanographic and marine data types, anticipating differences in capabilities of individual partners and the evolvement of new data types (www.sea-search.net).

SeaDataNet succeeded Sea–Search from 2006. It continued the operation and maintenance of the Sea-Search directory services and expanded its coverage to 36 countries in and around Europe and 2 international organisations. Thus it creates and operates a Pan-European distributed marine data management infrastructure, accessible on-line through a unique portal, and in agreement with the principles of the European initiative for a spatial data infrastructure, INSPIRE (www.seadatanet.org).

In summary, all of these initiatives are aware of inherent interrelationships between marine and coastal data and data covering inland regions which directly impact on the coast and near-shore waters. Therefore, if a harmonised, integrated and seamless spatial data infrastructure already existed throughout the European Union, the requirements of the Marine Strategy Directive, WFD, and ICZM Recommendation could be much more easily met than is the case today. A closer collaboration on a Pan-European scale is essential to achieve a more integrated and cost effective approach to ocean and marine data and information management and to fulfil the growing demand for ocean and marine data and information from different stakeholders.

3.3.5 Global initiatives

There are several initiatives currently underway at the global level. Of major importance is the International Hydrographic Organisation (IHO) involvement in developing a Marine SDI. IHO is working on a strategy to implement a Marine SDI to better manage global marine activities. In November 2005, IHO had organised and conducted a seminar in Rostock, Germany on "The Role of Hydrographic Services with regard to Geospatial Data and Planning Infrastructure". This seminar formally recognised an option for Hydrographic Offices (HO) to become responsible or partner in national Marine SDI and the possible connection of Marine SDI to the National SDI (IHO 2005). Following from that, at the IHO International Workshop on Marine SDI, held February 12 – 13, 2007, in Havana, Cuba, IHO discussed the role of a Marine SDI and the requirements and strategies to facilitate its development. The 17th International Hydrographic Conference, in May 2007, directed that Committee on Hydrographic Requirements for Information Systems (CHRIS) to establish a Marine Spatial Data Infrastructure Working Group (MSDIWG). The purpose of this working group was to analyse and recommend the nature and level of the IHO role in assisting Member States to support their National SDI through development of and / or aligning with the marine spatial data communities in the development of a Marine SDI. The MSDIWG was tasked with submitting a report with recommendations to CHRIS/20 in November 2008 for subsequent consideration at the 4th Extraordinary International Hydrographic Conference in 2009.

The recommendations of the MSDWG to CHRIS/20 are:

1. IHO develops its SDI policy towards Member States as part of its enhanced mission particularly aimed at Member States who, in their responses indicated a low level of maturity or which no information has been received.

2. IHO develops, through the MSDIWG, a definitive SDI "Cook Book" to assist IHO Member States to be better prepared to develop and / or join Marine SDI at their National or Regional level.

3. IHO develops its SDI capacity building plan (e.g. in-country practical training and advice) to provide the necessary skills, knowledge and understanding of key components of SDI as described above.

4. IHO considers the development of a web based facility to encourage knowledge transfer, best practice and on-line guidance and training material.

5. MSDI to be a standing agenda item on Regional Hydrographic Commissions in order to monitor and report progress in Member States' Marine SDI engagement and development. MSDIWG will provide benchmarks against which reporting might be measured.

6. IHO, through the CHRIS committee, supports the continuation of the work of the MSDIWG in 2009-2011.

Furthermore, aligned with this, is the development of marine and coastal atlases and portals such as International Coastal Atlas Network (ICAN) at the global level which can play an increasingly important role. The advantage of global coastal and marine network or atlases could be to facilitate global operational interoperability between different nations and states for enhanced data sharing in order to make integrated and holistic decisions.

3.4 SDI Developments – The Need for a Seamless Platform

All the initiatives described above share similar aims and similar methods for achieving these aims. They each describe the need for improved marine and/or coastal spatial data sharing and in response to this, each is developing a SDI or similar spatial data sharing initiative. Each initiative is debating the idea of extending their National SDI to include the marine environment, or to develop a Marine SDI from first principles. The main difference between all these initiatives is that some include the coastal zone as part of the Marine SDI and some only focus on the marine environment, and have not yet considered including the coastal zone. The overall definition for these – to develop a mechanism for different users, working in different sectors to share their spatial datasets aims to resolve the most basic problem that is the main driver for these initiatives.

Therefore, some countries are beginning to consider extending their land management systems to include the marine environment, while others are examining developing a different system to manage their marine area separately (Strain et al. 2004). However, most countries separate their land administration system from their emerging marine administration system, impeding management of the coastal zone. If a nation fails to manage its coastal zones effectively, neither its land management nor its marine management will work. This is especially true for nations formed by archipelagos or whose coastlines are extensive comparative to their land mass.

As a result, nations tend to produce diverse, silo-based, and generally unsatisfactory marine management systems and, consequently insufficient and uncoordinated marine information. That is each of the data categories sits in a separate silo. Each of the silos complies with a certain set of policies and considerations that may differ from other silos. Therefore, the need for expanding or creating new models to include the terrestrial environment as well as the marine and coastal environments has been recognised. There is a need to make the land and marine infrastructures interoperable so that planning, management and solutions can be identified in a seamless and holistic way.

Replacement of two separate systems by an integrated and seamless platform would allow robust administration of both coastal and off-shore resources and assure maximum return on investments in spatial data and management systems. Ideally, this would result in harmonised and universal access, sharing, and integration of coastal, marine, and terrestrial spatial datasets across regions and disciplines. The idea of a seamless administration system that covers both the marine and terrestrial environments is generally accepted and non controversial. A Seamless SDI is an essential implementation strategy that allows integrated spatial management of interoperable data from both environments. This SDI should deliver an integrated and seamless model that creates a spatially enabled land – marine interface and bridges the gap between the terrestrial and marine environments (Figure 3.12).

In this regard, the UN meeting recommended that countries with an extensive marine jurisdiction and administrative responsibilities be encouraged to develop a marine administration component as part of a Seamless SDI covering both land and marine jurisdictions to ensure a continuum across the coastal zone (UNRCC-AP 2006).

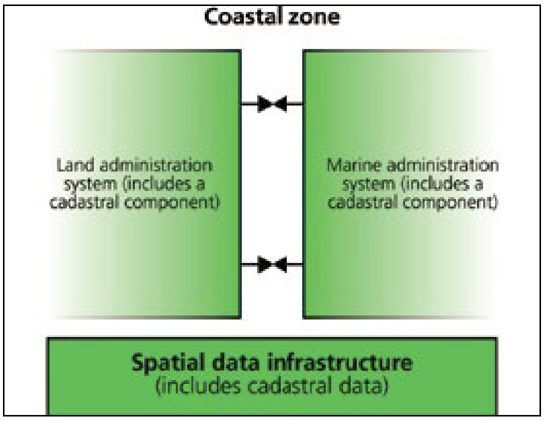

Figure 3.12 Successful marine administration demands seamless integration of both marine and land management (PCGIAP-WG3 2004).

The creation of SDI as an enabling platform allows and facilitates easier access to and use of spatial data not only for government and the wider community, but in particular, the spatial information industry. An enabling platform provides a technical, governance and legal structure to link data, services and products. If barriers are minimised, users can pursue their core business objectives with greater efficiency and effectiveness. Reduction of information costs encourages industries to invest in the capacity to generate and deliver a wider range of spatial information products and services to expanding markets. The design of an integration platform requires development of a set of concepts and principles that facilitate interoperability.

The next chapter (Chapter 4) identifies the main characteristics and principles for utilisation of a Seamless SDI model and examines the current barriers and challenges against implementation of this model.

3.5 Chapter Summary

Information and consequently information infrastructure are urgent demands of the new era, where data and information play a significant role in life and business. Spatial information enables the delivery of good governance and efficient business. As a result, spatial information must be accessible for analysis and use by decision-makers. SDIs are interpreted differently – with different meanings and components – by different communities. However, some critical objectives and components look the same. SDI aims to facilitate the sharing, exchange and integration of land and marine spatial information through the provision of standards, policy framework, access and the establishment of partnerships and collaborations among spatial stakeholders.

Furthermore this chapter has examined the Marine SDI concepts at national and international levels. It showed that Marine SDI initiatives are developing in many countries, all with the aim to facilitate marine and coastal spatial information sharing to improve decision-making and management of the marine and coastal environments.

Many countries with marine and coastal environments are now examining different approaches to better manage their marine jurisdictions, often using spatial technologies or spatial data management tools. However, there is a need for a seamless spatial information platform to facilitate the use and administration of these initiatives in a more holistic and sustainable manner. This chapter has given an overview of some of the most prominent examples of SDI or other spatial information initiatives that focus on the marine or coastal environments and has highlighted the need for a seamless platform across the land – marine interface. It has been recognised that there is a need for a better and more comprehensive way to link different off-shore initiatives offering a more integrated understanding of the marine and coastal environments as there is a close connection between inland and marine coastal areas. These findings further support the premise that Coastal SDI cannot and should not be developed in isolation from the broader National SDI of any jurisdiction.

The next chapter investigates the challenges and issues involved in creating a Seamless SDI model along with characteristics and components for the design of a Seamless SDI model.

CHAPTER 4

SEAMLESS SDI – THE CHARACTERISTICS AND COMPONENTS

4.1 Introduction

Managing the overlapping rights, restrictions and responsibilities of resources within the marine environment and the coastal zone has created one of the world's most complex areas of management. However, effective administration and management of these areas is required to meet the economic, social and environmental objectives of sustainable development.

Until recently, spatial information management and administration tools have focused on the terrestrial environment. As discussed in Chapter 3 the concepts of Marine SDI, Coastal SDI and marine cadastre have all emerged in response to a global realisation of the need to improve management and administration of the coastal and marine environments. 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, where the platform integrates land, marine and coastal environments. 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 – marine interface to more effectively meet sustainable development objectives.

This chapter discusses the potential for adding the marine and coastal dimensions to a SDI, in the context of a seamless model resulting in a better and more integrated management of the land – marine interface. Furthermore, this chapter evaluates influential treaties and conventions driving the development of the Seamless SDI. This is followed by an introduction to the overarching architecture for developing a Seamless SDI and its associated components that allows access to and interoperability of data from marine, coastal and terrestrial environments. Lastly, it identifies the main characteristics and criteria for utilisation of a "Seamless SDI model" and examines the current barriers and challenges against the implementation of this model.

This would help to develop an extended framework to support a spatially enabled jurisdiction covering the land – marine interface. Ideally this extended framework would result in harmonised and universal access, sharing and integration of coastal, marine and terrestrial spatial datasets across regions and disciplines.

4.2 Seamless SDI – Definition and Concept

An essential requirement for the consistent and effective management of the marine and coastal environments is reliable, comprehensive and accurate spatial data. The notion that considerable benefits accrue to a society by "freeing up" access to spatially referenced data has provided impetus for the construction of local, national, regional and global SDIs (Rajabifard et al. 1999; Rhind 2001). SDIs theoretically comprise networked, spatially-enabled databases or datasets that are accessible for downloading or manipulation using contemporary technologies, usually according to explicit institutional arrangements and are supported by policies, standards, and human capital (Rajabifard and Williamson 2001; Nebert 2004). However, the development of SDIs is confined to the land-ward or marine-ward of the coastal zone, with little or no thought given to the interaction between these two environments. The reality is that the need for access and coordination of spatial data does not stop at the coastline.

The complex physical and institutional relationships and interactions existing within the coastal zone make it impossible to develop a Marine SDI in isolation from land-based initiatives. Such land based initiatives need to be expanded to include a Marine SDI component due to the multiple physical and institutional spaces that exist within the coastal zone. 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 the two administration systems and make coastal zone management more difficult. Replacement of two separate systems by a seamless platform would allow robust administration of both coastal and off-shore resources.

Furthermore, a seamless platform 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), climate change and the potential sea-level rises. There is now an urgency to make coastal zone's spatial data accessible and understandable in order to facilitate better decision making, in shorter timeframes. Many coastal management issues could be overcome if a spatial data platform that enables a holistic, integrated and coordinated approach to spatial data for decision-making existed.

On land there are issues such as immature institutional arrangements, data integratability and data interoperability. However, there are more issues facing the marine environment considering it is highly dynamic with 4D boundaries. 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 as well as complex spatial and temporal interactions. Moreover, there is the lack of a framework for accessing and sharing marine spatial data. These difficulties compound in the coastal zone, as both the on-shore and off-shore environments interconnected. The integratability and interoperability of marine-based and land-based databases and also the data gaps over the coastal zone, are the major issues within this region. Figure 4.1 illustrates the entirety of these issues in land, marine and coastal environments. Some of these issues have been acknowledged by spatial data stakeholders involved in the management of Port Phillip Bay (PPB), being the case study area. Chapter 6 deals with the case study analysis in detail.

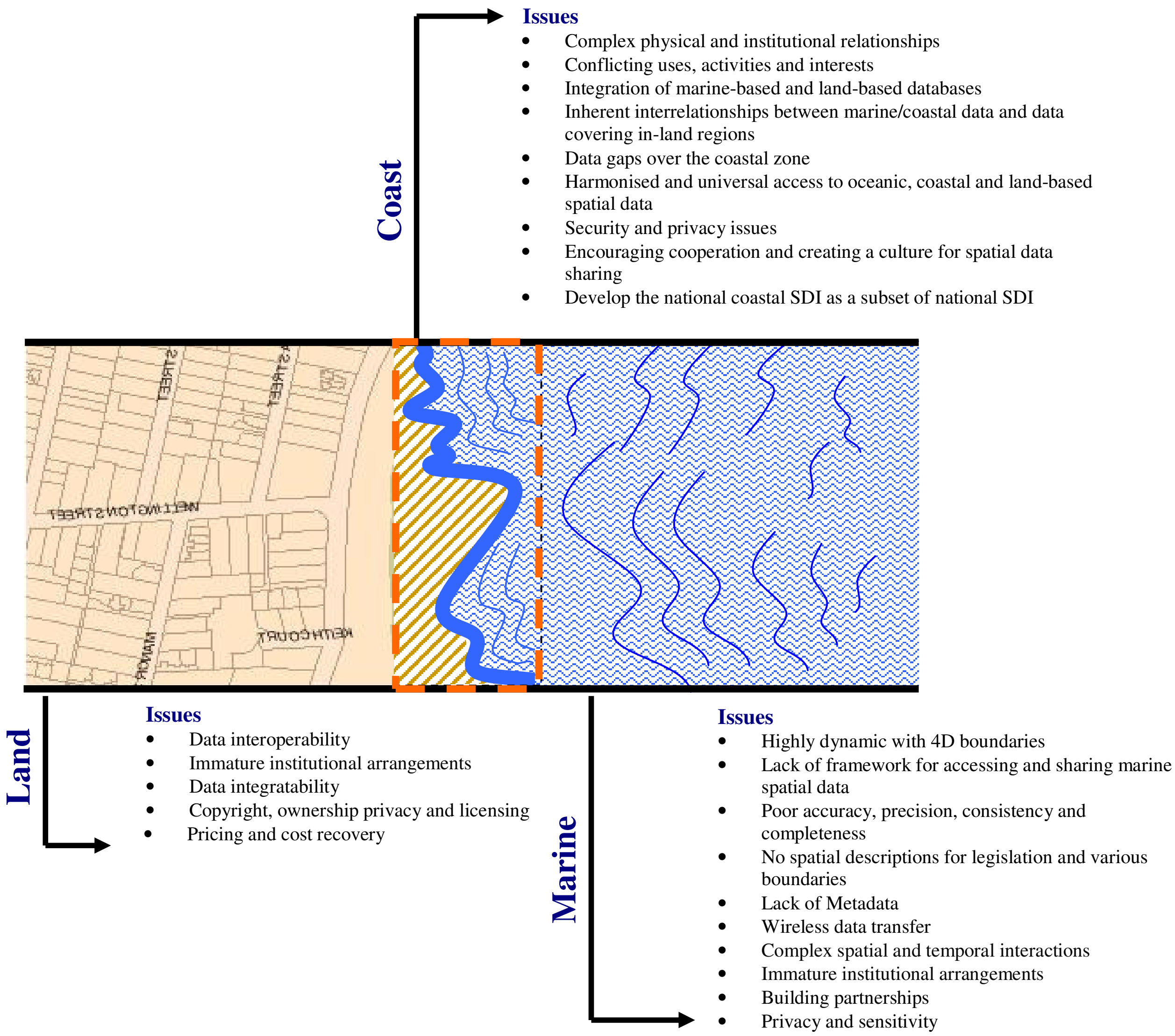

Figure 4.1 Issues of the land, coast and marine environments

To improve management of the coastal zone, there needs to be access to and interoperability of both marine and terrestrial spatial data through SDI development. This SDI should deliver a seamless model that creates a spatially enabled land – marine interface and bridges the gap between the terrestrial and marine environments. Ideally, this would result in harmonised and universal access, sharing, and integration of coastal, marine, and terrestrial spatial datasets across regions and disciplines.

Seamless SDI will recognise the interrelatedness of the marine and terrestrial environments and also improve management of activities or resources that occur across these boundaries. It 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, sea-level rise, shoreline erosion, global warming, weather forecasting and tourism development. The information derived from such a fully integrated information infrastructure will facilitate improved decision making at all levels.

A Seamless SDI should have the following characteristics:

- Seamless: the digital spatial data is stored continuously throughout and across jurisdictions;
- Multi-purpose: the same data can be used for different purposes;
- Multi-users: the same data can be accessed by different users concurrently; and
- Interoperable: the data stored in the database can be accessed using different GIS software and applications.

Therefore, 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. 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.

4.3 Influential Treaties and Conventions Driving the Development of Seamless SDI

The importance of land and marine information integration and seamless infrastructure has been highlighted in different workshops, declarations and resolutions, in particular, UN resolutions. A seamless infrastructure was endorsed by the UN as part of the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP) Workshop for Administering the Marine Environment held in Kuala Lumpur, Malaysia, 2004 (Rajabifard et al. 2005a). The workshop recommended that all countries in the

Asia-Pacific region with an extensive marine jurisdiction and administrative responsibilities be encouraged to include a marine dimension in their NSDI as part of their obligation to meeting their responsibilities under the United Nations Convention on the Law of the Sea (UNCLOS). It further recommends that a marine cadastre act as a management tool within a Marine SDI as an extension to National SDI's across Asia-Pacific. A resolution 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 (including a marine cadastral component) as part of a Seamless SDI to "ensure a continuum across the coastal zone" (UNRCC-AP 2006).

In November 2005, the International Hydrographic Organisation (IHO) has organised and conducted a seminar on "The Role of Hydrographic Services with regard to Geospatial Data and Planning Infrastructure". This seminar formally recognised an option for Hydrographic Offices to become responsible or partner in National Marine SDI and the possible connection of Marine SDI to the National SDI (IHO 2005). This was followed by a workshop in February 2007 on marine / hydrographic spatial data infrastructures (in conjunction with GeoCuba, Havana) to determine the need for IHO members to pursue the concept of Marine Spatial Data Infrastructure (MSDI) and develop a strategy for designing and implementing MSDI, including an assessment of associated benefits to society. It also recommends IHO Regional Hydrographic Commissions to have "Progress on MSDI Development and Land-Sea Data Integration" as a standing agenda of their meeting.

An international workshop for land and marine integration held in Dublin, Ireland in March 2007 determined and documented the progress at a national level and across Europe in integrating maintained national land and marine databases, specifically by exploring: the drivers for integration at national level, current status, issues that require attention and examples of best practice (http://www.eurosdr.net). This is also aligned with INSPIRE which recognised that "environmental problems have to be addressed globally", so there is need for a collaborative approach. In Europe, with regards to the land – marine environment, twenty-two of the 27 EU member states have a coastline, together the EU has a coastline seven times longer than that of the US and four times that of Russia; the Maritime Regions of Europe account today for almost half of the EU population and Gross Domestic Product (when the coastal zone is considered to reach 70 km. inland) and 80% of ocean pollution results from land based human activities (Toth

2007). Therefore INSPIRE identified the need to make the land and marine infrastructures interoperable so that planning, management and solutions can be identified in a seamless and holistic way. It recognised spatial data integration (combination) as one of its principles (INSPIRE 2006). Therefore, the INSPIRE implementation will gradually harmonise data and information services, eventually allowing the seamless integration of systems and datasets at different levels into a coherent European SDI (INSPIRE 2002b). The INSPIRE Directive will support this cause and the Implementing Rules and Data Specifications will be the vehicle to achieve this through work on the specifications for INSPIRE's themes.

Subsequently, the 17th International Hydrographic Conference, in May 2007, directed that Committee on Hydrographic Requirements for Information Systems (CHRIS) establish a Marine Spatial Data Infrastructure Working Group (MSDIWG). The purpose of this group was to analyse and recommend the nature and level of the IHO role in assisting Member States to support their NSDI through development of and / or aligning with the Marine Spatial Data communities in the development of a MSDI. The MSDIWG was duly constituted with an agreed work plan at CHRIS-19 and met initially in February 2008. This was achieved through the development and maintenance of a Special Publication (Publication C-17) "Spatial Data Infrastructure- the Marine Dimension" in October 2009. As a result the Marine SDI was defined as the component of National SDI that encompass marine geographic and business information in its broadest sense covering sea areas, inland navigable and non-navigable waters.

4.4 Design of a Seamless SDI Model –Characteristics and Components

The SDI concept has until recently only been used to describe land related spatial data and information. While these concepts might be applicable and desirable to improve marine administration, the nature, definition and components need to be examined and tested for their ability to describe marine and coastal spatial data and information. A SDI is a platform that facilitates the interaction between people and data by providing required access channels, policies and standards (Rajabifard and Williamson 2001; Nebert 2004; Masser 2006) as illustrated in Figure 4.2. All of these have their relevance and applications in the marine and coastal domains.

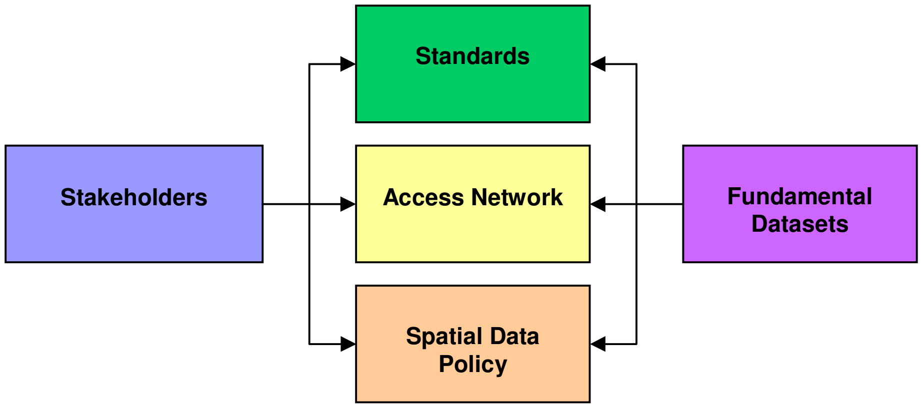

Figure 4.2 SDI and its components (Rajabifard and Williamson 2001)

This section examines each component of SDI (fundamental datasets, standards, policies, access networks and people) and discusses its applicability to Seamless SDI. The first two components primarily have a marine or coastal focus, which is sometimes missing from generic SDI initiatives. It is important to note that the concept is dynamic, in that it provides an ability to be updated with changing technology or human attitudes or with the need for including new environments. In design of this platform many of the characteristics and components of SDI in general will be used but the attributes of these components are different from the existing platforms.

4.4.1 Fundamental datasets

The lack of accurate information seamlessly crossing the land – marine 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. However, the marine environment is dynamic and multidimensional, providing a more difficult area for data collection and updating. Data is usually collected on a project-based approach and is rarely shared between different organisations (Strain et al. 2006). A key issue is the availability of data. There is a substantial amount of data collected about the marine and coastal environments, but it is often not available to all users. The other issue is that if it is available, it may not be interoperable. In the land environment a SDI includes “fundamental datasets”, those that will be needed to support most business processes, with a designated custodian responsible for managing them. It is a fundamental requirement of any SDI initiative. Such data provide a spatial structure and context for an organisation's more sector-specific work, and also through the standardisation implied in the effort of preparing them, these data provide a mechanism for integrating and linking other, thematic datasets from diverse sources, improving interoperability and reducing duplication. For example, the SDI for the State of Victoria, Australia, has geodetic control, cadastral, address, transport, administrative boundaries, elevation, hydrography and imagery fundamental datasets.

Furthermore, the IHO Marine SDI Working Group (MSDIWG) defined Marine SDI as the component of National SDI that encompasses marine geographic and business information in its broadest sense covering sea areas, inland navigable and non-navigable waters. This would typically include seabed topography, geology, marine infrastructure (e.g., bathymetry, wrecks, off-shore installations, pipelines and cables); administrative and legal boundaries, areas of conservation, marine habitats and oceanography.

The data requirements of coastal zone managers go beyond those of their more-terrestrially-focused or more marine-focused counterparts in scale, geographical extent and complexity of definition, leading to the need for specifically coastal-oriented SDI implementation. For most Regional and Global SDI initiatives, there is not sufficient detail in specification of data elements to determine whether or not the needs of coastal and marine resource managers and researchers will be met (Bartlett et al. 2004). Since the basic data will be collected at a national level, this might not appear to be a serious problem at the moment. Yet when data exchange is required for research purposes, for resolving boundary disputes, or to satisfy a nation's responsibilities regarding various international data exchange conventions, then the absence of regional and global agreement on SDI data contents and access issues will become noticed.

As shown in Table 4.1, very few National and Regional SDI implementations make much provision for inclusion of basic coastal or marine framework data. As one might suspect, where any such data exists, the most common themes encountered are bathymetry, boundary data and the shoreline, this last being the only one that is present in all the aforementioned initiatives.

Table 4.1 Fundamental datasets appearing in various National and Regional SDIs (Bartlett et al. 2004)

Fundamental datasets	USA	UK	Canada	INSPIRE -WFD	Asia-Pacific SDI
bathymetry	yes	yes	yes	yes	maybe
shoreline	yes	yes	yes	yes	yes
marine cadastre	yes	maybe	yes	no	yes
coastal imagery	maybe	maybe	maybe	yes	no
marine navigation	maybe	yes	yes	maybe	no
tidal benchmarks	maybe	yes	maybe	yes	no
benthic habitats	maybe	no	maybe	yes-WFD	no

A 'Yes' indicates that the component in the left-hand column is formally listed as an important data component in the definition of spatial data infrastructure at national, regional or global level. A 'No' appears mainly in regional or global initiatives while 'maybes' indicate that detailed user requirements or specifications have been identified and published, along with existing data sources that might provide this data. However, no firm decisions have been made as to how or if this data will be included within the higher-level SDI or not.

The Seamless SDI model as an infrastructure at the higher level needs to cover all the fundamental datasets from land, marine and coastal environments. This aligns with the INSPIRE Directive consisting of 34 spatial data themes required to successfully build environmental information systems. The integration of land and marine data is applicable to a number of themes in Annex I-III across the land and marine environments such as the elevation, hydrography/hydrology, transport networks, protected sides, buildings, land use, oceanographic geographical features, utility information, addresses, and geology. Other relevant themes are: environmental monitoring facilities, area management, natural risk zones, sea regions, bio-geographical regions, habitats and biotopes, species distribution and energy resources.

In some countries like USA, National SDI bathymetry is a sub layer of the elevation fundamental dataset. Also INSPIRE Annex III elevation dataset includes bathymetry and shoreline. This may be possible for other datasets. However, it is likely there will be datasets that are fundamental only for the marine environment (i.e. salinity, waves, and water quality).

4.4.2 Standards

SDI must be based on interoperability (seamless databases and systems). Interoperability is an important part of sharing spatial data in a SDI (Smith and Kealy 2003). The differences in the marine and terrestrial environments in fundamental datasets, data collection and technology used in these environments will make interoperability between marine and terrestrial spatial data a big challenge. Standards are used to ensure interoperability and integratability of different datasets (Strain et al. 2006). The implementation of spatial standards at national level will assure that every institution and organisation creates spatial data in the same manner and it will ease spatial data sharing and exchange.

Standards are common and repeated rules, conditions, guidelines or characteristics for data, and related processes, technology and organisation. These must be developed using international procedures and practises to cover not only the national needs, but also cooperation at an international level. Standards issues in the spatial data world are now much better addressed than a mere ten years ago, largely due to the extensive work of the International Standards Organisation's Technical Committee 211 (TC/211) on Geographic Information (GI) /Geomatics, which aims to create "a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth" (ISO 1999). This currently comprises some 40 new GI-related standards (ISO 2002), mostly concerned with terrestrial data, information products and the management of this information, but also in a fewer number of cases applying to their coastal and marine equivalents. Furthermore the global reach and uptake of the GIS interoperability work of the Open GIS Consortium, Inc. and OGC Europe, Ltd. is providing a clear way forward in regard to integrating GI applications and data sources, especially using the web as the service delivery machinery (OGC 2002).

In parallel with ISO, 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. IHO developed and maintained the S-57 (Special Publication No. 57) cartographic standard related to coastal and marine data. This standard is used for collection and exchange of hydrographic data among national Hydrographic offices globally. It is also very important for marine navigation, as applied to the Electronic Chart Display and Information Systems (ECDIS) being introduced throughout the maritime industry (Ward et al. 2000). S-57 comprises a hydrographic data model, an object catalogue and an Electronic Nautical Chart (ENC) product specification that are standard for ECDIS data. S-57 standard, although limited in scope and implementation, provides important compatibility for data sharing in the hydrographic information community.

The development of S-100 (the next edition of S-57) has been a great step toward creating a Seamless SDI. The next edition of S-57 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 spatial data. 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 purposes (Maratos 2007). It also plays a key role for IHO and hydrographic offices in any Marine SDI development.

Another initiative that aims for interoperability between datasets from different custodians is the development of Extensible Markup Language (XML). XML is an exchange data format that is used on the Internet and has been described as "the building blocks that house data" (Keely et al. 2006). XML is now used widely on the internet for conveying semantic content of information as opposed to only the display specifications provided by Hypertext Markup Language (HTML), and is becoming adopted as a data exchange format by a number of national mapping agencies and other data providers.

There are several projects around the world examining the creation of a marine specific implementation of XML. MarineXML is described as "an interoperability framework for global ocean observation systems" (IOC 2003), which will encompass coastal zone elements as well. The development work on MarineXML is being undertaken by the European Union, via a part-funded project in the EU's Framework RTD programme in conjunction with the Intergovernmental Oceanographic Commission's Committee on International Oceanographic Data and Information Exchange (IOC- IODE) based at

UNESCO headquarters in Paris (IOC 2003). The IOC has established a Marine XML consortium, which is looking at developing an international standard form of marine XML. Standardisation at an international level is required for interoperability on a global and regional level, otherwise MarineXML will become "just another data format" (Ronai et al. 2002). The main benefit of using XML is that it provides a common format to store data, and so allows data to be exchanged easily between providers, value adders, and users. Meanwhile, national initiatives on creating MarineXML specifications are also underway, for example in Australia and the USA (Sligoeris 2002; Davis 2002). Marine XML is being developed and used by the Australian Oceanographic Data Centre (AODC) to encode their marine data for storage and exchange (Ronai et al. 2002). Elsewhere, various shoreline and boundary data metadata standards have been developed at national level, for example in the USA within the FGDC shoreline metadata working group. Therefore common standards and well documented metadata are essential for data discovery, management and compatibility within a SDI. The main opportunity in developing a Seamless SDI is in the creation of interoperability standards that will allow a user to integrate data from any environment.

4.4.3 Policies

There need to be a policy to create information that is interoperable. This is often linked to a nation's or organisation's strategy for sharing and exchanging geographic information. Policies are influenced by international best practice in spatial data management and exchange. Appropriate policy and governance models could assist SDI development in several ways: by stimulating more rapid evolution of SDIs, by addressing current deficiencies in the application of standards, and by helping to achieve an increase in public penetration of SDI related technology and services through more tightly integrating a user-perspective in both SDI design and operational management.

Other issues also need to be considered, including the need for harmonised data access policies and exploitation rights for spatial data, data custodianship, conformity, quality, content, industry engagement, avoidance of duplication and sensitivity. These policies for terrestrial spatial data and marine and coastal spatial data are likely to differ in terms of data quality, data access and privacy. Data quality depends on collection, completeness, currency, reliability etc. and due to the complexity of the marine environment and the different technologies used for data collection, may be more difficult to achieve at the same level as terrestrial data. Fixed line data transfer supports data access on-shore. In the marine environment there may need to be the capability for wireless data transfer, for people accessing or uploading data off-shore.

Privacy over spatial data in the marine environment is a concern with many countries reluctant to share spatial data relating to their marine jurisdictions. In many parts of the world, access to detailed information about the coast is considered a very sensitive issue, primarily due to concerns over national security. Even though satellite remote sensing nowadays makes observation and monitoring of coastal zones accessible to all nations, irrespective of the wishes of individual governments, it still remains the case that possession and diffusion of detailed mapping of the coast may frequently run counter to local regulations, work practices and/or cultural sensitivities. As such there may be a need to maintain the different privacy policies for off-shore data. Therefore there is a need for an appropriate policy model to create a seamless infrastructure across jurisdictions.

Marine data management policies are developing in Australia and the USA. In the United States, NOAA Coastal Service Centre has developed a policy for Coastal National SDI that aims to link the coastal management community with the National SDI. Australia's Marine Science and Technology plan sets out policy for marine spatial data sharing and management. The policy includes: avoiding duplication, data consistency, improved access to data and coordinated data management.

There is an opportunity however to first establish and promote policies that relate to data sharing, use of common standards and avoidance of duplication. A lot of data collection is duplicated in the marine environment, and once these policies are established they can then be built upon. If all stakeholders in the marine and coastal environments have a policy for avoiding duplication of spatial datasets, they may be more likely to examine different ways to share and re-use data in order to comply with this policy. This is also true of a "promote data sharing" policy that would promote the idea of data sharing and encourage organisations to first examine different opportunities for accessing spatial data before collecting it themselves.

4.4.4 Access networks

Access networks usually comprise data warehouse, data portals, one-stop shops, on-line atlases or similar. It includes access and distribution networks, clearinghouse and other mechanisms for getting spatial information and data to the stakeholders. For the access network to support interoperable and coordinated data they must comply with SDI standards and policies.

Around the world these are being set up to facilitate access to terrestrial, marine and/or coastal spatial data. For example, in Australia, the NOO is developing an oceans portal, data is accessible through the AODC and each state has an off-shore atlas, as an online GIS that combines mapping capabilities and a link to metadata. Decisions affecting marine and coastal environment need to be timely and based on a strategic interpretation of all available data, presented in an easy and accessible format. The ability of potential users off-shore being able to access data is another issue. For example, bathymetry for navigation, the rights and restrictions attached to a particular location, or sea surface temperatures or currents in a search and rescue operation. The technology that allows data transfer and access on-shore will not be appropriate for use off-shore, and so alternatives, such as wireless data transfer will be needed.

An opportunity in developing a Seamless SDI is to enable all data to be available through one common portal. This would mean that potential data users only need to visit one web-site or internet portal to discover all the possible data that is available. At international and national levels as shown within the Marine Cadastre questionnaire that ability for one-stop shopping was regarded as important for easy access to spatial data (Strain et al. 2006).

4.4.5 People

This component is one of the most important components of SDI. The people in SDI are the data providers, value-adders and data users. In the marine environment these people will come from private industries such as shipping, defence, aquaculture and conservation, as well as from government at local, state and national levels. There will already be some degree of spatial data management that is occurring within these groups, even if only within or between organisations. It is important that this is recognised and can be built upon to facilitate the development of a Seamless SDI.

The key to success in SDI initiatives is partnerships within and between organisations involved in spatial information. Partnerships drive the development of SDI, allowing people to work together to achieve their respective goals. The opportunity in Seamless SDI is through improved vertical communication between the different SDI levels – global, national and state. At each level there are different ideas coming from the different people involved and while some coordination is apparent, such as the desire for use of OGC, ISO standards, the initiatives are developing separately. Communication between the different levels can help coordinate these initiatives better and this is particularly important in the marine and coastal environment, as state and federal governments have variable rights, restrictions and responsibilities over this area and different activities and boundaries can cross these borders.

Multiple reports internationally have highlighted the need for better coordination and integration between and within levels of government to improve coastal zone management (Hudson and Smith 2002; Middle 2004). Therefore a challenge in developing a Seamless SDI will be in encouraging cooperation and a culture for spatial data sharing between the institutions involved in marine and coastal spatial data collection and use (Rajabifard and Williamson 2003).

An international workshop for land and marine integration in March 2007 identified the need for a single body to support land-marine integration for the region to keep the land and marine communities working together was noted (http://www.eurosdr.net). However, many issues and challenges could be overcome through better coordination arrangements and existence of a single management authority or forum for collaborative planning, and deficient legislation. Promoting spatial data, sharing and using common standards and a single access network may help to counteract some of the unwillingness that exists, and encourage greater cooperation and collaboration in the coastal and marine sector.

More information about Seamless SDI is required to have a better understanding and knowledge about SDI among different institutions and organisations and there should be proper regulation to enforce that all spatial data providers should involve in and contribute to the development of a Seamless SDI.

4.5 Barriers and Challenges to Creation of a Seamless SDI

SDI creation can be a difficult and intimidating task, with both technological and organisational challenges. 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 a 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.

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 spatial datasets across the land – marine interface are needed by almost all users struggling with issues of navigation, resource management, planning, hazard delineation and mitigation, environmental studies, and regulation issues. Therefore, there is a need for data integration across land – marine interface.

The integration should be carried out for both land and marine spatial data to build a seamless spatial data management throughout any jurisdiction. The diversity and number of mapping organisations and data providers are the most significant barriers for effective spatial data integration (Clarke et al. 2002). Spatial data providers create and maintain spatial data for their own and their users' needs. Therefore, the datasets properly suit the requirements of the target users. Each of the data categories sits in a separate silo. Each of the silos complies with a certain set of policies and considerations that may differ from other silos (Williamson et al. 2003a). At the same time, many spatial applications manage some aspects of the environment that do not necessarily sit within the borders of any particular jurisdiction. Many of the spatial applications require spatial data from different areas. These applications provide additional value to the spatial data by integrating them.
The diversity of the requirements of spatial applications together with the diversity of standards, policies and approaches utilised by different spatial data custodians results in many issues that hinder effective data integration.

In order to implement spatial data integration efficiently, associated barriers and challenges should be investigated and identified. The following subsections discuss the barriers to spatial data integration from the perspective of author and other researchers. As stated by Syafi'i (2006) the integration of spatial data at national level encounters either technical or non-technical issues, however the non-technical issues are the most difficult issues to overcome. These issues and potential solutions are discussed below.

Successfully addressing the issues associated with building a Seamless SDI results in more efficient implementation of initiatives such as coastal flood visualisation, disaster management and response, and/or Integrated Coastal Zone Management (ICZM).

4.5.1 Technical issues

Spatial data may come from various sources or data providers. Each data provider has its policies and methods of managing spatial data. Often, land and marine data products are incompatible in terms of scale, projection, datum and format (Gillespie et al. 2000). Disparities between scale, symbology and datum cause various data integration issues when these datasets are joined. Interoperability issues related to reconciling these differences are heightened where shore-based and sea-based datasets meet in a coastal zone (Mackenzie and Hoggarth 2009). Align with this, recent terms of reference from the International Hydrographic Office (IHO) Marine Spatial Data Infrastructure Working Group (MSDIWG) recognised, "There is a need to identify and recommend solutions to technical issues related to interoperability between land and sea data" (IHO 2009). Therefore, there is a need to make the land and marine infrastructure interoperable so that planning, management and solutions can be identified in a seamless and holistic way.

The following are several technical issues that should be taken into consideration when integrating spatial data from various data sources:

- Differences in spatial reference system (horizontal datum, vertical datum, and coordinate system);
- Differences in storage format;
- Differences in data accuracies;
- Differences in scale of data source;
- Differences in feature or object definition (feature catalogue);
- Differences in spatial data quality due to the differences of resolution or data acquisition method; and

- Differences in spatial data modelling (geometry, features name, attributes, field type, topology and symbology) (Gillespie et al. 2000; Gomm 2005, Syafi'i 2006; Mackenzie and Hoggarth 2009).

In Europe (in the MOTIIVE project) these problems were also recognised by coastal managers added by the lack of metadata and correspondingly difficulties to discover data (see http://www.motiive.net). They can be summarised as follows:

- There is a lack of metadata and correspondingly difficulties to discover data;
- Currently a large variety of formats exist and these are not interoperable;
- Reference systems are not harmonised across borders;
- Data sources are not consistent;
- Scales are not compatible; and
- There are restrictions for data accessibility and data handling is costly.

Another concern linked to the establishment of a 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. Different representations of the coastline in marine and land datasets leads to data overlaps while most of the applications require a single seamless layer with no duplication of common features. Table 4.2 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. As shown coastlines in topographic maps would be taken from Mean Sea Level (MSL) which is determined by modelling the topography while coastlines in nautical charts are based on Local Astronomical Tide (LAT). Differences in horizontal and vertical datum and projection systems are other technical obstacles of marine and land spatial data integration. Datasets on land will often share a common height datum like Australian Height Datum (AHD); however different datums will usually be used for marine datasets. Frequently, with marine datasets having their origin form navigational charts, depth values will be typically based on LAT. Disparity of on-shore maps and off-shore charts in scales and storage formats and thus an inability to accurately represent coastal features or processes that cross the land/water interface are other issues relevant to land and marine data integration. Land-ward data are captured at large scale and the sea-ward side at small scale. The result of this is a disparity in the features common to both zones, and a greater density of detail on the land compared with the sea.

Table 4.2 Different aspects of land and marine spatial data integration

Item	Topographic Map	Nautical Chart
Coastline	- Mean Sea Level (MSL) which is determined by modelling the topography	- Local Astronomic Tide (LAT)
Horizontal Datum	- GDA94 - WGS84	- GDA94 - WGS84 - AGD66
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
Projection system	- Universal Transverse Mercator (UTM).	- Mercator
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
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 organisation 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. The fact that the international development of geographic standards is a consensus based activity that can begin (and end) with an "absence of any real theory or conceptual basis," often resulting in a standard with "little or no technical sustainability or long-term viability" (Tom 2003), can present implementation difficulties for those at the cutting edge of development.

The marine standards are not at the same level of completeness as the ISO TC/211 standards. The OGC/TC 211 implementation specifications were found to have deficiencies, particularly in relation to manipulating marine data types which typically have 3 or 4 dimensional components (e.g. latitude, longitude, depth, and/or time). For instance, based on the Australian Marine SDI activities, it was difficult to deal with the time dimension in OGC Web Map Services (Finney 2007). Woolf et al. (2005) also encountered this problem and reported other difficulties including the lack of appropriate support for using a range of vertical coordinate systems in the WMS specification, a specification that was essentially designed for 2D mapping. Furthermore, different standards need to be developed for marine spatial data exchange this will limit the interoperability between marine and terrestrial spatial data. It also creates confusion in the coastal zone as to which standard should be applied.

Another barrier to a Seamless SDI is in vertical and horizontal datum discrepancies regarding topographic and bathymetric datasets, which creates a problem in defining the parameters required for transformations. Bathymetric data displayed on nautical charts are referenced to a vertical datum where the water surface will not normally go below. This Chart Datum is usually the Lowest Astronomical Tide (LAT) or Mean Lower Low Water (MLLW). Topographic data, on the other hand, are often referenced to a local geodetic datum, approximated by Mean Sea Level (MSL), which is above LAT and MLLW. A geodetic datum is a continuous surface that varies with gravity. A chart datum is referenced to a low water determination relative to a localised area, and differs from chart to chart (Mackenzie and Hoggarth 2009). 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 metadata and existing transformation tools, vertical datum issues present the most serious challenge to this effort.

Two organisations that have developed processes for transforming between the various vertical datums are the National Oceanic and Atmospheric Administration (NOAA) in the United States and the United Kingdom Hydrographic Office (UKHO). NOAA has developed the VDatum tool set to transform datasets between standard vertical datums (See more at http://vdatum.noaa.gov). VDatum covers the transformation of various vertical datums in three groups: tidal, orthometric (relative to geoid) and ellipsoidal datums. NOAA has undertaken a pilot project in Tampa Bay, Florida for creating a seamless bathymetric/topographic dataset. The VDatum tool that they developed allowed the transformation of all bathymetric data from the MLLW datum to the ellipsoid (Ocean Studies Board 2004).This tool is limited to areas and datums which have a vertical transform model available and is largely limited to high traffic areas off the coast of the continental United States.

The UKHO has been developing a vertical datum transformation framework called the Vertical Off-shore Reference Model (VORF). This framework aims to model the relationship between Chart Datum, which is largely based on tidal levels at Lowest Astronomical Tide (LAT) and other vertical reference surfaces, such as topographic Digital Elevation Model (DEM). VORF incorporates various validation references, including satellite altimetry, geoidal models, tide gauge data throughout the United Kingdom, and GPS derived ellipsoidal heights and bathymetric models (Ruth et al. 2009). One limitation of these vertical datum models is their current limited coverage. While each is useful for their target areas, they are regional in nature. There is no global vertical datum model or transformation standard that is accurate for use at the regional or local level.

Shoreline

The shoreline is one of the most unique and important features on the surface of the Earth. The International Union of Geological Sciences (IUGS) has identified the shoreline as one of the 27 global geo-indicators (Berger and Iams 1996). It is also one of the 27 features recognised by the International Geographic Data Committee (IGDC) (Li et al. 2001). Measuring, describing and representing the shoreline are essential tasks within both SDI and ICZM initiatives. At the same time, the diversity of perceptions and definitions of the shore (each institution and discipline dealing with the coastal zone has its own defining criteria, according to its specific mandate and objectives), and the lack of standardised modelling criteria, make the shoreline one of the main barriers for data integration and interoperability, and hence pivotal to the success of any spatial information infrastructure

While most people will intuitively recognise the existence of the shoreline, it is virtually impossible to establish its absolute position at any given point in time (Bartlett 2000). The coastline is defined by the line of intersection between the land-mass and a nominated tidal place. Instead, established practice is to be use an approximation of this line, generalised at a certain spatial and temporal scale, choosing from a number of potential candidate "coastlines", including the mean sea level (MSL), the higher/lower equinoctial water tides line (HAT/LAT), the mean high/low water tide line (MHWT/MLWT) and many other recognised water level. Since shoreline definitions typically relate to a water level, the shoreline is dynamic, changing over various temporal and spatial scales. However, the coastline does not have a concise or unambiguous spatial or legal definition, creating uncertainty and potential conflict in the case of competing interests in the tidal zone. This also makes the delimitation of maritime boundaries dependent on the definition of the coastline somewhat problematic. Current technical issues that impact on the consistent delineation of the coastline to remove current ambiguity in the tidal zone and create a single national cadastre covering the both on-shore and off-shore environments have been identified (Quadros and Collier 2008).

Besides the complexity of representing the shoreline due to its dynamic and fuzzy nature, the uncertainty surrounding the nomenclature of shoreline components is a further important barrier to seamless data sharing between disciplines and administrative sectors. Several different shoreline definitions are in use by various federal, state, and local authorities to meet non-navigational needs. Moreover, given the diversity of stakeholders with different and often conflicting interests regarding the use of the shoreline space, there is an array of traditions in understanding the shoreline itself and its management. This confusion over terms and the determination of what is meant by "shoreline" creates uncertainty in the coastal zone management process (Lockwood and Fowler 2000) and 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. From this perspective, for any Seamless SDIs to be functional, it is necessary to somehow translate this diversity of perceptions into some form of standardised conceptual data model for the shoreline that allows unambiguous representation of this feature within existing and future SDI databases. This data model should aim to satisfy the requirements of the ICZM community based on commonly agreed definitions resulting from discussions among relevant actors, by recognition of the diversity and similarities, convergence and conflicts, needs and constraints that characterise users and producers of shoreline spatial data around the world. 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. It is also important to carry accurate metadata with shoreline dataset.

The following Table (Table 4.3) summarises the described technical issues and their potential effects.

Table 4.3 Technical issues in integrating land and marine datasets and their consequent effects

Technical Issues	Consequent Effects
The dynamic and fuzzy nature of the shoreline as the one of the main fundamental datasets within the coastal zone	Complexity in representation and also barrier to seamless data sharing between disciplines and administrative sectors
Existence of different data formats, reference frames and also lack of metadata and consistency in data	Lack of interoperability of different datasets
Difference in scale, quality , coverage and format of spatial data as well as the lack of, or poor quality metadata	Difficulty in integrating different datasets
S-57 hydrographic data standards is not at the same level of completeness as ISC/TC 211	Difficulty in the interoperability between marine and terrestrial spatial data creates confusion in the coastal zone
Different technology to capture spatial data in marine and coastal environment	Difficulty in achieving the same level of completeness, currency and reliability as terrestrial data

As mentioned earlier in this section, 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.

4.5.2 Non -Technical issues

There are several non-technical issues that should be overcome to develop a Seamless SDI. The non-technical obstacles of data integration can be caused by institutional, policy and legal issues (Williamson et al. 2006; Mohammadi et al. 2006; Burrough and Masser 1998; Van Loenen 2006).

a) Institutional issues

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). Both Binns (2004) and ANZLIC (2003a) have reported that a barrier to SDI development and especially marine and coastal SDI development is “immature institutional arrangements” and the reluctance of many organisations to share their data. Immature institutional arrangements result in organisations working in the same jurisdiction or in the same discipline collecting 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.

Each institution or organisation has different policies and rules on managing spatial data. Therefore, the main impediment to data sharing and developing a Seamless SDI comes from a lack of institutional willingness and ability to conform to national or state level set standards and policies in order to make their data available to others. It is mainly due to lack of resources, and limited spatial awareness. Another exiting barrier is that communication between different sectors is poor. There is little understanding of different organisational cultures and enormous administration fragmentation. As a result of this issue there are conflicts between marine and coastal users and pressures for services and facilities. Most conflicts have at least some relationship with the multi-objective nature of demand for coastal resources.

Many researchers have investigated institutional obstacles of spatial data integration. Some key findings are as follows:

- Inter- and cross-organisational access, retrieval and display arrangements (Zaslavsky et al. 2004; Baker 2005; EUROGI 1997);
- Sharing data among organisations (Weaver 2004; Baker 2005);
- Different coordination and maintenance arrangements (Ordnance Survey 2003);
- High degree of duplication (Baker 2005; Burgess 1999);
- Weak collaboration (Baker 2005);
- Uncoordinated specifications and standards across spatial stakeholders (Baker 2005);
- Lack of central access gateway (single point of access) (Baker 2005); and
- Building awareness and capacity (Clausen et al. 2006).

The coastal zone is difficult to manage due to a complex array of legislative and institutional arrangements varying from local to global levels. Furthermore, there is currently confusion about the management of the land – marine interface. This shows, for example, 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 and Williamson 2003).

Results from European Spatial Data Research (EuroSDR) questionnaire sent out to all European mapping agencies and hydrographic offices and geological organisations in late 2006 showed that only in a small number of cases the land and marine data is managed by a single organisation. In others collaboration across two or more organisations is required (typically national mapping agency, hydrographic office and sometimes the geological organisation) (Murray 2007). Institutional integration increases the efficiencies and effectiveness of the management in any jurisdiction with land and marine environments. If national mapping and hydrographic charting agencies are separate, they need to work under the same banner and their policy should align with each other and the national policy to create a Seamless SDI.

National mapping agencies and hydrographic offices use different coordinate systems, projections, horizontal and vertical datums and contents. Therefore users can not reference any object consistently across the coastal zone. A common framework will support interoperable coordinate systems and datums, interoperable objects along agreed boundary and interoperable feature catalogues. This agreed interoperable framework will contribute to the Seamless SDI.

However, it is believed that the above problems can be overcome through coordination arrangements and existence of a single management authority or forum for collaborative planning, and deficient legislation..There should be proper regulation to enforce that all spatial data providers should involve in and contribute to the development of the Seamless SDI. The Table 4.4 shows different institutional issues and their potential effects.

Table 4.4 Institutional issues in integrating land and marine datasets and their consequent effects

Institutional Issues	Consequent Effects
Various spatial datasets are collected and stored by different organisations	Finding and obtaining datasets is difficult
Immature institutional arrangements	Reluctance of organisations to share their data
Limited knowledge of marine and coastal environment, boundaries and their associated rights, restrictions and responsibilities	Inefficient and ineffective marine and coastal management and administration

b) Policy issues

The main policy issues that exist in the current SDI model that will hinder the development of a Seamless SDI relate to sensitivity, quality and pricing. As mentioned earlier, many data producers are reluctant to allow their data to be shared and while this is also true with the current SDI and the reason for these policies, it seems to be intensified with marine and coastal data. In many parts of the world, access to detailed information about the coast is considered a very sensitive issue, primarily due to concerns over national security. These restrictive policies lead to marine and coastal data being withheld from stakeholders and the general public. Therefore, while the current fundamental datasets that relate to the land environment are often provided to anyone who wishes to use them, and at minimal cost, this may be more difficult to achieve with marine and coastal data.

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 and policies. 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. 2006). Accordingly this complex, fragmented regulating framework for marine and coastal management causes the inability to adequately handle the pressure of different activities and stakeholders within the coastal zone.

From a policy perspective, the diversity of involved organisations with different policy drivers and priorities affect the integration of land and marine environments. Non-technical barriers that are more difficult to address include lack of harmonised data access policies and exploitation rights for spatial information, particularly for data collected by public sector agencies across different nations and even within single governments. Some of the key issues are listed below:

- Access policies (Donker and Van Loenen 2006): Concerning user requirements, users require both transparency of information policies and consistency in the access to policies throughout government.
- Differences in pricing, and liability regimes may result in confusion and ultimately limited use of the datasets. (Donker and Van Loenen 2006)
- Pricing models (Donker and Van Loenen 2006): As a consequence, it is time consuming to explore a potential avenue to cost-recovery, among other things (Donker and Van Loenen 2006).
- Use restrictions (Meixner and Frank 1997; Donker and Van Loenen 2006)

In Australia, the Australia’s Oceans Policy, which was released in 1998, guided the direction of the Australian Government’s programmes in the marine environment. The policy provides national coordination and consistency for marine planning and management, while allowing for regional diversity. As part of Australia’s Oceans Policy was a marine science and technology plan. One of its objectives is “Infrastructure for Understanding and Utilising the Marine Environment” which aims to achieve better coordination of marine spatial data. This objective recognises that “increasingly larger volumes of marine spatial data are being collected, analysed and stored by government and the private sector” and that there are obvious benefits in terms of resources saved if there was a better ability to share this data. The NOO (1999) states that the main impediment to achieving better sharing and coordination of marine spatial data are is the lack of an agreed framework of standards, policies, and coordination mechanisms that would enable different users to exchange their datasets. Table 4.5 outlines the current policy issues and their consequent effects.

Table 4.5 Policy issues in integrating land and marine datasets and their consequent effects

Policy Issues	Consequent Effects
Restrictive national security and pricing policy regarding marine and coastal data	Coastal and marine data being withheld from stakeholders and general public
Complex, fragmented regulating framework for marine and coastal management	Inability to adequately handle the pressure of different activities and stakeholders within the coastal zone
Lack of agreed framework of standards, policies and coordination mechanisms	Lack of coordination and sharing of marine and coastal spatial data

c) Legal issues

The integration of spatial datasets raises a number of legal issues. It is obviously necessary to clarify the nature of datasets and the stakeholders and their particular rights in data (Burrough and Masser 1998). In 1995, the European Umbrella Organisation for Geographic Information (EUROGI) commissioned RAVI, the Netherlands Council for Geographic Information, to conduct a survey on the legal problems:

- Different licence conditions (Donker and Van Loenen 2006; EUROGI 1997);
- Intellectual property (IP) and licensing (Baker 2005; Donker and Van Loenen 2006);
- Liability regimes (Donker and Van Loenen 2006).

The European Union is addressing this problem at a regional level with a “public sector information exploitation” Directive setting out an agreed EU-wide framework for access to and exploitation of public sector information (European Commission 2002). The impact such initiatives will have on the coastal zone and larger marine research communities cannot be underestimated due to the great volume of coastal and marine data that is collected by a large number of government agencies. Even in countries with strong "freedom of information" cultures, such as the USA, some public sector marine information is not disclosed due to fear of liability actions against the data providers (Lockwood and Fowler 2000). IP legislation is in a continual state of flux across the globe in order to adapt existing IP regimes and international IP conventions to the digital world.

Many of the discussed issues are closely connected. For example, the aversion to data sharing and integration hinders the establishment of effective cross-organisational access, retrieval and display mechanisms. Restricted pricing and access policies hinder maximum use and cause duplication of efforts. Diversity in coordination and maintenance arrangements result in different data characteristics including data models, quality, metadata content and coordinate systems etc. Therefore, without considering all the issues within a single holistic framework, effective spatial data integration cannot be achieved. The development of a framework such as a Seamless SDI would aim to aid in facilitating decision making to respond to these technical and non-technical issues, to facilitate more effective management of the land – marine interface.

4.6 Chapter Summary

The movement in the spatial community towards SDI has largely been focused on the land spatial datasets. This is changing partly because the management of the coastal zone has become more urgent in the light of rising sea levels. Decision-makers are realising that a clear picture of the coastal zone must include a combination of land and marine datasets. Therefore, there is an emerging focus on the inclusion of marine and coastal data to complete the picture at the national, regional and global level. By fusing the data from the land and sea in the coastal zone, stakeholders and planners can make informed decisions and have the benefit of deriving new features that lie across the combined surface. The objective to combine land and marine data is made more difficult because of the different technical and non-technical issues in these two areas.

This chapter introduced the concept of a Seamless SDI and highlighted its characteristics and components. 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 and facilitate better decision-making.

The chapter then listed a number of technical, institutional, policy, legal spatial data integration issues and problems associated with effective land and marine data integration. Issues of data integration have been discussed in two main categories: technical and non-technical issues, with some of the potential solutions having been given.

Chapter 5 (Seamless SDI Model) introduce the Seamless SDI conceptual model and governance model. The chapter discusses Seamless SDI implementation guidelines for any jurisdiction to facilitate the administration and management of the land and marine environments.

CHAPTER 5

DESIGN SEAMLESS SDI MODEL

5.1 Introduction

In Chapter 4, the Seamless SDI platform which would facilitate greater access to more interoperable spatial data and information across the land – marine interface has been introduced. This chapter aims to present the design and development of the Seamless SDI model. It proposes the conceptual model of Seamless SDI by using Hierarchical Spatial Reasoning. The Seamless SDI class and its inherited characteristics and properties will be discussed.

In addition to the conceptual phase, the development of a Seamless SDI model also consists of two more stages: design phase and implementation phase. The design phase is presented based on Unified Modelling Language (UML) providing a graphical notation of the architecture of the system. The Use Case Diagram and Object Diagram of the Enterprise Viewpoint are developed. Further, it highlights the importance of the creation of appropriate Seamless SDI governance structures that are both understood and accepted.

The model proposed in the design phase is developed during the implementation phase. In this regard, this chapter presents Seamless SDI guidelines as a necessary step by step approach to create a Seamless SDI for any jurisdiction with a marine environment which might support and participate in a Seamless SDI. It provides necessary information for practitioners to deal with the complexity of creating a Seamless SDI. The guidelines can be utilised as a part of the tool or as an individual document that helps identify potential barriers and possible enablers.

5.2 Seamless SDI Conceptual Model

There is a need to develop a Seamless SDI that can include data from the land, coastal and marine environments which will improve access and sharing of data between these environments. This leads to a more integrated and holistic approach to management. With this in mind, the importance of understanding the link between land and marine environments (they cannot be treated in isolation) and the need for cooperation between nations as maritime actions transcend national boundaries is a major issue as covered in Chapter 2 and 3. In order to have such an environment, there is also a need to identify technical, institutional and policy issues hindering the implementation of the Seamless SDI model (Chapter 4). Successfully addressing the issues associated with building a Seamless SDI results in more efficient implementation of initiatives such as coastal flood visualisation, disaster management and response, and/or Integrated Coastal Zone Management (ICZM). It is envisaged that the management of other geospatial data such as that used for aviation purposes could also benefit from this approach.

As discussed in Chapter 4, in designing the Seamless SDI model many of the characteristics and components of SDI in general will be used but the attributes of these components are different from the existing model. Overall, a Seamless SDI should have four characteristics which are 1) Seamless 2) Multi-purpose 3) Multi-users 4) Interoperable. Seamless SDI needs seamless spatial data from land and marine environments which is a continuous spatial dataset that traverses the coastal zone. It should be possible to combine seamlessly spatial data from different sources and share it between many users and applications. The seamless platform would facilitate greater access to more interoperable spatial data and information across the land – marine interface enabling a more integrated and holistic approach to management of the coastal zone.

However, in order to design and implement the Seamless SDI, a conceptual model of the Seamless SDI is required. The first step for implementing any model including the

Seamless SDI is developing a conceptual modelling. Conceptualisation phase comes before implementation and design phase. A conceptual model can be defined as a model which is made of concepts and their relationships. It is the first step before design phase and drawing a Unified Modelling Language (UML) diagram. Conceptual modelling is modelling of real-world situations on a higher level of abstraction, before a detailed logical and physical design takes place (Brodie et al. 1984). It helps to understand the entities in the real world and how they interact with each other. Conceptual models provide the description of space that is closer to human conceptualisation and its semantics. They communicate the formalised ideas of space and as such enhance communication between domain expert, system designer and end-user. With this in mind, this research has developed a Seamless SDI conceptual model.

In order to develop a conceptual model, Hierarchical Spatial Reasoning (HSR) and Object Oriented Modelling (OOM) methods have been used. As demonstrated by Rajabifard et al. (2002a) the principles and properties of HSR could be applied to SDI research to better understand their complex nature and to assist modelling of SDI relationships. The application of HSR to SDI research builds upon earlier work by (Eagleson et al. 2000; 2002a; 2002b) which applied hierarchical reasoning to the spatial problem of administrative boundary design. The main reason that a hierarchy concept is applicable to SDIs is that all properties and reasons for developing a hierarchical structure are applicable to the SDI concept (Williamson et al. 2003a). For example a SDI at a high level, like a global level, consists of one or more SDIs from a lower level. In hierarchy, any element of the higher level consists of one or more elements from the lower level (part-whole property). Any element at any hierarchical level also has two faces. One face looks towards wholes in a higher level and the other looks towards parts in a lower level. This property is called the Janus Effect. Another property of a hierarchical structure is decomposability. It represents the nesting of the system within larger sub-systems. It also states that interaction between various systems decreases in strength with distance from other systems.

Based on the Hierarchical Spatial Reasoning (HSR) and Object Oriented Modelling (OOM) method, several classes of SDI (land, coastal and marine), which have some properties in common, groups in to a more general super-class (Generalisation). The Seamless SDI model can be postulated as one abstract class SDI at the higher level (parent level) with attributes and operations/methods designated to this class. A Seamless

SDI as a super-class specialises in to land SDI, coastal SDI and marine SDI sub-classes (Specialisation). Each sub-class has same properties as well as special properties. Generalisation extracts similar properties and characteristics of these three sub-classes into a Seamless SDI super-class. Figure 5.1 illustrates inheritance along a generalisation hierarchy with the more general class at the top (Seamless SDI class) and more specialised classes (land, coastal and marine SDIs) at the bottom.

Properties which are common for Seamless SDI super-class and these sub-classes would be defined only once (with the Seamless SDI super-class) and inherited by all the sub-classes, but marine, coastal and land SDI sub-classes can have additional, specific properties and operations which are not shared by the Seamless SDI but they have strictly all operations and properties of Seamless SDI super-class. Therefore, while land coastal and marine SDI classes would inherit Seamless SDI properties, they continue to have their specific characteristics and components at the same time. Inheritance is the transitive transmission of the properties from one Seamless SDI class to all related subclasses, and to their subclasses, etc.

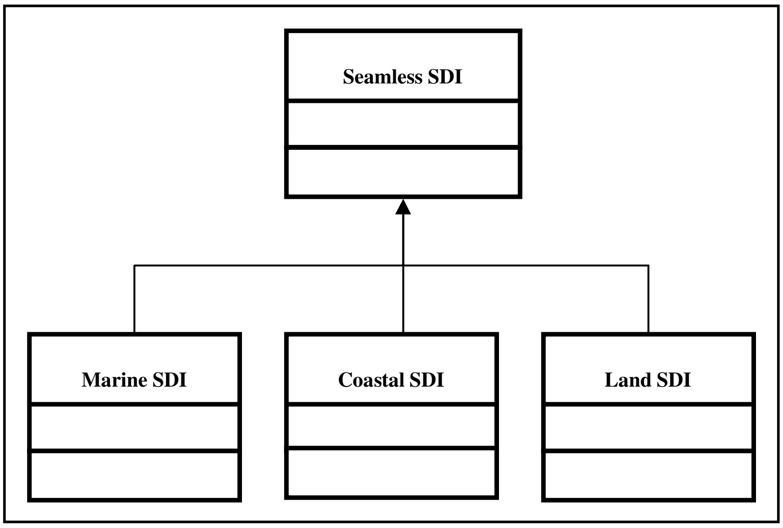

Figure 5.1 Seamless SDI model - inheritance along a generalisation hierarchy with the more general class at the top and more specialised classes at the bottom

According to Timpf (1998), the most common function to build a hierarchy is the aggregation function. Classes of individuals are aggregated because they share a common property or attribute. This is the other reason that a hierarchical concept can be applied to SDIs since, different SDI initiatives at a certain political/administrative level or in different environments can aggregate together to form the next higher level of hierarchy. This is the most common type of construction of hierarchy as introduced by Timpf (1998). Land, coastal, marine SDI will be combined to form a semantically higher level Seamless SDI (Aggregation). Each component refers to the parts of this composite class while it keeps its own functionality. The relationship among the components and the Seamless SDI is the part-of relationship, i.e. Seamless SDI consists of land, coastal and marine SDIs.

Just like abstraction is closely related to generalisation, the inheritance is closely related to specialisation. The specialisation and generalisation relationships are both reciprocal and hierarchical. Seamless SDI generalises what is common between land and marine SDI, and they specialise Seamless SDI to their own specific subtypes. Figure 5.2 illustrates a conceptual view of seamless platform architecture. As demonstrated Seamless SDI platform employs the components of SDI in general but the attributes of these components are different from existing platform. Land and marine SDI have additional, specific properties and characteristics which are not shared by the Seamless SDI but they all have components and properties of Seamless SDI super-class.

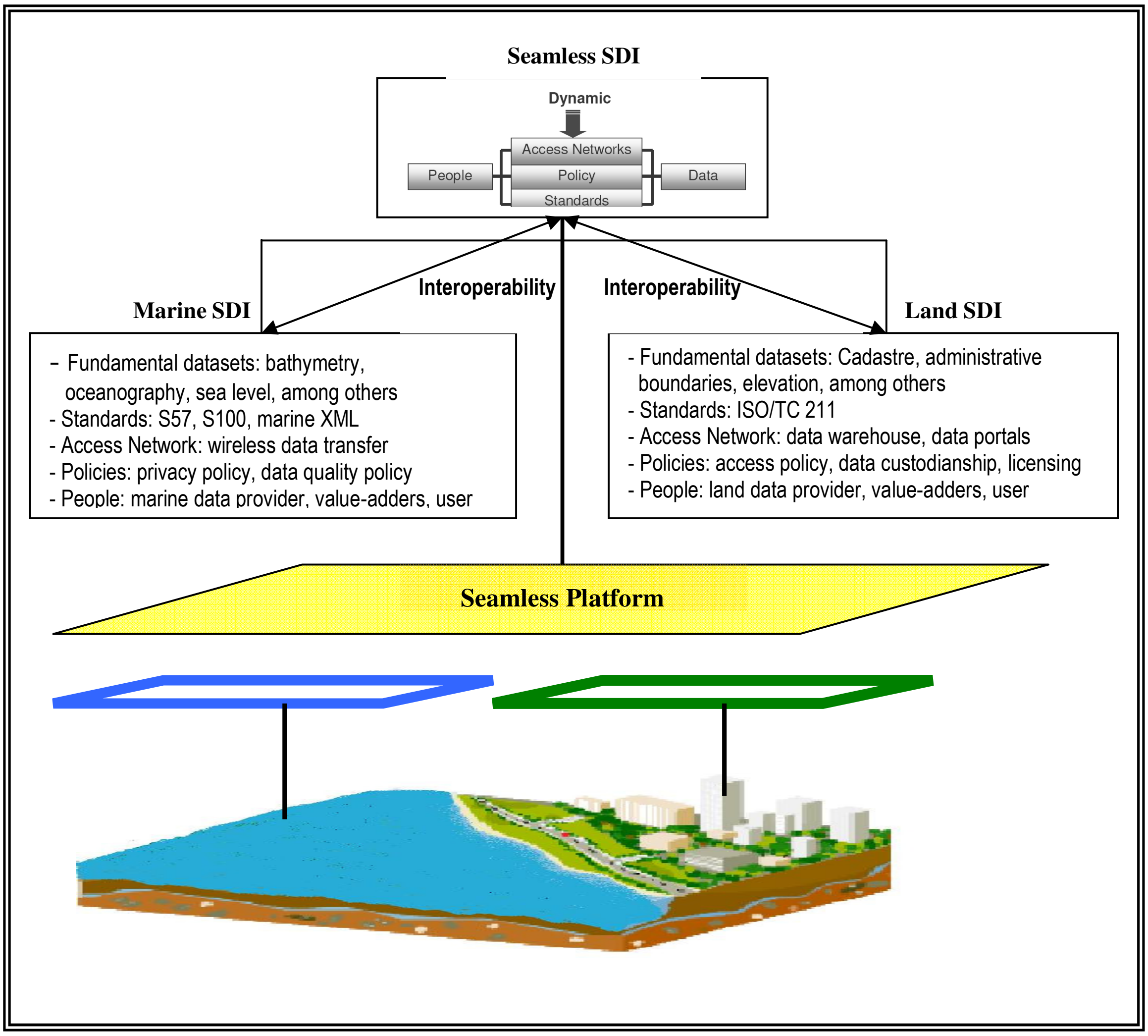

Figure 5.2 Conceptual model of Seamless SDI platform

5.3 Seamless SDI Design

The next step of conceptualisation phase of Seamless SDI would be a design phase which comes before the implementation phase. The design phase deals with learning objectives, assessment instruments, exercises, content, subject matter analysis and lesson planning. This section discusses the design of Seamless SDI model. The design stage has utilised Unified Modelling Language (UML) in order to model the architecture, components and activities within the system. UML provides a unified model that acts independently from the development environment and allows developers to easily interpret the components and interactions between them (Bell 2003). UML is probably the most widely known and used notation for object-oriented analysis and design. It is the result of the merger of several early contributions to object oriented methods. In this section we use it to illustrate how to go about object oriented analysis and design. It can be used to describe Seamless SDI systematically and its context, users, providers, services and so on, necessary to establish them.

5.3.1 UML

The Unified Modelling Language™ (UML) is an object oriented tool used widely for describing software systems, providing a graphical notation of the architecture of the system (Cooper et al. 2003). Since the late 1990, with the emergence of object oriented analysis and design, the UML approach has gained in popularity. It is now becoming widely used and accepted. Its use is not limited to software systems, and it is be useful to use UML to model (or describe) Seamless SDIs systematically. For example, UML is being used within the International Organisation for Standardisation's Technical Committee developing the international standards for geographical information and geomatics, namely ISO/TC 211, where it is used to encapsulate the essence of the standards, allowing their models to be harmonised. Since UML provides a standard notation for modelling and design, it ensures the ease of communication between designers and developers (Eriksson and Penker 2000). Therefore, by using UML Seamless SDI efficiently being maintained and developed.

The Reference Model of Open Distributed Processing (RM-ODP) (ISO/IEC 10746 1995) has been used. The choice of using RM-ODP concepts to model SDIs was motivated by RM-ODP being an international standard already, and that it is a good base to facilitate understanding of SDIs. It defines a framework comprising five viewpoints: Enterprise, Information, Computation, Engineering and Technology. RM-ODP allows describing complex distributed systems giving a framework of different levels of abstraction (Delgado 2004). The Enterprise Viewpoint, (the first) describes the purpose, scope and policies for a Spatial Data Infrastructure (SDI). The Information Viewpoint, the second view, describes the semantics of information and information processing incorporated into a SDI. The Computational Viewpoint, the third view, is a functional decomposition of the SDI into objects and services that interact at interfaces. The Engineering Viewpoint, the fourth, contains the mechanisms and functions required to support distributed interaction between the objects within a SDI. The Technology Viewpoint, the fifth and last viewpoint, contains the specific technology (ies) chosen for the implementation of a SDI. However, it is only the first viewpoint that we will take into consideration in this thesis.

This section presents a detailed introduction to UML methodology for a system design. It is important to emphasise that UML is a standard notation that defines a number of diagrams to describe a system using object oriented concepts, and what these diagrams mean. Such a process description includes a list of tasks that need to be done, in which order they should be done, the deliverables produced, the kinds of skills required for each task and so on.

UML consists of a number of diagrams for different aspects of modelling. The most useful, standard UML diagrams are Use Case Diagram, Class Diagram, Sequence Diagram, State Chart Diagram, Activity Diagram, Component Diagram, and Deployment Diagram (Eriksson and Penker 2000) which are useful in different model development phases. For instance, a Use Case Diagram provides a way of describing the external view of the system and its interactions with the outside world. The Class Diagram describes the types of objects in the system and various kinds of static relationships that exist between them. A Sequence Diagram is used to represent a scenario and shows the temporal ordering of events. In this research, the Use Case Diagram and Class Diagram are used for Seamless SDI design. These models could be seen as a contribution towards the overall model of the Seamless SDI and its technical characteristics.

a) Use Case Diagram

The Use Case Diagram models user requirements with use cases. It is a view of a system that emphasizes the behaviour as it appears to outside users. A use case model partitions system functionality into transactions (use cases) that are meaningful to users (actors). It shows use cases, actors and their relationships

i Use case

A sequence of actions, including variants, that a system (or other entity) can perform, interacting with actors of the system. It is drawn as horizontal ellipses.

ii Actors

Actors, drawn as stick figures, are persons, organizations, or external systems that play roles in interactions with your system.

iii System boundary

It is the boundary between the physical system and the actors who interact with the physical system.

iv Associations

Solid lines are used in use case diagrams to indicate the associations between actors and use cases. An association exists whenever an actor is involved in an interaction described by a use case.

v Generalisation

A taxonomic relationship between a more general use case and a more specific use case.

vi Extend

A relationship from an extension use case to a base use case, specifying how the behaviour for the extension use case can be inserted into the behaviour defined for the base use case.

viii Include

A relationship from a base use case to an inclusion use case, specifying how the behaviour for the inclusion use case is inserted into the behaviour defined for the base use case.

b) Class diagram

The Class Diagram is a central modelling technique that runs through nearly all object oriented methods. This diagram describes the types of objects in the system and various kinds of static relationships that exist between them. Identifying a set of objects or conceptual classes is at the heart of data modelling. The identification of conceptual classes is part of an investigation of the problem domain. The following definitions of elements described in the diagram are summaries derived from (Schmuller 2001), (Gimenes and Barroca 2002), (Fowler 2003) and (Larman 1997).

i Class

A class is expressed by a rectangle with three parts inside (Figure 5.3). The first part is the class name. For example, River is a class name. The second part contains all the attributes of the class. For example, name is an attribute. The third part contains all the operations within this class.

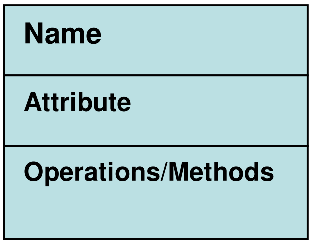

Figure 5.3 A class in UML in three parts

ii Object

An object is an instance of a class, with specific values of the attribute and methods.
The notation of object is a colon plus underlined class name, for example: River is one of instances of the River class

iii Method

A method is a function or transformation type that is applicable to objects of the class. Only operations specified by the class can be applied to objects in that class. An operation may also involve objects of other classes, as specified by parameters of the operation signature.

iii Multiplicity

Multiplicity defines how many instances of a class can be associated with one instance of another class. The multiplicity value communicates how many instances can be validly associated with another, at a particular moment.

iv Associations

An association is used to describe a relationship between two or more classes. It mirrors the different types of relationships: association, aggregation and composition.

Association – a relationship between two or more classifiers that involves connections among their instances (Figure 5.4).

Aggregation – relationship between two classes where one class plays the role of a container and the other plays the role of the contained entity (Figure 5.5).

Composition – a strong aggregation, used when the objects representing the parts of a container object cannot exist without the contained object.

At each end of the association, the role, that is the context an object takes within the association, may also be indicated. If an association is navigable in a particular direction, the model shall supply a "role name" that is appropriate for the role of the target object in relation to the source object. In a two-way association, two role names will be supplied.

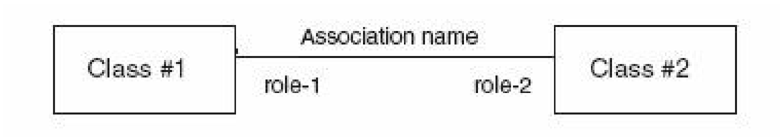

Figure 5.4 Association between classes

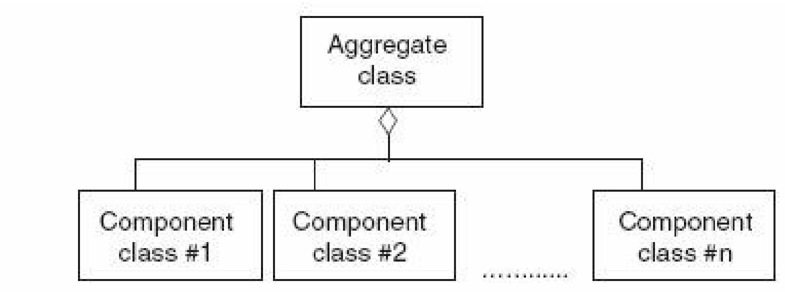

Figure 5.5 Aggregation between classes

v Generalisation

A generalisation is a relationship between a super-class and the sub-classes that may replace the super-class. The super class is the generalised class, while the sub-classes are specified classes.

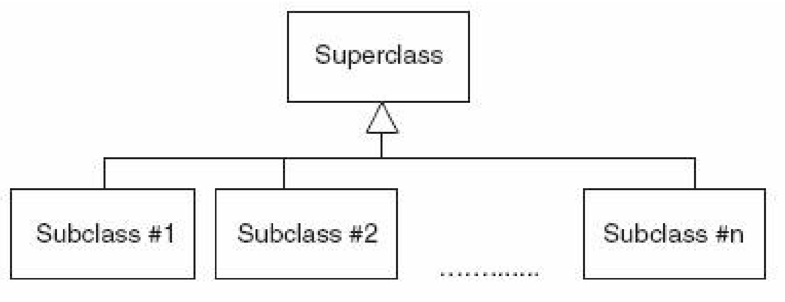

Figure 5.6 Class inheritance

vi Constraints

A constraint is a condition imposed on the elements of the model. Constraint is not behaviour, but some other kind of restriction on the design or project. It is also a requirement, but is commonly called “constraint” to emphasise its restrictive influence. UML uses the brace { } notation to show constraints on the structural model.

5.3.2 Seamless SDI Use Case Diagram

In many design processes, the Use Case Diagram is the first that designers will work with when starting a project. This diagram allows for the specification of high-level user goals that the system must carry out. These goals are not necessarily tasks or actions, but can be a more general required functionality of the system (Artiso 2008). More formally, a use case is made up of a set of scenarios. Each scenario is a sequence of steps that encompasses an interaction between a user and a system. The use case brings scenarios together that accomplish a specific goal of the user. A use case can be specified by textually describing the steps required and any alternative actions at each step. The Use

Case Diagram allows the designer to graphically show these use cases and the actors that use them.

The first step a conceptual diagram of a Seamless SDI delineating the border between a SDI and its neighbourhood with the central circle represents the Seamless SDI along with its surrounding actors who interact with Seamless SDI (Figure 5.7). The arrows indicate the interactions initiated by actors or by Seamless SDI. Base on this conceptual diagram a Use Case Diagram can be developed.

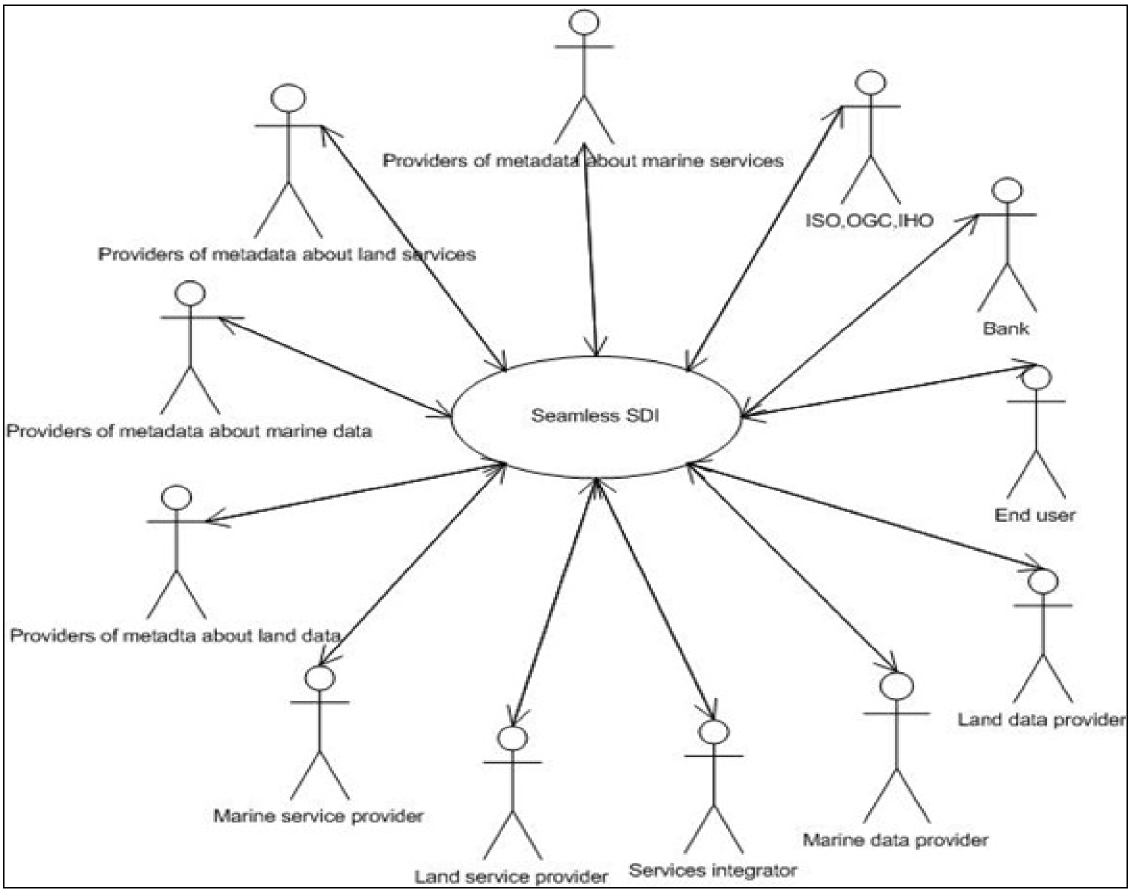

Figure 5.7 Conceptual diagram of Seamless SDI delineating the border between a SDI and its surrounding actors

Based on this conceptual diagram, a Use Case Diagram of Enterprise Viewpoint for Seamless SDI can be developed. It shows the stakeholders and their role within Seamless SDI. Stakeholder is an individual or group with an interest in the success of a SDI in delivering its intended results and maintaining the viability of its products. Stakeholders either affect the SDI or are affected by it (Hjelmager et al. 2008). As can be seen in the

Use Case Diagram (Figure 5.8), each stakeholder within a Seamless SDI can be part of different use cases. For example, here the same stakeholder could determine the scope of an Seamless SDI, use services from Seamless SDI (such as searching for, obtaining, and using data), and build the infrastructure used by the Seamless SDI (whether it be the networks, computers, software or whatever else). Each one of these interactions then comprises a separate use case.

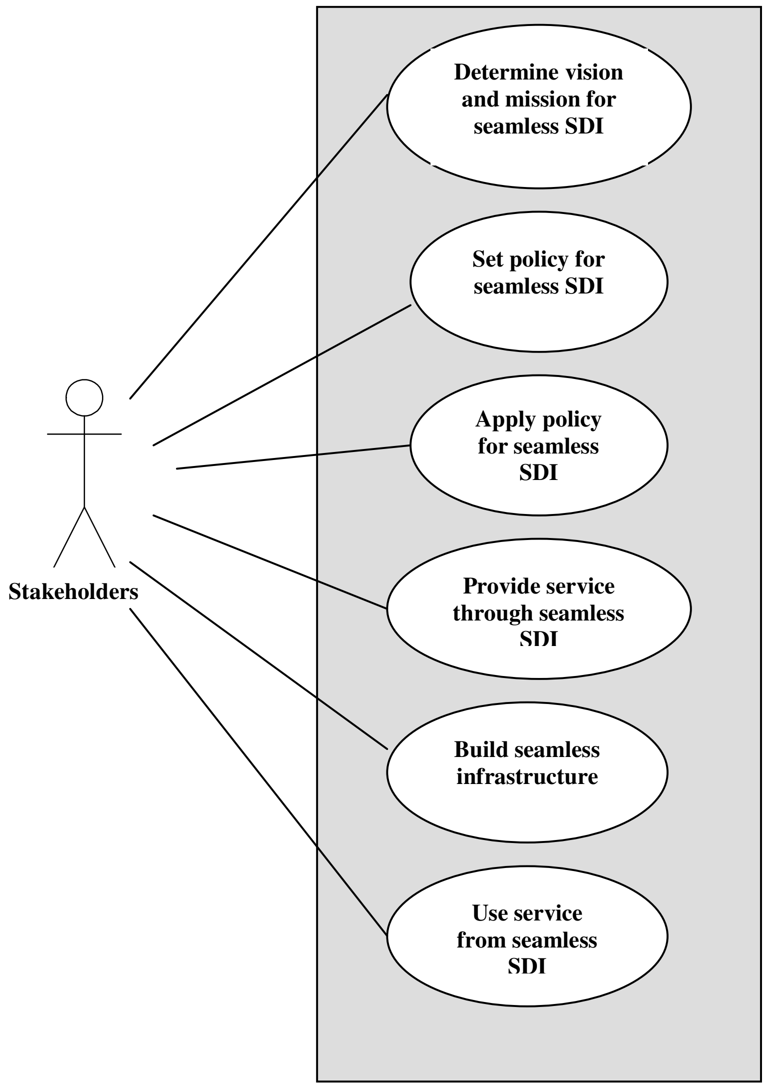

Figure 5.8 Use Case Diagram for Enterprise Viewpoint of Seamless SDI

Interactions with the scope and policies of a SDI can be separated into the various stakeholders that either define the scope or implement the scope. The same applies for the policy, thereby resulting in those that define and/or implement policy. The reason for this division of labour is that the groups responsible for developing and for maintaining the two parts of the use case have different interests and points of view from one other, even though on a high level their general interest should be mutual. The stakeholder actor in Figure 5.8 can be sub-divided into six individual actors which are provider, producer, policy maker, user, value added reseller and broker, all having a role to play in the use cases.

Use Case Diagram also helps the identification of required objects and relationships between them in a Class Diagram. The Class Diagram describes the types of objects in the system and the static relationships between the objects. The next section discusses the objects and relationships of Seamless SDI.

5.3.3 Seamless SDI Object Diagram

A Class Diagram is a type of static structure diagram that describes the structure of a system by showing the system's classes, their attributes, and the relationships between the classes. A Class Diagram partitions the system into areas of responsibility (classes), and shows "associations" (dependencies) between them. The purpose of a Class Diagram is to depict the classes within a model. In an object oriented application, classes have attributes (member variables), operations (member functions) and relationships with other classes (Martin 2008). The links between them define what interactions are possible between different classes of objects (CSCI 2007). The fundamental element of the Class Diagram is an icon that represents a class. In order to see how the different parts of the use cases fit together, an initial view Object Diagram for Seamless SDI have been developed, as shown in Figure 5.9. This diagram depicts different system's classes along with the relationships between these classes with SDI model. For an instance, it illustrates IHO, ISO, ICA, OGC are all systems' classes which develop SDI standards classes. However this is not a fully developed diagram. In the case of fully developed diagrams, there are problems of dealing with a large number of classes with a large number of associations.

The core components of Seamless SDI can be viewed as policies, services, standards, metadata and data. These components can contain people as well as systems. Different categories can be formed based on the nature of their interactions within the Seamless SDI framework. For example, consider policies, standards and services, by their nature, they are very dynamic due to the rapidity with which technology develops and the needs change for mediation of rights, restrictions and responsibilities between people and data. This suggests an integrated SDI cannot be composed of spatial data, value-added services and end-users alone, but instead involves other important issues regarding interoperability, policies and networks. This in turn reflects the dynamics of the whole SDI concept. Anyone wishing to access datasets must go through the technological components. These components need to set up appropriately to ensure interoperability.

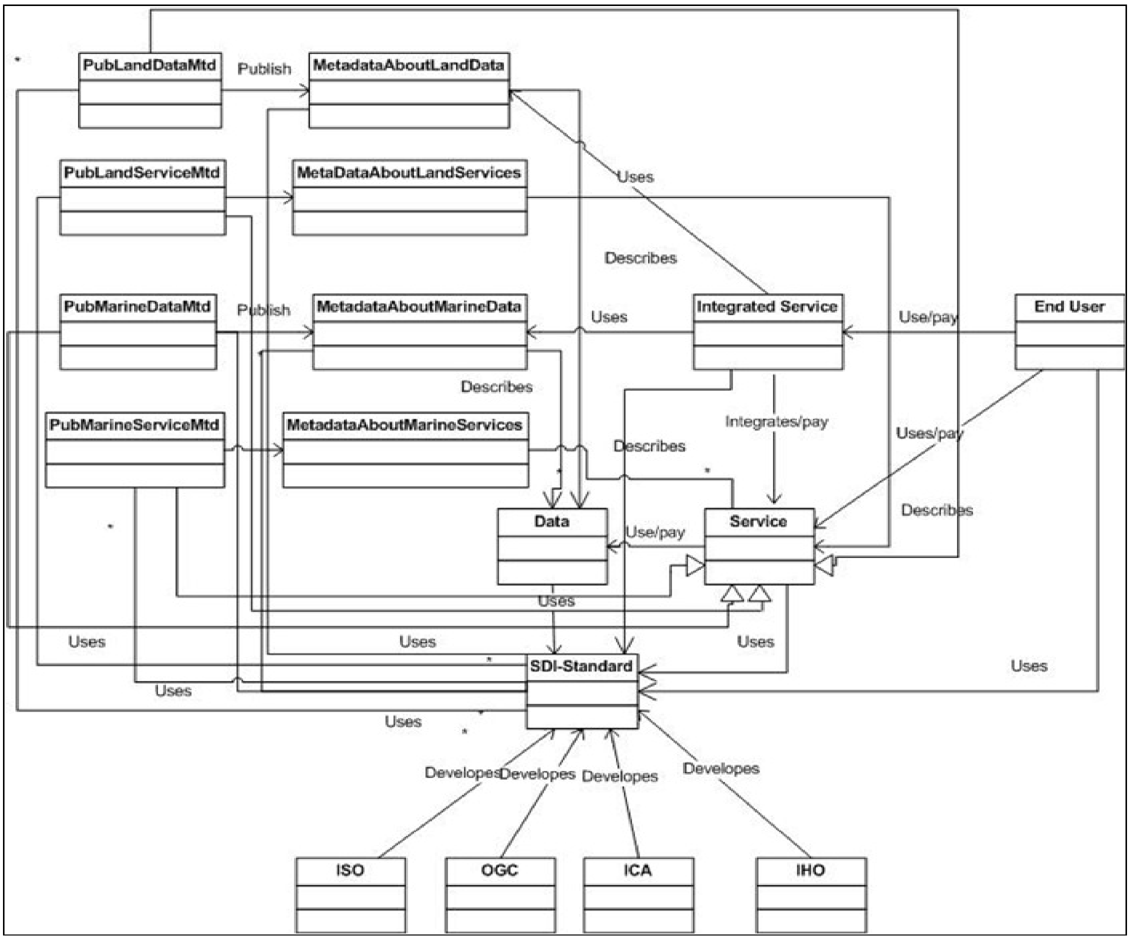

Figure 5.9 Object Diagram of Seamless SDI

Given the complexity of Seamless SDI with inter-related and interconnected technical and institutional elements and the multiplicity of stakeholders involved, it is clear that governance is an important aspect of the institutional framework necessary to support decision making about all aspects of this Seamless SDI. It is necessary to go beyond establishing the model for SDI coordination and give top priority to the creation of appropriate SDI governance structures that are both understood and accepted. The next section looks into SDI governance framework.

5.4 Seamless SDI Governance Model

Over recent years, governance has gained an important role in SDI literature with calls to develop appropriate governance arrangements to address contemporary SDI implementation challenges (Kok and van Loenen 2005; Masser 2005; Masser et al. 2007; Box and Rajabifard 2009). Similarly in practice, the need for improved governance has been recognised (FGDC 2005; Kelly 2007; Finney 2007).

In its most basic definition, governance is the act, process, or power of governing (American Heritage Dictionary, n.d.). The word "governance", when used in relation to fostering and maintaining SDIs, is usually applied to describe nationally specific political and institutional structures that have been established to govern or fund SDI initiatives, for example in the case of the US SDI (FGDC 2005). Governance deals with collective decision-making and is clearly a function or aspect of organisational arrangements. However, given the typically large number and diversity of SDI stakeholders linked through multiple overlapping and interacting networks and the need to facilitate the rapidly evolving and increasingly collaborative approaches to SDI implementation, governance represents a significant challenge (Box and Rajabifard 2009). In addition, the adoption of Service Oriented Architecture (SOA) approaches to building the SDI which necessitates collaboration between the owners, developers, operators, and users of the service across departmental and organisational boundaries brings a whole new set of governance challenges.

While there is recent acknowledgement that governance plays an important role in developing and sustaining SDIs (ANZLIC 2003a; Masser 2006), little detail has been presented in the literature on how formal governance models are being applied in this field. This is a significant gap if governance does have an appreciable effect on how SDIs are developed. It is suggested that appropriate governance models could assist SDI development in a number of ways by:

- Stimulating more rapid evolution of SDIs;
- Addressing current deficiencies in the application of standards; and
- Helping to achieve an increase in public penetration of SDI related technology and services through more tightly integrating a user-perspective in both SDI design and operational management.

As noted by Masser (1999) some current SDI initiatives have evolved out of pre-existing coordination arrangements and in many cases are embedded within them. Early initiatives to coordinate geospatial information activities focused on the needs of central government mapping agencies. With the shift from product to process based SDI models (Williamson et al. 2003a) came a shift in emphasis from concerns of the geospatial information producers to those of the users (Masser 2006) and a move from centralised organisational structures to decentralised and distributed networks (Masser 2005). SDI operations have also been increasingly decentralised to local levels (Masser et al. 2007). With decentralisation, the increased role of the private sector and the need to involve a large group of diverse stakeholders in decision-making, legacy organisational arrangements reflecting the focus of early initiatives, are not necessarily the most appropriate mechanisms to enable SDI (Masser et al. 2007). These realities have led to attempts to develop improved governance models aimed at more inclusive, whole-of-industry approaches to SDI (Masser 2005). This is evidenced by ongoing efforts to find improved governance models, for example, the US (FGDC 2005) and Australia (ANZLIC 2003a).

Many countries are recognising more inclusive models of SDI governance to meet the requirements of a multi-level multi-stakeholder SDI. Therefore, it seems necessary to go beyond establishing the machinery for SDI coordination and prioritise the creation of appropriate SDI governance structures. Obviously, it will often not be possible to bring all stakeholders together for decision-making purposes, and structures must be devised for keeping all informed and providing an opportunity to have their opinions heard. The simplest solution is to create hierarchical structures at national, state and local levels.

Masser et al. (2007) note that hierarchical governance structures are required to enable the participation of national and local governments and the private sector addressing decision-making in the context of multi-level SDI implementation. Hierarchical structures are typically perceived as operating “top-down” (Groot and Georgiadou 2001), with authority flowing from higher to lower levels and they refer the main to government initiated activities. However, SDIs are typically built at local levels from the “bottom-up” (Box and Rajabifard 2009). They contrast with “bottom-up” approaches, which occur predominantly at the local level and which guide the development of application-specific and enterprise-wide activity. At this level, the hard fabric of the infrastructure is being built by a networked community through the incremental development of services, by the deployment of applications, and through the adoption and development of standards.

In the case of Australia, experience gained in developing a Marine SDI has led to a proposal for a bottom-up governance framework. The framework is premised on the development of a SDI using an SOA approach, and is based around open source community governance models. The main components in the bottom-up governance framework are: a community-based standards management system that would link to national and international standards efforts; a system for managing the operation of the infrastructure; and methodologies, instruments and processes that would create a motivated, open, collaborative development environment (Finney 2007).

At a conceptual level, the governance model comprises three interrelated dimensions; ‘who’ – who is involved in the decision-making processes, ‘how’ – how is governance implemented (processes and mechanisms) and ‘what’ – what is the scope of decision-making and is based on the identification of the key role of agreements and registers in SDI governance (Atkinson and Box 2007). The high level conceptual model of governance comprises SDI components identified by Rajabifard and Williamson (2001) conceptually recast to emphasise the role of governance in binding the components together. As shown in Figure 5.10, the model comprises three core SDI components: people situated within organisations (who), agreements and geospatial resources (what), linked together through governance mechanisms (how).

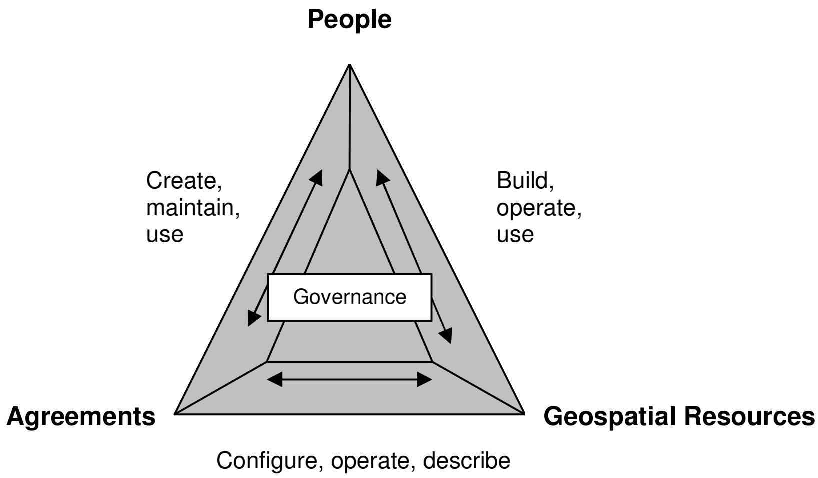

Figure 5.10 High-level conceptual model of governance (Box and Rajabifard 2009)

As described by Box and Rajabifard (2009), the need for clearly defined leadership, a sustained formal mandate including a policy framework, and the neutrality and community-oriented action of organisations playing key governance roles are all critical requirements for SDI governance.

Therefore, it is recommended that a high-level policy framework to provide sustained formal mandate and mechanism for collaboration between individual agencies in land and marine environments should be established. Aligned with that, there is a need for a lead agency to be identified and provided with a clear mandate to lead, a role that must be exercised with neutrality as well as an independent chair for the lead agency.

5.5 Seamless SDI Guidelines

Having discussed the conceptual and design phases, the next step would be the implementation phase of the Seamless SDI model. In Section 5.2 a conceptual model of the Seamless SDI has been developed by using Hierarchical Spatial Reasoning (HSR). The design stage has utilised UML in order to develop Use Case Diagram and Class Diagram for Enterprise Viewpoint of for Seamless SDI. These diagrams have been used to describe Seamless SDI systematically and its context, users, providers, services and so on, necessary to establish it.

The implementation phase takes the requirements and design phase products and implements them using appropriate tools. The model proposed in the design phase is developed during the implementation phase. In this regard, guidelines facilitate the development process.

The development of guidelines is highly dependent on the needs and objectives of the respective jurisdictions and the context of the respective SDIs. Each SDI has its own considerations and guidelines. They include the roadmaps, standards, policies and agreements that are developed within SDI to facilitate the coordination of spatial datasets. In the case of Seamless SDI, the guidelines are specifically focused on facilitating the integration of land and marine spatial datasets. The guidelines can be utilised by practitioners to learn the issues and problems expected and possible solutions.

Therefore, the Seamless SDI guidelines is a document that details the preliminary Seamless SDI framework for any jurisdiction with a marine environment which might support and participate in the Seamless SDI incorporating necessary step-by-step approaches to create a Seamless SDI. It provides necessary information for practitioners in order to deal with the complexity of creating a Seamless SDI. It also discusses potential barriers and proposes available technical solutions and non-technical enablers. It is not definitive in its nature, preferring instead to provide guidance on how best to achieve this through practical advice, simple step-by-step processes. Figure 5.11 below illustrates the incorporated components into the Seamless SDI guidelines.

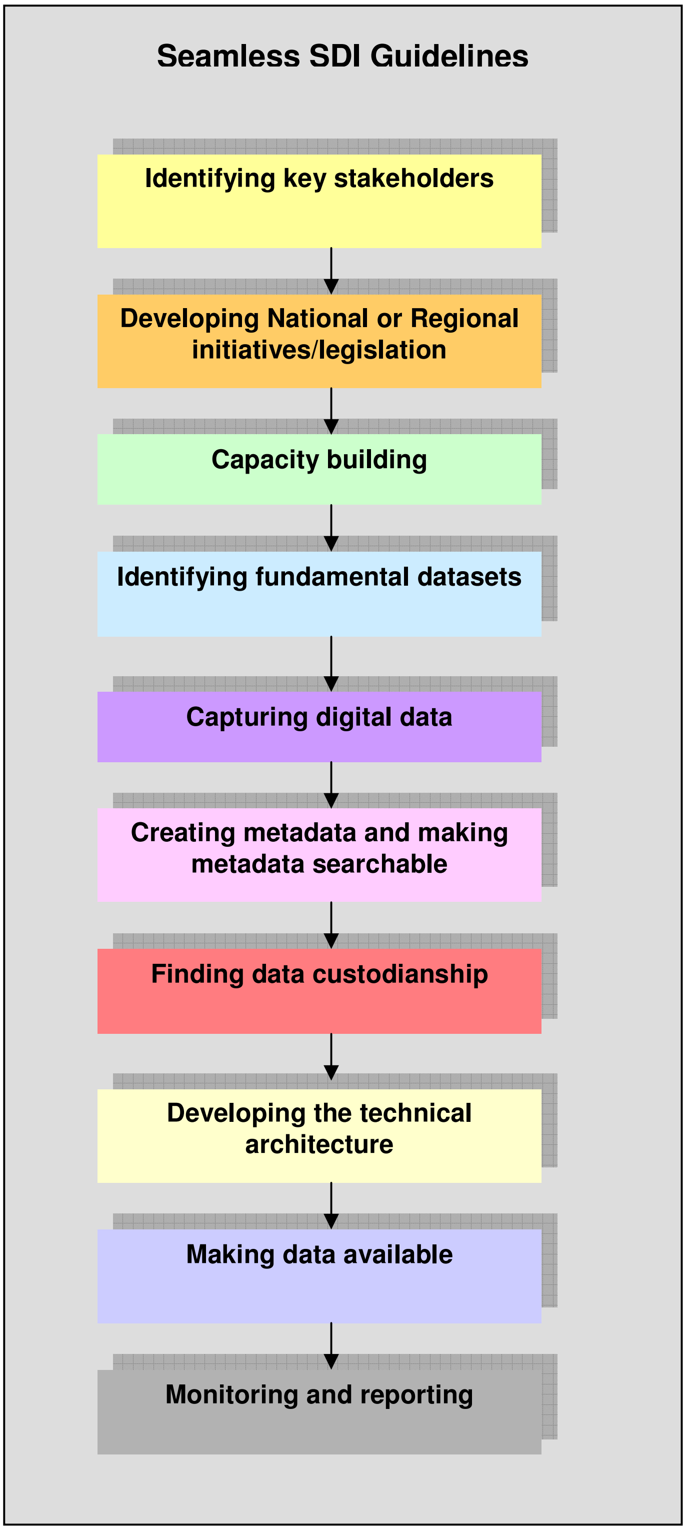

Figure 5.11 Seamless SDI guidelines components

Based on Figure 5.11, the following subsections investigate each of these components. Consequently, a general guidelines document is presented here which attempts to cover these components. The document presented here seeks to support Seamless SDI guidelines. However, SDI coordinators may develop and expand the components and items of beyond these guidelines.

5.5.1 Identifying key stakeholders

Key stakeholders of Seamless SDI include those who use, provide, value-add, manage or own the data in land, coastal and marine environments. Users can be corporate, small and large business or individuals, public and private sectors. It must be recognised that building an information infrastructure like Seamless SDI is a significantly resource-intensive business and requires the participation of several generic actors working in together: designers (both of components and standards); product manufacturers (implementing products that follow infrastructure standards); service providers; regulators; and users (an important and often under-valued part of the installed base that can influence the design by sheer force of numbers through their infrastructure component usage choices). All of these actors play a role, but no single type of actor can control the direction of the infrastructure, only shape parts of it (Hanseth and Lyytinen 2006). There needs to be a willingness and practical co-operation between the various organisations that create, share and use information to implement the overall infrastructure.

There is a need to improve and encourage communication between agencies at government level, who are often the main collectors of spatial data, and all other stakeholders, both governmental, commercial and citizens (Longhorn 2004). Partnerships are critical components of SDI development, which can be inter- or cross-jurisdictional (Williamson et al. 2003a). Building an effective Seamless SDI will require a well-coordinated partnership among land, coastal and marine governmental organisations at different federal, state, local levels, and academic institutions, as well as a broad array of private sector geographic, statistical, demographic, and other business information providers and users.

Developing an agreed interoperable seamless framework requires organisational collaboration and a clear use case and applications addressing interoperability cross borders and cross sectors (land – marine interface) scenarios. An overarching framework is supporting data policies, data access, data specifications (datum, feature catalogue) and standards implementation.

National mapping agencies and hydrographic offices use different coordinate systems, projections, horizontal and vertical datums and contents. Therefore users cannot reference any object consistently across the coastal zone. The common seamless framework will support interoperable coordinate systems and datums, interoperable objects along agreed boundaries and interoperable feature catalogues. This agreed interoperable framework will contribute to the Seamless SDI.

Institutional integration increases the efficiencies and effectiveness of the management in any jurisdiction with land and marine environments. If national mapping and hydrographic charting agencies are separate, they need to work under the same banner and their policies should align with each other and the national policy in order to create a Seamless SDI. Therefore, there is a need for a lead organisation or a champion to set out the access network, standards and policies and to encourage implementation of the common interoperable framework. While this does exist in Australia it is mostly focused on terrestrial spatial data and the difference between marine and terrestrial SDIs can be seen as partly a result. Promoting spatial data, sharing and using common standards and a single access network may help to counteract some of the unwillingness that exists, and encourage greater co-operation and collaboration in the marine and coastal sectors.

However, it is believed that these problems can be overcome through coordination arrangements and existence of a single management authority or forum for collaborative planning, and efficient legislation. More information about Seamless SDI is required to have a better understanding and knowledge about Seamless SDI among different institutions and oragnisations and there should be proper regulation to ensure that all spatial data providers are involved in and contribute to the development of Seamless SDI.

a) Hydrographic Offices' roles

Most Hydrographic Offices (HO) hold data to support nautical charting requirements. However, less emphasis is usually placed on providing that same data to support wider environmental and commercial coastal and off-shore activities. HO can be the competent authority concerning the provision of hydrographic and related data under any National and / or Regional SDI. Hydrography, with its subset of data themes, forms the key "base reference" or "core geography" layer for the sea space in any jurisdiction. In this capacity, HO data provides a rich and unparalleled resource for users at all levels.

Some HOs will already be involved in SDI whilst others will be considering participation and how such involvement might benefit both the HO and other marine/maritime data providers. Being involved in SDI does not mean that the data must be provided to a central information "warehouse" or database; it can be held and managed at the organisational level.

A Hydrographic Office as one of the key stakeholders is uniquely placed to play a central and leading role in the development of the marine component of Seamless SDI. Hydrographic Offices wishing to or being invited by their national governments to be involved in the development and management of National Seamless SDI should consider the following questions:

- Does the structure of the National SDI allow for a comprehensive Marine SDI (MSDI), a MSDI that excludes hydrographic information or only a specialised hydrographic SDI?
- Does the National SDI allow for a HO to become responsible for or partner in their National MSDI and its incorporation into the National SDI to create a Seamless SDI?
- Does the type of data provided by HOs support National SDI and / or MSDI?
- Does the HO collect data purely for the safety of navigation or does it meet the needs of a wider user community?
- Does the quality and usability of existing spatial databases within the framework of the National SDI include access to metadata?
- What are the requirements for quality assurance of data outside of its use in support of Safety of Life At Sea (SOLAS)?
- Does the establishment of user requirements for supply of hydrographic information impact on any necessary restrictions on data access?
- Does the financial, administrative and technical requirements and national policy on cost recovery impact on the establishment and maintenance of the infrastructure?

The Table 5.1 illustrates the benefits and opportunities which are likely to be realised when HOs engage with stakeholders involved in developing a Seamless SDI.

Table 5.1 Opportunities and benefits for HOs involved in developing a Seamless

Opportunities	Benefits	Best Practice Guidance
Embrace wider use of hydrographic data and information /development of new products and services	Stimulate additional resources and funding	Engage - respond-communicate
Improved decision making (e.g. spatial planning, integrated coastal zone management, flooding and climate change)	Increased security in data use and reduction of risk	End user engagement
Improved data management practises especially in the critical areas of land and marine convergence (coastal zone)	Cost savings through efficiencies (capture/correct once . use many times)	Adopt common standards/best practice
Realise inherent value/benefit in data	Increased market exposure through hydrographic information provided for non-navigational use/ additional revenue generation opportunities	Identify and respond to user requirements
Increased efficiencies in organisational processes (e.g. data collection and management) by reducing duplication and encouraging co-ordination	More effective use of public funds	Community based approach
HO will be in the mainstream of geospatial decision making	Greater co-operation with other information providers/ reduce isolation	Get involved

However there are some challenges a HO may face when participating in a Seamless SDI. Based on questionnaire circulated to member states by the International Hydrographic Bureau (IHB) in late April 2008 and detailed analysis of responses, the following barriers and challenges has been identified (IHO 2009):

- Being able to work with other organisations and adopting a partnership approach with non-marine stakeholders;

- Changing the organisational culture by winning over the sceptics at the organisational level;

- Challenging the way things are currently done to ensure they are undertaken more efficiently in the future;

- Accepting that hydrographic data is information rather than product;

- Investing in improved business processes and information management;

- Difficulty by the non-marine community to understand Marine SDI components, challenges and relevance;

- A lack of funding to progress their involvement in SDI;

- Persuading decision makers and budget managers to support SDI activities;

- Gaining the trust of other stakeholders especially the non-marine stakeholders; and

- Ensuring the HO has the knowledge, training and skills for involvement in developing the marine component of Seamless SDI.

These barriers and challenges are listed below and recommended actions to overcome these obstacles are highlighted in Table 5.2.

Table 5.2 Barriers and overcoming recommended actions

Barriers	Recommended Actions
Government Policy	Communicate and collaborate to develop policies together
Ethos/culture	Training and communication
Funding	Cost benefit analysis through defining value and benefit of "joined up" approach
Gaining the trust in other stakeholders	Mutual respect through working together
Resources	Demonstrate efficiency savings to achieve increased resources
Business Model	Demonstrate benefits of more inclusive and seamless approach
Objectives counter to SDI	Identify opportunities and benefits of SDI
Security	Demonstrate the benefit of release at appropriate resolution; define level of real risk
Knowledge	Training and capacity building
Value and benefit of SDI	Efficiency savings and more effective way of doing things

Based on the identified barriers and challenges, it is evident there is a need for assistance in developing HO roles in Marine SDI/ National SDI. The International Hydrographic Organsiation (IHO) needs to define its role and possible help it can give to member states as they work towards a fully optimised Marine SDI.

Noting that, the development and management of SDI rests with the member states and the role of National HOs within Seamless SDI will be for that country to define. Nevertheless, IHO has a significant role in raising awareness of the benefit of supporting Marine SDIs and Seamless SDIs across its membership. The IHO has an opportunity to take on a wider remit as part of its role in representing the hydrographic community and to ensure that its members' interests are represented in the creation of the Seamless SDI.

b) National Spatial Data Agencies' role

National Spatial Data Agencies include National Mapping Agencies, Cadastral Agencies and Land Administration Agencies. They are responsible for registrations in the public domain that play a key role in the development of SDI. These registrations are vital for economic development, societal stability and legal security. National Spatial Data Agencies in any jurisdiction work with the most advanced technological business processes in the public domain to create effective and efficient government and optimised service provision to their national society. They play a key role in the execution of e-government policy plans and provide interactive tools to citizens.

Cadastral and Land Administration Agencies are the lobbying institution for composing national standards, data sharing principles and portals, as well as legal and institutional arrangements in terrestrial domain. Opportunities for them in national and international perspectives are rapidly growing. They are more and more responsible for the creation, coordination and implementation of their SDI on national and international levels. Currently, there are many opportunities for them in developing a Seamless SDI.

Cadastral and Land Administration Agencies should initiate platforms in the public domain with other key SDI stakeholders and participants within land, marine and coastal environments to lobby for the implementation of a Seamless SDI. They can make institutional arrangements for Seamless SDI regulations and play a leading role in decision making at the central governmental level. This includes the regulation of leadership, the way in which coordination and cooperation will be realised and a committed communication strategy with all the key stakeholders. That means that they are the leading agency in the national geospatial information policy development, commitment building and decision making process

One of the key elements for the strategic role of Cadastral and Land Administration Agencies in Seamless SDI development / implementation is the fact that they provide well maintained and up to date data and services which are of eminent importance to the development of Seamless SDI. They stimulate the exchange of fundamental datasets with other organisations in the public domain, data sharing and data integration. These activities should be aligned with the Seamless SDI institutional arrangements and national policy framework. This will lead to creation of Seamless SDI and spatial enabled governments by arranging partnerships within and between the key spatial stakeholders in any jurisdiction. Furthermore encouraging the private sector in SDI development, innovation and competitive value addition, and providing clear terms and conditions for licence, development of maps, adding data should be given high priority.

The Global Spatial Data Infrastructure (GSDI) which is a lobbying and a bridge building organisation among nations has an opportunity to take on a wider remit as part of its role to work closely together with Cadastral and Land Administration Agencies of states for including Seamless SDI strategy arrangements in their SDI programs and ensure that different land administration and cadastral organisations' interests are represented in the creation of a Seamless SDI.

Therefore, identification of the Seamless SDI champion to influence, lead and gain support for Seamless SDI at the highest levels of leadership is the basic requirement for any Seamless SDI development. This may need to be at ministerial and/or senior management level.

5.5.2 National or regional initiatives/legislation

In order to make an interoperable spatial information framework, there needs to be an appropriate policy or strategy in place. This is often linked to a nation's or organisation's strategy for sharing and exchanging geographic information. For example, in the European Union, the Infrastructure for Spatial Information in Europe (INSPIRE) Directive became effective in May 2009. It requires all member states to develop interoperability between datasets (e.g. land and marine interface at the coast line), harmonise data and metadata standards, develop network services and encourage the re-use / sharing of public sector information. Therefore, national or regional legislations are important drivers of the creation of a Seamless SDI. In this regard, a designated authority to develop policy / strategy along with partnerships with bodies / authorities including data owners and users required to be set up.

In any jurisdiction with the marine environment, there is a need to prepare and define national marine policy in order to develop a Seamless SDI. A successful national marine policy will not only meet the requirements of the mariner but can provide additional and often greater benefits to the state. Such benefits include:

- Safe and efficient operation of maritime traffic;

- Coastal Zone Management;
- Exploration and Exploitation of Marine Resources;
- Environmental Protection ;and
- Maritime Defence.

However based on detailed analysis of Maturity Matrix and coded responses of IHO's member states which was undertaken during July 2008 by the UKHO Market Research Team in conjunction with members of the MSDWG and the IHB, the main barriers to progress of Marine SDI have been identified as follows:

- The main barriers were described as resources, funding and other policy priorities.
- No agreed national or common spatial data policy or framework.
- Marine SDI is subordinate to National SDI strategies and policies. Visibility of marine matters is low.
- No responsibility for / or responsible Marine SDI expert, so focal point needs to be designated.
- Barriers between agencies: historical, political, bureaucratic, and national versus local conflicts.
- Different departments involved have different priorities. Co-operation and coordination between stakeholders to be developed.
- Data held by different organisations and at different levels.
- The need for harmonisation and interoperability; decisions need to be made on vertical datum and format issues.
- Copyright, IPR, Digital Rights Management (DRM), licensing and cost of data, "free" data, etc.
- Basic geographic data with no legal obligations versus navigational geographic data with legal implications.
- Policy issues regarding distributing digital data via the internet.

One of the major concerns that should be defined in National Seamless SDI policy is regarding access to detailed information about the marine and coastal environments due to concerns over national security. Therefore while the current fundamental datasets that relate to the land environment are often provided to anyone who wishes to use them, and at minimal cost, this may be more difficult to achieve with marine and coastal data. There is a need to develop an acceptable level at which data can be made available either in-country or internationally. This may involve data thinning or gridding to a level where data may be declassified. Establishing a licensing regime supported and underpinned where applicable by government policy can be another solution.

5.5.3 Capacity building

Capacity building is an important challenge for SDI implementation across both the land and marine environments and is especially important if the vision to spatially enable government is to become a reality. SDI is still a fuzzy concept to many, with practitioners, researchers and governments adopting different perspectives depending on their needs and circumstances. Capacity building is a complex issue with the term capacity having many different meanings and interpretations depending on who uses it and in what context it is used.

Capacity is the power of something – a system, an organisation or a person to perform and produce properly. The conventional concept of capacity building has changed over recent years towards a broader and more holistic view, covering both institutional and country specific initiatives. As summarised by Williamson et al. (2003b), capacity is seen as two-dimensional: capacity assessment and capacity development.

SDIs are likely to be successful when they maximise the use made of local, national and global geospatial information assets in situations where the capacity exists to exploit their potential. The creation and maintenance of SDIs are also a process of organisational change management. Capacity building is important in less developed countries where the implementation of SDI initiatives is often dependent upon a limited number of staff with the necessary geospatial information management skills.

There are different capacity factors that are important for the success of SDI implementation. These capacity factors are technological capacity, human capacity, and financial capacity. Some examples of capacity factors are: the level of awareness of values of SDIs; the state of infrastructure and communications; technology pressures; the economic and financial stability of each member nation (including the ability to cover participation expenses); the necessity for long-term investment plans; regional market pressures (the state of regional markets and proximity to other markets); the availability of resources (lack of funding can be a stimulus for building partnerships, however, there should be a stable source of funding); and the continued building of business processes (Williamson et al. 2006).

Capacity and capability across the marine community need to be improved through increased resources, funding and policy development. In this regard, IHO can have an important role in developing SDI capacity building plan (e.g. in-country practical training and advice) to provide the necessary skills, knowledge and understanding of key components of Seamless SDI. It examines the requirements of its members and provides capacity building support to requests from member states. This can be done through the development of a web based facility to encourage knowledge transfer, best practice and on-line guidance and training material. These websites can also include reference standards and specifications, list of SDI software providers, practical training/ coaching courses, and new publications concerning SDI and identification of Seamless SDI champion.

Private sectors and academia can have the key role in carrying Seamless SDI forward by designing and delivering training courses and workshops being held in the SDI arena as well. Moreover, IHO needs to determine its role within the framework of an evolving GSDI and the possible collaboration and partnership regarding developing guides and the best practices in implementation a Seamless SDI.

5.5.4 Identifying the fundamental datasets

Having discussed the key stakeholders of Seamless SDI and their roles followed by national policy and legislation driving the development of Seamless SDI, the next step would be identifying fundamental datasets. Fundamental datasets are at the core of any SDI and should ideally include application-neutral data, thereby ensuring that it meets the needs of the widest user base. Users should have immediate and easy access to up-to-date, accurate and appropriate information that allows interoperability with data provided from land, coastal and marine sources. Data can be described in the following illustration (Figure 5.12).

- **Base Reference Information**; Geographic features that are used as a location reference for application information by a majority of users. Reference information is formed of base and associated reference information (e.g. topography and geology of the seabed).

- **Application or Subject Information**; Any business-oriented information that requires connectivity through a geographic reference of some kind (such as a chart, temperature and salinity) to enable the end-user to analyse, model and interpret the integrated information from different sources.

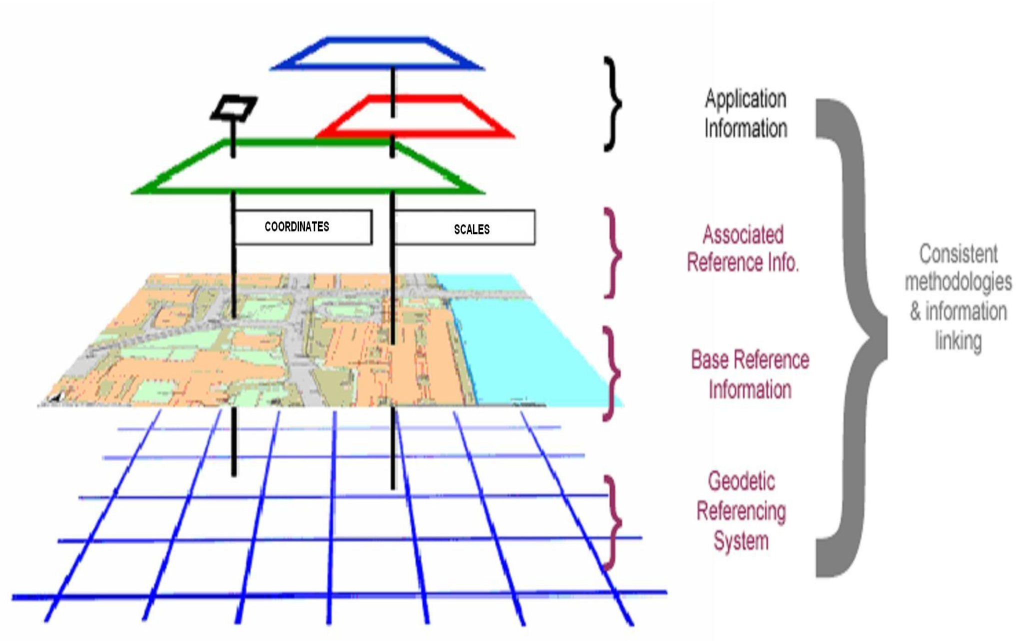

Figure 5.12 Layers of content within a National SDI (DNF 2004)

The SDI cookbook (2004) describes the importance of framework or fundamental data (base reference information). Many organisations will spend most of their budget collecting the fundamental data and have no resources left to collect the application or project data. Much of the data that is considered fundamental in the marine and coastal environment is not available and most of the stakeholders were collecting it themselves. However, they play a determinant role in the development of coastal related planning and management strategies. Although no real studies have been carried out about these issues, the "information" dimension probably represents 10 to 20% of the total cost of coastal zone management – including coastal engineering projects (MOTIIVE 2007). Further, CSIRO (1998) stated that within Australia millions of dollars per year are spent on collecting marine and coastal spatial data. At the same time it is highly likely that many other organisations either have or are collecting the same data. There is clearly an opportunity to share these resources through developing common, available fundamental datasets. Fundamental datasets exist in most SDI initiatives, but are generally related to the land environment.

The datasets that could be considered fundamental in the marine environment are significantly different from those for the land. A suggestion to accommodate marine datasets in the current list of fundamental datasets is to extend them out into the marine environment. For example in the USA, National SDI bathymetry is a sub-layer of the elevation fundamental dataset (Bartlett et al. 2004). This may be possible for some datasets; however it is likely there will be some that will be regarded as fundamental only in the marine environment (i.e. salinity, waves, water quality), and these would need to be developed separately.

There is a growing need for better and harmonised data and information for the integrated management of the coastal and marine environment. Better ecosystem and sea bed information is needed to spatially plan marine protected areas, to regulate marine resource exploitation, including extractive and shipping industries. Regarding the stakeholders involved in shipping and management of low–lying areas, forecasts of waves and surface currents are essential. Furthermore, those developing and/or protecting coastlines need tidal patterns, erosion rates and sea-level rise predictions, to name a few. Therefore, the common objective must be to better facilitate sharing of marine and coastal information.

Types of fundamental datasets within the marine environment may include:

- Bathymetry (e.g. DEM, TIN, Grid, points)
- Coastline
- Tidal data (heights and streams)
- Oceanographic data (e.g. sound velocity, salinity, temperature, currents)
- Aids to navigations (e.g. lights, landmarks, buoys)
- Maritime information and regulations (e.g. administrative limits, traffic separation schemes)

- Obstructions and wrecks
- Geographical names (e.g. sea names, undersea feature names, charted coastal names)
- Seafloor type (e.g. sand, rocks, mud)
- Constructions/infrastructure at sea (e.g. wind farms, oil platforms, submarine cables, pipelines)
- Shoreline constructions/infrastructures (e.g. tide gauges, jetties)
- Benthic habitat, flora and fauna
- Marine cadastre
- Boundary data, including physical boundaries and legal marine boundaries

Some of the above themes of data might be held by other authorities who are also providing inputs to a SDI. Ideally, the marine data providers should discuss with other data providers where potential overlaps exist in data holdings.

As the marine cadastre shows all the different boundaries in the marine environment and their associated rights, restrictions and responsibilities it will be an important data layer for many people involved in managing the marine environment. The opportunity lies in the development of a marine cadastre as one of the fundamental datasets using the common standards and policies and made available through a common access network. Using these fundamental datasets and a marine cadastre could be the stepping stones to a functional Seamless SDI. However only some of the above are supported by the basic fundamental datasets appearing in most National SDI programmes and even that level of data is not yet harmonised across national boundaries.

Hydrographic Office data which should be part of the Seamless SDI includes any navigational or other water body data and comprises at least:

- source data (e.g. dense bathymetric data) and/or
- product data (e.g. ENC data, digital nautical publications, DEM) complete with metadata (data about data).

Figure 5.13 illustrates the importance of hydrographic dataset within the Seamless SDI sphere.

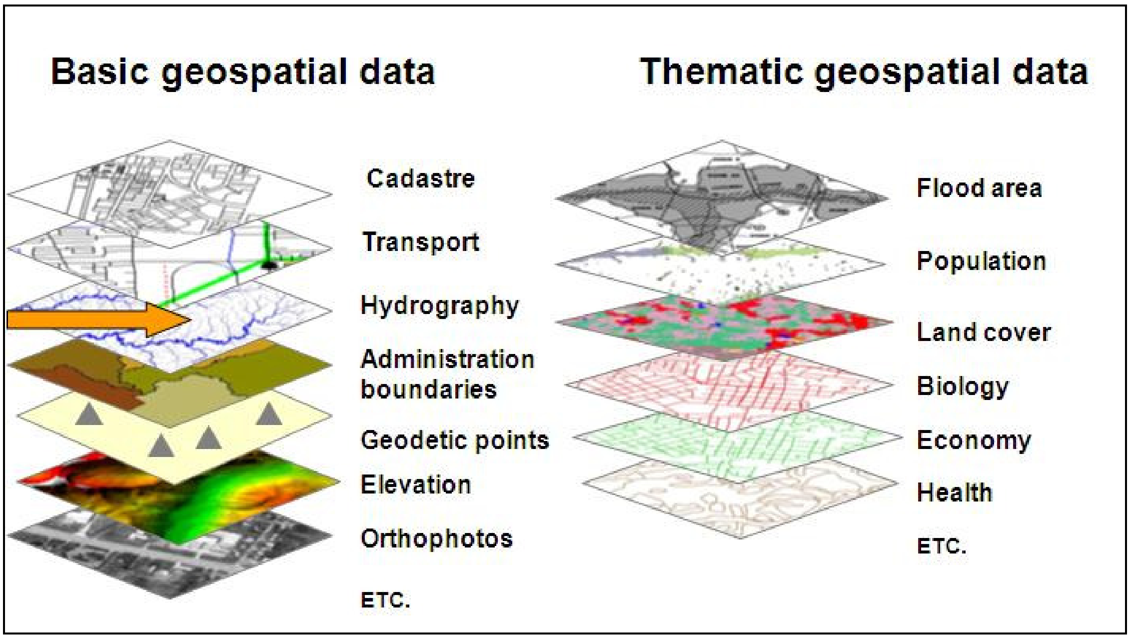

Figure 5.13 The importance of Hydrographic datasets in the Seamless SDI

Fundamental datasets will allow potential data users to access geospatial data with known standards that they can use for their own purposes. This will also encourage data users to adopt these common standards, so that their data is interoperable with the fundamental datasets. The other benefit of fundamental datasets is that resources can be pooled to create and maintain them, so that many agencies are creating the one dataset, instead of many agencies making duplications of one dataset. This should lead to better quality fundamental datasets.

A Seamless SDI that bridges the land – marine interface allows users to build applications and decision-making tools necessary to promote the shared use of such data throughout all levels of government, the private and non-profit sectors, and academia. This seamless framework also serves to stimulate growth, potentially resulting in significant savings in data collection, enhanced use of data and assist better decision-making.

5.5.5 Capturing digital data

Data capture to obtain digital maps can be done in two ways:

1. Primary data collection. New digital maps may be generated from aerial photography, remote sensed imagery, and field surveys.
2. Secondary data collection. Existing analogue maps may be digitized.

Primary data collection is done whenever existing maps are inaccurate, outdated, or unavailable. Secondary data collection is usually preferred when available analogue maps are accurate and up to date, and adequate data capture tools exist.

Following the identifying of fundamental datasets within land and marine environments, the collection and updating/maintenance of quality data at scales (medium to high resolution) appropriate to different levels, needs to be acquired. This aids to develop a seamless validated database of vector data using international standards, e.g. S-57 or S-100 feature data dictionary or data model in marine environment.

Analogue hydrographic maps are paper maps of the coast and seabed, showing depth values, contours of constant depth, symbols denoting underwater rocks and other features, and grid lines. Given a set of existing paper maps to be digitized, the appropriate data capture tools depend on the type and print quality of the paper maps, and the ultimate digital representation of the map. A digital map may exist in raster or vector format (and sometimes even in both).

Below are the steps regarding capturing digital hydrographic data:

- Scan manuscript documents into TIFF, GeoTIFF or JPEG format ensuring that the scan density is such that users can use it without resorting to the hard copy to resolve readability.
- Capture the data in vector format where possible. This could be done using optical character recognition methods or capture using double digitisation to ensure the quality and completeness of data capture (e.g. hand-drawn soundings).
- Ensure rigorous checking and validation is in place.
- Capture data as close to source scale or highest resolution as possible (i.e. not at product scale).
- Update the metadata search facility to identify raster or vector data availability.

5.5.6 Creating metadata and making metadata searchable

In order to facilitate accessing of up-to-date fundamental datasets, metadata needs to be created and made searchable. Metadata, commonly defined as "data about data", is a structured summary of information that describes data (SEDAC 2006). Metadata provides information on different technical and non-technical characteristics of spatial datasets. It includes information such as jurisdiction, custodian, data source, quality items, access channel and restrictions. Metadata is critical to document, preserve and protect agencies' spatial data assets. An appropriate content of metadata can facilitate the integration of land and marine spatial datasets.

Much of the information describing a dataset should be included in its metadata if present. As well as accompanying a dataset, metadata are now frequently being held on readily accessible databases, allowing users to identify datasets suitable to their requirements. The international standard for digital geospatial metadata (ISO 19115) is now being adopted by many national bodies, such as US Federal Geographic Data Committee (FGDC) for its Content Standard for Digital Geospatial Metadata (CSDGM) (http:// www.fgdc.gov/metadata/metadata.html/), and the UK's Association for Geographic Information (AGI) with its GIGateway project (http://www.gigateway.org.uk/default.asp/).

However, in coastal and marine environments the main limitation for accessing marine and coastal spatial data is the lack of metadata for these datasets. Although metadata creation might seem quite logical and inherent to the production of datasets, especially regarding geographical datasets, lack of metadata remains one of the main problems coastal managers face frequently. Little or poor quality metadata makes it difficult for a potential user to assess the accessibility and applicability of the dataset. This issue was highlighted at all Marine SDI levels and was found in the data audit in the PPB case study and caused some datasets to be unavailable for use (Strain 2006). Accurate and complete metadata will be needed in order to include marine and coastal spatial data within Seamless SDI.

Ensuring interoperability between land and marine SDIs requires agreement on metadata schemas and formats, data models and encodings, and service interfaces for accessing both data and discovery metadata (Nebert 2004). The minimum set of metadata required for data discovery for marine requirements should describe information about the identification of the data, the extent of data, the quality of the data and the spatial/temporal reference systems used for the data. An essential part of metadata includes information on the Geographic Reference Systems used. This includes both horizontal and vertical datum, projection codes and coordinates (e.g. xyz). In this regard, it is important to carry accurate metadata with the shoreline datasets. This should include details about the coordinate reference information and should facilitate future vertical adjustments or extractions. For example, a major product of the US FGDC Marine Boundary Working Group (MBWG) which was formed in 2001 is the FGDC's Shoreline Metadata Profile.

Currency is another aspect which is sometimes overlooked from a dataset's specification. Metadata creation should ideally allow for the recording of temporal information at feature level. This can include creation date, capture date and modification date (with the nature of the modification). Occasionally, temporal information will be limited to the date of the dataset's last update. The temporal information is especially important for marine and coastal datasets as it would be needed for detailed analysis. For example, the ability to select the position of the top and bottom of coastal slopes for a given year can allow predictive analysis of coastal erosion process to be studied (Gomm 2005).

With huge amount of spatial information being generated, a spatial application must be sufficiently flexible to extract and update spatial metadata automatically. By contrast, in current applications, the extract and update process is undertaken manually, making changes to spatial metadata relatively more difficult and expensive (Kalantari et al. 2009). Therefore, there is a need for consistent and automated Metadata. Metadata contains a rich source of information on different characteristics of spatial datasets. This rich and consistent content can greatly facilitate different spatial data use, evaluation, coordination and integration. Effective data integration requires data evaluation (Mohammadi 2008). Conversely, automation of spatial data validation and integration requires measurable and machine-readable content of metadata. Therefore, a suitable metadata for spatial data integration should have a number of key characteristics, including:

- consistent content
- rich and current content
- machine-readable content

- measurable content.

Consistent metadata content provides a homogeneous structure to store and maintain information on spatial data. The rich and current content of metadata that covers different aspects and the latest information of spatial data are also essential characteristics of suitable metadata for spatial data integration. Machine-readable metadata content also facilitates the automated extraction of information from metadata. There are different forms that meet this objective. For structured, machine-readable and self-descriptive information management, the increasingly popular XML provides an appropriate form to store metadata. Another important issue is the measurability of the content of metadata. For spatial data validation and integration, metadata content needs to be measurable and provide elements that can be measured and compared with others. However, many metadata items including quality are descriptive and most target the manual use of metadata rather an automated approach (Kalantari et al. 2009).
In creating a Seamless SDI, metadata should:

- provide data producers with appropriate information to characterise their geographic data properly;
- facilitate discovery, retrieval and re-use of data so that users will be better able to locate, access, evaluate, and utilise their geographic resources;
- enable users to apply geographic data in the most efficient way by knowing its basic characteristics;
- provide optional metadata elements to allow for more detailed description of geographic data; and
- Use the ISO 19115 as the standard to ensure full interoperability.

The next steps would be updating the metadata to identify raster or vector data availability, enable the search for metadata by subject, area and/or key word and make it searchable through some search engine.

5.5.7 Data Custodianship

Data custodianship is the means of ensuring accountability for the care and maintenance of fundamental datasets. There are often various agencies managing related datasets at varying degrees of accuracy and quality, creating duplication and decreasing the amount of time and money that can be spent on maintenance or the creation of other data sets.

The role of the custodian of spatial datasets has been developed to address this problem, with the one agency or custodian responsible for managing a dataset on behalf of all other users. The selection of custodians, in relation to fundamental datasets in the terrestrial environment, must be done in consultation with the broader spatial information community. This ensures a level of confidence in the data by users, as the custodians have been endorsed, accepted and hence trusted by the community at large. This is also needed in the selection of custodians for fundamental and business datasets in the marine environment.

According to the Geospatial Information Custodial Guidelines for Victoria, developed as part of the Victorian Spatial Information Strategy (VSIS), custodians are expected to provide information on the description, quality, metadata, pricing, licensing and access of each dataset. They must also undertake methods to maintain the dataset to an agreed standard of accuracy and quality, the level of which must be agreed upon by the spatial information community. Within the marine environment, it would seem logical to assign relevant industry agencies as data custodians, e.g. Australian Fisheries Management Authority (AFMA) to fisheries data, Australian HO to nautical charts etc. There is also the option of employing private sector agencies as custodians, as seen in the terrestrial environment.

As mentioned in Section 5.5.1, the development of partnerships is one of the major factors in the successful implementation of the Seamless SDI. The involvement of private sector companies as custodians of data fosters the development of such partnerships between not only the public/private sectors, but also between private companies, creating follow-on benefits for the development of the Seamless SDI.

A distributed network of custodians within land and marine environments who retain full control of their respective datasets and commit to managing them and making them available is required. Land and marine spatial datasets custodians are responsible for:

- Data collection;
- Maintenance and revision;
- Standards development;
- Quality;
- Access;

- Metadata; and
- Privacy.

In the marine environment, an HO which provides data for a SDI must take steps to ensure that it owns the data or the rights to the data to allow it to populate the Marine SDI. Often, HOs rely on the provision of bathymetric survey data from other parties such as port authorities, the off-shore industry and other HOs. In this case, the HO is not the "owner" of the data but rather a "custodian". When considering what data the HO may contribute to a SDI, it should be aware that it may not have authority to include source data for which it is not the owner. Generally the HO would be able under its agreements with the data suppliers to include product level data. However, addressing legal concerns (such as licencing and liability) that act as barriers to geospatial data sharing within Seamless SDI needs to be addressed.

5.5.8 Developing the technical architecture

Provision of the technical infrastructure that will enable the delivery of data and services to allow the viewing, transformation and downloading of information such as the ability to reference geodetic systems and transform data between such systems is another requirement in building a Seamless SDI.

Most SDIs will soon converge around a Service Oriented Architecture (SOA) using Information Technology (IT) standards promulgated primarily by the Open Geospatial Consortium (OGC) and ISO Technical Committee 211. There are very few examples of these types of architected SDIs in action (Finney 2007). SOA is an IT architectural style based around discrete software services that can be aggregated to create applications. Although services are heterogeneous, distributed and under the control of different owners, they are interdependent. This necessitates collaboration between the owners, developers, operators, and users of the service across departmental and organisational boundaries (Josuttis 2007). SOA is a conceptual approach to building infrastructure to meet business needs and theoretically allow development communities to establish a shared architectural view, while still permitting considerable flexibility, a component approach, and diversity in terms of any devised solutions.

In theory, central to any SOA initiative is the concept that services will be business aligned, re-usable, durable, discoverable, interoperable, composable (i.e. designed such that one service can be incorporated readily into another or be part of a service chain), loosely-coupled, and relatively coarse-grained (Marks and Bell 2006). In practice the design of these services with such characteristics is a very subjective activity, mostly coloured by the particular skills of the designers, the technologies, and the development methodologies with which they are familiar. Many pieces of the geospatial SOA standards jigsaw have been created as paper-based exercises, so harnessing these and fitting them together in a real world situation to achieve interoperability between land and marine systems is still very much a novel activity.

From a SDI perspective, it represents a very tangible way of connecting many disparate, unconnected agency-based IT systems via the internet, without requiring that each agency dismantles its existing legacy systems. Organisation can mask what is behind their firewalls as long as they present services that conform to the standards stipulated for the SDI. However, fitting all the pieces together and making sense of the technologies, standards, and people issues involved in rolling out SOA-based SDIs is still in its infancy. Mature National SDIs were not originally based on this paradigm and are either in the process of transitioning to it, (for example, Canada (GeoConnections 2005), USA, and Australia) or are planning to do so. Some new SDIs such as INSPIRE, the European regional SDI initiative (Smits 2002), and Australia's marine thematic SDI have begun using this architecture from their inception. There are currently no successful and mature SOA-based SDI implementations from which to extract wisdom concerning building the Seamless SDI.

There are four entities that make up a SOA. The first three are architectural elements, i.e. a service provider, a service registry, and a service consumer (or service requestor). The fourth is the contract that binds the consumer and provider (Figure 5.14). This contract (or service definition) contains a description of the functionality that the service provider offers, along with other technical information required for the services to be used by any potential consumer. A service provider publishes this contract in a services registry in order to make requestors aware that the service is available (Brauer and Kline 2005).

Service consumers access a registry to find a particular service that meets their requirements and then implement the elements from the contract that are necessary to invoke the service. The only agreement between the service provider and service consumer is expressed through the contract itself. So that SDI stakeholders are able to implement agreements and thus build, operate and use geospatial resources, community agreements need to be accessible. In addition, as agreements are reviewed, revised, and retired, to steer the SDI initiative they need to be managed throughout their lifecycle. These transactions typically occur through the utilisation of a range of standard, mainstream IT protocols and languages such as the:

- Universal Discovery, Description and Integration (UDDI) protocol for composing registries (Clement et al. 2004);
- Simple Object Access Protocol (SOAP) defining how to format a message to communicate between applications (W3C 2003);
- Web Services Description Language (WSDL), describing services and how to access them (Christensen et al. 2001);
- Hyper Text Transfer Protocol (HTTP), defining how messages are formatted and transmitted (http://www.w3.org/Protocols); and
- Extensible Mark-up Language (XML), using tag-based language to describe data elements and for electronic data interchange (http://www.w3.org/XML/).

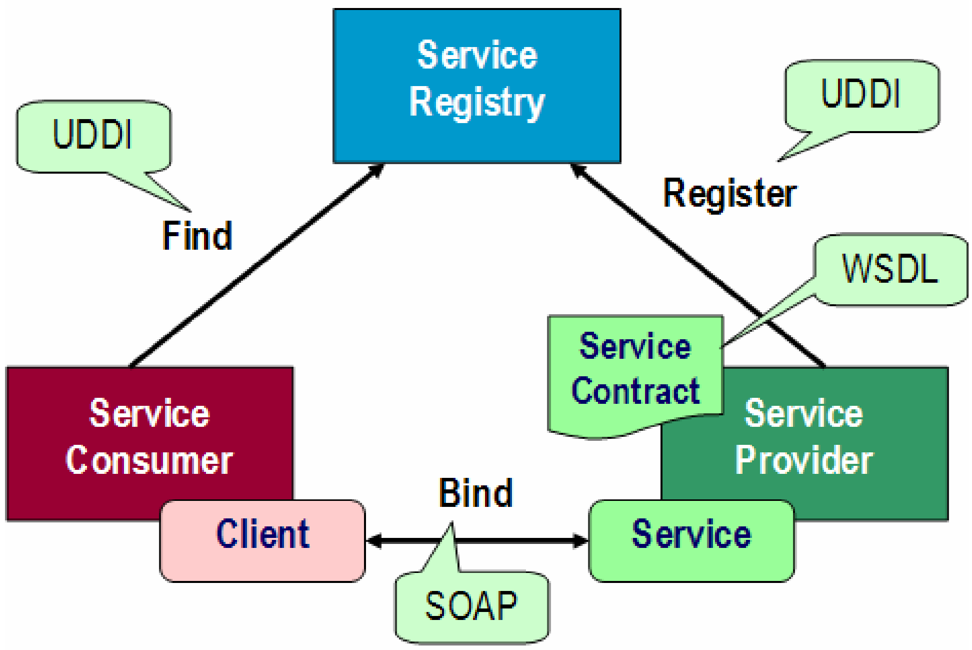

Figure 5.14 Service-oriented architecture - publish, find, bind paradigm (Brauer and Kline 2005)

In the past few years, the geospatial community, mainly lead by the OGC and the ISO Technical Committee 211 for Geographic Information/Geomatics, has embraced the SOA model but developed alternate standards that are designed specifically to deliver or discover geospatial data payloads (see http://www.opengeospatial.org/standards and http://www.isotc211.org/). For example, instead of UDDI and WSDL, the OGC has developed a registry interface standard, the OpenGIS Catalogue Service (CS-W) and three types of web services with their own messaging formats, the Web Maps Service (WMS - http://www.opengeospatial.org/standards/wms), Web Feature Service (WFS - http://www.opengeospatial.org/standards/wfs) and Web Coverage Service (WCS). These web services and other spatially-based standards are expressed in GML (Lake et al. 2004), an XML-based language tuned for representing spatial objects.

In order to develop the Seamless SDI database one option can be a data centric model. The merger of topographic and hydrographic data into a single database allows specialised products to be developed that contain a combination of relevant topographic and hydrographic features (e.g. products for coastal management). Using a data centric model allows source objects to exist with an endless variety of representations, thus allowing the source data to be leveraged to create an endless variety of data products (Figure 5.15). As more source data are incorporated (such as hydrographic, topographic, aeronautical, cadastral, environmental, or biological data) better quality data products can be produced (Mackenzie and Hoggarth 2009).

Data centric model solutions can provide a mechanism for storing land and sea features in a single database, and can therefore facilitate the production of coastal zone maps that incorporate the relevant topographic and hydrographic features. The discovery portals by which data holdings can be found and accessed and exploitation terms can be determined more easily. In order to take advantage of the efficiencies that a data centric approach to data management and product creation can provide, a flexible and comprehensive data model is required. The data model facilitates the storage of all the geospatial features in the database and how these features interact. Data dictionaries describing features and their attributes need to be created; ideally these data dictionaries should conform to international standards and can be a combination of several thematic dictionaries to allow as many data types to reside together as possible. All the features in the data dictionary will require symbols, line patterns or area fills associated with them, depending on the geographic object type (point, line, area etc).

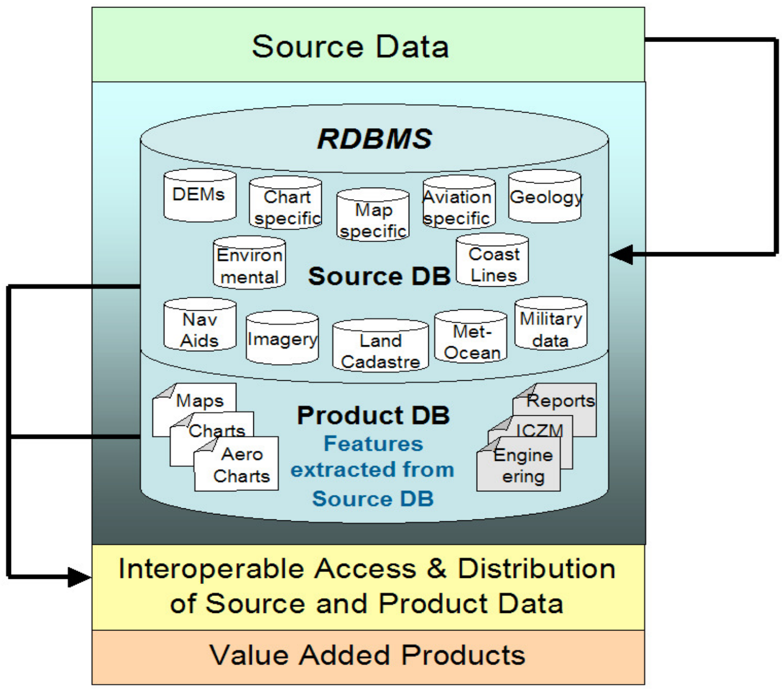

Figure 5.15 A data centric source database can facilitate multiple products (Mackenzie and Hoggarth 2009)

Figure 5.16 illustrates Seamless SDI warehouse architecture. Land, coastal and marine spatial data are integrated into a single clearinghouse. The seamless datasets can be used for different applications and web services as well as metadata search engines. Updating and maintenance of this warehouse is another requirement.

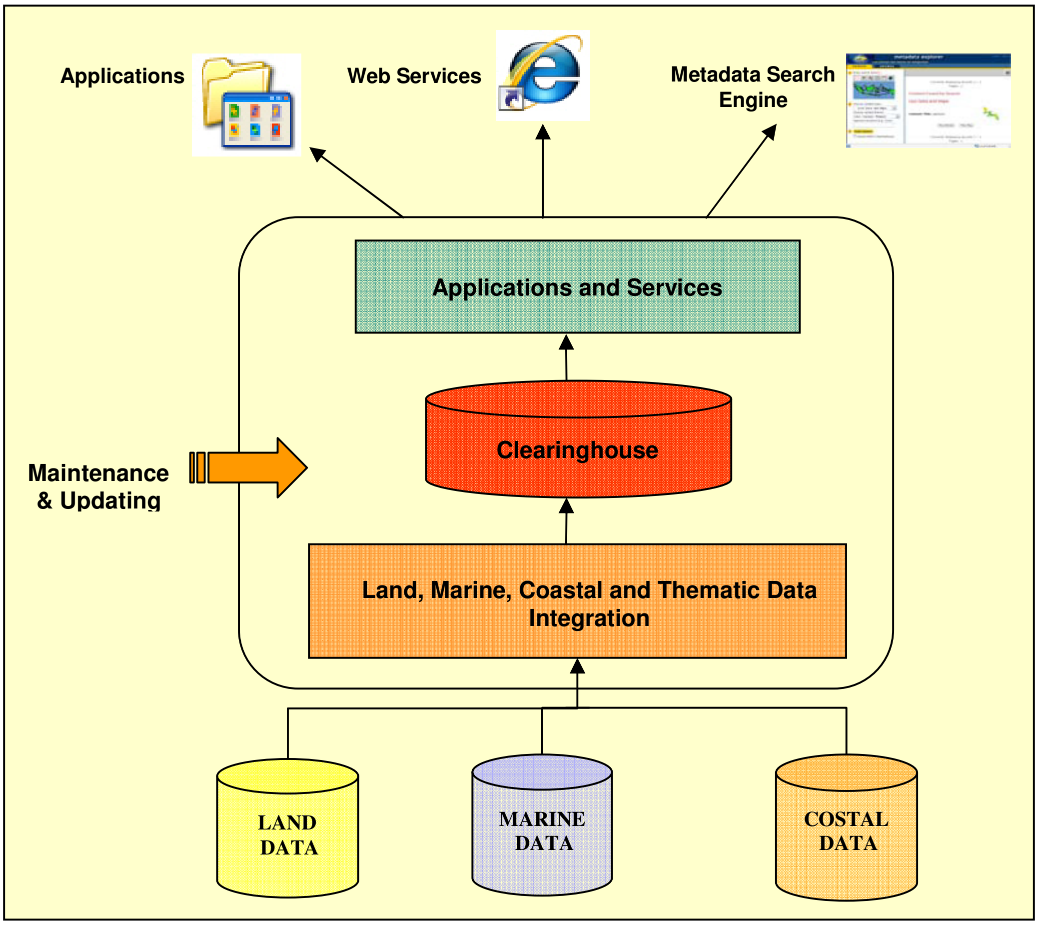

Figure 5.16 Seamless SDI clearinghouse architecture

5.5.9 Making data available

Despite the fact that the technical infrastructure will enable the delivery of data and services, access to data and data acquisition can still be challenging if data access and acquisition tools are not available. These tools comprise not only technical tools including web services and single point of access, but also provide non-technical mechanisms including legal, social, policy and institutional considerations to facilitate data access and acquisition.

Data exploration is important and in some cases leads to data acquisition, but in most cases, where users need accurate, detailed business datasets, they need to find a communication channel with data providers. In some cases users know where data lies but they cannot find any channel to communicate and collect data. Easy access to an effective communication channel requires the provision of tools to link users to data providers including data dictionaries. The following are required steps in order to make the data available in Seamless SDI:

- Develop download facilities for data sets (note that for some dense datasets, the use of web delivery is not possible).

- Develop automated search and download of data sets via web mapping services.

- Develop a seamless validated database of vector data using international standards (e.g. S-100 feature data dictionary or data model).

- Where security of data is an issue, develop an acceptable level at which data can be made available either in-country or internationally. This may involve data thinning or gridding to a level where data might be declassified.

- Facilitate automated search and download of data via web feature services.

- Establish a licensing or cost recovery regime supported and underpinned where required by government policy.

5.5.10 Monitoring and reporting

Shortcomings often become apparent only after design decisions have already been taken and development effort has begun. The need for efficient feedback mechanisms between community-based developers and international standards bodies in such circumstances has been recognised. This is even if only to communicate what deficiencies have been found pending a longer-term process to gain a consensus solution. Therefore, the main goals include improving monitoring programs for creation of Seamless SDI at the national level, integrating interagency research efforts and improving data management.

There is potentially a key role here for consumers to play in providing feedback on the quality of available services. In this regard, HOs should also provide reports to their respective Regional Hydrographic Commission (RHC) meetings on the progress the HO is making towards building and/or contributing to a Seamless SDI. Such a report should include:

- What data is being disseminated (through web based access or manual dissemination);

- Identify which datasets complete with metadata are to be provided into a Seamless SDI and report progress in preparation;

- Monitor and report on feedback from users and stakeholders; and

- What type of data services and products are being offered by the HO.

In addition to testing its usage by stakeholders' feedback, rigours criteria to monitor and report on the performance (e.g. effectiveness, efficiency) of the design and development of the Seamless SDI model itself is also needed. Evaluation involves assessing the strengths and weakness of guidelines, policies, personnel, product and organisations to improve their effectiveness. The evaluation is about finding answers to questions such as "are we doing the right thing" and "are we doing things right". These are prominent questions for SDIs including Seamless SDI, the development of which has been very dynamic over the last decade and has involved significant learning from other national or local initiatives.

Each component of the Seamless SDI as highlighted in Chapter 4 (policies, standards, access network, people and data) can be considered as separate criteria for evaluation of this model. For example, the data component can be evaluated by assessing the data models of land and marine spatial datasets of different organisations, the creation of land and marine fundamental datasets, data capture methods, data maintenance as well as data quality and accuracy. Good practice might be when data is defined in integrated and transparent ways (content, quality, accuracy) so that they can easily and readily be shared among different stakeholders. The access network component is to be evaluated by considering the type of available network and its capacity and reliability. Indicators might be data volume and response time and good practice would be when the network can handle a large data volume reliable with a short response time. Other components of

Seamless SDI may be considered as the main evaluation areas based on the predefined indicators.

Seamless SDI needs to be as a standing agenda item on high level Regional /National Commissions in order to be monitored as well as report progress in states' Seamless SDI engagement and development. Moreover, the benchmarks against which reporting might be measured should be developed.

In order for the Seamless SDI to operate at its optimum level, minimum requirements in terms of data management will be required. Data Management will probably include inputs such as policy and plans necessary to deliver metadata, data sharing and exchange mechanisms, levels of data interoperability, network services including "discovery", "view", "download", "invoke" and "transform" and other plans necessary to ensure compliance with SDI requirements (e.g. data licensing, digital rights management, pricing). Figure 5.17 illustrates a Seamless SDI data management flow diagram.

In conclusion, the involvement of marine and coastal stakeholders within Seamless SDI architecture presents a desirable way forward in achieving best practise in the way spatial data is captured, ingested, managed, discovered and disseminated. Because many marine and coastal agencies will be approaching the SDI question from a point of low knowledge and understanding, it is very important that they should focus initial efforts on the obvious need to get their processes and procedures right; to view data as the important commodity by understanding what data they hold, by describing it, and by making it discoverable to users. Only then they should consider contributing to a Seamless SDI.

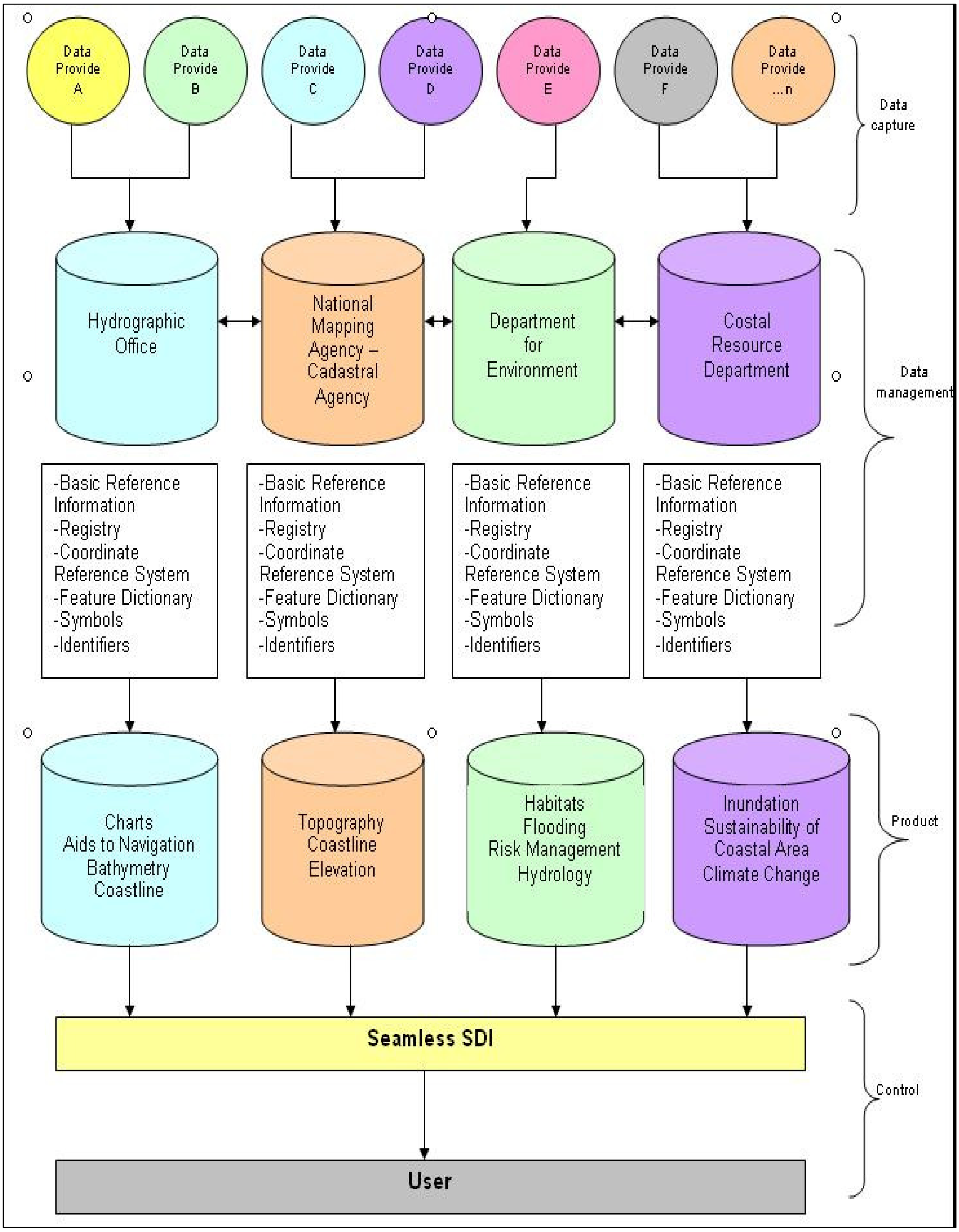

Figure 5.17 Seamless SDI data management flow diagram

5.6 Chapter Summary

In order to design and implement a Seamless SDI, we need a conceptual model of a Seamless SDI. Based on Hierarchical Spatial Reasoning and Object Oriented Modelling method, the Seamless SDI model can be proposed as one abstract class SDI at the higher level (parent level) with attributes and operations/methods designated to this class. A Seamless SDI as a super-class specialises in land SDI, coastal SDI and marine SDI sub-classes. As demonstrated in this chapter the Seamless SDI platform employs the components of SDI in general but the attributes of these components are different from the existing platform.

In this chapter, the Use Case Diagram and Class Diagram have been developed for the Seamless SDI design. These models could be seen as a contribution towards the overall model of the Seamless SDI and its technical characteristics. The Use Case Diagram shows the stakeholders and their role within the Seamless SDI. It also helps the identification of required objects and relationships between them in a Class Diagram. In order to see how the different parts of the use cases fit together, an initial view Object Diagram for Seamless SDI has been developed. The Class Diagram describes the types of objects in the system and the static relationships between the objects. These diagrams described the Seamless SDI systematically and its context, users, providers, services and so on, necessary to establish them.

Furthermore, given the complexity of the Seamless SDI with inter-related and interconnected technical and institutional elements and the multiplicity of stakeholders involved, it is clear that governance is an important aspect of the institutional framework necessary to support decision making about all aspects of this Seamless SDI. It has been proposed that appropriate governance models could assist SDI development.

In implementing the Seamless SDI model for any jurisdiction, guidelines consisting of ten components, have been outlined. These items were:

- Identifying key stakeholders within land and marine environment;
- Developing national or regional legislation/ policy;
- Capacity building;
- Identifying fundamental datasets in land and marine environments;
- Capturing digital data;

- Creating metadata and making them searchable;
- Developing the technical architecture;
- Making data available; and
- Monitoring and reporting.

The Seamless SDI guidelines detail the key considerations for effective land and marine spatial data integration. The guidelines discuss the potential technical and non-technical barriers as well as available solutions. The guidelines provide necessary information for practitioners in order to deal with the complexity of creating a Seamless SDI. The guidelines can be utilised as a part of the tool or as an individual document that helps identify potential barriers and possible enablers. However, the guidelines' development is highly dependent on the needs and objectives of the respective jurisdiction and the context of the respective SDI. Each SDI has its own considerations and guidelines. It includes the roadmap, standards, policies and agreements that are developed within each SDI to facilitate the coordination of spatial datasets.

The next chapter uses a case study approach to demonstrate the advantages of integrating terrestrial, coastal and marine data and the need for a seamless platform across the land – marine interface.

CHAPTER 6

RESEARCH DESIGN AND CASE STUDY

6.1 Introduction

This chapter charts the development of the project's research design. It returns to the underlying research problem and explains how the findings of the background chapters were used to generate a research hypothesis. The chosen case study approach is outlined and justified.

With regard to case study, the chapter introduces and outlines the current management and administration framework of Port Phillip Bay's marine and coastal areas. The second part of the case study analysis aims to evaluate the availability, accessibility and interoperability of spatial data in the case study area and outlines the justification for seamless information. This is achieved by testing the integration of different datasets. The third part of the case study analysis investigates use, management and sharing of spatial data about Port Phillip Bay from the perspective of the people involved in managing this area. It draws out the current issues from the perspective of the interviewed stakeholders responsible for managing Port Phillip Bay.

Consequently, the results of the case study lead to the demonstration of the limitations and opportunities of integrating terrestrial, coastal and marine data and the need for a seamless platform between land and marine areas to enable effective management of the coastal zone.

6.2 The Scientific Method

The scientific method, modernised by Kuhn (1962), involves identifying a problem and then generating theories or hypotheses to best explain why the problem is occurring or how it might be overcome (Figure 6.1). The hypotheses are then applied to more specific research objectives, which leads to the definition and testing of measurable variables (McDougall 2006). This deductive approach provides a framework for the study and an organizing model for the research questions and data collection procedures (Creswell 2003). Each of these stages and their application to the research are now discussed.

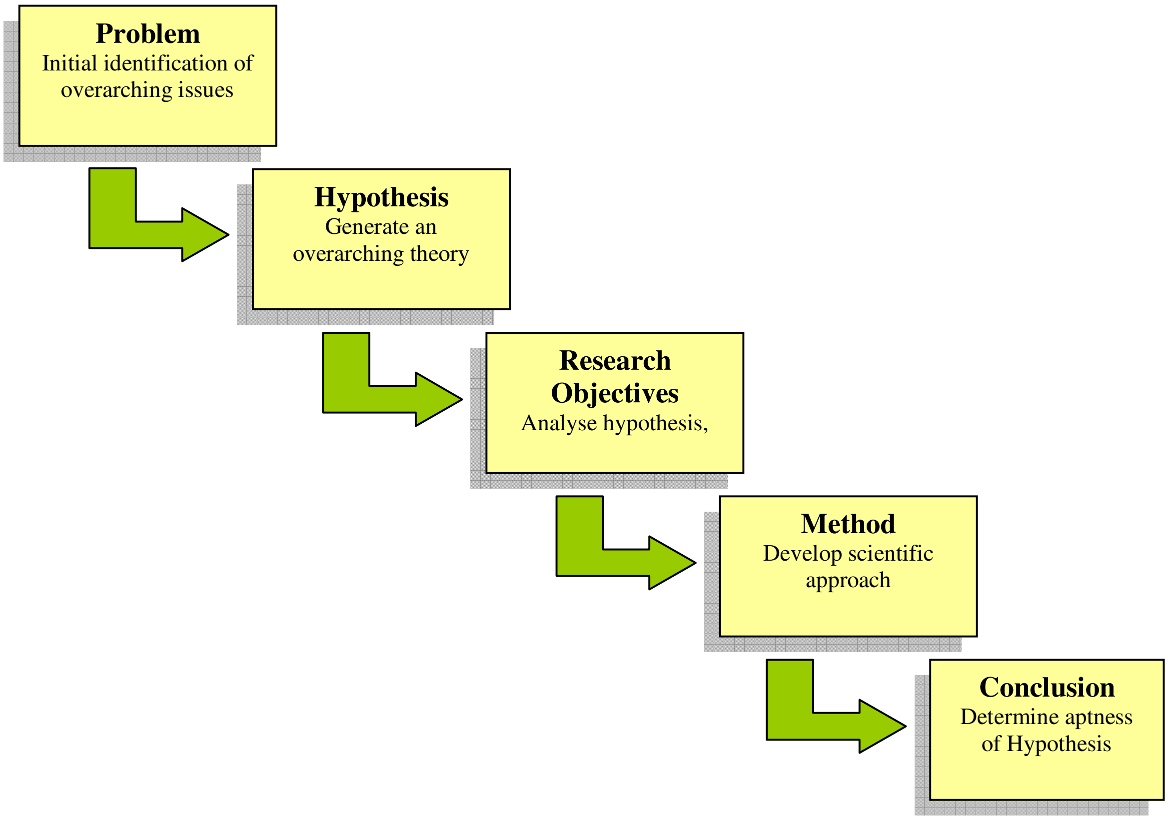

Figure 6.1 Scientific Method

Research problem

The first stage of the scientific method involves clearly articulating the problem. It should identify and provide definitions of the subject. As stated in the introductory chapter, the research problem was articulated as:

> The research problem is that current SDI design is focused mainly on access to and use of land related datasets or marine related datasets, with most SDI initiatives stopping at the land-ward or marine-ward boundary of the coastline, institutionally and/or spatially. Consequently, there is a lack of harmonised and universal access to seamless datasets across the land – marine interface from marine, coastal and land based spatial data providers. This leads to the creation of inconsistencies in spatial information policies, data creation, data access, and data integration across the coastal zone that limits sustainable management and development of the coastal zone.

Formulating the hypothesis

The second stage of the scientific method involves the proposal of a hypothesis that best explains why the problem is occurring or how it might be solved. In the context of this research, the marine and coastal management issues, described in the Chapter 2, provide the best starting point. The background chapters were structured around the justification of the need for seamless information across the land – marine interface.

While current SDI design is focused mainly on access to and use of land related datasets or marine related datasets, most SDI initiatives stop at the land-ward or marine-ward boundary of the coastline, institutionally and/or spatially. With this in mind the research hypothesis was generated:

> The development of a seamless platform covering the land and marine environments as part of the National SDI would facilitate greater access to more interoperable spatial data and information across the land – marine interface enabling a more integrated and holistic approach to management of the coastal zone.

Articulating the research objectives

The third stage of the scientific method involves using the hypothesis to develop a set of research objectives. By answering the research objectives the appropriateness of the hypothesis can be deduced. In the context of this research the background investigations resulted in a number of objectives which relate directly to the hypothesis as follows:

1) Investigate and justify the need for seamless information across the land – marine interface in support of better management of the coastal zone;
2) Investigate and understand current land and marine SDI initiatives and concepts at both national and international levels;
3) Investigate the characteristics and components for the design of a Seamless SDI model;
4) Develop and propose a Seamless SDI model and associated guidelines using current SDI theory and models to incorporate identified characteristics and components; and
5) Test the limitations of developing a Seamless SDI with a particular focus on Australia's marine jurisdictions.

Designing the experiments

The fourth stage of the scientific method involves designing experiments to answer the research objectives. In terms of answers, each of them demands qualitative responses.

Qualitative methods involve concentrated exploration of a small number of individual people or events to understand how and why certain phenomena are occurring. Qualitative research differs from quantitative research: the data it produces cannot be statistically analysed or graphed. It produces descriptive data relating to the people or activities being studied. While the outcomes of quantitative methods can be conclusive, qualitative methods tend to be merely suggestive. Well known techniques for qualitative methods include case studies, ethnographies, personal experience, narrative research, action research, introspection, observation, and visual texts (McDougall 2006; Denzin and Lincoln 1994).

In the context of this research, qualitative research methods could be used to answer all of the research objectives. Qualitative methods would facilitate greater understanding of the existing land and marine SDI models in terms of their attributes and underlying infrastructure. The opportunities and barriers for combining land and marine components could all be identified and used to inform the design of a new SDI model.

There are many types of qualitative research; however, consideration is now given to the type applicable in this research: the ‘case study’ approach. Case studies examine a trend in its natural setting and use multiple data collection methods along with a small number of entities (Benbasat et al. 1987). Case studies rely upon multiple sources of evidence (Yin 2003). Examples include interviews, surveys, legislation, strategic plans, management reports, operational procedures, brochures and independent reports relating to the public and private organisations.

The case study approach is appropriate when the phenomenon under study is not readily distinguishable from its context and when there is a need to define topics broadly and rely on multiple rather than singular sources of evidence (Yin 1993). Indeed the case study approach is the only way to understand the broad field of SDI: cases help to address contextual conditions and not just the overarching phenomenon of the study.

In the context of this research, case studies, particularly the ‘descriptive’ form, appeared highly relevant for a number of reasons. Firstly, it would allow for analysis and description of coastal and marine management framework. Secondly, as outlined by Yin (1993), there was a need to define topics broadly and not narrowly: coastal and marine interests, their management and impact were seen as very broad. Thirdly, case studies allow multiple sources of evidence to be studied. It was anticipated that data would be gathered from a range of sources including interview material, legislation, government policies and literature produced by non-government groups. Fourthly, the coastal and marine management could be studied in their normal settings. This provides the opportunity to learn from current approaches and practice (Benbasat et al. 1987; Maxwell 1996).

Case Study Location

The selection of the case study area was based upon a number of criteria. Firstly, the jurisdiction needed to have a coastal and marine environment. Secondly, the jurisdiction needed to have a defined management framework. Thirdly, it needed to represent a heavily used and heavily populated coastal and marine environment. Finally, the jurisdiction needed to be accessible to the researcher.

Port Phillip Bay (PPB) which is located in Victoria, Australia was the chosen jurisdiction. While most of the Asia and Pacific countries matched the criteria, Australia was local to the researcher and would offer the easiest means of travel and repeat visits.

As discussed in Chapter 2, the management of Australia's off-shore area is shared between the states (including Northern Territory), which have jurisdiction within coastal waters (waters from the Territorial Sea Baseline out to a limit of three nautical mile and also includes nearly enclosed bays, harbours or other waterways), and the Commonwealth, which has jurisdictional responsibility from the three nautical mile limit (5.5 km.) out to the limit of the Exclusive Economic Zone (EEZ). In order to select an appropriate case study that combined the state and local governments an area such as PPB was used. It is more of a local/ state level SDI as the state government is responsible for the low water mark and the local government is responsible for the area above the low water mark. This is a smaller scale area comparatively to the state's marine jurisdiction and an area that has a defined management framework.

Port Phillip Bay is an area with significant and varying rights, restrictions and responsibilities for many stakeholders. This area was also chosen because it represents a heavily used and heavily populated coastal and marine environment within Australia. Many different activities take place within the bay, for example: shipping, fishing, aquaculture, conservation, recreation and tourism. The capital city of Victoria, Melbourne, is located at the top of the bay and it is heavily populated around the perimeter. The bay acts as a main hub for Melbourne and thus has many private and government sectors operating over the area. Port Phillip Bay covers approximately 1,950 km^2. It is the entrance to Australia's busiest port and a popular recreation destination in Victoria. Every year millions of people enjoy its vast coastline, world-class swimming beaches and coastal parks. It is one of Victoria's most densely populated catchments with over 3.2 million people living around its shore. The bay is a large expanse of water that is surprisingly shallow in many places. Nearly half the bay is less than 8 metres deep. Its greatest depth is 24 metres. The bay is a dynamic and self sustaining ecosystem of relative health when compared to other bays in close proximity to large cities (Parks Victoria 2009).

Figure 6.2 Port Phillip Bay, located in Victoria, Australia

Processing results and making conclusions

The fifth and final phase of the scientific method involves analysing the results, answering the research objectives and consequently making conclusions about the hypothesis.

The answers to each of the research objectives are presented in Chapter 2, 3, 4, and 5. However, the answers were tested or checked through the case study analysis. The implementation of a case study as part of the overall project will enable theoretical ideas and concepts to be tested and evaluated. The case study relies on knowledge of who is responsible for managing PPB, and collecting all available spatial data from these organisations for PPB.

This case study was used complete the assessment of the potential for a Seamless SDI through examining Marine SDI as a state/ local level. In the context of this thesis, the major objectives of the case study are:

1) Identification of governing bodies and relevant legislation operating over the PPB case study area;

2) Investigation of the current management framework of PPB including manager, regulator, planner, stakeholders and users of spatial data over the area;

3) Examining availability, accessibility and interoperability of spatial data within PPB through collecting all available data;

4) Justification of the need for seamless information across the land – marine interface by integrating all available datasets.

5) Identification of the current use, access and sharing of spatial data in PPB from the perspective of the selected stakeholders responsible for managing this area; and

6) Examining common problems and limitations in use, access and sharing of spatial data from the interviewed stakeholders' point of view.

In order to respond to these objectives the case study involved three parts. These were:

Part 1 – Assessing Port Phillip Bay management and planning framework;
Part 2 – Analysing/ examining available spatial data about PPB;
Part 3 – Interviewing relevant stakeholders of PPB about sharing and use of spatial data;

After this analysis the resulting set of answers were compiled and the hypothesis tested. This discussion is undertaken in Chapter 7.

6.3 Case Study Part 1 – Assessing Management and Planning Framework

The first part of case study analysis is dealing with assessing Port Phillip Bay management and planning framework. PPB is managed by state and local governments. Local governments have jurisdiction above low water mark; however in some municipal councils, jurisdiction is extended seawards to 600m from the low water mark to include jetties, marinas, breakwaters and other coastal infrastructure. The State government is responsible for the area off-shore: the waters and seabed from high water mark to the three nautical mile limit; however governance of the area is also controlled by legislation from higher levels as shown in Figure 6.2.

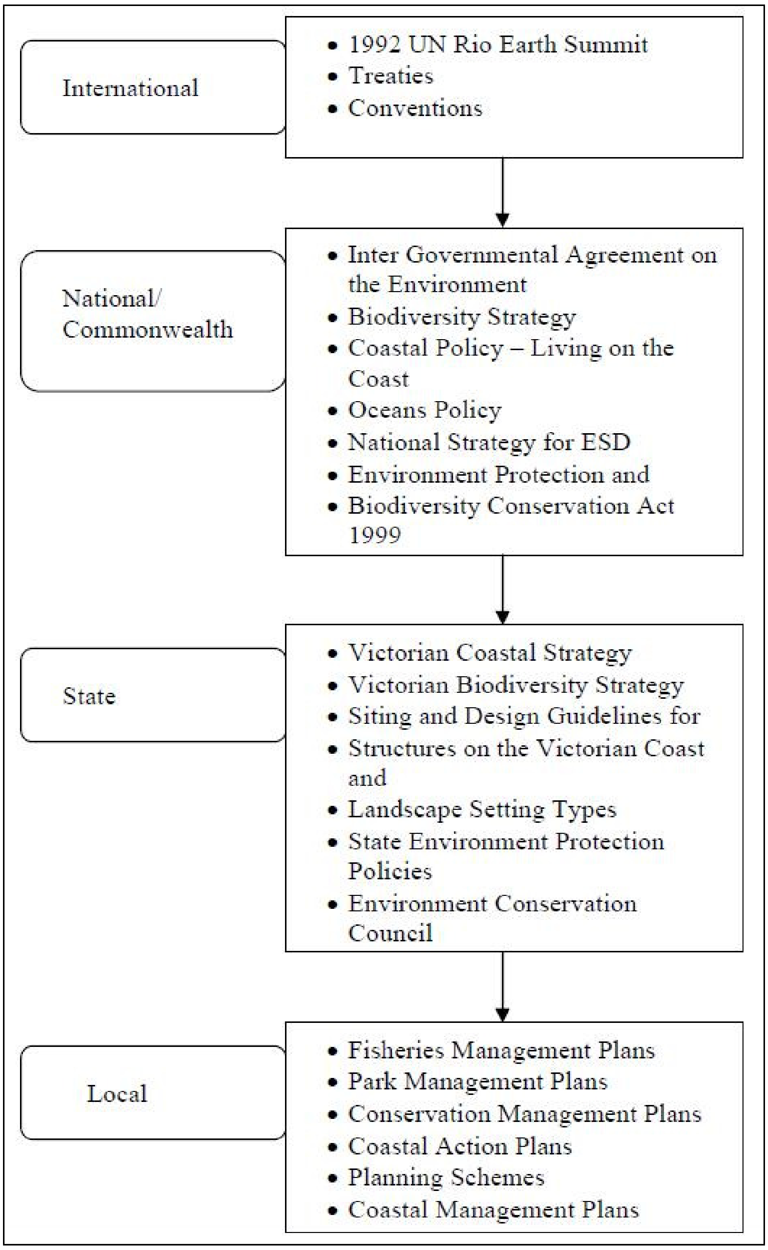

Figure 6.3 Port Phillip Bay's legislative governance framework (ABM 2000)

The planning and management framework of PPB is made up of a number of key agencies responsible for:

- the ownership of the land or waters,
- the management of the land or waters,
- planning the way in which the land or waters are to be used,

- regulating activities on land and waters.

To understand the planning and management framework, it is important to recognise who owns the asset, who is charged with direct management of the land or waters, and who is responsible for planning and regulating the way in which the land or waters can be used at a local or state level. It is also necessary to consider PPB in terms of its waters, coastal foreshore land and its regional catchments. Activities in the broader catchments have a direct impact upon the marine environment of PPB. The coastal foreshore includes both public and private land that forms the important land and water interface of the Bay.

The use and development of coastal private land is primarily governed by the provisions of the *Planning and Environment Act 1987* which is administered by the Minister for Planning. Responsibilities for planning land use regulation are delegated to Municipal Councils who act as planning authorities under the Act. On the other hand, coastal public land and waters both below and above high water mark in PPB are unalienated Crown land that falls into three main categories:

- National Parks and other park areas designated under the provisions of the *National Parks Act 1975*;
- Crown land that is "reserved" for a particular public purpose under the *Crown Land (Reserves) Act 1978*;
- Crown land that is "unreserved" and administered under the *Land Act 1958*.

National and other parks

The *National Parks Act 1975* provides for the protection and preservation of a range of specific park areas throughout PPB and Victoria, including National and State Parks, Wilderness Parks, Coastal Parks and Marine Protected Areas as well as a number of other nominated parks. Parks Victoria is responsible for the management of these parks.

Reserved Crown land

The management of Crown land that is reserved under the *Crown Land (Reserves) Act* is delegated by the Minister for Conservation and Environment to land managers that are appointed as Committees of Management under the Act. Land managers for foreshore reserves include Parks Victoria, Municipal Councils or Committees of Management that are made up of publicly elected representatives of the community or appointments made by the Minister. The majority of coastal land within PPB is reserved Crown land managed by these delegated land managers.

Unreserved Crown land

Crown land that is unreserved is managed directly by The Department of Natural Resources and Environment (NRE) under the provisions of the *Land Act 1958*. In PPB the only significant area of unreserved land is the seabed of the Bay.

The relationship between the land and marine owners and land and marine managers is shown in the Figure 6.3 below, along with the primary management Act.

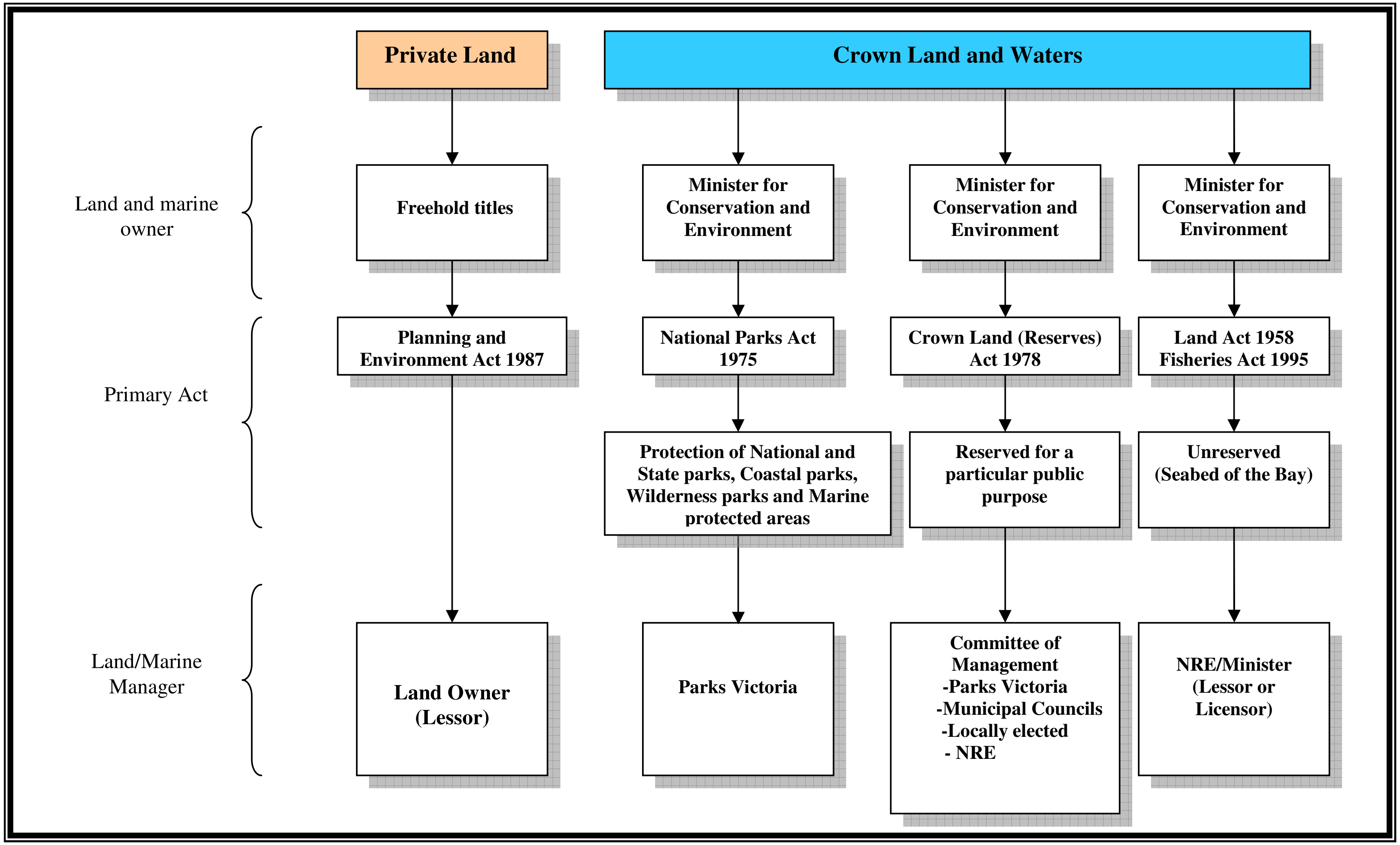

Figure 6.4 Relationships between the land/marine owners and land/marine managers

Planning for the coast and marine environment is undertaken by land managers and key advisory bodies with responsibilities at a state, regional and local level as shown in the Figure 6.4 and explained in the following subsections.

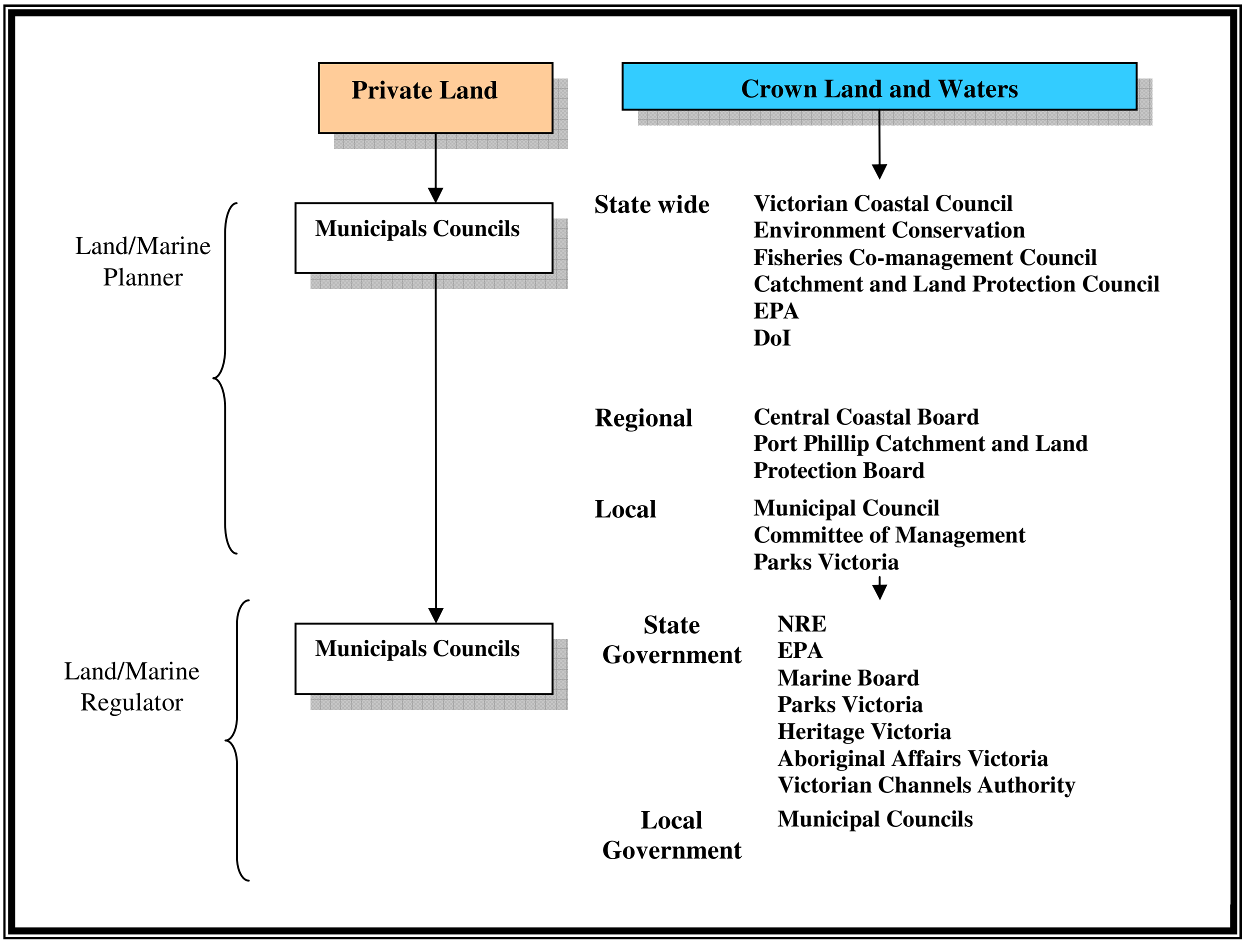

Figure 6.5 Land and marine planners and regulators within Port Phillip Bay

State and regional planning

1) Victorian Coastal Council

The Victorian Coastal Council (VCC) is the State's central advisory and coordinating agency for coastal planning and management. The Council was established in August 1995 under the *Coastal Management Act* to oversee strategic planning and management for the whole Victorian coast. The VCC is ultimately responsible for ensuring that land managers, key government agencies, and the community progressively implement the priority actions of the Victorian Coastal Strategy and the objectives for coastal planning and management as set out in the Act.

2) Central Coastal Board

At a regional level, the Central Coastal Board has similar functions to that of the VCC however it is focused on the Port Phillip Region. The Central Coastal Board is responsible for development of Coastal Action Plans, providing advice to the Minister and the VCC on coastal development in the region, preparing guidelines for coastal planning and management in the region, implementing the Victorian Coastal Strategy, and facilitating a co-operative approach to coastal planning and management from Government departments and agencies, Municipal Councils, community groups and bodies and industry sectors.

3) Environment Conservation Council

The Environment Conservation Council (ECC) advises the Victorian Government on the use of public land; it makes recommendations not decisions. The ECC's aim is to balance the competing needs of the environment and public land and water users, in order to achieve ecologically sustainable and economically viable public land. The ECC has made recommendations on Victoria's marine, coastal and estuarine areas.

4) Advisory Bodies

Advisory bodies such as the Fisheries Co-management Council, the Catchment and Land Protection Council, Port Phillip Catchment and Land Protection Board, and the State Boating Council all have a broad strategic planning roles, influencing fisheries management, catchment and waterway management, and recreational boating outcomes for PPB. In addition, these bodies are responsible for coordinating the implementation of a range of actions in the Victorian Coastal Strategy and providing input on coastal and marine issues to the VCC on behalf of their stakeholders.

5) Department of Natural Resources and Environment

The Department of Natural Resources and Environment (NRE) is responsible for development of state-wide policy and strategic directions for natural resource management. NRE is one of the primary agencies for implementation of a range of programs which influence planning and management across public and private coastal land. These programs include Coasts and Ports, Parks, Flora and Fauna, and Catchment Management and Sustainable Agriculture, and Fisheries Management. NRE is a lead agency for implementation of many of the priority actions of the Victorian Coastal Strategy and provides support to the VCC.

6) Environment Protection Authority

The Environment Protection Authority (EPA) has a primary role in ensuring the protection of water quality in PPB and in dealing with pollution issues that affect the Bay, foreshore and the regional catchment. In addition to its regulatory function, the EPA is proactive in the development of waste minimisation policies and strategies, and formulation of best practice guidelines and codes of practice for a range of land use activities.

7) Department of Infrastructure

The Department of Infrastructure (DoI), through its Ports and Marine division, has a key role in developing strategies and implementing policies for Victoria's ports and marine sectors. DoI also has planning and environmental responsibilities in the administration of the *Planning and Environment Act 1987* and the *Environment Effects Act 1978*. The Department has a key role in the development of planning policies for Victoria and in the ongoing implementation of reforms to the land use planning system.

Local planning

At a local level, planning for coastal land is undertaken on a site specific basis by the delegated land managers in their role as committees of management. These land managers include Parks Victoria, Municipal Councils and committees of management which may be locally elected community representatives or Ministerial appointments.

While a municipal council may be a committee of management for a foreshore reserve, all local councils are also responsible under the *Planning and Environment Act 1987* for planning decisions, that is, decisions about the use and development of land in a municipality. Each local council develops a planning scheme which guides planning decisions through the application of strategic planning policies and development controls.

Each planning scheme includes a State Planning Policy Framework which embraces state-wide policy objectives including coastal issues.

State Government regulates activities on waters and both public and private land in the Bay, foreshore and catchment though a variety of agencies. Table 6.1 shows these organisations and their particular responsibilities.

Table 6.1 Main stakeholders in the case study area (adapted from ABM 2000)

Government Agency	Activities that are regulated
Natural Resources and Environment (Department of Sustainability and Environment (DSE), Department of Primary Industries (DPI))	-Use and development of coastal Crown land -Protection of rare and threatened flora and fauna -Aquaculture -Commercial fishing -Minerals exploration and exploitation -Dredging and spoil disposal
Environment Protection Authority	-Licensing of waste disposal -Water Quality -Oil Pollution
Marine Board of Victoria	-Marine navigation and recreational boating activities
Parks Victoria	-Port works and facilities in Port Phillip Bay -Recreational use of waters
Melbourne Port Corporation	-Management and operation of the Port of Melbourne
Victorian Channels Authority	-Management and operation of the Port Phillip Bay shipping channels
Aboriginal Affairs Victoria	-Aboriginal heritage
Heritage Victoria	-Shipwrecks and maritime heritage
Municipal Council	-Planning and building approvals, waste disposal approvals, local regulations and by-laws affecting the use and development of coastal foreshore areas in public and private ownership

Analysing and investigating planning and management system of PPB led to the development of use case diagrams of its management system. Figures 6.5 and 6.6 illustrate the main stakeholders involved in PPB planning and regulating systems by using use case diagrams. Many different local, regional and national government agencies are responsible for different aspects of the management and different uses of the PPB. It is evident that these stakeholders come from land, coastal and marine environments with different rights, interests, or responsibilities for management of this area.

These figures imply that these rights and responsibilities regularly overlap, creating the need for interaction between a wide range of stakeholders and activities. The task of efficiently and effectively managing all stakeholders is complicated by the fact that their rights can often overlap, creating competing rights, restrictions and responsibilities. This gives rise to the need for cooperation between agencies, something which can be difficult to achieve. Part 1 of the case study recognised the existence of complex interactions between competing rights of, stakeholders within the PPB and the need to integrate planning and management over the land – marine interface.

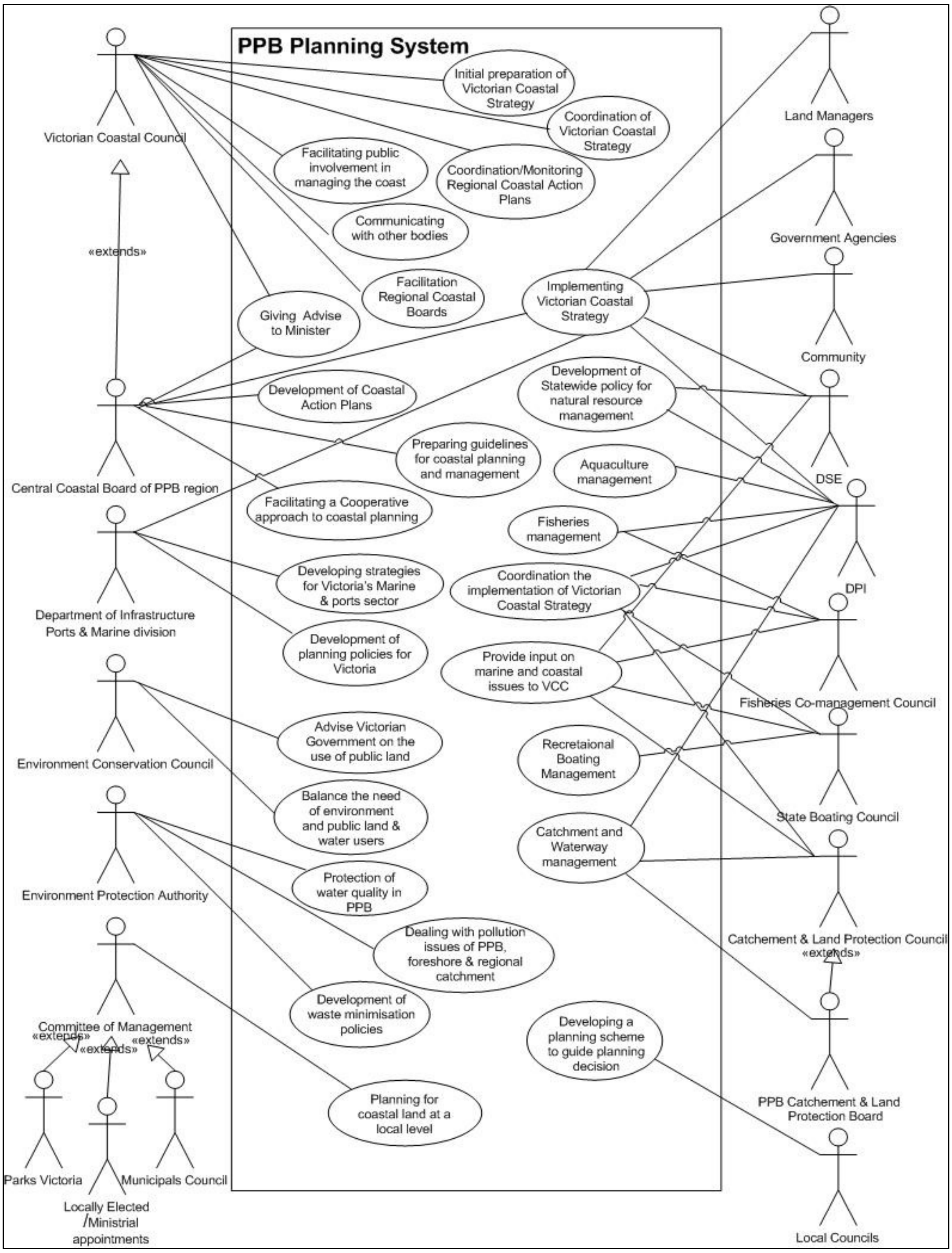

Figure 6.6 Stakeholders involved in PPB planning system

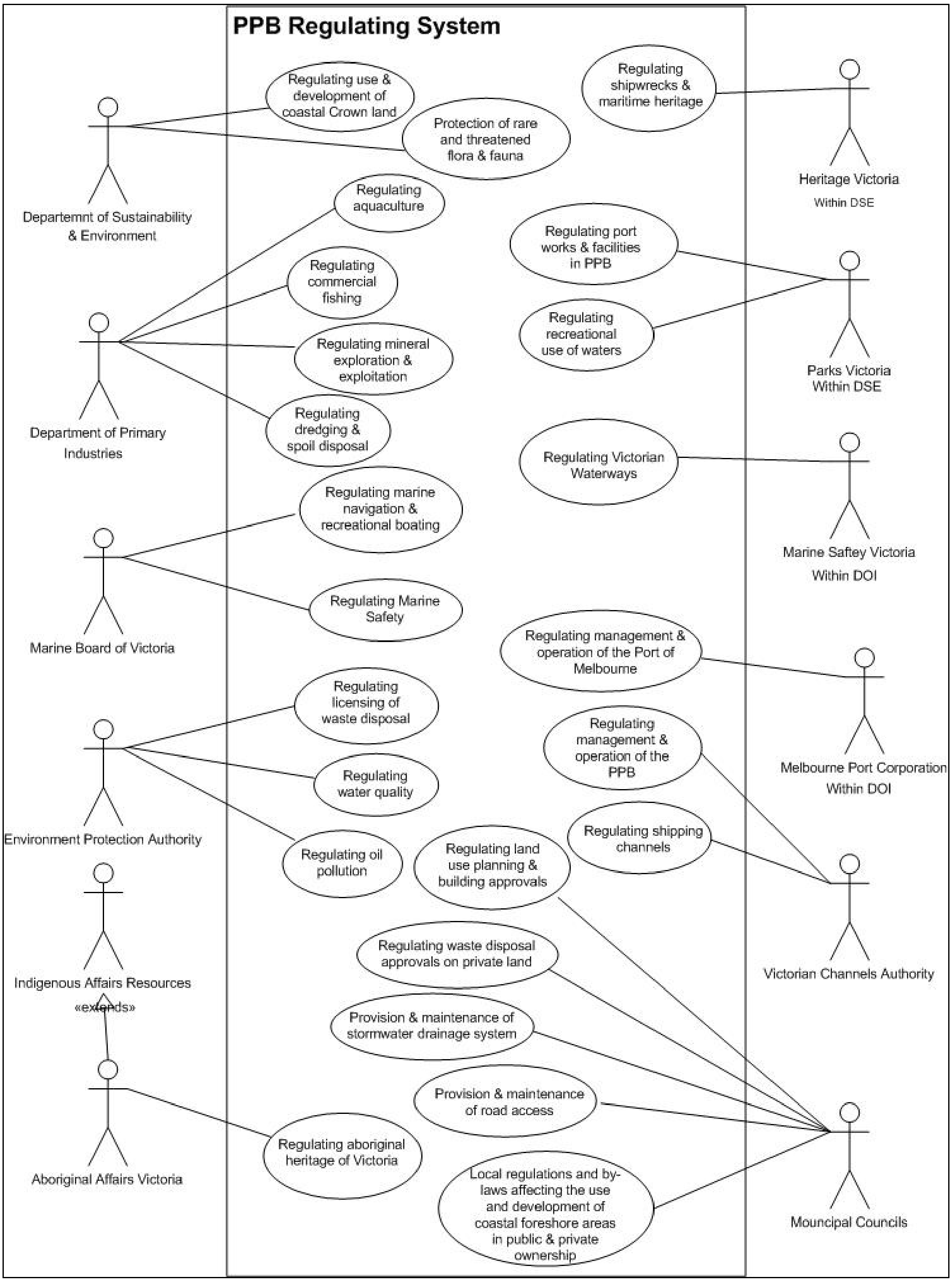

Figure 6.7 Stakeholders involved in PPB regulating system

6.4 Case Study Part 2 – Analysing/ Examining Available Spatial Data

The second part of the case study analysis involved obtaining available spatial data of PPB and examining and analysing this data. In this regard, a search was conducted to establish the available datasets for the marine and coastal areas of PPB. This involved searching various data directories and Internet portals online, data warehouses throughout Victoria and Australia, as well as collected through agreements with The University of Melbourne. This was done to provide an audit of all available data for the case study area at national, state and local scales (Table 6.2).

Table 6.2 Available datasets for Port Phillip Bay at different national, state and local scales

Available Datasets	Custodians
Victorian Coastline Data	GA
Melbourne and Surrounds	GA
AMBIS	GA
Bathymetry/Topography	GA
Boat Facilities	DOI
Marine Facilities	DOI
Aerial Photography	DOI
Wetlands	DSE
Marine National Parks	DSE
Watercourses- Vicmap	DSE
Shoreline -Vicmap	DSE
Bioregions	DSE
Oil and Gas Facilities	DSE
Pipelines	DSE
Environmental Vegetation Classification	DSE
Wetlands	DSE
Bathymetry	DSE
Aerial Imagery	DSE
TM Imagery	DSE
Off-shore Features	DPI
Coastline	DPI
Vessel Tracks	DEH/NOO
Defense Areas	DEH/NOO
Ammunition Dumps	DEH/EA
Boats Dumps	DEH/EA
Navigational Charts	Hydrographic Service R.A.N
Depth and Parcel Data	PoMC
Marine National Parks	Parks Victoria

In collecting the available datasets within the case study area, the main impediment to obtaining data was that there are some general datasets available, but there is limited data that is specifically related to PPB. When planners, managers and decision-makers need data for a particular area it will generally be collected on a once-off basis, used and then rarely used again. This project-based data is not available for re-use by someone else.

Metadata is also another important part of assessing the availability of spatial data. Some of the datasets did not come with metadata and this makes it very difficult to use the data. For example, the Melbourne and surrounds data was downloaded from GA's website but did not come with metadata or any other kind of data descriptions. Other aspects of the data such as the scale, reference frame and accuracy are critical in using the data, and need to be documented in the metadata. This part of case study revealed that data producers in the marine environment did not always produce or supply metadata with spatial datasets. Table 6.3 delineates the datasets within the case study and the availability of their metadata.

Table 6.3 Datasets in PPB case study and their availability of metadata

Dataset	Metadata
Victorian Coastline Data (GA)	Yes
Boat Facilities (DOI)	No
Marine Facilities (DOI)	No
Wetlands (DSE)	Yes
Marine National Parks (DSE)	Yes
Watercourses (DSE) - Vicmap	Yes
Shoreline (DSE) – Vicmap	Yes
Shoreline (DPI)	No
Bioregions (DSE)	Yes
Depth and Parcel Data (PoMC)	No
AMBIS (GA)	Yes
Bathymetry/Topography (GA)	Yes
Oil and Gas Facilities (DSE)	No
Pipelines (DSE)	No
EVC Wetlands (DSE)	Yes
Bathymetry (DSE)	No
Off-shore Features (DPI)	Yes
Vessel Tracks (DEH/NOO)	Yes
Defence Areas (DEH/NOO)	No
Ammunition Dumps (DEH/EA)	No
Boats Dumps (DEH/EA)	No
Aerial Imagery (DSE)	No
TM Imagery (DSE)	No
Navigational Charts (Hydrographic Service R.A.N.)	No

The only way in which users are able to make effective decisions is through knowledge of the accuracy and limitations of the data that they use. Metadata provides such knowledge, and would need to be provided for any dataset used within a Seamless SDI. This is especially so for fundamental and business datasets, although this would be part of any custodians role.

In order to investigate the need for seamless information, each dataset was assessed and included in the GIS. There were quite a few datasets available that had information about PPB, and that only two of these datasets could not be used because of interoperability issues.

Interoperability is the ability of a system or components of a system, to provide information portability and inter-application cooperative process control. In simple terms, interoperability is the ability of software and hardware on different machines from different vendors to share data (Webopedia 2008). To be interoperable, one should actively be engaged in the ongoing process of ensuring that the systems, procedures and culture of an organisation are managed in such a way as to maximise opportunities for exchange and re-use of information, whether internally or externally (Miller 2006).

Interoperability of the different datasets is critical as it can limit the usability of several datasets. In order to assess the interoperability of datasets within the case study area, the characteristics of data as format, licensing, pricing, scale and reference frame have been further analysed. Table 6.4 shows the results for the datasets for PPB.

Table 6.4 Interoperability of datasets for PPB

Dataset	Format	License	Pricing	Scale	Reference
Marine National Parks	ArcView shapefile	No	Free	Unknown	GDA 94
Coastline	ArcView shapefile	Yes	Free-agreement with Melbourne Uni	Unknown	GDA 94
Coastline	ArcView shapefile	No	Free	1:250,000	GDA 94
Depth and parcel data	ArcView shapefile	No	Free	Unknown	None

Melbourne and surrounds	ArcView shapefile	Yes	Free	1:250,000	GDA 94
AMBIS		Yes	Free	1:150,000	GDA 94
Arial photography	Image	Yes	Free-agreement with Melbourne Uni	1:15,000	
Bathymetry/Topography	ASCII or ER mapper	Yes	Free	1:13,000,000	WGS84

Table 6.4 shows that different data formats and scales limit the data interoperability and data integration of datasets within the main stakeholders of PPB. Most datasets came with a license, except those that were obtained directly from the custodian. All datasets were obtained free of charge, although normally the DSE data from Land Channel would have a nominal fee (the University of Melbourne has an agreement with the DSE and students can use the data free of charge through the University of Melbourne data library). Pricing and licensing indirectly affect the interoperability of the data as they are often important components for the data producers. They allow data producers to freely share their data without concern of misuse or worry about liability of a wrong decision made with their data. They also provide a nominal payment for the use of the data, supporting the ability of the data producer to conform to the recommended standards and policies. Licensing and pricing information therefore makes the data more available and more likely to be interoperable. This part of the case study analysis demonstrated the importance of not only making spatial data available, but of also having common standards and policies to make the data interoperable.

Considering all the limitations and issues regarding interoperability of datasets, Table 6.5 outlines the datasets that could be used for this research. It also gives the custodian, and the method of accessing the data.

Table 6.5 Availability of datasets for Port Phillip Bay

Dataset	Custodian	Access
Marine National Parks	Parks Victoria	contact custodian
Coastline	DSE	Land Channel
Coastline	DPI	contact custodian
Depth and Parcel data	PoMc	contact custodian
Melbourne and surrounds	GA	downloaded from internet
AMBIS	GA	downloaded from internet
Aerial photography **Not used**	DoI	Land Channel
bathymetry/topography **Not used**	GA	downloaded from ga.gov.au

The next step was the refinement and integration of data. Initial data refinement was based on spatial extent, appropriate scale and relevance to the coastal zone. Each dataset was individually assessed to ensure the scale was of sufficient resolution, its spatial extent encompassed Port Phillip Bay or surrounds, and its attributes were relevant to the coastal zone. Interoperability issues were then resolved where possible including varying projections and datums; data was refined and modified to geographic GDA94 coordinates as a base standard. All datasets were also converted as required to shapefile from other data formats. Throughout integration, metadata for each dataset (where available) was checked, and where possible features were appropriately attributed.

Investigation of spatial datasets in the case study highlighted a number of coastal management issues due to the lack of seamless information across the land – marine interface. In this section, two specific examples of these issues were highlighted for demonstration (Figures 6.8 and 6.9). For instance, there are discrepancies in datasets, mainly in the coastal area where the two coastline datasets that are available and the data from Geoscience Australia (GA) also showing the coastline are slightly different. Figure 6.8 illustrates the inconsistencies observed. Different organisations and agencies can delineate the same spatial feature in separate datasets without agreement on boundary location. The national GA coastline was more generalised; it simplified the coastline by ignoring smaller detail. The DSE Victorian shoreline showed much more detail and included more islands that are possibly temporary or only evident at low tide. GA's Victorian coastline was very similar to the DSE coastline but highlighted some different island features around the bay, one of which is evident in the centre of Figure 6.8 to the north of the mainland. The biggest difference at any point along the coast between the different versions was 1.3 km, and given the small scale and large positional uncertainty of one dataset, and that the scale and accuracy of the others is unknown, it is impossible to discern whether there is in fact any significant difference between the two, and thus which is the true coastline.

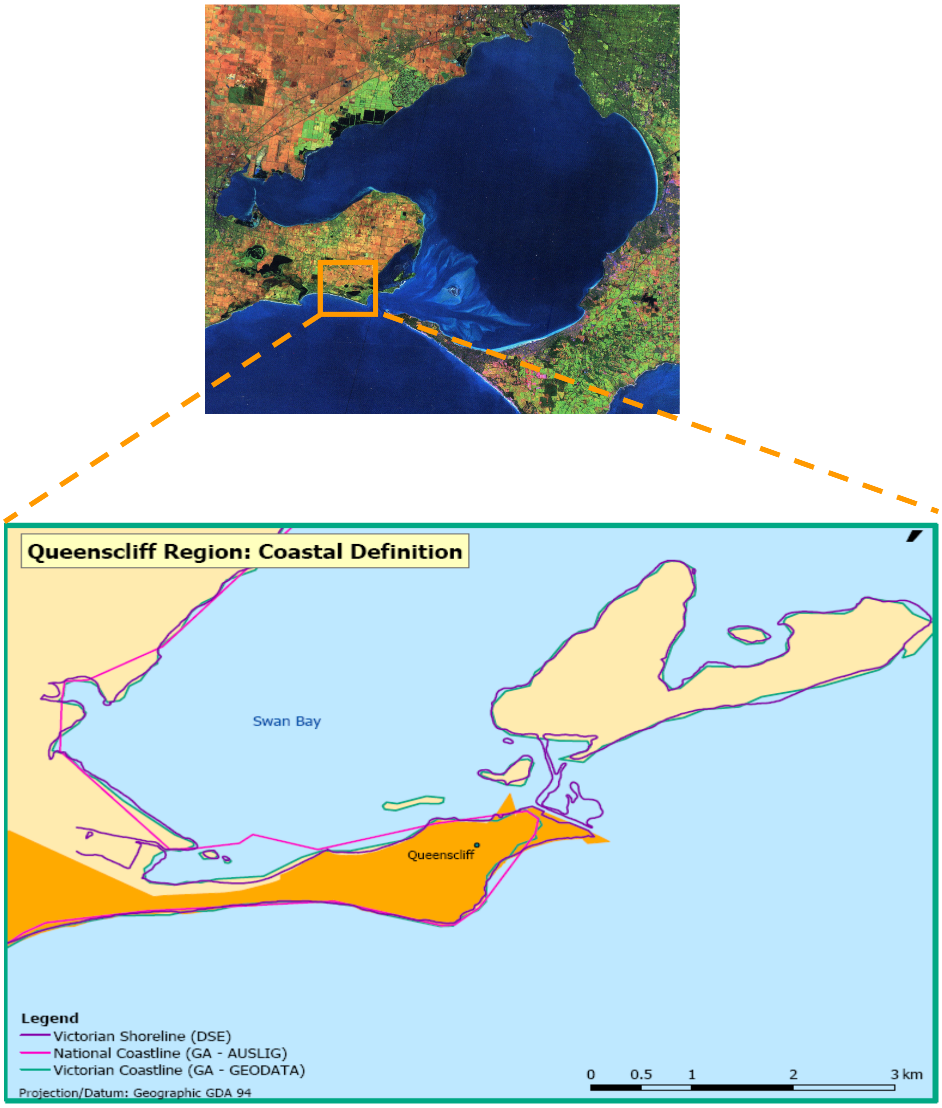

Figure 6.8 Coastline Differences in Port Phillip Bay case study data

There exists another discrepancy between the terrestrial based and marine based data sets over the coastal zone in the Port Melbourne Region of PPB. This is illustrated in Figure 6.9 where the terrestrial based topography and marine based bathymetry, both supplied by DSE, differs. Current bathymetry covers the area up to the low water mark, leaving a gap over the coastal zone between high and low a water mark that is not accounted for, largely due to the dynamic nature of the boundary. 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.

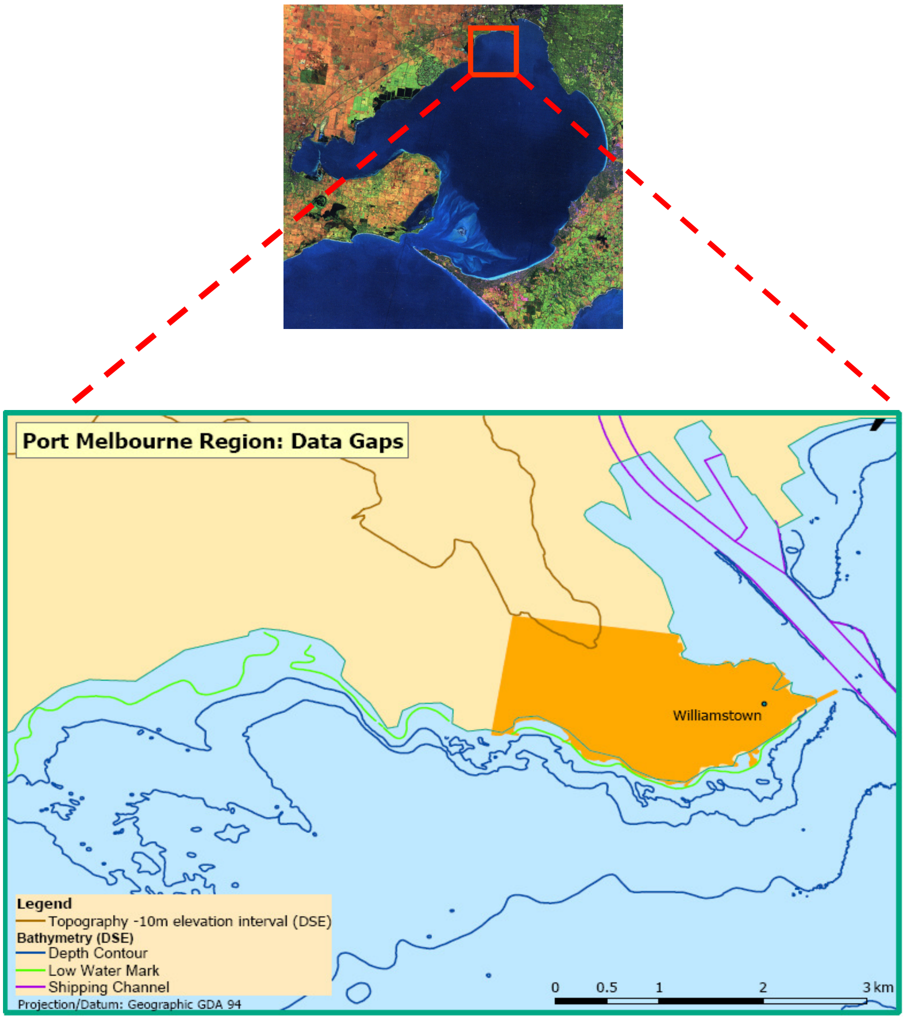

Figure 6.9 Data Gap over the land and marine interface

This part of the case study highlighted the limitations of integrating spatial data over the coastal zone. A major limitation of integrating existing coastal and marine spatial data is that no standard exists for data collection and maintenance, or metadata. Standards, policies and procedures involving coastal and marine spatial data need to meet SDI initiatives and function within the conceptual model of the Seamless SDI to effectively integrate and manage the coastal zone. If such a seamless system were adopted across the area many of these issues could be resolved or reduced through holistic and integrated management.

The next section of this chapter examines the accessibility and usability of spatial data from the point of view of stakeholders in PPB.

6.4 Case Study Part 3 – Interviews with Port Phillip Bay Management Authorities

The objective of the third part of the case study analysis was to identify current use, management and sharing of spatial data about Port Phillip Bay from the perspective of the people involved in managing this area. Furthermore, it aimed to identify the main limitations and opportunities in use, access and sharing of spatial information about PPB.

Spatial data plays an important role in aiding planning and management decisions in both the terrestrial and marine environments. The issues of access to and requirements of such data are well documented for land, but less so for the marine environment.

However different activities are involved in the management and administration of the marine and coastal environments which will require access to spatial information for better decision-making. Therefore, a common theme from many of the initiatives that aim to improve coastal and oceans management is the desire for access to appropriate and reliable spatial information to support these initiatives. Often the various spatial datasets are collected and stored by different organisations which can make them difficult to determine their existence and access. CSIRO (1998) describes the wide range of availability and accessibility of datasets within Australia and states that there needs to be an overarching framework that identifies common access policies, standards and networks.

In order to assess the current use and management of spatial data within the case study area, the main marine and coastal stakeholders in PPB were identified. Several organisations involved in management of PPB were selected to assess the nature of their responsibilities as well as their level of spatial data usage regarding the management and administration of the case study area (Table 6.6).

Table 6.6 Main stakeholders of PPB and their use of spatial data

Main Stakeholders in PPB	Nature of the Work	Use of Spatial Data
Victorian Coastal Council – within DSE	Manages the land and resources of Victoria's coastline and marine habitats, ensuring they are looked after for their environmental, conservation and recreational values.	Yes
Heritage Victoria – within DSE	The Victorian State Government's principal cultural heritage agency.	Yes
Department of Primary industries (DPI)	Concerned with conversion of natural resources to products. The Department supports the agriculture, fisheries, petroleum, minerals, energy, and forest industries in Victoria	Yes
Department of Environment and Heritage (DEH)	Develops and implements national policy, programs and legislation to protect and conserve Australia's natural environment and cultural heritage.	Yes
National Oceans Office (NOO) - within DEH	In 1998 Coasts and Oceans within DEH developed the NOO within the department of Environment Australia. NOO overseas the implementation of the Oceans Policy.	Yes
Department of Infrastructure (DOI)	Provider of essential infrastructure in Victoria	Yes
Marine Safety Victoria - within DOI	The State's marine safety agency, responsible for administration of the *Marine Act 1988* and the *Marine Regulations 1999*.	Limited
Port of Melbourne Corporation - within DOI	Manages business interests in the Port of Melbourne involving a large number of organisations.	Yes
Environment Protection Authority	EPA Victoria's purpose is to protect, care for and improve our environment.	Limited
Geoscience Australia (GA)	The national agency for Geoscience research and geospatial information. Provides Geoscientific information and knowledge important to industry, tourism and resources.	Yes
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	Australia's national science agency. Has diverse involvement in National and International activities including Agribuisness, Information, Manufacturing and Minerals, and Sustainable Energy and Environment.	Yes
Parks Victoria	Parks Victoria is the custodian of a diverse estate of significant parks in Victoria and of the recreational management rivers and	Limited

	bays.	
Indigenous Affairs Resources (National) Aboriginal Affairs Victoria (State)	The Victorian Government's central point of advice on all aspects of Aboriginal affairs in Victoria.	Limited
Municipal Councils	The peak representative and lobbying body for Victoria's 78 councils	Limited
NOTE - DNRE was replaced by the Department of Primary Industries and the Department of Sustainability and Environment in 2002.		

As illustrated by Table 6.6 most of the main stakeholders in PPB consider spatial data as an essential or important part in their day-to-day business activities while the other agencies such as Parks Victoria, Marine Safety Victoria, Environment Protection Authority, Aboriginal Affairs Victoria shows there is still a limited level of spatial data sharing and use.

Within this third part of the case study, a smaller number of the above organisations involved in management of PPB were selected for interview. Table 6.7 sets out the selected organisations and the interview questions.

Table 6.7 Selected organisations and the interview questions

Selected Organisations	**Questions**
1. Victorian Coastal Council	1) What spatial data is used 2) Who uses it and what for 3) How do they obtain this data 4) What standards and policies govern this data 5) Do they share their data directly or indirectly 6) What are the issues regarding spatial data use and sharing
2. Heritage Victoria	
3. Department of Primary Industries	
4. Port of Melbourne Corporation	
5. Bayside City Council	
6. Parks Victoria	
7. Marine Safety Victoria	

The number selected was determined by resource and time limitations. The questions were concerned with spatial data use, availability, accessibility, sharing, collection, standards and policies. The interviews were semi-structured as they required the ability for discussion as well as obtaining answers to the same questions. Table 6.8 describes the issues identified regarding spatial data accessibility, sharing, collection, standards and policies within the interviewed organisation.

Table 6.8 Issues with spatial data use and sharing within PPB

Stakeholders in PPB	Access Network	Standards/ Policies	Sharing	Issues
Victorian Coastal Council– within DSE	DSE internal data library or collected for a project	Set within DSE, i.e. at an organisational level	Don't share data with other organisations directly, but indirectly through DSE data library	-Different technologies -Different data formats -Compatibility -Data currency
Heritage Victoria– within DSE	Through DSE and Collected internally	-DSE standards and policies -No metadata -Privacy policies	Sometimes with PoMC	-Inconsistent formats -Inconsistent reference frames
Department of Primary Industries	-Land Channel /Geospatial Library - Contact custodian directly -Collect internally	-Australian Marine Safety Authority standards for OSRA -Standards based on project needs for other data -No metadata	-OSRA available for those working in oil spill response -Other DPI data rarely shared	-Inconsistent coverage -No budget for making data available and compliant with other standards -No one central authority or database where all data is stored
Port of Melbourne Corporation	Mostly collected by PoMC and use some VICMAP data	-Internal PoMC -Surveying standards for reference frame, precision and accuracy. -No metadata	Share data with Heritage Victora, the DSE, DPI and with their tenants. This is done through direct custodian contact	-Need large scale Data -No resources for improving data sharing -Compatibility of technology and data
Bayside City Council	Use Vicmap Data - Through DSE -Collected internally using contractors	No defined standards or Policies	Rarely	-Updating data -Limited funding and resources for improving spatial data use and collection
Parks Victoria	Through DSE and collected	Sometimes use ANZLIC or DSE standards	Within DSE	-Unwilling to make data compliant with set standards and

	internally	Often no standards or policies		policies -Poor spatial understanding -Lack of availability of data
Marine Safety Victoria	-Through DOI at an organisational Level -Collect internally through contractors	No defined standards or policies	Rarely	-Expense -Hardware issues -Connectivity -Keeping spatial data current

The results of this analysis show that while the stakeholders in PPB all want better access and sharing of spatial data, there are some common problems and limitations that are faced by each of them. These lead to poor interoperability between and within the stakeholders involved in management of the case study area. These issues are listed below:

- Most of them, such as Parks Victoria, have problems with data availability. The most fundamental data such as bathymetry does not exist on the scale required by the stakeholder.

- Spatial data is usually collected for a specific project and is collected at standards that are the best for that project. These policies and standards are set at an organisational level. Consequently it is unlikely that this project-based data would be made available for public use.

- As different datasets are collected by different agencies there will be a range of accuracies, standards, data formats, completeness and consistencies within the different spatial datasets which creates a lack of interoperability. Often those designing the datasets have little spatial understanding and do not take these issues into consideration.

- Most of the data sharing and access occurs on an informal and ad-hoc approach. It is believed that better access and sharing of data could be achieved by a more formalised approach; this would allow more organisations to share their datasets.

- Some agencies, such as Heritage Victoria, require policies, mostly concerning privacy as often the information they are dealing with is sensitive, as well as standards to govern the use of this spatial data.

- Often these stakeholders do not have metadata for their datasets as spatial data was collected and developed for in-house use without appreciation of metadata.

- The difficulties in collecting data are affected by differing availability: some spatial data is readily available, while, other data is much more difficult to collect. For example fishing catch data has privacy restrictions under the *Fisheries Act 1995* and so is only available with a filter and is difficult to obtain and rarely comes with metadata.

- Lack of budget/ resources within these agencies to make the data and metadata available or for further data maintenance, updating or conforming to certain standards.

- Project-based spatial data is collected for a one-off project is unlikely to likely be updated and maintained with the consequence that its accuracy is limited within a certain time-frame. The same data will not be collected again unless another project requires it.

- The difficulty with accessing data is that there is no one central authority or database containing all the available spatial data, and consequently it is difficult to ascertain the data custodian.

- The other main problem with using and sharing spatial data is that sometimes non-spatial stakeholders collecting the data such as marine biologists or geologists have limited spatial understanding, and do not appreciate the need for consistent standards or reference frames.

Overall these results have shown some of the limitations for the development of a Seamless SDI, or a SDI that can accommodate data from terrestrial as well as marine and coastal environments.

The results of the PPB case study can be compared to the previous research conducted by the marine cadastre research group within the Department of Geomatics, University of Melbourne in order to test the reliability of the case study. As part of the ARC marine cadastre project, there have been several attempts to assess user needs and current marine spatial data use and accessibility. A questionnaire was formulated as a tool to evaluate the usage and requirements for spatial data in the marine environment. It was made available to the public on-line from September 2002, with over 110 responses from stakeholders in the marine environment received over the following four months (Forse and Collier 2003). While this questionnaire was not directed at local/ state government level, most of the responses came from state and territory government agencies and departments, which is similar to the target audience for the PPB case study and as it is at a national scale there were responses from all around Australia, which can be used to verify the reliability of the PPB case study. Those who responded to the survey were nearly all users of spatial information and most of these were also suppliers and producers

The most relevant results from the questionnaire to the current case study research are summarised below:

- The importance of spatial information as perceived by respondents is overwhelming with 94% stating that it is an essential or important part of their business operations.

- Half of the respondents indicated that they have trouble accessing the spatial data that they need.

- The majority of respondents require 3 and 4 dimensional spatial information in the marine environment to adequately address their needs.

- Users of off-shore data are also very dependent on the data being up-to-date, reflecting recent changes in the marine environment, with no respondents stating that it was not important at all.

- Metadata (data that provides information or documentation of other data) is also very important to respondents, with over 30% citing it as critical to their needs.

- Despite the importance of metadata, the producers of data do not always supply such information to marine stakeholders. Some producers were even unsure whether they do or do not provide metadata.

- Those surveyed stated that the main impediments to accessing data were ascertaining its existence and the cost of the data. Format and licensing were also seen as major issues (Binns 2004).

However, there are some differences between this case study and previous research which came from the differences in the aims between the two. The third part of the PPB case study focused on spatial data use, management and sharing, while the previous research examined the possibility of an Australian marine cadastre and discussed spatial data within that context.

The results of this analysis demonstrate the common limitations and problems facing by each of the stakeholders in the development of a Seamless SDI. This further supports the findings regarding the barriers against implementation of a Seamless SDI model which have been discussed in Chapter 4 and Chapter 5.

6.5 Overall Findings

Overall these results have shown some of the limitations and problems for the development of a Seamless SDI, or a SDI that can accommodate data from terrestrial as well as the marine and coastal environments. The first part of the case study demonstrated the complexity of the management framework and the stakeholders' involvement from land, coastal and marine environments. These stakeholders have different rights, interests, or responsibilities for the management of this area. The task of efficiently and effectively managing all stakeholders' interests is complicated by the fact that their rights can often overlap, creating competing rights, restrictions and responsibilities. This gives rise to the need for cooperation between agencies, something which can be difficult to achieve. However, it is believed these problems can be overcome through coordination arrangements and the existence of a single management authority or forum within a

Seamless SDI model for collaborative planning. There should be proper regulation to enforce that all spatial data providers should be involved in and contribute to the development of a Seamless SDI.

Further, the second part of the case study investigated the availability, accessibility and interoperability of spatial data within PPB through collecting all available data. One of the most significant problems found with integration of land and marine spatial data was the lack of interoperability of different datasets from different custodians. The biggest impediment to interoperability was that not all organisations used the same data format, and so their data could not be integrated with other data. The other problems were the differences in scales, quality and coverage of spatial data and the lack of or poor quality of metadata. The ability to use another's data often relied on that data including comprehensive metadata and this was not always available. Therefore, an issue that was brought up in this part of the case study was the need for interoperability across the land – marine interface. The stakeholders in PPB are responsible for managing not only marine and coastal areas, but also terrestrial areas, and activities (i.e. tourism, oil and gas mining) that may cover all of these environments. Thus, there is a need for seamless layers of spatial data that could cover all of these areas, or datasets that are able to be integrated from all areas. This part of the case study can be compared to the research from Chapter 2 into marine and coastal management issues and the justification for seamless information.

Lastly, the third part of the case study examined the current use, access and sharing of spatial data from the perspective of the selected stakeholders responsible for managing this area. The third part of the case study research highlighted the fact that marine and coastal spatial data is used by many different organisations and sectors. All organisations reviewed described spatial data as important for their business activities while much time and resources were spent on data collection. Spatial data is shared between some organisations, and within departments. The common datasets that were used are: transport, parcels, reserves, cadastre, wharfs, land use, land values, imagery, emergency zones, utilities, channels, pipelines, navigation aids, and historical features. This data comes from both the land and marine environments. Therefore, the Seamless SDI model at the higher level should accommodate fundamental datasets from land, coast and marine environments.

Further, it showed the same main problem with data sharing from the data user perspective including a lack of interoperability from different data formats, reference frames and metadata, caused by institutional unwillingness and a lack of ability to adopt common data standards and policies. As identified from the user perspective, determining what data is available is difficult because there is no one organisation or authority that holds all spatial data, so that users could generally only contact the possible data custodian directly. It results from the lack of a formalised approach to data collection, maintenance and sharing in the marine and coastal environments and many users believed that improvements could be made if there was a formal and common approach. From the provider perspective making data available is difficult because data is usually collected for a particular project, and is rarely made available for other organisations to use, as this would involve adapting the data to common standards and policies. The interviews highlighted that there is much duplication in collecting spatial data in PPB and that the stakeholders in this area are becoming more open to the idea of sharing spatial data within a common framework.

This further supports the need for a common and seamless platform which leads to the promotion of data sharing and communication between organisations thus facilitating better decision-making involving marine and coastal spatial information.

6.6 Chapter Summary

This chapter described the research design and the case study that were undertaken within this research project. The aim of the case study was to describe and examine the limitations and barriers to development of a Seamless SDI. It discussed the potential for extending the Australian SDI to include the marine environment, within the context of local and state SDI levels. While the research was based on a case study of a small part of Australia, the results and principles can be applied generally with the outcome being extended model for the whole country.

The chapter examined availability, integratability, accessibility and sharing at the state and local jurisdictional level, identifying the current limitations and opportunities from the perspective of the main stakeholders responsible for managing Port Phillip Bay. The case study research can be compared to the research findings from Chapter 4 (issues and barriers of creating a Seamless SDI) and the emergence of a Marine SDI at national and international levels, and more general SDI research and the Australian SDI from Chapter 3.

The case study showed that spatial data is an integral business component for the many organisations that manage PPB. Spatial data is used in many different activities from maintaining heritage sites to harbour control and marketing. While all organisations are collecting their own data and using their own standards and sharing policies, there is some coordination within the organisations that are a part of the DSE. Many organisations also stated that there was improved use and appreciation of common standards internally and that they are beginning to examine other opportunities for obtaining spatial data other than collecting it themselves.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

This research investigated the potential for adding the marine and coastal dimension to a SDI in the context of a seamless model to facilitate marine and coastal zone administration thus resulting in better and more integrated management of the land – marine interface. The research identifies the main characteristics and criteria for utilisation of a "Seamless SDI model". In this regard, a Seamless SDI conceptual model and its key components have been developed and associated guidelines proposed.

This chapter returns to the research design to close the loop on the scientific method. It reviews the earlier chapters and synthesizers the key research findings. The chapter aims to determine the success and limitations of the research design used to develop the Seamless SDI conceptual model. It also looks to the future and discusses the potential research opportunities in the field of a Seamless SDI model.

7.2 Research Summary

The research problem was defined as:

"The research problem is that current SDI design is focused mainly on access to and use of land related datasets or marine related datasets, with most SDI initiatives stopping at the land-ward or marine-ward boundary of the coastline, institutionally and/or spatially. Consequently, there is a lack of harmonised and universal access to seamless datasets across the land – marine interface from marine, coastal and land based spatial data providers. This leads to the creation of inconsistencies in spatial information policies, data creation, data access, and data integration across the coastal zone that limits sustainable management and development of the coastal zone."

The overarching hypothesis of the research was therefore:

"The development of a seamless platform covering the land and marine environments as part of the National SDI would facilitate greater access to more interoperable spatial data and information across the land – marine interface enabling a more integrated and holistic approach to management of the coastal zone."

In the context of this research the background investigations resulted in a number of objectives which relate directly to the hypothesis. By answering the research objectives below the hypothesis can be proven. As such the research has fulfilled its objectives.

7.2.1 Objective 1: Investigate and justify the need for seamless information across the land – marine interface

The justification of the need for seamless information across the land – marine interface by using examples has been achieved in Chapter 2. This chapter identified major current marine and coastal management issues and their potential impacts with the primary focus being Australia's coastal and marine jurisdiction. The chapter examined the management and administration of rights, restrictions and responsibilities in Australia's coastal and marine environments and discussed how the ability to map and spatially define such issues would be an essential component for a more efficient and effective management regime, balancing the rights and responsibilities of multiple users. The legislation that controls the marine and land – marine interface was analysed.

Furthermore, the link between the terrestrial and marine environments was recognised and consequently that marine and land spatial data cannot be treated separately. However, the research revealed current regulatory methods for the management of the coastal zone separate it into land and sea, with the use of spatial information for this area also remaining separated. This separation hinders the development of solutions to identified marine and coastal management issues which straddle the land – marine interface, such as the pollution of the marine environment from land-based sources. For an integrated management regime to result, the integration of land and marine spatial data within the coastal zone needs to occur. This led to justification of the need for seamless information across the land – marine interface.

7.2.2 Objective 2: Investigate and understand current land and marine SDI initiatives and concepts at both national and international levels

Investigation of current land and marine SDI initiatives and concepts at both national and international levels was undertaken in Chapter 3. This chapter gave an overview of some of the most prominent examples of SDI or other spatial information initiatives that focus on the marine or coastal environments and highlighted the need for a seamless platform across the land – marine interface. It reviewed the current developments and implementations of Marine SDIs in Australia, Canada, Europe and US.

The research showed that Marine SDI initiatives are developing in many countries, all with the aim to facilitate marine and coastal spatial information sharing to improve decision-making and management of the marine and coastal environments. It has been shown that there is a need for a better and more comprehensive way to link different off-shore initiatives offering a more integrated understanding of the marine and coastal environments as there is a tight connection between inland and marine coastal areas. These findings further support the premise that Marine SDI and Coastal SDI cannot and should not be developed in isolation from the broader National SDI of any jurisdiction.

7.2.3 Objective 3: Investigate the characteristics and components for the design of a Seamless SDI model

The potential for adding the marine and coastal dimension to a SDI in the context of a seamless model resulting in better and more integrated management of the land – marine interface has been introduced in Chapter 4. This is followed by an introduction to the overarching architecture for developing a Seamless SDI and its associated components that allows access to and interoperability of data from marine, coastal and terrestrial environments.
The chapter then listed a number of technical, institutional, policy and legal spatial data integration issues and problems associated with effective land and marine data integration. Issues of data integration were discussed in two main categories: technical and non-technical issues and some of the potential solutions. The current barriers and challenges against implementation of this model were investigated.

7.2.4 Objective 4: Develop and propose a Seamless SDI model and associated guidelines using current SDI theory and models to incorporate identified characteristics and components

The development of a Seamless SDI model and implementation guidelines has been built on the investigation of real life experiences, discussion with practitioners and current theory and practice in SDI development throughout the world.

Chapter 5 addressed objective 4 of this research by presenting the design and development of a Seamless SDI model. It proposed the conceptual model of a Seamless SDI by using Hierarchical Spatial Reasoning and the Seamless SDI class and its inherited characteristics and properties as discussed. In the design phase, the Use Case Diagram and Object Diagram of the Enterprise Viewpoint were developed. These diagrams described Seamless SDI systematically and their context, users, providers, services and so on, necessary to establish them.

The model proposed in the design phase was developed during the implementation phase. In this regard, Chapter 5 presented Seamless SDI guidelines as a necessary step by step approach to create a Seamless SDI for any jurisdiction with a marine environment which might support and participate in a Seamless SDI. It provides necessary information for practitioners in order to deal with the complexity of creating a Seamless SDI. The guidelines can be utilised as a part of the tool or as an individual document that helps identify potential barriers and possible enablers.

7.2.5 Objective 5: Test the limitations of developing a Seamless SDI with a particular focus on Australia's marine jurisdictions

Testing the limitations of developing a Seamless SDI has been achieved by using a case study approach in Chapter 6. This chapter examined availability, integratability, accessibility and sharing of spatial data at the state and local jurisdictional level, drawing out the current limitations from the perspective of the main stakeholders responsible for managing Port Phillip Bay.

This further supports the need for a common and seamless platform which leads to the promotion of data sharing and communication between organisations thus facilitating better decision-making involving marine and coastal spatial information.

7.3 Key Findings and Contributions to Knowledge

This research revealed the need for seamless information across the land – marine interface that could cover land, marine and coastal environments. This was achieved by describing the examples of current marine and coastal issues through examining the management and administration of rights, restrictions and responsibilities in Australia's coastal and marine environments. It demonstrated the ability to map and spatially define such issues. This would be an essential component for a more efficient and effective management regime and balancing the rights and responsibilities of multiple users.

Hence, there is a need to build a seamless platform that underpins off-shore rights and responsibilities and sensibly matches to its on-shore counterpart. This development can be aggregated flexibly and incrementally in a spatial framework underpinning the administrative infrastructure.

The investigation of SDI concepts, components and the salient properties of current SDI initiatives (both land based and marine based and/or straddling the land – marine interface) within Australia and internationally were conducted. This led to the identification of the commonalities and differences between land and marine based SDI initiatives along with influential treaties and conventions driving the development of a Seamless SDI.

Further, this research introduced the concept and definition of the Seamless SDI and generally highlighted its characteristics and components. It recognised the attributes and characteristics of the Seamless SDI platform are different from the existing platform. It identified that building a Seamless SDI encounters several technical and non-technical issues, however the non-technical issues are the most difficult problems to overcome. It listed a number of technical, institutional, policy and legal spatial data integration issues associated with effective land and marine data integration and some of the potential solutions.

The major contribution of this research is the development of a Seamless SDI conceptual model and implementation guidelines. They have been built on the investigation of real life experiences, discussion with practitioners and current theory and practice in SDI developments throughout the world. Defined actions were utilised within each of the SDI components of people, data, access network, standards and policies in order to overcome identified barriers to the creation of a Seamless SDI. By using Hierarchical Spatial Reasoning, the conceptual model of Seamless SDI has been proposed and the Seamless SDI class and its inherited characteristics and properties have been discussed. The model proposed addresses the objectives of the research and responds to the problems discussed earlier. Furthermore, the Use Case Diagram and Class Diagram of a Seamless SDI have been designed. These diagrams described a Seamless SDI systematically and its context, users, providers, services and so on, necessary to establish them. These models could be seen as a contribution towards the overall model of the Seamless SDI and its technical characteristics.

It further noted that the task of evaluating a Seamless SDI is difficult due to its complex, dynamic and constantly evolving nature. However, each component of the Seamless SDI namely policies, standards, access network, people and data can be considered as the main evaluation areas based on the predefined indicators.

Furthermore, the Seamless SDI guidelines need to be tested and evaluated in different jurisdictions. Each jurisdiction has its own considerations and guidelines for developing their SDIs and a set of indicators for assessing its different components. It is not definitive in its nature, and is highly dependent on the needs and objectives of the respective jurisdictions and the context of the respective SDIs.

The case study demonstrated the complexity of a management framework and the stakeholders' involvement coming from land, coastal and marine environments in Port Phillip Bay. These stakeholders have different rights, interests or responsibilities for the management of this area. The task of efficiently and effectively managing all stakeholders' interests is complicated by the fact that their rights can often overlap, creating competing rights, restrictions and responsibilities. This gives rise to the need for cooperation between agencies, something which can be difficult to achieve.

Furthermore, the case study demonstrated the difficulties of integrating terrestrial, coastal and marine data and the need for a seamless platform across the land – marine interface. It found the biggest problem was the lack of interoperability of different datasets from different custodians in PPB. The major impediment to interoperability was that not all organisations used the same data format, and so their data could not be integrated with other data. The other problems were the differences in scales, quality and coverage of spatial data and the lack of or poor quality of metadata. The ability to use another's data often relied on that data including comprehensive metadata and this was not always available. As a result, the overarching issue was the need for interoperability across the land – marine interface.

The case study highlighted the same problem with data sharing from the data user perspective including a lack of interoperability from different data formats, reference frames and metadata, caused by institutional unwillingness and lack of ability to adopt common data standards and policies. From the provider perspective making data available is difficult because data is usually collected for a particular project, and is rarely made available for other organisations to use, as this would involve adapting the data to common standards and policies. This highlighted the current limitations from the perspective of the selected stakeholders responsible for managing the PPB.

The result of the research is a Seamless SDI conceptual model and its implementation guidelines that seamlessly covers both land and marine environments and can be used by jurisdictions to create an enabling platform for the use and delivery of spatial information and services. This development aims to meet the initial needs of stakeholders in the coastal zone in line with the sustainable development (economic, environmental and social) goals of the region. The seamless enabling platform provides more efficient and effective decision-making capabilities across both the marine environment and land – marine interface.

Successfully addressing the issues associated with building a Seamless SDI results in more efficient implementation of initiatives such as coastal flood visualisation, disaster management and response, and/or Integrated Coastal Zone Management.

7.4 Assumptions and Limitations

While there are many different SDI definitions resulting from the different country contexts or disciplines, the SDI model defined by Rajabifard and Williamson (2001) (Figure 3.1) has been be adopted for SDI throughout this thesis.

In design of the seamless platform, the well-recognised SDI components namely people, access network, policy, standards and data are considered as main components of the Seamless SDI. However, the attributes of these components are different from the existing SDI platform.

Despite the fact that the research design has been justified, there are a number of limitations. These are predominately time and resource constraints. No case studies were conducted outside Australia. An in-depth case study of nations formed by archipelagos or whose coastlines are extensive comparative to their land mass would have provided additional validation of the Australian case study results.

The Use Case Diagram and Object Diagram of Enterprise viewpoint were not fully developed. The UML was used to describe the different elements that make up the Seamless SDI, both physical and conceptual. In the case of fully developed diagrams, there are problem of dealing with a large number of classes with a large number of associations. The resulting model is a preliminary model of a Seamless SDI. These limitations could be used as starting points for future research in the area.

7.5 Recommendations for Further Research

The outcomes of this research have highlighted a number of areas that require further research.

Firstly, the integration of land and marine spatial data across the coastal zone needs further work by addressing the technical and non-technical barriers and possible solutions.

Secondly, further investigation of the application of the Seamless SDI guidelines in different jurisdictions is required since they are highly dependent on the needs and objectives of the respective jurisdiction and the context of the respective SDI. Each jurisdiction has its own considerations and guidelines for developing their SDIs.

Thirdly, further evaluation of the performance of the Seamless SDI model and its associated guidelines would improve the Seamless SDI model. The current research is a starting point for developing an assessment framework on the performance of the Seamless SDI model.

Finally, the Seamless SDI model presented in this research is not the ultimate model of SDI, but provides a useful starting point for developing a systematic model of Seamless SDI. Other issues that could be considered when developing such models include:

- Funding model;
- Governance framework;
- Capacity building;
- Interoperability issues between land and marine environments;
- Semantic model of a Seamless SDI; and
- Using OWL Language in line with UML for designing a Seamless SDI.

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APPENDIX 1: LIST OF PUBLICATIONS

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1) **Vaez, S**., Rajabifard, A., Binns, A. & Williamson, I. (2007), 'Seamless SDI Model to Facilitate Spatially Enabled Land Sea Interface', *Proceedings of SSC 2007 ,The national biennial Conference of the Spatial Sciences Institute*, May, Hobart, Australia.

2) Rajabifard, A., **VAEZ, S.** & Binns, A (2007), 'Marine SDI to Facilitate Spatially Enabled Government and Society', *Proceedings of 5th International Congress Geomatica 2007 "Workshop on Marine/Hydrographic Spatial Data Infrastructure",* 12 February 2007, Havana, Cuba.

3) **Vaez, S**., Rajabifard, A. & Williamson, I. (2007), 'The Role of Marine SDI to Facilitate Marine Administration', *GeoConference* 2007, October, Quebec, Canada.

4) **Vaez, S**., Rajabifard, A., Binns, A. & Williamson, I. (2007), 'Developing a Seamless SDI Model across the Land-Sea Interface',*CoastGIS07,*8-10 Octobor2007, Santander, Spain.

5) **Vaez,S**., Rajabifard, A. & Williamson, I. (2007), 'Facilitating Land- Sea Interface through Seamless SDI', Coordinates, Volume III, Issue 10,pp.14-18.

6) **Vaez,S**.(2007), **'**Seamless SDI Model to Facilitate Spatially Enabled Society', Rajabifard, A. (edt),*Towards a Spatially Enabled Society*, 1st edn, The University of Melbourne, Australia, pp.343-351.

7) **Vaez,S**., Rajabifard, A. & Williamson, I. (2007),'Developing Marine SDI to Facilitate Marine Administration-the Spatial Dimension', *Proceedings of Hydro2007-Focus on Asia,* 21-24 November 2007, Cairns, Australia.

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10) Vaez,S., Rajabifard, A. & Williamson, I. (2009), 'Seamless SDI Model Bridging the Gap between Land and Marine Environments', NCG, Nederlandse Commissie voor Geodesie, Netherlands Geodetic Commission SDI Convergence. Research, Emerging Trends, and Critical Assessment (Editors) B.van Loenen, J.W.J. Besmer, J.A. Zevenbergen.