UNIVERSITY OF SOUTHERN QUEENSLAND

SPATIAL INFORMATION SHARING FOR CATCHMENT MANAGEMENT IN AUSTRALIA

A Dissertation Submitted by

Dev Raj Paudyal

BSc (TU), MSc (ITC)

For the award of

Doctor of Philosophy

July 2012

CERTIFICATION OF DISSERTATION

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

Parts of this work were published in refereed conference proceedings, journals and book chapters as listed page number xvii.

________________________________ ______________

Dev Raj Paudyal, Candidate — Date

ENDORSEMENT

________________________________ ______________

A/Professor Kevin McDougall, Principal Supervisor — Date

________________________________ ______________

A/Professor Armando A Apan, Associate Supervisor — Date

ABSTRACT

Spatial information plays an important role in many social, environmental, economic and political decisions and is increasingly acknowledged as a national resource essential for wider societal benefits. Natural Resource Management (NRM) is one area where spatial information can be used for improved planning and decision-making processes. Traditionally, state government organisations and mapping agencies have been the custodians of spatial information necessary for catchment management. Recent developments in Information Communication Technology (ICT) tools and spatial technology have provided community groups and grass-root citizens with no prior experience in spatial technology with a new opportunity to collect and manage spatial information. With these opportunities, regional NRM bodies in Australia are collecting a significant amount of property and catchment scale spatial information. The access and sharing of spatial information between state government agencies and regional NRM bodies is therefore emerging as an important issue for sub-national spatial data infrastructure (SDI) development.

The aim of this research is to identify key factors which influence spatial information sharing between state government organisations and regional NRM bodies/catchment management authorities within Australia and to formulate strategies to facilitate spatial information sharing and hence support SDI development. The hypothesis is that the spatial information sharing in natural resource management needs to be improved and that a networked based spatial data infrastructure model may be an appropriate approach.

This research explored the theoretical foundation for SDI development and utilised social network theory to explore spatial information sharing arrangements between regional NRM bodies and state government organisations. A mixed method research approach was utilised where a survey and the case study data were collected and analysed sequentially (i e in two phases). The findings from the national survey of NRM bodies and the case study were integrated and interpreted to identify the key factors influencing spatial information sharing and catchment SDI development in Australia.

A national survey of regional NRM bodies investigated the spatial information access, use and sharing arrangements between regional NRM bodies and state government organisations. The results of the survey indicate that the spatial data access policy of state government organisations impacts on spatial information sharing across NRM bodies. The regional NRM bodies have a strong spatial capacity and are emerging as key players in spatial data infrastructure development in the natural resource management sector. An ongoing issue is the difficulty to locate which organisation holds each type of spatial data and accessing these datasets. Data sharing and spatial information management is a key area of collaboration and is based on the partnerships with state government organisations or community organisations. An emerging area for collaboration in the NRM sector is knowledge sharing.

The case study explored the effectiveness of the Knowledge and Information Network (KIN) project in promoting spatial information sharing arrangements between regional NRM bodies and state government organisations. It identified the role of intermediary organisations and professionals such as the Regional Groups Collective (RGC) and knowledge coordinators as being critical to improving the communication and spatial information sharing across catchments.

Using the mixed method design framework, the key factors which influence spatial information sharing between state government organisations and regional NRM bodies/catchment management authorities were classified into six major classes as organisational, economic, policy, legal, cultural and technical. Major strategies were formulated and it is suggested that the adoption and implementation of these strategies can facilitate spatial information sharing and hence SDI development across the natural resource management sector.

ACKNOWLEDGEMENTS

There are many people and organisations to thank for their support in making this thesis a reality. Associate Professor Kevin McDougall, my principal supervisor, has been a source of encouragement throughout this journey. You are a true mentor. I was dispersing my research concept throughout this world and I felt so lucky that you showed interest in my research ideas. You not only teach me "research stuff" but many other things which are needed to be a true researcher. If 5% of your character reflects on me I shall feel that I am respectful upon you. I am grateful to you for the respect you have always shown for my ideas and for my mistakes. I am also indebted to Associate Professor Armando Apan, my associate supervisor, for his motivation, helpful comments and challenging questions that encouraged me to look further in my PhD journey. His rich knowledge in natural resource management and experiences with handling many post-graduate students helped me to complete this dissertation on time.

I am grateful to Professor Harlan Onsrud, Professor David Coleman, Dr Bastiaan van Loenen, and Dr Joep Crompvoets for their mentoring during a PhD workshop at Singapore. The speed networking was really a wonderful experience. Thanks are also due to the other distinguished Professors Abbas Rajabifard, Arnold Bregt, Francis Harvey, Ian Masser, Paul van der Molen, Yola Georgiadou, and Zorica Nedovic-Budic who provided invaluable advice, critical comments and research direction during PhD workshops and whenever I approached them. It was really a great experience to share knowledge with other PhD fellows around the globe. Ara Toomanian (U of Lund), Boris Mericksay (U of Laval), Christine Richter (ITC), Danny Vandenbroucke (KU Leuven), Ezra Dessers (KU Leuven), Frederika Welle Donker (TU Delft), Glenn Vancauwenberghe (KU Leuven), Halim Hamzah (Universiti Putra Malaysia), Heri Sutanta (U of Melbourne), Lukasz Grus (U of Wageningen), Prasanna Kolte (ITC), Tara van Dijk (U of Amsterdam), and Walter de Vries (ITC) deserves special thanks.

I am grateful to the Australian Government, USQ Faculty of Engineering and Surveying and Australian Centre for Sustainable Catchments (ACSC) for providing me the financial support to complete this study. My thanks go to the staff members of the Faculty of Engineering and Surveying, the Office of Research and Higher Degrees, Human Research Ethics Committee, Library and Student Guild Board for their kind support. I especially thank Professor Frank Bullen for providing me a comfortable research platform, Professors David Buttsworth and Thiru Aravinthan, the then Associate Dean of Research, for encouragement and support, Mrs Juanita Ryan for administrative support, Mr Dean Beliveau for accommodation and socialisation and Mr. Clinton Caudell for technical support. My due respect and thanks goes to my colleagues from Surveying and Spatial Science discipline, Dr Peter Gibbings, Dr Glenn Campbell, Mr Shane Simmons, Dr Kithsiri Perera, Mr Zhenyu Zhang, Dr. Xiaoye Liu and Ms Marita Basson. I am also indebted to Faculty librarian Ms Sandra Cochrane for her librarian support and proof-reading my draft manuscript. My special appreciation goes to Mrs Bernie Lang for the final proof reading and editing of this dissertation.

I am very thankful to the post-graduate mates who shared experiences and time with me: Allan Manalo, Abdul Aziz Hairuddin, Ahmad Suriadi, Alison McCarthy, Dao Minh Ho, Gavin Brink, Ibrahim Khalil, Sileh Khalid Hashim Saleh, Mior Azman Meor Said, Nazmi Mat Nawi, Precila Salcedo, Ray Malpress, Sarang Ghude, Shahab Abdulla, Uddin Md Jasim and Ziad Awad.

My special thanks go to Sudarshan Karki, Govind Prasad Baral and Bijay Gyawali for encouragement, support and care of my children in my absence. My Nepalese post-graduate research folks: Arun Dhakal, Roshani Shrestha, Rohini Prasad Devkota, Arjun KC, Sanjib Tiwari, Arjun Neupane, Shiva Pandey and Hemang Sharma deserve very special appreciation, also all members of Nepalese Association of Toowoomba (NAT) including undergraduate Nepalese students and their dependents who made my residing very comfortable deserve appreciation. There are many other names I am missing but you all are in my heart.

I would like to express my sincere thanks to Badri Basnet for his unconditional continuous support from social to academic spin. I finally decided to stay near you to pay your debt. Also, I would like to express my gratitude to other Nepalese community members Tek Maraseni, Saru Maraseni, Tunna Burathoki, Manju

Burathoki, Bhagwati Basnet, Ramesh Damai and Kamala Damai for their continuous inspiration and encouragement.

I would like to thank all representatives from the 56 regional NRM bodies who understood the value of my research and provided 100% response rate to my online survey. Very special thanks are due to spatial leaders in Queensland NRM groups: Allison Hackwell (BMRG), Brett Coppard (QMDC), Roxane Blackley (QMDC), Doug Willis (NQ Dry Topics), Emily Maher (BMRG), Isherwood Miya (TSRA), Jade Fraser (DCQ), Lucy Richardson (Condamine Alliance), Ric Newson (SW NRM), Andrew Drysdale (RGC), Lee Blacklock (RGC), Kenyon Kirstin (DERM), Bronwyn Fryar (FBA), Michael Digby (N Gulf), Trevor Parker (N Gulf), Reuben Sinclair (Terrain NRM), and Raymond De Lai (HRIC) for their invaluable input and support.

I would also like to thank my seniors and colleagues in Survey Department of Nepal who have supported and encouraged me in this PhD study. Thanks are due to Raja Ram Chattakuli, the then Director General of Survey Department, Babu Ram Acharya, the then Secretary Ministry of Land Reform and Management, Tirtha Bahadur Pradhananga, Narayan Bahadur Karki, Rabin Kaji Sharma, Jagat Raj Paudel, Krishna Raj BC, Krishna Prasad Sapkota, Ganesh Prasad Bhatta, Narayan Kumar Shreshtha, Dilli Raj Bhandari, Khil Raj Chauhan, Khim Lal Gautam and other colleagues who had assisted me in many ways.

I am indebted to my parents, Dilli Raj Paudyal and Hari Kala Paudyal. This degree was the dream of my father too. My special gratitude is due to my brothers: Ghanashyam and Madan, my sisters: Sita and Prabha, and their spouses for their loving support. I would also like to thank my father-in-law Surendra Sapkota and mother-in-law Urmila Sapkota, Santu and Sachin (brothers-in-law), Pratibha and Ayushma for their enthusiastic support and encouragement. Of course special thanks go to my lovely wife Charu and two Socceroos Utkrist and Prasiddha for their sacrifices in supporting my studies. Every day they were asking me how many pages of thesis were due. They had a simple mathematical calculation that if I wrote two pages daily, why it is taking more than four years of time to finish 250 pages of dissertation. Finally, I did it and now I am with you…………Hurray!!!

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AANRO	Australian Agriculture and Natural Resource Online
ABARES	Australian Bureau of Agricultural & Resource Economics Sciences
ACT	Australian Capital Territory
ALIC	Australian Land Information Council
AND	The Australian Bibliographic Database
ANRII	Australian Natural Resource Information Infrastructure
ANT	Actor-Network Theory
ANZLIC	Australian New Zealand Land Information Council
ASDD	Australian Spatial Data Directory
ASDI	Australian Spatial Data Infrastructure
AusGOAL	Australian Governments Open and Access Licencing
BRS	Bureau of Rural Sciences
CANRI	Community Access to Natural Resources Information
CAP	Catchment Action Plans
CGDI	Canadian Geospatial Data Infrastructure
CMA	Catchment Management Authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAF	Department of Agriculture and Food
DCDB	Digital Cadastral Data Base
DEC	Department of Environment and Conservation
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DERM	Department of Environment and Resource Management
DIKW	Data, Information, Knowledge and Wisdom
DNRW	Department of Natural Resources and Water
DPIPWE	Department of Primary Industries, Parks, Water and Environment
DoW	Department of Water
EPA	Environmental Protection Authority
ERIN	Environmental Resources Information Network
EU	European Union
EUROGI	European Umbrella Organisation for Geographic Information
FGDC	Federal Geographic Data Committee
FIG	International Federation of Surveyors
FTP	File Transfer Protocol
GI	Geographic Information
GII	Geographic Information Infrastructure
GIS	Geographic Information System
GSDI	Global Spatial Data Infrastructure

GSEC	Government Spatial Executive Committee
HRIC	Herbert Resource Information Centre
HSR	Hierarchical Spatial Reasoning
ICM	Integrated Catchment Management
ICSM	Intergovernmental Committee on Survey and Mapping
ICT	Information and Communication Technology
INSPIRE	Infrastructure for Spatial Information in Europe
IOR	Inter-organisational Relationship
IPR	Intellectual Property Rights
ISO	International Organisation for Standardisation
IT	Information Technology
IQ	Information Queensland
KIN	Knowledge and Information Network
KM	Knowledge Management
LGA	Local Government Authority
LWA	Land and Water Australia
LIDAR	Light Detection and Ranging
LIS	Land Information System
LIST	Land Information System Tasmania
MDBA	Murray Darling Basin Authority
MOU	Memorandum of Understanding
NAP	National Action Plan
NHS	National Health Service
NHT	Natural Heritage Trust
NIE	Neo-Institutional Economics
NII	National Information Infrastructure
NRC	National Research Council
NRM	Natural Resource Management
NRETAS	Natural Resources, Environment, the Arts and Sport
NSDI	National Spatial Data Infrastructure
NSW	New South Wales
NT	Northern Territory
NTLIS	Northern Territory Land Information Council
NTSDI	Northern Territory spatial data infrastructure
NVIS	National Vegetation Information System
OGC	Open GIS Consortium
OMB	Federal Office of Management and Budget
OMG	Object Management Group
OO	Object Oriented
OSDM	Office of Spatial Data Management
P-A	Principal-Agent

PCGIAP	Permanent Committee on GIS Infrastructure for Asia & The Pacific
QGIS	Queensland Government Information Service
QLD	Queensland
QLIC	Queensland Land Information Council
QMDC	Queensland Murray Darling Committee
QSIC	Queensland Spatial Information Council
QSIIC	Queensland Spatial Information Infrastructure Council
RAVI	Dutch Council for Real Estate Information
RGC	Regional Groups Collective
SA	South Australia
SDI	Spatial Data Infrastructure
SDS	Spatial Data Sharing
SEDAC	Socioeconomic Data and Applications Center
SI	Spatial Information
SIS	Spatial Information System
SLIP	Shared Land Information Platform
SNT	Social Network Theory
TAS	Tasmania
TAMS	Territory and Municipal Services Directorate
TCM	Total Catchment Management
UK	United Kingdom
UML	Unified Modelling Language
UN	United Nations
USA	United States of America
USGS	United States Geological Survey
VGI	Volunteered Geographic Information
VGIS	Victorian Geographic Information Strategy
VIC	Victoria
VRO	Victorian Resource Online
VSIS	Victorian Spatial Information Strategy
WA	Western Australia
WALIS	Western Australia Land Information System

OPERATIONAL DEFINITIONS

The following brief operational definitions of terms which are used throughout this dissertation are provided to clarify the context in this research.

Catchment: A catchment is a discrete geographical area of land whose boundaries are derived primarily from natural features such that surface water drains and flows to a river, stream, lake, wetland or estuary.

Catchment Management: Catchment management refers to the practice of managing natural resources using river catchment systems as the unit of management. From a theme perspective, catchment management is about management of land, water, biodiversity, coast and marine themes.

Catchment Management Authorities: Catchment management authorities (CMAs) are the natural resource management bodies responsible for management of land and water resources in the catchment. All states/territories have some form of catchment management authority or natural resource management group within their jurisdiction. There are 56 regional NRM bodies/CMAs responsible for catchment management in Australia. In particular, they called catchment management authorities in New South Wales and Victoria.

Knowledge Sharing: Knowledge sharing is defined as the process of exchanging knowledge (skills, experience, and understanding) amongst stakeholders. For the purpose of this thesis, stakeholders includes government agencies, regional NRM bodies, community organisations, private sector and academia.

Regional Groups Collective: The regional groups collective is a representative body for natural resource management in Queensland which provides a single, strong voice for its members. It supports regional NRM groups to deliver sustainability outcomes by coordinating statewide programs, providing mentoring and leadership, advocacy for improved investment in natural resource management, and identifying areas for training and improvement

Spatial Information Sharing: Spatial information sharing is the exchange or transfer of spatial information between two or more organisations.

PUBLICATIONS

Papers Published from this Dissertation

1 Paudyal, Dev Raj, McDougall, Kevin and Apan, Armando (2012) *Exploring the Application of Volunteered geographic information (VGI) to Catchment Management: A Survey Approach*, XXII ISPRS Congress, 25 August - 1 September 2012, Melbourne (accepted for ISPRS Annals of Photogrammetry, Remote Sensing and the Spatial Information Sciences).

2 Paudyal, Dev Raj, McDougall, Kevin and Apan, Armando (2012) *Spatially Enablement of NRM Communities through Spatial Knowledge and Information Network Development*. In: Rajabifard, Abbas and Coleman, David (eds) *Spatially Enabling Government, Industry and Citizens: Research and Development Perspectives*, GSDI Association Press, USA 978 pp 82-102, ISBN 978-0-9852444-0-8.

3 Paudyal, Dev Raj, McDougall, Kevin and Apan, Armando (2011), *Assessing Spatial Information Access, Use and Sharing for Catchment Management in Australia*, Proceedings of the Surveying & Spatial Sciences Biennial Conference, 21-25 November 2011, Wellington, New Zealand.

4 Paudyal, Dev Raj and McDougall, Kevin and Apan, Armando (2011) *Spatial Data Infrastructure Convergence: Building Spatial Data Infrastructure Bridges to Address Climate Change at Catchment Scale.* In: Joshi, P K, Joshi, A and Singh, T P, (eds) *Geoinformatics for Climate Change Studies.* Teri Press, New Delhi, India, pp 377-392, ISBN 8179934098.

5 Paudyal, Dev Raj, McDougall, Kevin and Apan, Armando (2010) *A Regional Collaborative Network to Improve Spatial Information Sharing in Australia.* Proceedings of GSDI-12 Conference, 19-22 October 2010, Singapore.

6 Paudyal, Dev Raj, McDougall, Kevin and Apan, Armando (2009) *Building SDI Bridges for Catchment Management.* In: van Loenen, Baastian, Besemer, Jaap and Zevenbergen, Jaap, (eds) *Spatial Data Infrastructure Convergence: Research, emerging trends, and critical assessment*. Netherlands Geodetic Commission, Delft, the Netherlands, pp 265-279, ISBN 978 90 6132 310 5.

7 Paudyal, Dev Raj, McDougall, Kevin and Apan, Armando (2009) *Spatial Data Infrastructure for Catchment Management: A Case Study of Condamine Catchment, Australia.* Indian Cartographer, 28, pp 439-444, ISSN 0972-8392.

8 Paudyal, Dev Raj and McDougall, Kevin (2008) *Building Spatial Data Infrastructure to Support Sustainable Catchment Management.* Proceedings of Queensland Spatial Conference, 17-19 July 2008, Surfers Paradise, Australia.

Other Publications

1 Paudyal, Dev Raj (2011) *Pro-poor Land Management in Developing Countries: A Case Study in Nepal and India*. VDM Verlag Dr Muller, Germany, ISBN 978-3-639-34775-3.

2 Paudyal, Dev Raj and McDougall, Kevin (2010) *Spatial Data Infrastructure for Pro-poor Land Management.* Proceedings of XXIV FIG International Congress, 11-16 April 2010, Sydney, Australia.

Chapter 1

Introduction

1.1. Background to Research

Catchment management is an approach to managing natural resources using river catchment systems as the unit of management (Commonwealth of Australia 2000). It involves integrating and managing ecological, economic and social aspects of land, water and biodiversity resources around an identified catchment system. Catchment management issues are characterised by multiple stakeholders and multiple goals which cut across traditional as well as administrative boundaries (Love et al 2006). Catchment management requires an integrated management approach as different institutions and individuals need to work together towards sustainable catchment outcomes (Paudyal and McDougall 2008). Effective institutional arrangements and technical solutions are needed to bring different organisations together for catchment management. Spatial information is recognised as an essential resource that supports the economic, social and environmental interests of a nation, and is one of the most critical elements underpinning decision-making for many discipline (Clinton 1994; Gore 1998; Rajabifard et al 2003a) including catchment management. With different organisations under different jurisdictions working towards catchment management, the access, use and sharing of spatial information to support multi-stakeholder decision-making processes and policy development continues to be problematic.

The development of a Spatial Data Infrastructure (SDI) facilitates the exchange and sharing of spatial information between stakeholders within the spatial community (Feeney et al 2001; McDougall 2006). Current SDI initiatives focus on SDI development at different administrative/political levels ranging from local to state/provincial, national, regional and global levels (Chan and Williamson 1999; Rajabifard and Williamson 2001). However, catchment management does not follow the rules of administrative/political hierarchies as it has its own spatial extent and coverage. Therefore, to successfully address catchment management objectives, SDI frameworks must carefully consider the institutional arrangements and the needs of the various stakeholders across these catchment environments (Paudyal and McDougall 2008).

This research will focus on understanding the current mechanisms of spatial information access, use and sharing amongst regional NRM bodies/catchment management authorities (CMAs) and state government organisations for sustainable catchment management outcomes. Further, it will identify key factors which influence spatial information sharing between state government organisations and regional NRM bodies/CMAs within Australia and formulate appropriate strategies to facilitate spatial information sharing and hence support SDI development.

1.2. Reseach Formulation

1.2.1. Research Problem

Spatial information plays an important role in many social, economic and political decisions (McDougall et al 2007) and is increasingly acknowledged as a national resource essential for sustainable development (Warnest 2005). Accurate, up-to-date, relevant and accessible spatial information is critical to addressing various global issues such as climate change, urbanisation, land use change, poverty reduction, environmental protection and sustainable development. One of the areas where spatial information can be more effectively utilised for decision-making is catchment management (Paudyal et al 2009a). However, the spatial data available have different scales, content and formats, and hence sharing of spatial data for catchment decision-making is often problematic. It is therefore necessary to understand current arrangements for spatial information access, use and sharing mechanisms in order to develop appropriate strategies to improve sharing outcomes.

Rajabifard (2002) argues that a hierarchical SDI model that includes SDIs developed at different administrative/political levels is an effective tool for the better sharing and utilisation of spatial information. However, existing hierarchical models for SDI development are not suitable for catchment management as issues may extend beyond a single jurisdiction. In some cases, catchments even cross the territory of several countries. Further, the existing SDI models are based on the authoritative data held by government agencies. For catchment management, the community groups, including regional NRM bodies, require catchment or property scale data, but they also collect a significant amount of large scale spatial information of interest to government. There is also a need to better understand the spatial information access and sharing issues for catchment SDI development. Therefore, the central research problem for this study was:

"In Australia, catchment management activities have evolved within a complex jurisdictional environment involving multiple levels of government, multiple organisations and multiple stakeholders. As a consequence, the current spatial information sharing arrangements are hindering effective decision making in the catchment management environment."

1.2.2. Research Hypothesis and Aim

The research hypothesis was built on the understanding of the key factors that influence spatial information sharing between state government organisations and regional NRM bodies in Australia.

Specifically the research hypothesis was:

"Spatial information sharing strategies which are formulated to address of the institutional, technical, cultural and economic factors will improve the spatial information sharing between state government organisations and regional NRM bodies/catchment management authorities in Australia and hence promote spatial data infrastructure development at the catchment level."

This hypothesis states the spatial information sharing strategies will improve the information sharing between state government organisations and regional NRM bodies and promote sustainable catchment decisions. The identification of key factors are essential to formulate the strategies.

In line with the research problem and research hypothesis, the central aim of the research was:

"To identify key factors influencing spatial information sharing between state government organisations and regional NRM bodies/catchment management authorities within Australia, and to formulate appropriate strategies to facilitate spatial information sharing and hence contribute to SDI development."

1.2.3. Research Questions and Objectives

In considering the above research problem and aim the following research questions were formulated:

1 Can the understanding of existing theory on spatial data infrastructure (SDI) be applied to improve existing government-community spatial information sharing?

2 What are the key issues for catchment management in Australia, and how can SDI help to improve catchment outcomes by addressing these issues?

3 What is the current status of spatial information access, use and sharing between regional NRM bodies and state government organisations in Australia? Can the varying institutional arrangements and jurisdictional environments impact on spatial information access and sharing?

4 How effective are existing collaborative NRM projects for spatial information sharing? Can these collaborative arrangements be utilised to develop future SDI development at sub-national levels?

5 What are the key factors or issues that influence the sharing of spatial information between regional NRM bodies and state government organisations and contribute to the development of SDI at catchment scale? How can we formulate appropriate spatial information sharing strategies for improved spatial information sharing across catchments?

The following specific objectives were formulated to answer the research questions and to achieve the research aim:

1 To review the SDI theoretical foundations to develop a conceptual framework for the research;

2 To describe and classify the existing institutional and jurisdictional dimensions of catchment management in Australia and identify key catchment management issues and spatial information requirements for catchment decisions;

3 To assess the current status of spatial information access, use and sharing between state government organisations and regional NRM bodies/CMAs and assess SDI development in catchment management in Australia;

4 To explore the effectiveness of spatial information and knowledge sharing initiatives in the natural resource management environment; and

5 To identify the key factors and formulate spatial information sharing strategies for improving data sharing across catchment management and facilitate SDI development.

1.3. Research Justification

The justification for this study is based on five inter-related grounds. Firstly, more than half the countries in the world are developing spatial data infrastructures (Crompvoets 2006). Research indicates that there is a need for spatial data infrastructure to be more network orientated and to facilitate greater spatial data sharing (de Man 2006; Harvey and Tulloch 2006; Omran 2007; Vandenbroucke et al 2009). McDougall (2006) explains that sub-national government structures are generally hierarchical in nature but SDI development does not appear to fit neatly within this hierarchical framework. Therefore, it would be valuable to explore the extent to which hierarchical government environments contribute to different components of SDI development. Likewise, Masser (2006) identified four challenging areas for SDI-related research as SDI diffusion, SDI evolution, data sharing in SDIs and the hierarchy of SDIs. He highlighted the core research areas for SDI research and explained why SDI related research needs special attention. The issue of data sharing is critical for effective catchment management.

Secondly, the concept of SDI for catchment management is a relatively new domain with little theoretical research. Much of the current institutional SDI research (McDougall 2006; Pollard 2006; Salleh 2010; Warnest 2005) is focussed on the existing hierarchical government environments and there has been little research within natural boundaries like catchments. Furthermore, the role of the community for natural resource management is highly regarded, but involvement of communities for SDI development is largely ignored due to traditional institutional structures and business processes.

Thirdly, as catchment management issues are characterised by multiple stakeholders and multiple goals, there are many complex issues to be addressed under the catchment management domain. Due to the increasing development of land and natural resources, the management of rights, restrictions and responsibilities between people and land/water is becoming an important issue under this domain (Paudyal and McDougall 2008). There are some innovative approaches emerging within catchments and/or for natural resources planning to support regional decision making. However, Australia is still faced with the pressing need to be able to promote an information-based approach to decision-making in natural resources management by users (Feeney and Williamson 2000).

A dialogue about SDI and its role in promoting sustainable development and global issues such as climate change, land use change, poverty reduction and good governance has commenced. In the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP), a discussion has started to better understand and describe spatial enablement of society and how spatial technologies can be used in more dynamic, transformational ways to address global issues like the conservation of natural resources and planning for sustainable growth (Holland 2006). Now that the emphasis has moved to the development of sub-national (operational) SDIs (Masser 2009), there is a need to better understand the organisational, policy, economic, cultural and technical issues (ICT strategy and business process) in the development and implementation of SDIs at sub-national level.

Finally, there are many frameworks developed for sharing spatial data (Kevany 1995; McDougall 2006; Omran 2007; Onsrud and Rushton 1995; Warnest 2005; Wehn de Montalvo 2003). However, the frameworks are mainly based on the spatial data provider's point of view and do not recognise the power of users. Readily accessible and available spatial technologies like Google Earth, hand-held navigation systems (including smart phones, GPS, etc), Web 2.0/3.0 technology and social media has created the opportunity for users to contribute towards SDI development. Therefore, it is important to examine the spatial information sharing issues and to formulate strategies from the user's or community's perspectives.

1.4. Summary of Research Approach

This research has utilised a mixed-method design integrating both quantitative and qualitative approaches. A survey and case study have been used to collect quantitative as well as qualitative data. Case studies can be exploratory, explanatory or descriptive (Yin 1994; Yin 2009a). This dissertation has adopted the descriptive and explanatory approach for analysing and describing the spatial information access, use and sharing between regional NRM bodies/CMAs and state government organisations in Australia. The research design is broken down into four main stages as shown in Figure 1.1.

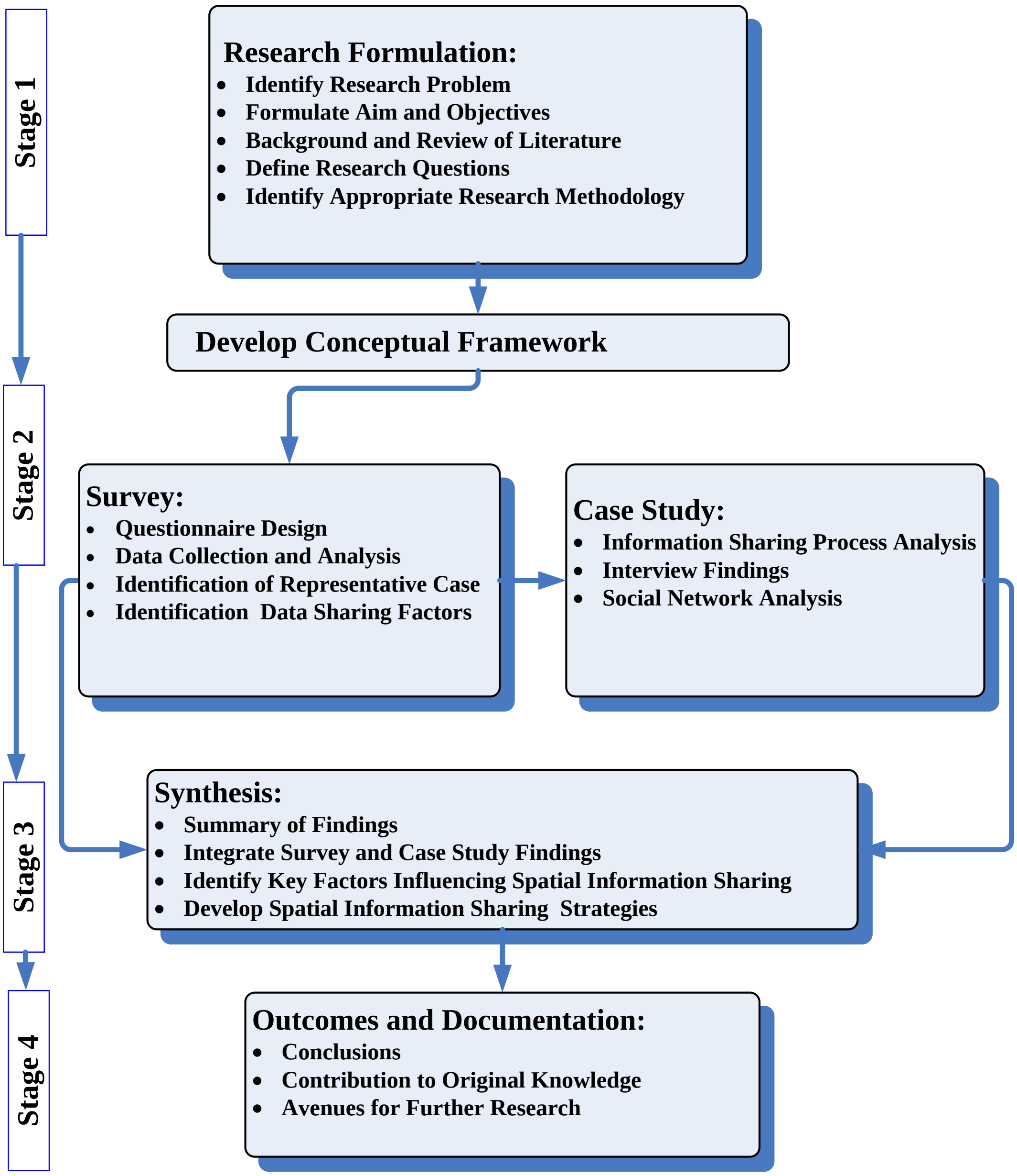

Figure 1.1: Research design

The research formulation includes identification of the research problem and formulation of the research aim, hypothesis as well as objectives. It also includes a review of existing literature in SDI and catchment management areas and a study of the theoretical background to formulate the research questions and identify an appropriate research methodology.

The research design includes the conceptual framework development, the survey, and the case study. The research questions, formulated through the background studies, were found to be difficult to answer by a single approach. Therefore, a mixed method research approach has been selected. It integrates the qualitative data collected through case study and the quantitative data collected through the survey, to identify key factors influencing spatial information sharing between regional NRM bodies and state government organisations. The case study area for this research is the KIN (Knowledge and Information Network) project in Queensland. The KIN project stakeholders were targeted for a semi-structured interview to obtain the opinions and attitudes of stakeholders about the issues related to spatial information sharing and catchment SDI. The quantitative component consisted of a questionnaire that was distributed to 56 regional NRM bodies which work closely at the grass-root level to achieve sustainable catchment outcomes. The triangulation of existing theory, questionnaire data and case study results has been integrated to identify the key factors that influence spatial information sharing across catchment management areas.

The synthesis includes an integration and interpretation of the questionnaire analysis and case study findings. The mixed methods embedded design framework has been utilised to integrate the case study and questionnaire results to identify and consolidate spatial information sharing issues and to formulate strategies for improved spatial information sharing across catchments.

The final step is outcomes and documentation which includes the review of achievement of the research aim and objectives, contribution to original body of knowledge, and avenues for further research.

1.5. Structure and Outline of Thesis

The structure of the dissertation has been presented in four parts as illustrated in Figure 1.2 and is organised into eight chapters. Each chapter has been organised so that it answers the research questions and achieves the research aim/objectives. The first part comprises Chapter One, the second part comprises Chapter Two and Three, the third part comprises chapter Four, Five and Six, and the fourth part comprises Chapters Seven and Eight. Each chapter has been organised so that it answers the research questions and achieves the research aim/objectives.

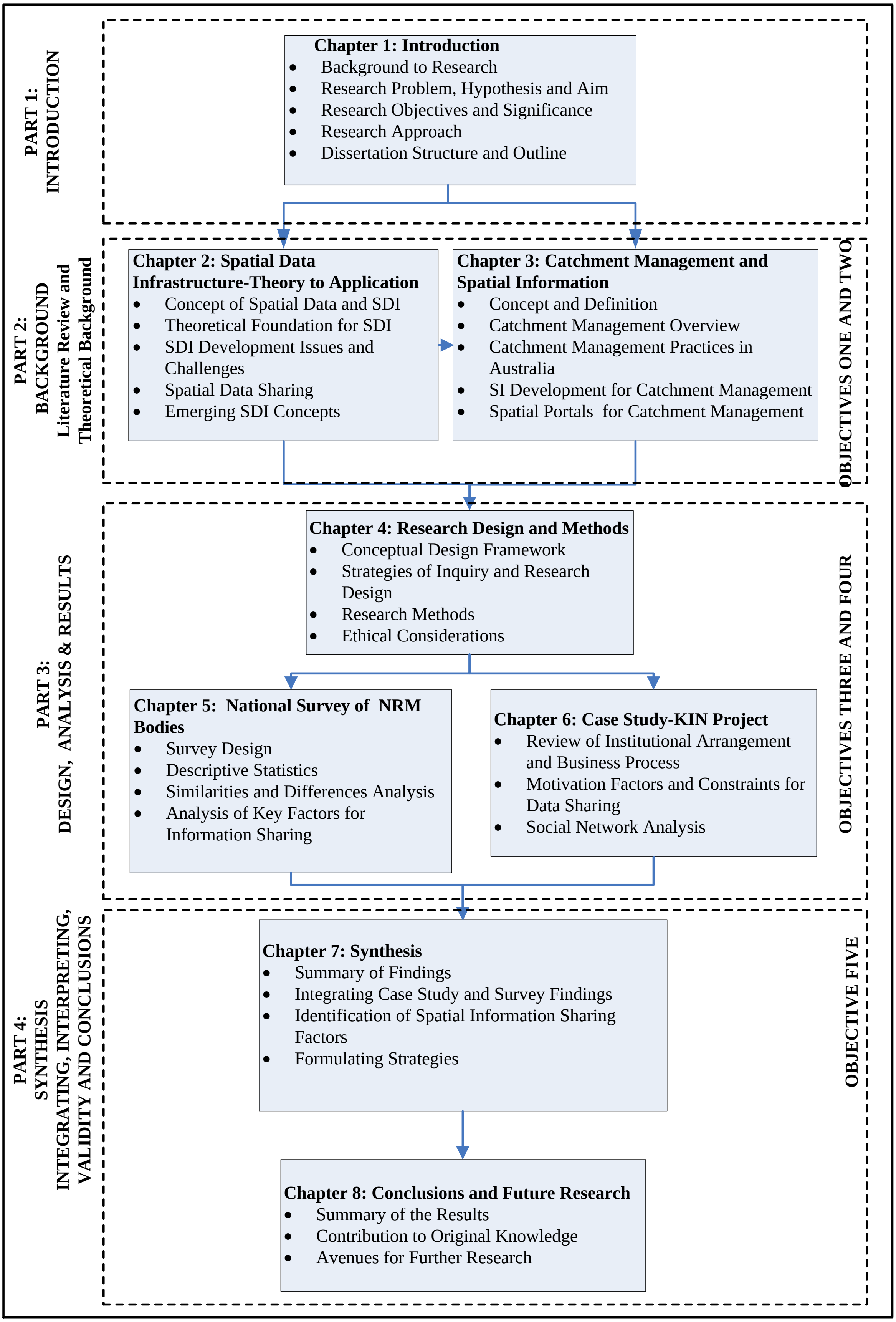

Figure 1.2: Structure of the thesis and relationship to objectives

Chapter One provides an introduction to the research investigation including a synopsis of the body of literature and prior work that led to the statement of the problem, hypothesis, aim and objectives. The chapter outlines the research approach and thesis structure, including the contribution of each chapter to achieving the objectives.

Chapter Two describes the theoretical aspects of SDI development and spatial data sharing. The chapter describes the definition and components of SDI and relevant theory applicable to SDI development. Further, it explains emerging SDI development issues and challenges and identifies spatial data sharing as an issue for SDI development. It also explains the emerging SDI concepts such as spatially enabled society and user driven SDI.

Chapter Three reviews catchment management and the role of spatial information in catchment management. The chapter focuses on the application of spatial information and SDI for catchment management. It describes the existing spatial portals, NRM tools and the process for catchment decisions using spatial data infrastructure as a platform.

Chapter Four sets out the research method and design. It describes the conceptual framework derived from the theoretical background and proposes the mixed method framework to address the research questions posed in earlier chapters.

Chapter Five documents the results of the survey of 56 regional NRM bodies in Australia which examines the status of spatial information access, use, and sharing for the catchment decisions throughout Australia. A descriptive and comparative analysis of jurisdictional and institutional issues is presented.

Chapter Six provides the results of the case study of the KIN project in Queensland. It outlines the case study overview, institutional arrangements and spatial information sharing processes. It identifies motivational factors and constraints for collaborating and the spatial information sharing process through a semi-structured interview. It assesses the information flow and relationship of stakeholders for data sharing via social network analysis.

Chapter Seven integrates the findings from Chapters Five and Six to identify the key factors influencing spatial information sharing between regional NRM bodies and state government organisations. It also formulates the strategies to minimise the issues related to spatial information sharing and catchment SDI development.

The final chapter, Chapter Eight, presents the research achievements and conclusions. The contribution to original knowledge is examined and avenues for further research are provided.

1.6. Research Scope and Key Assumptions

This research focuses on existing access, use and sharing of spatial information between state government agencies and regional NRM bodies including a survey of 56 regional NRM bodies in Australia. Initially, the Murray-Darling Basin (MDB) was selected as a case which included four state jurisdictions (Queensland, Victoria, New South Wales, South Australia) and one territory (Australian Capital Territory). However, later it was decided that a broader study should be performed in all 56 regional NRM bodies in Australia and that the NRM bodies which are associated with MDB should be compared separately. The KIN project of Queensland was selected as an ideal case for a detailed study to explore the spatial information and knowledge sharing arrangements between regional NRM bodies and state government organisations. The main criteria for the case study selection were accessibility, geographical location and the potentiality to be a representative case. The criteria for selection are elaborated in section 4.4.2.

The basin SDI is the highest level of SDI hierarchy within the catchment management framework. In some countries a basin may cross international boundaries and, as a result, the catchment management issues may become far more complex. In Australia, however, it is not possible to study catchment management issues which cross international boundaries. It was deemed that given the existing federated arrangements (national, state and local) are already complex, it was beyond the scope to extend the research to the international arena.

During this research, spatial data sharing arrangements, institutional arrangements and technological innovations have continually changed. The dynamic nature of these settings is an important consideration, however, continual updating and revisiting of the case study was not practical. The description and documentation is therefore valid at the time of data collection only, and it should be recognised that changes may have taken place since that time.

1.7. Concluding Remarks

This chapter introduced the key research problem, aim and objectives. The research problem was justified and the research methodology was briefly described. A justification of the research methodology has also been provided. The thesis structure has been outlined and research scope and key assumptions have been explained. Chapter Two provides a background of the theoretical framework for spatial data infrastructure (SDI) development, spatial data sharing and emerging SDI concepts.

Chapter 2

Spatial Data Infrastructure: From Theory to Application

2.1. Introduction

The purpose of this chapter is to explore the concept of spatial information and information infrastructures. Specifically, the concept of spatial data infrastructures (SDI) is examined through definition, theoretical foundation and its practice/applications. This chapter consists of six sections. Section 2.2 describes the concept of spatial data infrastructure (SDI) introducing various terminologies used in this dissertation and provides an overview of historical SDI developments. The development and evolution of spatial data infrastructure from its concept to reality is discussed and the understanding about the SDI components by different practitioners is explored. Section 2.3 attempts to explore other theories related to SDI development. Section 2.4 describes the SDI development issues and challenges. Section 2.5 introduces spatial data sharing concept, data sharing frameworks/models, and motivators and barriers for spatial data sharing. Finally, Section 2.6 describes the emerging SDI applications to create a spatially enabled society are discussed and the chapter concludes with the summary of findings.

2.2. Concept of Spatial Data and Spatial Data Infrastructure (SDI)

2.2.1. Definitions

Throughout this thesis, and this chapter specifically, the terms “spatial data/spatial information”, “information infrastructure”, “spatial data infrastructure (SDI)” will be utilised and discussed. It is therefore useful to clarify this terminology and its use by different practitioners.

2.2.1.1. Spatial Data and Information

Spatial information (also known as geographic information) is any information that can be geographically referenced, ie describing a location, or any information that can be linked to a location (ANZLIC 2010). Examples are topography, including geographic features, place names, height data, land cover, hydrography, cadastre (property-boundary information), administrative boundaries, resources and environment, socio-economic information(Rajabifard et al 2003a).

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). About 80% of all information utilised by decision-makers is spatial information (Klinkenberg 2003; Ryttersgaard 2001). Spatial information is a key and integral component for the delivery of good governance, promoting efficiency in business and supporting sustainable development. It provides an enabling framework for modern societies and is recognised as fundamental for wealth creation and good decision making. As a result, policy-makers and managers have begun to realise the value of spatial data to their business. They consider spatial data as a resource and also a part of fundamental infrastructure that needs to be coordinated and managed effectively (Ryttersgaard 2001).

2.2.1.2. Information Infrastructure

In Webster's Dictionary (2008) "infrastructure" is defined as "the basic framework or underlying foundation; especially, the basic installations and facilities on which the continuance and growth of a community, state, etc depends as roads, schools, power plants, transportation and communication systems, etc." According to Hanseth and Monteiro (1998), the core aspects of infrastructure are:

1 Infrastructures have a supporting or enabling function;

2 Infrastructures are open;

3 Information Infrastructures are more than "pure" technology, they are rather socio-technical networks; and

4 Infrastructures are connected and interrelated, constituting ecologies of networks.

Based on the above properties of infrastructure, the definitions given by Hanseth and Lyytinen (2010) as "a shared, open, heterogeneous and evolving installed base" and by Pironti (2006) as "all of the people, processes, procedures, tools, facilities and technology which support the creation, use, transport, storage, and destruction of information" are useful for this research. Roger Clark (2006) defined information infrastructure (II) as a network perspective “the communications networks and associated software that support interaction among people and organisations.” Information infrastructure is useful as a collective term to cover both present networks (including the internet, and the underlying long-distance and short-distance communications technologies) and likely future facilities.

The consideration of information as infrastructure began to take form in the late 1980s (Branscomb 1982) and was formalised in September 1993 when the Clinton administration released a statement elaborating on its National Information Infrastructure (NII) agenda (Executive Office of the President 1994b). The term National Information Infrastructure (NII) was popularised in the mid-1990s by US Vice-President Al Gore. Many people, in and beyond the USA, prefer the term Global Information Infrastructure (GII), in order to emphasise the interconnectedness of the network of countries and of people (Clark 2006). A comprehensive definition including information content and people is “a technical framework of computing and communications technologies, information content, services, people, all of which interact in complex and often unpredictable ways” (Borgman 2000 p. 30).

2.2.1.3. Spatial Data/ Information Infrastructure

Within the information infrastructure, spatial information may be considered a special type of information. This speciality has resulted in the emergence of spatial data infrastructures (SDI) as part of, or independent of, information infrastructures (Van Loenen 2006). SDI is defined in the literature in many different ways (de Man 2008). Within the SDI community there are differences in the understanding of SDI and its potential benefits (Grus et al 2007). Current progress of SDI initiatives show that SDI is viewed, defined and interpreted differently by different practitioners. SDI is an initiative which is defined in many different ways. However, SDI has a common intent to create an environment in which all stakeholders can cooperate with each other and interact with technology to better achieve their objectives at different political/administrative levels (Rajabifard et al 2003b).

Spatial Data Infrastructure (SDI) is about the facilitation and coordination of the exchange and sharing of spatial data between stakeholders in the spatial data community. SDI is a network-based solution to provide easy, consistent, and effective access to geographic information and services to improve decision-making in the real world in which we live and interact (Onsrud 2011). The ultimate objectives of these initiatives, as summarised by Masser (1998), are to promote economic development, to stimulate better government and to foster environmental sustainability. The principal objective of SDIs is to facilitate access to the geographic information assets that are held by a wide range of stakeholders with a view to maximising their overall usage (Masser 2011). Hendriks et al (2012) critically reviewed 28 definitions published in both scientific- and practice-oriented publications using a system-theoretical understanding of infrastructure. They argue that SDI definitions can be classified by the objective of the infrastructure which could include data-related, user-related and broader objectives.

Table 2.1 illustrates the range of SDI definitions and perspectives.

Table 2.1: Differing perspectives of SDI (after McDougall, 2006)

Source	SDI Definition
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.
ANZLIC (2003)	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.
Coleman and McLaughlin (1998)	A Global Geospatial Data Infrastructure encompasses the policies, technologies, standards and human resources necessary for the effective collection, management, access, delivery and utilization of geospatial data in a global community.
Executive Office of the President (1994b)	National Spatial Data Infrastructure (NSDI) means the technology, policies, standards and human resources necessary to acquire process, store, distribute, and improve the utilization of geospatial data.
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 and Williamson (2001)	Viewing the core components of SDI as policy, access network, technical standards, people (including partnerships) and data, different categories can be formed based on the different nature of their interactions within the SDI framework.
UN Geospatial Information working Group (2007)	Spatial data infrastructure is infrastructure for sharing and use of geospatial information.
EU (2006)	SDI is defined as a coordinated framework of technologies, standards and data, supported by policies and institutional arrangements that enable sharing and effective usage of geospatial information.
Onsrud (2011)	SDI is a network-based solution to provide easy, consistent, and effective access to geographic information and services to improve decision-making in the real world in which we live and interact.

Table 2.1 includes most of the SDI definitions and emphasises the core elements that comprise an SDI include data, people, access mechanisms, standards and policies. In addition, these definitions also emphasise that an SDI is a coordinated framework for access, sharing and use of spatial information.

2.2.2. Hierarchy and Continuum of Data to Wisdom

The relationship of data, information, knowledge and wisdom (DIKW) is well documented in the knowledge management and information science literature. Basically, there are two concepts. The first is a hierarchical concept and the second is continuum concept. In the information science domain, Herlan Cleveland (1982) publicised the DIKW hierarchy concept in a *Futurist* article. Russell Ackoff (1989), a professor in organisational change, was the initiator of the DIKW hierarchy concept in the domain of knowledge management (KM) as illustrated in Figure 2.1.

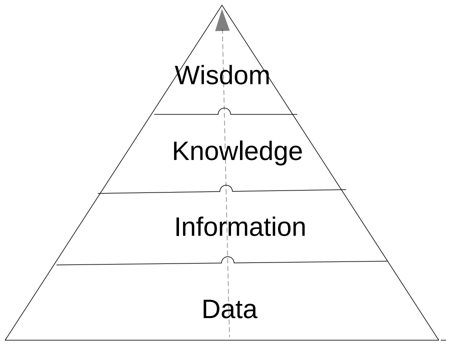

Figure 2.1 Knowledge hierarchy (Ackoff 1989)

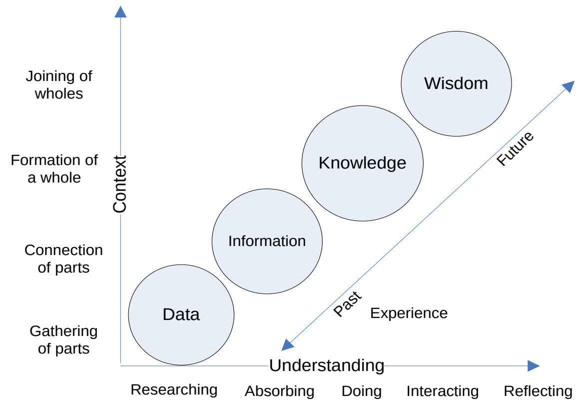

Figure 2.2: Interdependence of data to wisdom (Bellinger et al 2004)

Ackoff used a hierarchical concept to contextualise data, information, knowledge and wisdom with respect to one another. Further, he used the hierarchical concept to identify and describe the processes involved in the transformation of an entity at a lower level in the hierarchy (eg data) to an entity at a higher level in the hierarchy (eg information). He denotes data as symbology, or a raw representation without meaning, information as data that are processed to be a meaningful assemblage of data, knowledge as the application of data and information to identify patterns and relationships, and wisdom evaluated understanding, requiring previous knowledge and experience. The data, information, knowledge and wisdom (DIKW) hierarchy demonstrates the reliance of the higher orders on the assembly of the lower. The implicit assumption is that data can be used to create information; information can be used to create knowledge, and knowledge can be used to create wisdom. Data is considered most prolific, being at the base of the pyramid, whilst wisdom is far less common as it distils understanding from data, information and knowledge (McDougall, 2006).

Figure 2.2 illustrates the interdependence relationship of data to wisdom. Bellinger et al (2004) present a useful and less involved schematic of the relationships defined by Ackoff to show the transitions from data to wisdom and the dependence on understanding to support the transition. The main difference of this concept is that understanding is not a separate level, but rather that it supports the transition from each stage to the next. The distinction between concepts like data, information, knowledge and wisdom is not discrete; it is a continuum (McDougall 2006), and thus the distinctions between each term often seem more like shades of grey, rather than black and white (Shedroff 2001). Data and information deal with the past. They are based on the gathering of facts and adding context. Knowledge deals with the present. However, wisdom is the ultimate level of understanding and deals with future.

In the context of SDI, this relationship provides an understanding of the dependence of social imperatives upon a sound information and knowledge base. SDI is concerned with the realm of spatial data and the transition to information. Decision support systems build upon SDI to interpret, compare and analyse the cumulative spatial information to produce knowledge, with lessons and trends learnt over time resulting in collective wisdom (Warnest 2005). This phenomenon has opened the door to conceptualise spatial knowledge infrastructure, another emerging area to be considered when developing spatial data infrastructure (SDI).

2.2.3. Spatial Data Infrastructures: From Concept to Reality

Beginning in the late 1970s many national surveying and mapping organisations recognised the need to create strategies and processes for standardisation to, and application of, spatial data (Groot and McLaughlin 2000). Examples include the establishment of the Australian Land Information Council (ALIC) in early 1986 (ANZLIC 1992), Major Surveys Review in the Federal Government of Canada (Canadian Government 1986), the Report of the Government of United Kingdom (Department of the Environment 1987), the Report of the National Research Council of the USA (National Research Council 1993), and the Netherlands Council for Geographic Information (RAVI 1995).

The notion of a data infrastructure as a mechanism for providing more effective access to spatial data first emerged in the early 1980s in Canada (Groot and McLaughlin 2000). The federal and provincial surveying and mapping organisations were developing spatial databases and improving business processes through more comprehensive ways of incorporating the infrastructure concept for effective spatial data access. However, the concept of Spatial Data Infrastructure (SDI) was first publicised in the mid-1980s around the need for cooperation and sharing of spatially related information across a nation.

In the United States of America (USA), discussion about the national SDI initiative initially began primarily in the academic communities around 1989 and soon after in the government (National Research Council 1993). These discussions progressed rapidly when, in the early 1990s, the National Research Council's (NRC) Mapping Science Committee identified 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 of the President 1994a). 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 the early 1990s, establishing the National Spatial Data Infrastructure (NSDI) has been the basis for leveraging and applying spatial data, technologies, and analysis to national issues (McLaughlin 1991). The NSDI is broadly defined in Executive Order 12906 as the "technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve the utilization of spatial data." Since then, the FGDC has 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. This eventually led to the formation of a committee responsible for SDI development (Williamson et al 2003). Both national and subnational agencies have taken the lead role for accessing and sharing spatial information. National leadership is being provided by ANZLIC (Australian and New

Zealand Spatial Information Council), and various whole-of-government spatial information initiatives are being developed at the subnational level (Rajabifard et al 2011).

These 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 spatial information accessible on the Internet, while provincial and territorial governments and the private sector invested over $50 million in funding (GeoConnections 2004). In 2010, the Government of Canada renewed funding for Geoconnections, a national initiatives led by Natural resources of Canada and provided further funding of $30 million over five years for the program (GeoConnections 2012). GeoConnections developed the policies, standards, technologies, and partnerships needed to build the Canadian Geospatial Data Infrastructure (CGDI). The CGDI is an on-line resource that improves the sharing, access and use of spatial information. During the following years GeoConections developed a number of pilot projects involving the core elements of an operational infrastructure. It also delivered a common agreement on data licensing and substantially strengthened federal, provincial and territorial collaboration (Last and Rojas 2007).

In Europe, the Commission of the European Communities (2004) submitted a proposal to the European Parliament and the Council of the European Union and the Infrastructure for Spatial Information in the European Community (INSPIRE) initiative was adopted by the Commission. The proposal aimed to make interoperable spatial information readily available in support of both national and community policy, and to enable public access to this information. This was a major milestone for the use of European spatial information as a contributor 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 (European Commission 2007). This initiative facilitates and enables the access, reuse and sharing of spatial information created and maintained by different agencies in Europe and contributes to better environmental decision-making including catchment management.

Many other countries are also developing SDI at different jurisdictional levels (Crompvoets 2006). Each jurisdiction has its own definition of SDI that springs from jurisdictional backgrounds and requirements. Developing countries like Colombia, Cuba, Nepal, Indonesia, Nigeria, and Ethiopia are also developing SDI (Eelderink et al 2008).

2.2.4. SDI Components

Many models of SDI have been published and adopted throughout the world, for example United States' NSDI (FGDC 1997; FGDC 2011), the Dutch National Geographic Information Infrastructure (Van Loenen 2006; VROM 2008), The Canadian Geospatial Data Infrastructure (CGDI), Asia-Pacific SDI (Holland et al 2001) and the Australian Spatial Data Infrastructure (ASDI) (ANZLIC 2003). Although the models possess common components, the core components have been defined differently by different communities.

Nebert (2010) defined SDI as the relevant base collection of technologies, policies and institutional arrangement that facilitates the availability of, and access to, spatial data. He describes an SDI component stack emerging from data sources, access services, and integrative services to ultimately produce user interfaces. The 'infrastructure' is made up of the lower stack elements (data sources, access services and integrative services) with 'applications' (made up of integrative services and user interfaces) represented by the higher elements in the stack. Integrative services provide the important link between infrastructure and applications (Figure 2.3).

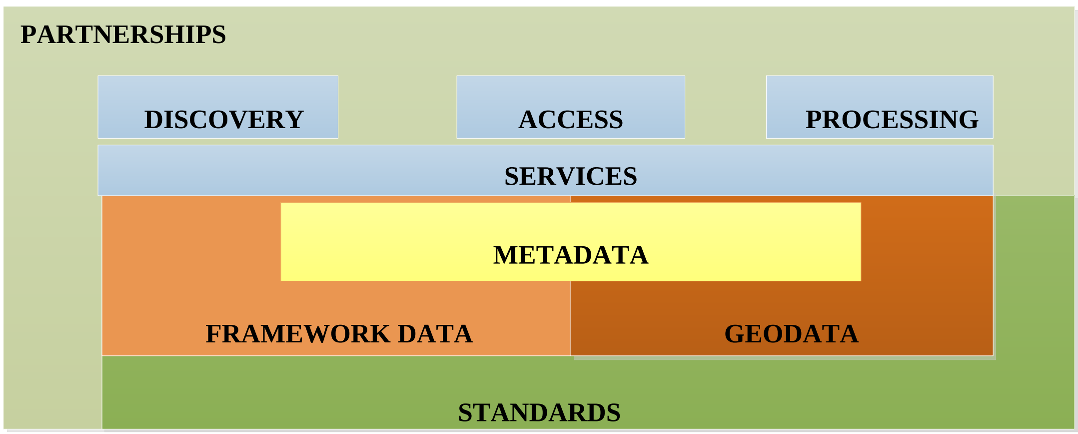

Figure 2.3: SDI components (Nebert 2010)

The Executive Office of the President of the United States (2002) introduced five components for the USA national SDI. The components of the SDI included fundamental data themes, metadata, the national spatial data clearinghouse, standards, and partnerships (Figure 2.4).

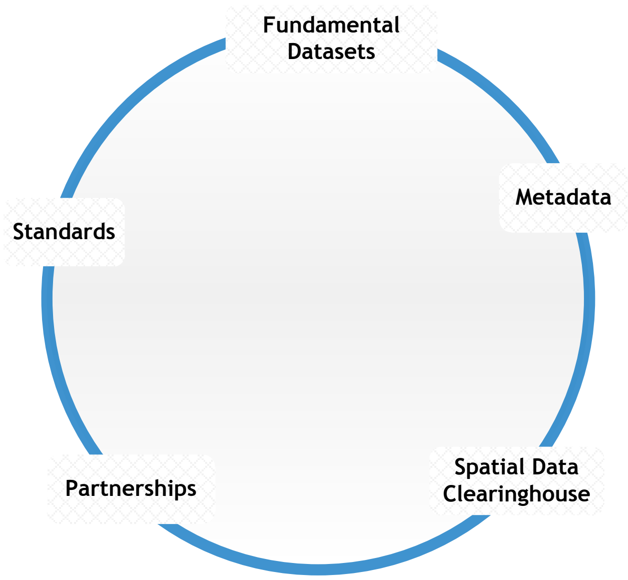

Figure 2.4: SDI components (Executive Office of the President 2002)

The fundamental spatial datasets and attributes are organised in distributed repositories and the documentation of this information is done through metadata. A spatial data clearinghouse is a means to discover, visualise and evaluate the spatial information (catalogues and web mapping). The framework includes a set of agreements with respect to technical (standards), organisational, and legal issues to coordinate and administer spatial information and services on a local, regional, national or transnational scale and contributes to standards and partnerships.

In Canada, the Canadian Geospatial Data Infrastructure (CGDI) has identified five main components as technology, policy, framework, standards and access network as illustrated in Figure 2.5 (GeoConnections 2004). The Canadian Geospatial Data Infrastructure comprises all of the five components necessary to harmonize all of Canada's spatial databases, and to make them available on the Internet.

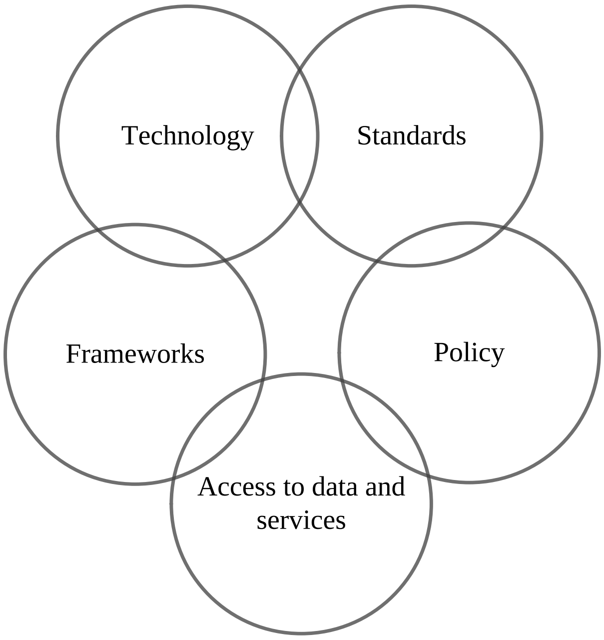

Figure 2.5: SDI component (GeoConnections 2004)

Van Loenen (2006) described the core components of SDI/GII as an institutional framework, policies, financial resources, human resources, standards, and technology (Figure 2.6) and explained the importance of SDI components for SDI development.

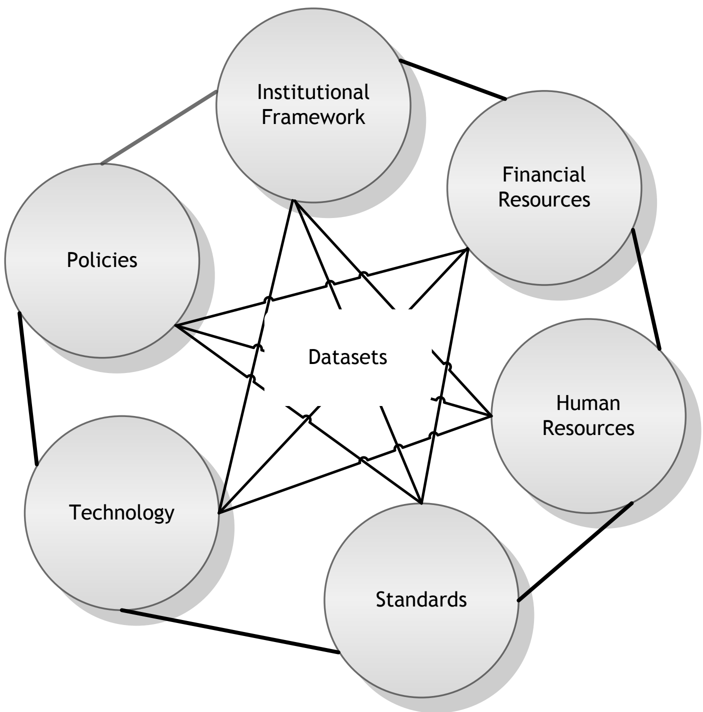

Figure 2.6: SDI components

Rajabifard and Williamson (2001) have proposed a five component SDI structure. 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 2.7.

Figure 2.7: SDI and its components (Rajabifard and Williamson, 2001)

The Australian Spatial Data Infrastructure (ASDI) model consists of four linked core components:

- an institutional framework that defines the policy and administrative arrangements for building, maintaining, accessing and applying the standards and data sets;
- a set of technical standards that define the technical characteristics of the fundamental data sets;
- a collection of fundamental data sets produced within the institutional framework and fully compliant with the technical standards; and
- a clearinghouse network that makes the fundamental data sets accessible to the community, in accordance with policy determined within the institutional framework, and to the technical standards agreed.

The core components of the ASDI, as initially defined by Rajabifard and Williamson (2001) are people, access, policy, standards and data (refer to Figure 2.7) remain relevant today and support the vision for the ASDI moving forward. However, in light of the ASDI providing more than just access to data, the nature and configuration of these components should be revised. There are basically two types of concepts: one is a hierarchical concept and another is a network concept. Combining both of these concepts, a hybrid SDI component has been proposed by the Intergovernmental Committee on Surveying and Mapping ICSM (2008) for ASDI as shown in Figure 2.8.

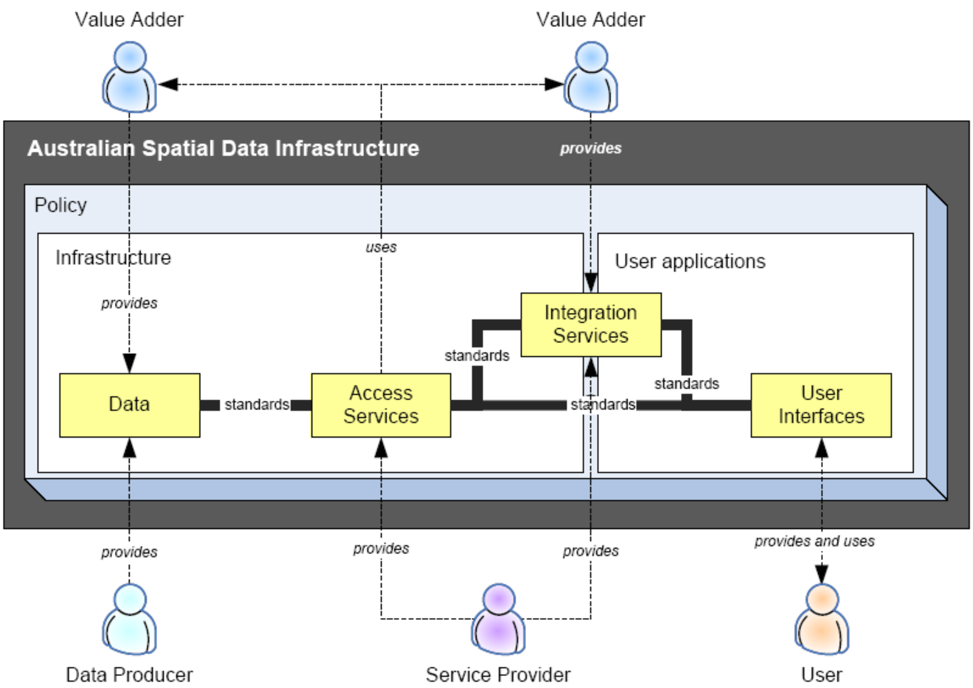

Figure 2.8: ASDI components (ICSM, 2008)

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 as having a significant impact on the effectiveness and success of SDIs (Mohammadi 2008). Table 2.2 summarises the most important components of SDI.

Table 2.2: SDI components (Mohammadi 2008)

Data	Data themes are electronic records and coordinates for a topic or subject, such as elevation or vegetation. Themes providing the core, most commonly used set of base data are known as framework data, specifically geodetic control, orthoimagery, elevation and bathymetry, transportation, hydrography, cadastral, and governmental units.
People	Includes stakeholders who use, provide, value-add, manage or own the data. Users can be corporate, small and large business or individuals, public and private sectors.
Institutional Framework/Policy	Includes the administration, coordination, policy and legislative components of an SDI. The institutional framework is reliant on successful communication and interaction between stakeholders within and across jurisdictions.
Standards	Standards are common and repeated rules, conditions, guidelines or characteristics for data, and related processes, technology and organisation. To broaden the global use of federal data and services, international standards and protocols must be used.
Metadata	Metadata, commonly defined as “data about data”, is a structured summary of information that describes data (SEDAC 2006). Metadata contains information about data and/or geospatial services, such as content, source, vintage, spatial scale, accuracy, projection, responsible party, contact phone number, method of collection, and other descriptions. Metadata is critical to document, preserve and protect agencies’ spatial data assets.
Access Network	Includes access and distribution networks, clearinghouse and other mechanisms for getting spatial information and data to the stakeholders
Partnership	Partnerships are critical components of SDI development, which can be inter- or cross-jurisdictional (Williamson et al 2003). Building an effective SDI will require a well-coordinated partnership among federal, state, local government, and academic institutions, as well as a broad array of private sector and other business information providers and users.
Data Sharing	Spatial Data Sharing (SDS) is defined as transactions in which individuals, organisations or parts of organisations obtain access from other individuals, organisations or parts of organisations to spatial data (Omran 2007).
Governance	It is necessary to go beyond establishing the machinery for SDI coordination and give top priority to the creation of appropriate SDI governance structures that are both understood and accepted.
Capacity Building	SDIs are likely to be successful when they maximise the use made of local, national and global GI 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 GI management skills.

2.3. Theoretical Foundation for SDI Development

SDI development is supported by various theoretical backgrounds (Masser 2006; Paudyal et al 2009a). The important theories relevant to the development of SDI for catchment management are Hierarchical Theory, Social Network Theory, Diffusion

Theory, Actor-Network Theory and Principal-Agent Theory as illustrated in Figure 2.9.

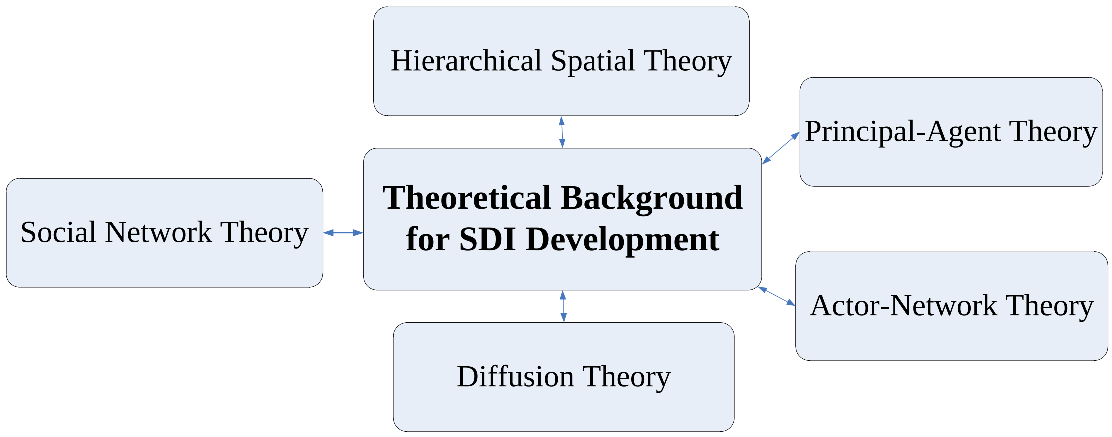

Figure 2.9: Theoretical foundation for SDI development

The following section describes the importance of these theories to the development of SDI for catchment management.

2.3.1. Hierarchical Spatial Theory

Past research has been conducted toward maximising the efficiency of computational processes by using hierarchies to break complex tasks into smaller, simpler tasks (Car et al 2000; Timpf and Frank 1997). Examples of hierarchical applications include the classification of road networks (Car et al 2000), and development of political subdivisions and land-use classification (Timpf et al 1992). The complexity of the spatial field, as highlighted by Timpf and Frank (1997), is primarily due to the space being continuous and viewed from an infinite number of perspectives, and at a range of scales.

Rajabifard et al (2000) demonstrated that the principles and properties of hierarchical spatial reasoning could be applied to SDI research to better understand their complex nature and to assist modelling of SDI relationships. The hierarchical nature of SDI is well established in describing relationships between the administrative/political levels (Rajabifard et al 2000). They support two views which represent the nature of the SDI hierarchy namely: the umbrella view - in which SDI at the higher level encompasses all SDIs at a lower level, and the building block view - where a level of SDI such as at the state level, supports the SDI levels above (ie national, regional) with their spatial data needs. Rajabifard (2002) made use of hierarchical reasoning in his work on SDI structures in which an SDI hierarchy is made up of inter-connected SDIs at corporate, local, state/provincial, national, regional (multi-national) and global levels. In the model, a corporate SDI is deemed to be an SDI at the corporate level - the base level of the hierarchy. Each SDI, at the local level or above, is primarily formed by the integration of spatial datasets originally developed for use in corporations operating at that level and below. Hierarchical government environments have the potential to contribute to different components of SDI development and hence are important from a catchment management perspective.

Hierarchical spatial theory (Car 1997) as cited by (Car et al 2000), describes the vertical (inter) and horizontal (intra) relationships between different levels of SDIs. It assists the modelling and understanding of SDI relationships. The horizontal or intra-jurisdictional relationship between different hierarchies may not easily be accommodated by these theories. These relationships are particularly important for catchment governance

2.3.2. Diffusion Theory

Diffusion can be referred to as the process of communicating an innovation to and among the population of potential users who might choose to adopt or reject it (Zaltman et al 1973) as cited by Pinto and Onsrud (1993). Gattiker (1990) views diffusion as “the degree to which an innovation has become integrated into an economy.” He emphasises the relationship between innovation and an economy. Spence (1994) describes diffusion as “the spread of a new idea from its source to the ultimate users”. Diffusion can be viewed as “the process by which an innovation is communicated through certain channels over time among the members of a social system” (Rogers 1983). This definition gives rise to four elements of diffusion namely the innovation, the communication channel, time and the social system. This constitutes the foci of research activities in the past decades. Further, Rogers explains that it is a special type of communication in which the messages are about new ideas.

The newness, in this case as highlighted by Chan and Williamson (1999), means that some degree of uncertainly is involved in diffusion.

Although the diffusion of innovations model has been criticised for its pro-innovation bias, the theory of diffusion as an innovation model (Rogers 1995) is appropriate for the study of SDI diffusion. More than half the world's countries claim that they are involved in some form of SDI development (Crompvoets 2006), but most of these initiatives can better be described as 'SDI like or SDI supporting initiatives.' Only a few countries can be described as having operational SDIs. The diffusion of SDI came from a tradition of SDI-like thinking or national GI systems before SDI itself formally came into being.

Cultural factors are also likely to influence SDI adoption. de Man (2006) used a four dimensional model developed by Hofstede and Hofstede (2005) to assess the cultural influences on SDI development. They found that national cultures varied with respect to four main variables: power distance (from small to large), uncertainty avoidance (from weak to strong), masculinity versus femininity, and collectivism versus individualism. In an SDI environment, de Man argues that cultures where there are large power distances are likely to use SDI to reinforce the influence of management, whereas those with small power distances will be more receptive to data sharing and accountability. Both diffusion and innovation theory are potentially important to understanding the adoption of SDI within catchment management environments.

The diffusion theory (Rogers 1971; Zaltman et al 1973) describes the spread of a new idea from its source to the ultimate users. The concept of SDI has emerged from developed economies and has spread all over the world. Now, the developing countries are also initiating various forms of SDIs to improve the utilisation of their spatial data assets for economic and social well-being. The limitation of diffusion theory is that it has an innovation bias and some degree of uncertainty is involved. Diffusion theory is also applicable for catchment management as new ideas are spread to the community and stakeholders though diffusion.

2.3.3. Principal-Agent (P-A) Theory

According to neo-institutional economics (NIE), the Principal-Agent (P-A) theory which focuses on authority and sharing responsibilities (North 1990) provides another relevant perspective for SDI development. In P-A relationships three aspects are considered. The first is the definition of who has authority/responsibility (principal) and who is carrying out work on the behalf of an authority (agent). The second describes the extent to which a principal can control or check the agent, and the third considers the extent to which an agent can take on authority/responsibility. P-A theory may be useful in defining SDI partnerships or collaborations as there is often multi-level stakeholder participation in SDI implementation, particularly for catchment management.

Effective data sharing among participants is needed for SDIs to become fully operational in practice. Continuous and sustainable data sharing is likely to require considerable changes in the organisational cultures of the participants. To facilitate sharing, the GIS research and user communities must deal with both the technical and institutional aspects of collecting, structuring, analysing, presenting, disseminating, integrating and maintaining spatial data. For this reason there is a pressing need for more research on the nature of data sharing in multi-level SDI environments.

The studies that have been carried out by Nedovic-Budic and Pinto (1999) and Nedovic-Budic et al (2004) in the USA provide a useful starting point for work in other parts of the world. Similarly, the findings of Harvey and Tulloch (2004) during their survey of local governments in Kentucky demonstrate the complexity of the networks involved in collaborative environments of this kind. Wehn de Montalvo’s (2003) study of spatial data sharing perceptions and practices in South Africa from a social psychological perspective also highlights the issues associated with the sharing of data. This study, which utilised the theory of planned behaviour, found that the personal and organisational willingness to share data depends on attitudes to data sharing, social pressures to engage or not engage, and perceived control over data sharing activities of key individuals within organisations. Likewise, McDougall

(2006) reported on critical factors that impact on the success of partnerships for spatial data sharing including policy, governance, funding, leadership and vision.

The Principal-Agent (P-A) theory is useful for gaining a better understanding of the relationships in sharing spatial data and partnership/collaboration. The first and most important task is identification of stakeholders and determining their interests, importance and influence. This could be determined by an interest power matrix (deVries 2003). This will then enable strategies to be developed for community led stakeholders' participation for catchment governance and management.

2.3.4. Actor-Network Theory (ANT)

Actor-network theory (ANT) is a social theory, also known as the sociology of translation, which emerged during the mid-1980s, primarily with the work of Bruno Latour (1987), Michel Callon (1986), and John Law (Law 1992). ANT is a conceptual framework for investigating society-technology interactions and its primary building blocks are interaction between actors. It considers the whole world as patterned networks of heterogeneous entities containing both human and non-human elements. Harvey (2001) defined actor networks as "the traces of relationships between people, institutions, and artifacts connected by agreements and exchanges." Shi (2008) has used ANT for analysing and understanding the social and technical nature of the watershed management process and decision tools.

The relevance of ANT theory for SDI developments and GIS projects has been explored by a number of authors (Crompvoets et al 2010; de Man 2006; Harvey 2000; Harvey 2001; Reeve and Petch 1999). Reeve and Petch (1999) argue that the success of GIS projects depends upon the consideration of socio-organisational contexts, ie actor-network theory. Harvey (2001) puts the actor network of the professional GIS-user in the centre of the technology proliferation process. His approach incorporates all network activities, including technological ones. Based on research in Switzerland, he asserts that actor networks and technology, basically GIS-technology, affect one another. Data exchange stimulates the emergence of effective inter-organisational de facto standards. They help to maintain actor networks, while prescribed standards do not work and consequently will not have an impact.

de Man (2006) argues that the process of developing networked assemblies is viewed by ANT as interplay between heterogeneous actors and social elements tied together in actor-networks. The actor-network perspective views SDIs as resulting from continuous ‘translations’ between heterogeneous actors and, hence, as potentially unstable. Alliances may be locked into collaboration but generally only temporarily. He concludes that the actor-network perspective calls attention to the dilemma of how to navigate between the needed authority and some form of central control, and active involvement (participation) in developing SDI initiatives. Crompvoets (2010) argued that spatial data infrastructure is a complex actor-network and the value of spatial data can be added through complex value network process. Their value is added through the translations between the different actors. Therefore, the value of spatial data can be assessed realistically only when the interests, beliefs and values of the individual actors are taken into account. This theory can be useful for spatially enablement of community, government and society.

2.3.5. Social Network Theory

The Social Network Theory is a social science concept that explores the connection and relationship in a social structure (Kadushin 2004). It aims to represent and understand latent social structures and social relations. According to Brass (1992), a social network is a set of nodes or actors that are connected by a set of social relationships. It views social relationships in terms of nodes and ties. Nodes are the individual actors within the networks, and ties are the relationships between the actors. The actors can be all types of social entities, for example, individuals, groups, organisations, or nation-states (Wasserman and Faust 2008). The outputs from social network analysis can be presented in a graphical or mathematical way (Keast and Brown 2005). Graphical analyses concern the mapping of all of the relevant ties between the nodes and are often displayed in a social network diagram, where nodes are the points and ties are the lines. Mathematical analyses involve advanced calculations (measure of centrality and density of network or actors) and statistical analysis of the data.

The ties are based on conversation, affection, friendship, kinship, authority, economic exchange, information exchange, or anything else that forms the basis of a relationship. Four potential types of relational ties have been distilled from the literature (Scott 2000; Tichy et al 1979) as cited by Keast and Brown (2005), namely ties that:

- affect exchange (liking, friendship, kinship);
- influence or power exchange;
- information exchange; and
- goods and services exchange.

In a network, flows between objects, actors and exchanges, which might contain advice, information, friendship, career or emotional support, motivation, and cooperation, can lead to very important ties (Kadushin 2004). These relationships can then be analysed for structural patterns that emerge among these actors. Thus, an analysis of social networks looks beyond attributes of individuals to also examine the relations among actors, how actors are positioned within a network, and how relations are structured into overall network patterns (Scott 2000; Wasserman and Faust 1994).

Social network theory is being increasingly utilised for spatial data sharing and SDI related research. Omran (2007) used social network theory and social network analysis to explain spatial data sharing (SDS) behaviour. He used social network analysis to map organisational networks and to determine the actual SDS-behaviour. His study was focussed on understanding motivations for data sharing and how this was related to network topology. Van Oort etal (2010) utilised social network analysis to study spatial data sharing across organisational boundaries. This study was focussed on how the network can be used for the purpose of sharing of metadata, requests for help, feedback on product quality, innovative ideas, and so on. Vancauwenberghe et al (2011) argued that SDI can be viewed from a network perspective and social network analysis can be used as a method for SDI research. The case consisted of a sub-national case of SDI in Flanders and analysed the Flemish spatial data exchange network.

A number of authors (Coleman 2010; Elwood 2008; Goodchild 2007; Goodchild 2008; Kuhn 2007; McDougall 2010) have begun to explore the application of social network theory to Volunteered Geographical Information (VGI) and spatial information sharing. The term Volunteered Geographical Information (VGI) was first used by Michael Goodchild to describe the diverse practices of observing, collecting and producing geographic information by citizens with no formal expertise in the area (Goodchild 2007).

The first research specialist meeting on VGI was organised under the auspices of NCGIA, Los Alamos National Laboratory, the Army Research Office and The Vespucci Initiative and brought researchers from around the globe to discuss the potential of VGI for spatial information management. Coleman (2010) took a close look at how the concept of VGI fits within spatial data infrastructure (SDI). The utilisation of VGI for spatial information collection and updating is now widely used by OpenStreetMap, TeleAtlas, NAVTEQ and Google Maps. Government organisations have now also realised the power of VGI and crowd sourcing and are interested in utilising this technology for spatial data infrastructure development. U.S. Geological Survey was an early examiner of this technology. State governments in Victoria (Australia), and North-Rhine Westphalia (Germany) are two good examples of employing volunteered input to their mapping programs in the government sector (Coleman 2010). The Department of Sustainability and Environment (DSE) in Victoria employ notification and editing services (NES) to improve processes for notifying and updating changes to Victoria's authoritative spatial datasets accommodating internal contributions of volunteered geographic information. The NES is available to state and local government organisations that already participate in data sharing and data maintenance programs within the DSE. With their volunteer inputs they can amend or update Victoria's authoritative spatial datasets (Department of Sustainability and Environment Victoria 2012).

Coleman (2010) suggested eight potential motivations for volunteers to contribute VGI as altruism, professional or personal interest, intellectual stimulation, protection or enhancement of a personal investment, social reward, enhanced personal reputation, to provide an outlet for creative and independent self-expression, and pride of place. Thompson et al (2011) explored altruism, and outlets for creative self-expression were the main motivations for participants to utilise VGI approach in support of local landscape planning. Connors et al (2011) critically assessed the environmental monitoring case study and identified the motivations for participants to utilise VGI. They argued that producer from the civic and governmental context were likely to be motivated by professional or personal interest, intellectual stimulation, and protection or enhancement of a personal investment. However, the others were motivated by agendas (eg, preserving or diminishing real estate values or promoting landscaping services).

Social Network Theory illustrates the network perspectives of SDI and is useful for volunteered geographical information (VGI) and spatial information sharing related research. The Social network analysis provides some useful measures to understand and visualise the various relationships in collaboration and networking.

Table 2.3 summarises the various SDI theory/citations, main contributors of that theory in spatial science domain, their characteristics, strengths, limitations, and value of catchment management.

Table 2.3: SDI theoretical foundation and value for catchment management

SDI Theory/Citation	Characteristics	Strength	Limitations	Value for catchment management
Hierarchical Spatial Theory Car (1997)	Describes the vertical (inter) and horizontal (intra) relationships between different levels of SDIs.	Assist modelling of SDI relationships in structured environments	Horizontal relationships between different levels is not well addressed	Horizontal (intra) relationships between different levels of SDIs is useful
Diffusion theory Rogers (1971), Zaltman et al (1973)	Process of innovation of a new idea from its source to the ultimate users	Special type of communication in which the messages are about new idea	Innovation bias and some degree of uncertainty involved	New ideas move to the community via diffusion
P-A Theory North (1990)	Determine who has authority/responsibility and who is carrying on the behalf of authority	Useful for SDI partnership and collaboration	Does not cope with the theory of planned behaviour as organisational willingness is important for data sharing	Useful for data sharing and partnerships
Actor-network theory (ANT) Latour (1987, Callon (1986) Law (1992)	Investigates society-technology interactions	Understand the social and technical nature	Views SDIs as resulting from continuous translations between actors	Useful for spatial enablement development
Social Network Theory Brass (1992)	Discusses the connection and relationship in a social structure	Views the network perspectives of SDI	More social bias and sometimes delayed the implementation	Useful for VGI and spatial information sharing

2.4. SDI Development Issues and Challenges

Many countries are developing SDIs to improve access and sharing of spatial data (Crompvoets 2006) however there are many issues and challenges which need to be overcome to have a full functioning SDI (Williamson et al 2006a). SDI development issues can be seen from technical, political, institutional, legal and financial perspectives. However, SDI development issues can broadly be categorised into technical as well as non-technical issues. Masser (2011) argues that the development of SDIs in particular countries must be user driven as their primary purpose is to support decision-making for many different purposes. SDI implementation not only includes technical matters such as data, technologies, standards and delivery mechanism but also institutional matters related to organisational responsibilities, national policies, financial, and human resources. Many SDI practitioners (Masser

2006; Mohammadi 2008; Onsrud et al 2004; Van Loenen 2006; Williamson et al 2006a) argue that the non-technical issues are more complex in comparison with the technical issues. Williamson et al (2006a) introduced and discussed the following six SDI challenges and issues to meet the sustainable development objectives of society:

- SDI to facilitate spatially enabled government;
- role of government, private and academic sectors;
- development of SDI vision, mission and road map - where are we heading?
- SDI to facilitate integration of natural and built environment datasets;
- SDI to support marine administration - Seamless SDI model; and
- capacity building.

Onsrud et al (2004) argued that social and institutional issues were the most challenging issues for SDI development. The authors also recommended ten research projects that might be undertaken within the context of SDIs. The major research project themes includes measure of legal, economic, and information policy, evaluate the costs-benefits of current government information polices, explore and develop a range of institutional and legal arrangements for accessing geographic resources, strategy development for increasing public access to government information and compare government spatial information dissemination policy.

During spatial data integration and harmonisation, Mohammadi (2008) categorised five areas of SDI issues as technical, institutional, policy, legal and social as shown in Table 2.4.

Table 2.4: Spatial data integration issues (adapted from Mohammadi, 2008)

Technical Issues
Different data sources and accuracies, data quality, multiple raster and vector formats, variety of spatial resolution, temporal resolution, different scales, metadata concerns, interoperability problems, different semantics and representations, compilation standards, differences in datum, projections, coordinate systems, data models, precision and accuracy, different purposes of datasets, and different base maps
Institutional Issues
Inter- and cross organisational access, retrieval and display arrangements, sharing data among organisations, different coordination and maintenance arrangements, high degree of duplication, weak collaboration, uncoordinated specifications and standards across spatial stakeholders, lack of single point of access, and building awareness
Policy Issues
Pricing models, access policies, and use restrictions
Legal Issues
Different license conditions, intellectual property rights, licensing, and liability regimes
Social Issues
Silo mentality without effective mergers among silos, and aversion against data sharing and integration

Salleh and Khosrowshani (2010) conceptualised the spatial data sharing issues from critical analysis of literature and categorised the issues into technical and non-technical issues. The non-technical issues include institutional (responsibility, environment, outcomes and resources), political (policy, power, bureaucracy, power and constraints), legal (liability, confidentiality and pricing), and social (awareness, motivation, behaviour and insufficient staff).

Therefore, in this research the SDI development issues are broadly categorised into technical and institutional issues/legislative issues and covered under economic, social, political, and environmental challenges.

2.5. Spatial Data Sharing

One of the key motivations for spatial data infrastructure (SDI) development is to provide ready access to spatial data to support decision-making (McDougall 2006). This section describes the spatial data sharing concept and different spatial data sharing models and frameworks.

2.5.1. Spatial Data Sharing Concept and Rationale

Calkins and Weatherbe (1995) defined spatial data sharing as "the (normally) electronic transfer of spatial data/information between two or more organisational units where there is independence between the holder of the data and the prospective user." Omran (2007) defined it as "those transactions in which individuals, organisations or parts of organisations obtain access from other individuals, organisations or parts of organisations to spatial data." McDougall (2006) clarified that the term "transaction" could be routine or non-routine, may be internal or external to the organisation, but importantly it is an "arm's-length exchange or transfer."

Bregt (2011) reviewed the book "Building European Spatial Data Infrastructures" by Ian Masser (2010) and advised that the narrative anchor for SDI is "sharing spatial data." Spatial data sharing is recognised as one of the important components in spatial data infrastructure design and development. There are many studies done by scholars for sharing spatial data (Kevany 1995; McDougall 2006; Omran 2007; Onsrud and Rushton 1995; Warnest 2005; Wehn de Montalvo 2003), however, the studies were mainly based on the spatial data provider's point of view and do not recognise the power of spatial data users. Due to the advent of spatial technology and spatial awareness, spatial information users are becoming more important for the spatial data infrastructure design and development and hence it is necessary to look from the users' perspectives.

The rationale for sharing spatial data is that the data sharing processes provide a number of benefits to the organisations involved. Its benefits are clearly elaborated in the GIS literature (Azad and Wiggins 1995; Kevany 1995; Masser 2005; National Research Council 1993; Nedovic-Budic and Pinto 1999; Nedovic-Budic et al 2011; Onsrud and Rushton 1995; Williamson et al 2003). This literature identified the benefits as:

- saving costs and time in data collection;
- avoidance of duplication of efforts and unnecessary data redundancy;
- improved data availability and providing better data for decision making;
- enhanced inter and intra organisational relationships;
- creating "connections" among widely dispersed databases;
- expanding spatial markets;

- facilitating the development of spatial knowledge infrastructure;
- providing efficient services;
- improving the value and quality of information;
- aids cross-jurisdictional or cross organisational analyses and decision making; and
- promoting spatially enabled society.

Despite all these benefits, spatial data sharing is easier to advocate than to practise (Azad and Wiggins 1995). There are many issues that hinder sharing spatial information between organisations. The issues can be categorised into organisational/institutional issues, technical and technological issues, economic issues, legal considerations and political issues (McDougall 2006). McDougall (2006) undertook a critical analysis of the spatial information issues through a literature study and concluded that the growing importance of the Internet connectivity, resourcing, trust and institutional frameworks (particularly policy), are key issues.

2.5.2. Data Sharing Frameworks and Models

Various frameworks and models on data sharing are found in the literature. Among them are a generic model of the Mapping Science Committee of the National Research Council (National Research Council 1993), taxonomy for research into spatial data sharing (Calkins and Weatherbe 1995), antecedents and consequences of information sharing (Pinto and Onsrud 1995), factors relevant to GIS data sharing (Kevany 1995), a typology of six determinants of inter-organisational relationships (Oliver 1990), typology based on inter-organisational relations and dynamics (Azad and Wiggins 1995), an organisational data sharing framework (Nedovic-Budic and Pinto 1999) a model of willingness based on theory of planned behaviour (Wehn de Montalvo 2003), interaction between organisational behaviour of spatial data sharing and social and cultural aspects (Omran 2007), a collaboration model for national spatial data infrastructure (Warnest 2005), local government data sharing (Harvey and Tulloch 2006; Tulloch and Harvey 2008), the local-state data sharing partnership model (McDougall 2006) and geospatial one-stop (Goodchild et al 2007). McDougall (2006) examined the empirical research on spatial data sharing and SDI and summarised the spatial data sharing models/frameworks into characteristics, strengths and limitations. The existing spatial data sharing models/frameworks, their characteristics, strengths and limitations are summarised in Table 2.5.

Table 2.5: Summary of spatial data sharing framework (after McDougall, 2006)

Model/Framework	Characteristics	Strengths	Limitations
Mapping Science Committee of the National Research Council (1993)	An operational model based on process	Simple model that recognises different levels, standards, quality and role of agreements	Model does not recognise the important organisational complexities and context
Calkins and Weatherbe (1995)	Taxonomy based on characteristics of organisation, data exchange and constraints/impediments	Framework recognises organisational issues and nature of exchange	Limited with respect to motivations, policy and capacity of organisations
Kevany (1995)	Factor and measurable based model	Very comprehensive list of factors that can be rated based on existing exchanges	Based on personal experience and not supported by theoretical foundations
Pinto and Onsrud (1995)	Conceptual model based on antecedents and consequences	Based on exchange and organisational theory. Basis for further research	Mainly conceptual and has limited depth or justification of factors
Azad and Wiggins (1995)	Typology based on IOR and dynamics	Attempts to classify organisation dynamics and behaviour (Oliver 1990).	Lack of justification of the initial premise that data sharing leads to the loss of autonomy and independence, and lack of empirical evidence
Nedovic-Budic and Pinto (1999) Nedović-Budić et al, (2011)	Based on the theoretical constructs of context, motivation, mechanisms and outcomes	Broad theoretical basis supported through later quantitative validation in later studies	Limited exploration of the exchange processes
Wehn de Montalvo (2003)	Based on theory of planned behaviour	Strong theoretical basis that is strengthened through a mixed methods approach	Model is predictive (by design) and may not be directly applicable to the analysis of existing initiatives.
Nedovic-Budic and Pinto (2000)	Empirical model based on context, structure, process/issues and outcomes	Model enabled the empirical assessment of the detailed model issues via a case study approach	Limited to five case studies only and a larger application of model would further verify outcomes
McDougall (2006)	Generic model consists of contextual factors, collaborative process and outcomes.	Model recognised the nexus between the collaborative process and the institutional and	do not adequately consider a range of technical, institutional, political and

		jurisdictional environments and designed for sharing of spatial data between state and local governments	economic factors and limiting their contribution to SDI development
Tulloch and Harvey (2008); Harvey and Tulloch (2006)	Typology based on conceptual issues and characteristics (organisational, community, political, legal, financial, and personalities)	Model explored typology of local government spatial data sharing via a case study approach. It explored the four types of spatial data sharing models as Open shop, Hub-and spoke, Federation by accord and Federation by mandate	Limited to US National Spatial Data Infrastructure (NSDI) case study and a broader quantitative study is required in order to expand the significance of these findings
Omran (2007)	Model explored the interaction between organisational behaviour of spatial data sharing and social and cultural aspects from network topology perspectives	The collective properties of spatial data sharing in organizations was investigated using social network analysis	Complex interactions that exist between information type, network structure, and individual behaviour, were not explored

Most of these frameworks were based on the authors' experiences and have not been proven empirically except for Nedovic-Budic and Pinto's (1999), Wehn de Montalvo's (2003) Harvey and Tulloch's (2006) and McDougall's (2006).

2.5.3. Motivators and Barriers for Spatial Information Sharing

This section presents the motivators and barriers for spatial information sharing. The issues that impact on the sharing of spatial information are broad-ranging and include organisational/institutional issues, technical and technological issues, economic factors, legal considerations and political issues (McDougall 2006). Nedovic-Budic and Pinto (2000) identified two factors that shape the processes involved in data sharing activities and their outcomes: motivations for engaging in data sharing activities, and structural characteristics of the interaction mechanisms implemented by the data sharing entities. Many researchers (Harvey 2001; Harvey and Tulloch 2006; McDougall 2006; Nedovic-Budic and Pinto 2000; Nedovic-Budic et al 2011; Omran 2007; Onsrud & Rushton 1995; Wehn de Montalvo 2003) tried to understand the spatial data sharing issues and the benefits and constraints in spatial data sharing. McDougall (2006) categorised these issues into barriers (constraints) and the benefits (which will motivate). Table 2.6 summarises the motivators and barriers for spatial data sharing (ie why organisations may or may not engage in spatial data sharing). These motivators and barriers for spatial information sharing were determined through the literature review.

Table 2.6: Motivators and barriers for spatial information sharing

Motivators
Cost saving through lack of duplication of data collection and maintenance efforts
Improved data availability and quality
Enhanced organisational relationships through promotion of cross organisational relationships
Reduction in risk if organisations are prepared to contribute to the costs or development time for a shared initiative
High returns on investment
Improved user satisfaction
Barriers
Cost recovery, copyrights and legal liability
Priorities of the organisation, organisational disincentives and lack of support from management
Trust and unequal commitment from organisations
Insufficient staff, staff turnover and lack of technical resources
Networking costs; data confidentiality, liability and pricing
Differences in data quality
Lack of common data definitions, format and models
Conflicting priorities
Lack of leadership and coordination mechanism
Cultural (political and institutional)
Power disparities and differing risk perception

2.5.4. Spatial Information Sharing Components

Australian Government Information Management Office (2009) has proposed some nine conditions for information sharing. They include provision of leadership, demonstrate value, act collaboratively, establish clear governance, establish custodianship guidelines, build for interoperability, use standards-based information, promote information re-use and ensure privacy and security. Pinto and Onsrud (1995) argued the factors to facilitate spatial information sharing between two or more GIS using organisations are superordinate goals, bureaucratisation rules and procedures, incentives, accessibility, quality of relationships and resource scarcity. They demonstrated how these antecedent variables influenced the efficiency, effectiveness and enhanced decision making ability of organisation. This approach is based on organisational theory. The Office of the Director of National Intelligence (2008) has proposed a range of issues for information sharing that span governance, policy, technology, culture, and economic facets. Based on these three literatures five areas and their attributes are identified for spatial information sharing through collaborative networks. Table 2.7 describes these five key areas and their main attributes for spatial information sharing to improve NRM planning and decision making process.

Table 2.7: Spatial Information Sharing Components (Paudyal et al 2010)

Components	**Attributes**
Governance (Sharing environment)	mission, goal, objectives, stakeholders (data producers and users), leadership, custodianship, roles and responsibilities, rights and restrictions, governance methods
Policy (Rules for sharing)	laws, rules and regulations, policies and procedures, protocols, accessibility, privacy, liability, copyrights, IPRs
Technology (Capacity to enable sharing)	data model, standards, software, security, tools/mechanism, data quality, metadata, resource, interoperability
Culture (Willingness to share)	Trust, motivation, communication, adaptation during circumstances changes, reciprocity, relationship
Economics (Value of sharing)	funding, incentives, pricing, cost recovery, transaction cost

2.6. Emerging SDI Applications

One of the key motivations for spatial data infrastructure (SDI) development is to provide ready access to spatial data to support decision-making (Feeney 2003). SDI is recognised by many countries as an essential modern infrastructure like information communication technology (ICT), transportation, etc (Ryttersgaard 2001; Williamson et al 2003). Importantly, SDIs are the product of the information age and the basic difference between other kinds of infrastructure and SDIs is that its characteristics are virtual rather than physical. SDI application areas and custodianship of spatial information are changing with the emerging technologies and the societal needs.

The emerging application areas are also linked to the creation of economic wealth, social stability and environmental protection objectives and can be facilitated through the development of products and services based on spatial information collected by all levels of society including government, the private sector, and the citizens (Rajabifard et al 2010). These objectives can be realised through the development of a spatially enabled community, government and society. Spatial enablement requires data and services to be accessible and accurate, well-maintained and sufficiently reliable for use by the majority of society which is not spatially aware (Williamson et al 2010). Traditionally, the mapping and spatial data infrastructure development was accomplished by government agencies, particularly national/state mapping agencies. However, this is not the case, with all sectors of society increasingly becoming spatially enabled and contributing to the development of SDI. The easily accessible and available spatial products such as Google Earth, hand-held navigation systems (including smart phones, GPS, etc), web 2.0 technology, and social media has opened the way for spatial data collection and management and is contributing towards a spatially enabled society and next generation of SDI development. The next section describes the emerging SDI concepts, particularly the spatial enablement.

2.6.1. SDI Towards a Spatially Enabled Government

One of the emerging application areas where SDI is applicable is for e-government services. The term e-government is of recent origin and there exists no standard definition (Yildiz 2007). According to the World Bank (2011) "e-government refers to the use by government agencies of information technologies (such as Wide Area Networks, the Internet, and mobile computing) that have the ability to transform relations with citizens, businesses, and other arms of government." These technologies can serve a variety of different ends: better delivery of government services to citizens, improved interactions with business and industry, citizen empowerment through access to information, or more efficient government management. The resulting benefits can be less corruption, increased transparency, greater convenience, revenue growth, and/or cost reductions. The generally accepted definition is "e-government or electronic government refers to the use of Information and Communication Technologies (ICTs) by government agencies for any or all of the following reasons." (Curtin 2008):

- exchange of information with citizens, businesses or other government departments;
- speedier and more efficient delivery of public services;
- improving internal efficiency;
- reducing costs or increasing revenue; and
- re-structuring of administrative processes (http://www.nisg.org).

SDI is a crucial component in providing the best available information for good governance of the community. In most societies, citizens view government at all levels with suspicion (Warnest 2005). It is the responsibility of government to change that perception and that can only be achieved by performance coupled with good governance and transparency (Grant 1999). Nowadays, spatial data is framed within strategies that primarily aim to work towards a better government and improved living standards for society (Blakemore, 2004).

Williamson et al (2006b) identified Spatially Enabled Government (SEG) as an enabling infrastructure to facilitate use of place or location to organise information about activities of people and businesses, and about government actions, decisions and policies. They conclude that a whole of government approach is needed to ensure that the spatial enablement of interoperable networked systems goes beyond the existing core businesses of land administration organisations and spatial information policy become crucial.

The achievement of the SEG vision requires SEG to build on SDI initiatives that are an important and integral part of a country's infrastructure (Mohammadi 2008). SDIs aim to develop an enabling platform, including institutional arrangement. SEG is also an important part of countries' ICT, e-government and information-sharing strategies as a key activity that fosters innovation. The focus of SEG is on the use of spatial information to achieve government policy objectives, though SDI is essential to achieving SEG outcomes (Williamson et al 2007). The "FIG-Task Force on Spatially Enabled Societies" identified six key elements which are critical for SEG implementation as legal framework, common data integration concept, positioning infrastructure, SDI, land ownership information and data and information concepts

(Steudler and Rajabifard 2012). They argue that SDIs provide the physical and technical infrastructure for spatial data and information to be shared and distributed.

2.6.2. SDI Towards a Spatially Enabled Community/Society

SDIs are now moving to play a role in underpinning communities' enablement outside the surveying and mapping and land administration area including environmental management, counter-terrorism operations and emergency management through the provision of timely and relevant information to the community, business and government. Therefore, SDI promotes the ability to design and develop a spatially enabled platform for decision-making in support of sustainable development. There are both top-down as well as bottom-up approaches for SDI development. The bottom-up approach basically focuses on the spatial enablement of community to foster environmental sustainability, poverty reduction and sustainable development. SDI creates opportunities for NRM agencies and community groups by ensuring that the most current information is used for decision making.

Societies can be regarded as spatially enabled "where location and spatial information are regarded as common goods made available to citizens and businesses to encourage creativity and product development" (Wallace et al 2006). The SDI should be designed and developed so that it will provide an enabling platform that will serve the majority of society who are not spatially aware. Masser et al (2008) highlighted four strategic challenges that need to be addressed for developing a spatial data infrastructure (SDI) that will provide an enabling platform to serve the majority of society who are not spatially aware (Figure 2.10) .

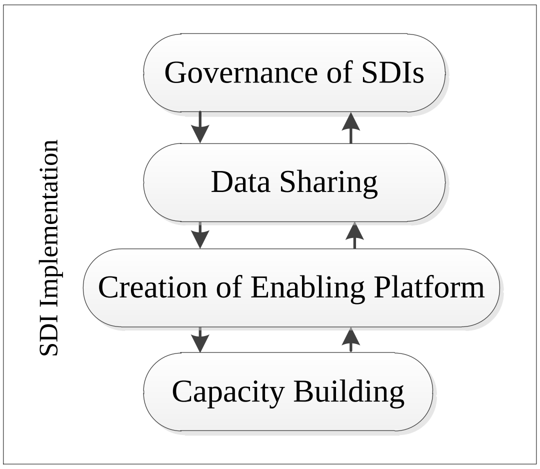

Figure 2.10: Strategic challenges (adopted from Masser et al 2008)

The first of these is the need for more effective, robust and inclusive models of governance given that SDI formulation and implementation involves a very large number of stakeholders from all levels of governments, communities, private sectors and academia. The second concerns the promotion of data sharing between kinds of organisation. In some cases, this may require new forms of organisation to carry out these tasks (Rajabifard 2007). The third challenge is the creation of enabling platforms to facilitate access, use/re-use and dissemination of spatial data and services. The fourth challenge relates to capacity building tasks to create a full spatially enabled society. The creation of such a platform will involve large numbers of organisations and people working together over a long period of time.

2.6.3. Relationship between Spatially Enabled Government, Community and Society

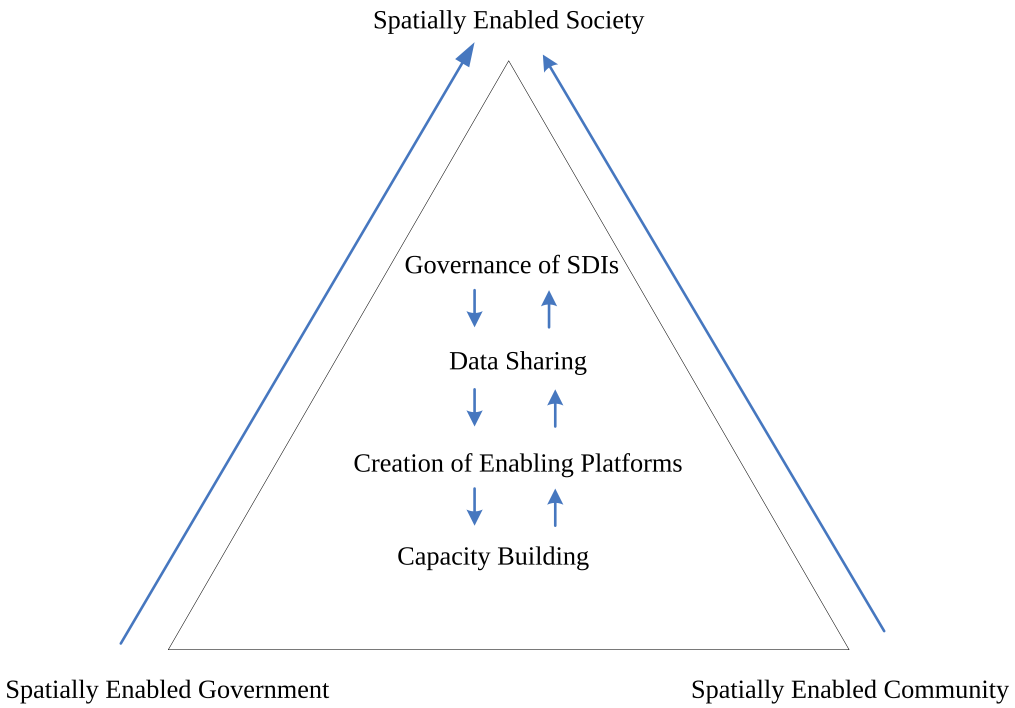

Figure 2.11: Strategic challenges (modified from Masser et al 2008)

Figure 2.11 demonstrates the relationship between the spatially enabled government, spatially enabled community and spatially enabled society. Spatial enablement requires data and services to be accessible and accurate, well-maintained and sufficiently reliable for use by the majority of society which may not be spatially aware (Williamson et al 2010). Traditionally, the mapping and spatial data infrastructure development was accomplished by government agencies, particularly national/state mapping agencies. However, this is now not the case, with all sectors of society increasingly becoming spatially enabled and contributing to the development of SDI. The readily accessible and available spatial products such as Google Earth, hand-held navigation systems (including smart phones, GPS, etc.), web 2.0 technology, and social media has opened the way for spatial data collection and management and is contributing towards the next generation of SDI development and a spatially enabled society. The community and government work together and contribute to a spatially enabled society. Creating an enabling platform for community and government can contribute towards a spatially enabled society.

Basically, the enabling platform will serve the majority of society who are not spatially aware. The four strategic challenges are interconnected and the goal of spatially enabled society can be achieved to address these challenges.

2.7. Chapter Summary

Spatial data and spatial data infrastructure (SDI) are crucial to satisfying the requirements of people and businesses and assisting them with informed decision making. Eighty per cent of the information utilised by people and businesses are spatial or have spatial dimensions (Klinkenberg 2003; Ryttersgaard 2001). The data/information has the power to create knowledge and promotes the knowledge based society. Current progress of SDI initiatives shows that SDI is viewed, defined and interpreted differently by different practitioners. However, some critical objectives and components are similar. Facilitating the use, exchange, sharing, access and distribution of spatial data is the most important task of SDI, while components like fundamental data, spatial data stakeholders, policy framework, standards, access networks, partnerships, governance and capacity building have been highlighted as the most crucial components required to fulfil these tasks. From theoretical perspectives, five theories (Hierarchical Theory, Social Network Theory, Diffusion Theory, ANT Theory and Principal-Agent Theory) were found to be relevant to SDI development.

The understanding of spatial data sharing concept and differing spatial data sharing models/frameworks were explored and the motivators and barriers for spatial information sharing were discussed. Spatial data sharing literature highlighted the organisational and cultural issues which continue to be the significant challenges for improving spatial information sharing outcomes.

Initially, SDIs were implemented as a mechanism to facilitate access and sharing of spatial data hosted in distributed GISs. Users, however, now require precise spatial information in real time about real-world objects and SDI is emerging as an enabling platform. These days SDI is emerging to fulfil the societal needs and support for sustainable development.

Chapter three describes catchment management and the relationship of spatial information for NRM operations. The application of spatial information and SDI for better catchment outcomes is examined.

Chapter 3

Catchment Management and Spatial Information

3.1. Introduction

The previous chapter examined the development of Spatial Data Infrastructure (SDI) from a theoretical aspect and discussed the emerging SDI applications, including the spatially enabled society. The purpose of this chapter is to understand the concept of catchment management, its policy context, and explore the application of spatial information and SDI for improved catchment management outcomes. This chapter consists of five sections. Section 3.2 describes the various terminology used for catchment management and its history from Australian policy perspectives. Section 3.3 describes the institutional arrangements in the Australian jurisdictions. Section 3.4 describes catchment management practices in Australia. Section 3.5 describes spatial information developments for catchment management in Australia. Section 3.6 describes Modelling SDI for Catchment Management. Finally, section 3.7 concludes the chapter with a brief summary.

3.2. Catchment Management Overview

This section describes the common terminology used in this thesis and the history of catchment management in Australia from a policy context.

3.2.1. Definitions

3.2.1.1. Catchment

Catchments are naturally occurring divisions in the landscape, defined by the flow of surface waters. A catchment is a discrete geographical area of land whose boundaries are derived primarily from natural features such that surface water drains and flows to a river, stream, lake, wetland or estuary (Commonwealth of Australia 2000).

3.2.1.2. Catchment Management

Catchment management refers to the practice of managing natural resources using river catchment systems as the unit of management. As an approach to managing land and water resources, catchment management involves integrating ecological, economic and social aspects of natural resource management around an identified catchment system. It aims to integrate these considerations in the way that best ensures long-term viability whilst at the same time serving human needs

(Commonwealth of Australia 2000). Catchment management is the holistic management of natural resources within a catchment unit encompassing interrelated elements of land and water, managed on an ecological and economic basis and incorporating social systems. It is a system that favours the integration of environmental policy across government, community and industry sectors through partnerships and extensive stakeholder inclusion (Agriculture Forests and Fisheries Australia AFFA 2002). The term *catchment management* and *watershed management* are used interchangeably. In USA and Canada the term watershed management is used, however in Australia, the term catchment management is more widely accepted.

3.2.1.3. Total Catchment Management (TCM) and Integrated Catchment Management (ICM)

Catchment management is not readily amenable to systems analysis in a precise fashion, partly because of the complexity of the land, water and environment relationships and the lack of management tools capable of handling this in a spatial context. There are two main schools of thought in the catchment management doctrine, namely: the total catchment management (TCM) and the integrated catchment management (ICM) approaches.

TCM is a holistic approach that seeks to integrate water and land management activities and the community and government involvement associated with these activities in a catchment. Total catchment management involves the coordinated use and management of land, water, vegetation, and other physical resources and activities within a catchment to ensure minimal degradation of the environment (Cunningham 1986). The boundary of a catchment in the context of TCM is (at least in theory) the entire catchment, including all biophysical processes active within that catchment.

ICM aims to coordinate the activities of landholders, community groups, industry groups and all spheres of government within the river catchment (CCMA 2001). It seeks to achieve the long-term sustainable use of land, water and related biological resources. It is taken to mean integrating ecological, economic and social aspects of natural resources management, within an identified catchment system, to ensure long-term viability and sustainability while, at the same time, serving human needs (Pigram 2006). It mostly considers issues and problems which are known and whose affects are being felt by those within the catchment and is the management philosophy more commonly adopted by most states in Australia. The common attributes of integrated catchment management include a system approach, a stakeholder approach, a partnership approach, a balanced approach and an approach in which attention is directed to key issues and variables, rather than all issues and variables (Carr 2002).

3.2.2. Historical Context of Catchment Management in Australia: Policy Context

Australia, like many developed countries, utilises the catchment based approach for the management of natural resources including land and water. Since European settlement of Australia in 1788, the occupation has resulted in the eutrophication of waterways, extensive land clearing, and rising salinity which would be extensive to rectify (Pigram 2006). The severe drought beginning in the 1890s and continual agricultural land degradation and soil erosion changed how Australian farmers thought about managing nature resources (Campbell 1994; Godden 2006).

A catchment based approach to the management of Australia's agricultural lands began in the early 1900s (Agriculture Forests and Fisheries Australia AFFA 2002). The concept of a catchment based approach stems from the models of the Tennessee Valley Authority and the Muskingum (Ohio) watershed Conservancy District from USA (Central Coast Regional Catchment Committee 1999). Following the Second World War it was recognised that the management of Australia's water resources would be critical to economic development and that planning for the use of water resources would involve considering each river valley as a whole. The Hunter Valley Conservation Trust, which was established in 1950, pioneered the introduction of a catchment based approach to manage land and water in Australia (Central Coast Regional Catchment Committee 1999).

After 1960, a number of people emerged as champions of the catchment approach to natural resource management, including Mr Ernest 'Watershed' Jackson from Albury (Millar 2007). Mr. Jackson gained the nickname of 'Watershed' for his promotion of the catchment philosophy over some 40 years, particularly in the Murray-Darling Basin. He swayed the political consciousness regarding catchment management philosophy through writing books and articles and serving on numerous high level committees. Since the late 1960s, the nation has become increasingly aware of a decline in the quality of the Australian environment (Roberts 1990).

During the 1970s, the catchment management movement gained impetus with numerous community projects being implemented and endorsed by government agencies. By the late 1970s environmental degradation caused by agricultural and other land use practices had been recognised and soil conservation agencies moved towards taking a whole of catchment approach to control erosion and better managed land farming group conservation areas (Central Coast Regional Catchment Committee 1999).

The NSW Soil Conservation Service had a long history of catchment management activities dating back to 1915. During the 1970s, the Service demonstrated an interest in catchment philosophy with several official documents and deploying field officers in the rural parts of the state.

The recognition of the existence of significant natural resource management problems requiring action at a national level led, from the early 1980s, to a series of targeted national and state legislative interventions and activities. These included the advent of catchment education in schools and communities (Griffith conference 1983 and Melbourne workshop 1988), formation of Streamwatch/Waterwatch and Saltwatch groups (in the late 1980's), formation of Landcare groups (in 1986-Victoria), formation of the Murray Darling Basin Committee (in 1988), endorsement of the Nature Conservation Act (1980) and the Catchment Management Act (in 1989-New South Wales) and the formation of the Inter-Departmental Soil Conservation Committee (1980-Tasmania) (Central Coast Regional Catchment Committee 1999). Over this time, the philosophy of catchment management became more comprehensive and state government organisations embraced community-government partnership for the sustainable management of natural resources on a catchment basis. The two state agencies particularly concerned with catchment management were those charged with soil conservation and water resources management (Laut and Taplin 1989).

The catchment management approach has enjoyed widespread community support since 1990. The current approach to catchment management relies upon the cooperation of the three tiers of government and community. The establishment of Natural Heritage Trust (NHT) in 1996 was the Commonwealth Government's major contribution to natural resource management including catchment management (Davidson et al 2007; Marshall 2001). A major national legislative initiative occurred in 1999 with the enactment of the Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999.

All state and territory governments are clear about the catchment management philosophy and work with community groups and local government to achieve an ecologically sustainable Australia. Regional delivery of NRM in Australia is founded on a policy framework of investment through agreements between the national and state or territory governments under the Natural Heritage Trust (NHT) from 1997 and the National Action Plan on Water Quality and Salinity (NAP) from 2001 to the consolidation of most NRM programs under Caring for our Country (2008) (Cockfield 2010; Davidson et al 2007).

Each Australian state had its own historical roots and policy frameworks before the establishment of Natural Heritage Trust (NHT) in 1996. Bellamy et al (2002) summarised the history of catchment issues and catchment management policy framework in Australian states (see Table 3.1).

Table 3.1: History of NRM issues and catchment management (after Bellamy, 2002)

NSW	1	Hunter Valley Conservation Trust established in 1950 to coordinate the management of land and water resources in that catchment.
	2	Catchment Management considered as a state environment planning policy under the Environment Planning and Assessment Act 1979.
	3	Total Catchment Management concept began to be promoted in the 1980s and was enabled through the Catchment Management Act 1989.
VIC	1	Historically, the timing of initiatives to tackle catchment management issues reflected the priorities of the day eg the Thistle Act 1856 and the Rabbit Suppression Act in the 1870s.
	2	The findings of an interdepartmental Erosion Investigation Committee led to the Soil Conservation Act 1940. The Soil Conservation and Land Utilization Act 1949 provided for a Soil Conservation Authority (SCA) with greater powers than the previous Board.
	3	By late 1950s, the development of cooperative projects was becoming an important feature of the SCA's work. The Soil Conservation and Land Utilization Amending Act introduced in 1962. Landcare program launched in 1986.
	4	State Salinity Strategy released in 1987.
	5	Catchment and Land Protection Act introduced in 1994.
WA	1	Massive expansion of agriculture from mid 1940s-1960s under a broad philosophy of settlement and development.
	2	By 1980s, considerable concern about land degradation and associated socio-economic problems. Salinity had begun to appear in the landscape.
	3	Amendments (in 1982) of the Soil and Land Conservation Act 1945 which provided the legal basis for Land Conservation Districts (and Committees).
	4	ICM policy released in 1988 and independently reviewed in 1991.
SA	1	Seriousness of wind and water erosion identified in 1938; led to the Soil Conservation Act 1939. An amendment to the Act in 1945.
	2	Water Resources Act 1976 was the first integrated water resources management legislation in Australia; developed in response to concern for the sustainable management of the State's water resources.
	3	Soil Conservation and Landcare Act 1989 enacted to support SA's commitment to the National Soil Conservation Strategy and the Decade of Landcare.
	4	Introduction of the Catchment Water Management Act 1995.The role of the community in integrated water resources planning has been further empowered in the Water Resources Act 1997.
QLD	1	Land degradation became a popular concern in the 1940s.
	2	River Improvement Trusts established in the 1940s which was one of the earliest examples of community-local government based arrangements..
	3	Community-based District Advisory Committees formed in the 1970s, in declared areas of Soil Erosion Hazard (later disbanded in 1986).
	4	ICM program launched in 1991.
TAS	1	The Water Act 1957 was introduced and amended in 1999 as Water Management Act 1999.
	2	The Local Government Act 1993 has laid the way for substantial involvement of local government in regional planning for natural resources in Tasmania..

3.3. Catchment Management Practices in Australia

Catchment-based management is the approach used for land and water resource management in Australian states and territories (Commonwealth of Australia 2000).

This management approach is implemented through the creation of partnerships between the different levels of government, community groups, industry groups and academia. The catchments of creeks, gullies and streams combine to form the catchments of small rivers, which together form the catchments, or river basins, and these combine to form drainage divisions.

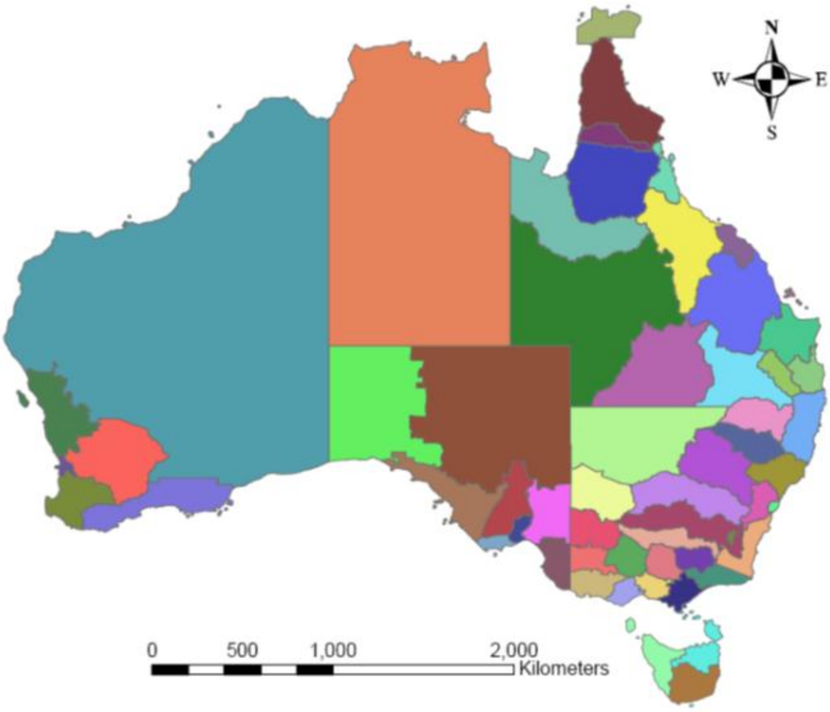

Figure 3.1: Australia's NRM regions (ERIN 2010)

Within Australia, there are 12 drainage divisions, 56 NRM regions and 324 catchments (Commonwealth of Australia 2000). The Murray-Darling Basin (MDB) is one of the best known drainage divisions in Australia. The boundaries of 56 NRM regions are based on catchments or bioregions as shown in Figure 3.1. They straddle the administrative boundaries and create institutional complexities for catchment management. An effective cross-jurisdictional linkage will be required to improve the efficacy of information flows and institutional arrangements. Table 3.2 illustrates the boundary overlap between catchment management authorities and local government authorities under the jurisdiction of MDB. Administratively, the MDB falls under the four state government jurisdictions, namely Queensland (QLD), New South Wales (NSW), Victoria (VIC), South Australia (SA) and one territory, the

Australian Capital Territory (ACT). It is noteworthy that a large number of LGAs straddle catchment boundaries.

Table 3.2: Local authorities and catchment boundaries status (Paudyal et al 2009a)

STATE (Name)	CMA (Number)	Number of LGA that falls under catchment boundary	Number of LGA that straddle catchment boundary	Total Number of LGA that fall/straddle catchment boundary	Proportion of LGA that straddle catchment boundary
QLD	4	9	29	38	76%
NSW	9	30	48	78	62%
VIC	5	10	24	34	71%
SA	3	4	15	19	79%
ACT	1	1	0	1	NA
Total	22	54	116	170	

3.3.1. Institutional Framework

The success of catchment management lies in development of effective institutional arrangements. Catchment management arrangements in Australia are implemented through the partnerships of government, community groups, private sector and academia as shown in Figure 3.2.

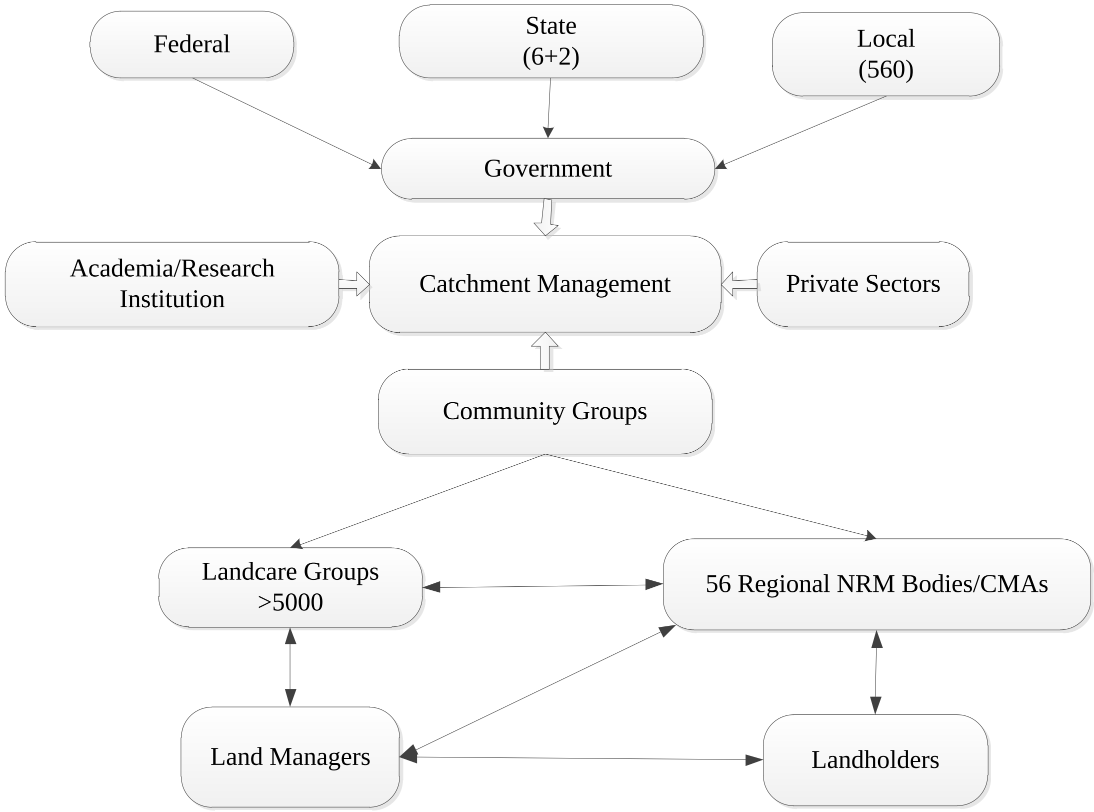

Figure 3.2: Institutional setting for catchment management in Australia

The organisations discussed in the following sections are working towards sustainable catchment outcomes in Australia.

3.3.1.1. Government

Three tiers of government exist in Australia and influence catchment management activities. The local government is the lowest level of government in the administrative hierarchy. It fosters community awareness and the formation of catchment care groups. It promotes the development of catchment management strategies and implements them on the relevant parts of local authority plans and procedures. There are about 560 local governments in Australia (Australian Local Government Association 2011).

There are a total of six state governments and two territory governments working in Australia. State governments establish policies, institutional arrangements and necessary legislation to facilitate the sustainable catchment management, and promote community awareness through education and services. They also provide technical and financial support to catchment coordinating committees as resources permit.

The Commonwealth (Federal) Government is the highest level of government in the administrative hierarchy. It fosters the catchment management strategies by participation in the strategy formulation process and provides financial support for priority catchment projects of national interest. It is also responsible for ensuring Australia meets its international obligations in relation to the environment and the sustainable management of natural resources. Further, it provides the policy and economic framework that will enable catchment management to be effective (Commonwealth of Australia 2000). The Constitution of the Commonwealth does not confer upon the Commonwealth Parliament any specific power to make laws in respect of the environment, land management or water use. However, the laws that are made for environmental matters draw their validity from other heads of power in the Constitution.

3.3.1.2. The Community Groups and Individual Land Owners

Community groups and individual land owners can play an important role in catchment management as they are directly concerned with land, water and nature of their locality. They are the focal nodes for catchment management at the grass-root level. The community groups involve local land care groups, catchment groups, indigenous communities, conservation groups, farm/water improvement groups, service groups and industry associations. The landcare program is a very successful program involving community members and land owners for catchment management. Indigenous communities' traditional knowledge has an important role in catchment management particularly in maintaining cultural heritage. Individual landowners/farmers are also actively involved in catchment management at the grass-root level.

3.3.1.3. Regional NRM Bodies/ Catchment Management Authorities

There are 56 regional NRM bodies which are responsible for catchment management in Australia. The regional NRM bodies are different in their name, corporate structure, catchment management philosophy, relationship to the state government organisation. However, the overall objective is to work for better catchment outcomes. In New South Wales and Victoria, they are termed as catchment management authorities. Regional NRM bodies/ catchment management authorities (CMAs) have been established to address complex catchment management issues that involve many community groups and government agencies. CMAs comprise representatives of the major sectors of the community and government which are involved in, or influenced by, the management of land and water resources in the catchment. Their major role is to provide a forum for community input and discussion, prioritise the issues, and develop and promote the adoption of catchment management strategies. All states/territories have some form of catchment management authorities or natural resource management groups under their jurisdiction. .

3.3.1.4. Academia and Research

Academia and the research community support education, research and technology development for catchment management. They help to build capacity for catchment management and support catchment management activities through research and education.

3.3.1.5. Industry Groups/Private Sector

Industry groups/private sector are the other major stakeholder group that plays a significant role in developing management tools for ecologically sustainable catchments. They also rise to the challenge by pooling resources to assist in sustainable catchment management.

3.3.2. Catchment Management by Jurisdiction

As a result of the uncertain power to legislate for environmental management problem by the Commonwealth Government, the primary responsibility for land use and land management has been assumed by the states and territories. Further, the Commonwealth of Australia Constitution gives the power to states responsible for land and water management within their boundaries (Marshall 2001). State government organisations are primarily responsible for catchment management activities and natural resource management. In each state/territory, there is a principal state government organisation which is responsible for catchment management.

Some are governed by members of the community and some are established by government. Those which are established by the state government have statutory responsibilities (Ryan et al 2010). The jurisdictional models in the states are either statutory (New South Wales, South Australia and Victoria) or non-statutory (community based) (Western Australia, Queensland, Tasmania). The territory models are evolving towards independent boards but are still heavily dependent on territory government structures and processes.

There is also inconsistency between states in the name given to the regional NRM bodies. They are termed catchment management authorities in New South Wales and Victoria, catchment councils in Western Australia, NRM boards in South Australia, regional NRM groups in Queensland and Regional committees in Tasmania. Some states and territories have legislation to support catchment management, whereas in other states management is voluntary or occurs as an element in a wider natural resource management practice. Table 3.3 differentiates the name, corporate structure (statutory or non-statutory), catchment management philosophy, functions and key state agency.

Table 3.3: State NRM framework characteristics (modified Pannell et al 2008)

State	Title of regional body (number)	Status	Catchment philosophy	Functions and accountability	Key state agency
NSW	Catchment Management Authorities (13)	Statutory (CMA act 2003)	TCM	Support property vegetation plan under Native Vegetation Act 2003 Board reports directly to Minister	Office of Environment and Heritage (Department of Environment and Climate Change and water) (DECCW)
VIC	Catchment Management Authorities (10)	Statutory (CALP act 1994	ICM	Beds, banks and floodplains of rivers Board reports to agency head	Department of Sustainability and Environment (DSE)
WA	Regional Catchment Groups or Catchment Council (6)	Non-statutory	ICM	Functions decided by the groups Report to stakeholders	Department of Agriculture and Food (DAF)
SA	Regional NRM Boards (8)	Statutory	ICM	Water allocation planning, pests and weeds, soil conservation and biodiversity Board reports to Minister	Department of Environment and Natural Resources (DENR)
QLD	Regional Committees, Groups or Organisations (14)	Non-statutory	ICM	Functions decided by the groups Report to shareholders and stakeholders	Department of Environment and Resource Management (DERM)
TAS	Regional NRM Committees (3)	Statutory	ICM	Required to nominate member to NRM Council and report annually to parliament	Department of Primary Industries, Parks, Water and Environment (DPIPWE)
NT	Territory Natural Resource Management (1)	Non-statutory	ICM	Management of natural resources such as land, water, soil, plants and animals, etc Reports to shareholders	Department of Natural Resources, Environment, The Arts and Sport (NRETAS)
ACT	ACT NRM Council (1)	Non-statutory	ICM	Council members are appointed by the ACT Government Reports to Minister	The Environment and Sustainable Development Directorate

3.3.2.1. New South Wales (NSW)

The Office of Environment and Heritage (the then Department of Environment, Climate Change and Water) is the principal state agency responsible for catchment management in New South Wales. The other relevant state agencies include the Department of Primary Industries (DPI) and the NSW Office of Water. The state philosophy for catchment management in NSW is total catchment management (TCM). TCM began in NSW in 1984, and was formalised with the introduction of the Catchment Management (CMA) Act in 1989 (Commonwealth of Australia 2000). Under the CMA Act 2003, thirteen CMAs have been established to manage the state's natural resources at the catchment level. The CMAs are responsible for developing catchment action plans (CAPs) and facilitating natural resource management (NRM) investment in their regions (Pannell et al 2008).

NSW has developed the NRAtlas (http://www.nratlas.nsw.gov.au) to help users find information about natural resources in NSW. The NRAtlas is the NSW NRM portal consisting of a comprehensive catalogue of authoritative spatial information related to natural resources and managed by state agencies, as well as providing links to significant spatial information holdings in local and federal government agencies. The online NRAtlas sources its information in real time directly from data providers.

3.3.2.2. Victoria (VIC)

The Department of Sustainability and Environment (DSE) is the principal state agency responsible for catchment management in Victoria. The other relevant state agencies include the Department of Primary Industries (DPI) and the Environment Protection Authority (EPA). The catchment philosophy of Victoria is integrated catchment management (ICM) which underpins the sustainable management of land and water resources and contributes to biodiversity management. The principal ICM legislation in Victoria is the Catchment and Land Protection (CAP) Act 1994 (Pannell et al 2008). The Act established the Victorian Catchment Management Council, a peak body that provides advice to government on natural resource management issues (Davidson et al 2007). Ten catchment management authorities (CMAs) have been created under this Act. The Department of Sustainability and

Environment (DSE) is also responsible for administering 103 Acts of Parliament, with many of these relating to ICM (Commonwealth of Australia 2000).

Victoria has developed Victorian Resources Online (VRO) (http://www.dpi.vic.gov.au/vro) to help users find spatial information related to natural resources. VRO is the gateway to a wide range of spatial information necessary for catchment management at both state-wide and regional levels across Victoria.

3.3.2.3. Western Australia (WA)

The Western Australian government supports an integrated approach to catchment management aiming to bring all stakeholders together to form a plan of action that addresses social, economic and ecological concerns within a catchment (Commonwealth of Australia 2000). The Department of Agriculture and Food (DAF) is the lead agency, however a number of state government agencies are responsible for catchment management. There is no legislation that provides a total framework for the 77 legislative acts, which have both direct and indirect effect on catchment management (Commonwealth of Australia 2000). Six regional catchment groups or catchment councils have non-statutory status and are responsible for catchment management.

The Western Australian Land Information System (WALIS) is a dynamic partnership and collaboration of government agencies, statutory authorities, community groups, and private sector organisations to access, manage and disseminate State Government spatial information (Western Australian Land Information System 2011). A Shared Land Information Platform (SLIP) has been established in Western Australia to provide ready access to a wide range of spatial (mapped) data and information products from state repositories via web services (Armstrong 2009). One of the focussed areas of the SLIP is natural resource management. Additionally, a number of mapping portals are available for users to interactively access and use spatial information. Find Your Farm, SLIP NRM Info, Weed Watcher, Geophysical Mapping Products for NRM, and Rainbow Lorikeets are a few examples where the spatially enabled community is contributing.

3.3.2.4. South Australia (SA)

The Department of Environment and Natural Resources (DENR) is the principal state agency responsible for the management and administration of South Australia's natural resources. The Department of Water is another relevant state agency which is responsible for catchment management, particularly water. The Minister for the Environment and Conservation is responsible for the overall direction of catchment management activities in South Australia with a range of powers and functions provided to a state NRM council, eight regional NRM boards and local NRM groups.

The NRM Council is the peak advisory body and each of the eight regional NRM boards develop their own regional NRM plan to meet the needs of the local regions and contribute to state level planning. Each regional board has several sub-regional groups. The Natural Resource Management Act 2004 has overhauled natural resource management in South Australia with the aim of achieving integrated catchment management by reforming current institutional arrangements and decision-making processes (Pannell et al 2008). The catchment philosophy of South Australia (SA) is ICM and defined as 'the management of water resources in an integrated way to achieve economic, environmental and social goals', and is primarily undertaken in accordance with arrangements set up under the Water Resources Act 1997 (Commonwealth of Australia 2000).

The Atlas of SA (http://www.atlas.sa.gov.au) is an initiative of the South Australian Government to provide an easy access to spatial information in an interactive atlas format. The Atlas has been sponsored by Government Spatial Executive Committee (GSEC) which is made up of representatives across government.

3.3.2.5. Queensland (QLD)

The Department of Environment and Resource Management (DERM) is the principal state agency responsible for catchment management in Queensland. The state philosophy for catchment management in Queensland is integrated catchment management (ICM) which began in 1991 and was formalised with the introduction of the Catchment Management Act in 1989 (Commonwealth of Australia 2000). There are currently 14 regional NRM bodies operating in Queensland. The Queensland Regional Groups Collective (RGC) is the lead agency for regional NRM bodies and represents the interests of the 14 regional natural resource management (NRM) bodies in Queensland. There is no direct legislative base for the ICM framework in Queensland, however, catchment management can be indirectly affected by a number of the 19 acts of parliament administered by the DERM (Commonwealth of Australia 2000).

Information Queensland (IQ) (http://www.information.qld.gov.au) provides direct access to government held spatial information, through its Atlas and Queensland Government Information Service (QGIS). QGIS provides access to a range of free or saleable spatial information and associated data. The enQuire (http://www.enquire.net.au) is an integrated state-wide web based application that assists the Queensland State Government agencies and regional NRM bodies in improving the quality of NRM activities by facilitating improved collaboration, coordination, management and reporting. It is supported through state government under the Q2 Coast and Country Program, and the Australian Government through Caring for Our Country programme.

3.3.2.6. Australian Capital Territory (ACT)

The Environment and Sustainable Development Directorate is the key state agency responsible for catchment management in the Australian Capital Territory. The other supporting institution is the Territory and Municipal Services Directorate (TAMS). The ACT NRM Council is one of the 56 regional NRM bodies which works with the ACT and Australian Government to deliver sustainable catchment management outcomes. The Council is a non-statutory advisory committee to the Minister for the Environment and Sustainable Development. The ACT Government follows ICM principles and defines ICM as an approach to planning and natural resource management based on ecological, social and economic considerations. There is currently no legislation which completely covers ICM, however, the ICM framework in the ACT is guided by the ACT Decade of Landcare Plan (1991) and the Territory Plan (1993). It is also partly covered by the Environment Protection Act 1997, the Water Resources Act 1998 and the Nature Conservation Act 1980, 92 and to a lesser extent, some of the 72 Acts of Parliament (Commonwealth of Australia 2000).

3.3.2.7. Tasmania (TAS)

The Department of Primary Industries, Parks, Water and Environment (DPIPWE) is the lead state agency for catchment management in Tasmania. The state philosophy for catchment management in Tasmania is ICM and defined as "the co-ordinated and sustainable use and management of land, water vegetation and other natural resources on a regional water catchment basis so as to balance resource utilisation and conservation" (Commonwealth of Australia 2000). The Tasmanian Government has developed a state policy on ICM, however ICM can also be influenced by many of the 95 acts of parliament currently administered by the DPIPWE. The NRM Act 2002 (http://www.austlii.edu.au/au/legis/tas) provides a legislative basis for sustainable catchment outcomes in Tasmania. There are three regional NRM bodies namely: NRM North, Cradle Coast NRM, and NRM South which are responsible for catchment management. These regions are based on regional local government boundaries and coincide with the Cradle Coast Authority, Northern Tasmania Development, and the Southern Tasmanian Councils Authority boundary (Commonwealth of Australia 2000).

The Land Information System Tasmania (LIST) (http://www.thelist.tas.gov.au) is a whole of government service that delivers integrated land information online. LISTmap includes a wide range of administrative, topographic, environmental and socioeconomic data. The LIST is managed by the Information and Land Services Division of the DPIPWE.

3.3.2.8. Northern Territory (NT)

In the Northern Territory, there is a single regional NRM body, the Territory Natural Resource Management, that is responsible for catchment management. ICM is the catchment philosophy in the NT. The key state agency to implement ICM in the NT is the Department of Natural Resources, Environment, The Arts and Sport (NRETAS). Department of Lands, Planning and Environment (DLPE) is another supporting state agency. Catchment management in the NT is affected by legislation administered through all these state agencies. These departments administer 83 pieces of legislation, many of which impact on catchment management. Two major

Acts include the NT Water Act 1992, and the Fisheries Act 1999 (Commonwealth of Australia 2000).

Northern Territory Land Information System (NTLIS) (http://www.nt.gov.au/ntlis) is a coordinated approach and a cooperative arrangement between the NT Government agencies to develop a Northern Territory Spatial Data Infrastructure (NTSDI) to create and manage essential spatial information resources and make them available. NT Atlas is an online application to view and query NT Government fundamental spatial information and provides an interface to the NT Spatial Data Directory (NTSDD).

3.4. Spatial Information for Catchment Management in Australia

The recognition of the need of spatial information for natural resource management in Australia can be traced back to the late 1970s when soil conservation agencies moved towards taking a whole of catchment approach to control land erosion and better land management forming group conservation areas (Laut and Taplin 1989). In the beginning, state government agencies were utilising spatial information for the development of land information systems (LIS) (Whinnen 1988). The federal government organisations also showed interest in land related data, especially in the environmental and natural resources areas and started to utilise topography and land use data for catchment management activities (Kelly 1986).

The evolution of internet technology and PC based standard GIS software encouraged state government organisations to organise and better manage their databases. In mid-1993, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) initiated a discussion with key stakeholders to acquire base data at a scale of 1:10000 for catchment planning. The cost of acquiring this data exceeded the capacity to pay by one of the interested organisations (Johnson et al 1997). This event compelled them to collaborate and a centre called the Herbert Resource Information Centre (HRIC) was established in 1996. The HRIC was very successful and a model project that inspired the creation of similar GIS collaborative works in other geographical locations of Australia for natural resource management.

These days a number of NRM tools and spatial data infrastructure (SDI) initiatives have been initiated for catchment management which include development of atlases, spatial data directories, on-line spatial services, community resource centres, and the development of specific decision support tools.

3.4.1. Role of Spatial Information and SDI for Catchment Management

Spatial data underpins decision-making for many disciplines (Clinton 1994; Gore 1998; Longley et al 1999; Rajabifard et al 2003a) including catchment management. It necessitates the integration of spatial data from different sources with varying scales, quality and currency to facilitate these catchment management decisions. However, the institutional arrangements for catchment management do not easily align with the SDI development perspectives as multiple stakeholders work to achieve multiple goals with government organisations, often guiding many catchment decisions.

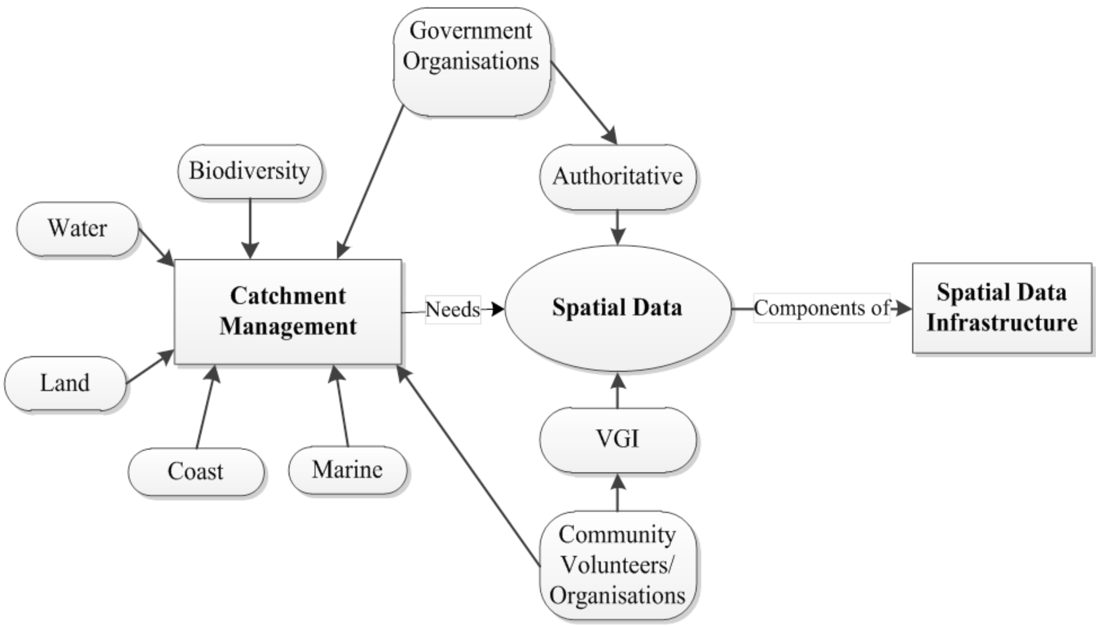

Figure 3.3: Catchment management and spatial data infrastructure

As shown in Figure 3.3, If we observe from a theme perspective, catchment management is about management of land, water, biodiversity, coast and marine themes. By developing theme based SDI such as marine SDI (Vaez 2010) can contribute SDI development (Paudyal et al 2012). There are both top-down and bottom-up approaches exist for catchment management. Government organisations are leading from a top-down approach and the activities of community/volunteer organisations are bottom-up. Basically two types of spatial data can be utilised for catchment management. State government organisations and mapping agencies are the custodians of authoritative spatial and community volunteer organisations can contribute for volunteered geographic information (VGI). The integration of authoritative and VGI data sets is important for developing catchment SDI.

SDI can facilitate access to the spatial data and services through improving the existing complex and multi-stakeholder decision-making processes (Feeney 2003; McDougall et al 2007). Moreover, it can facilitate (and coordinate) the exchange and sharing of spatial data between stakeholders within the spatial information (SI) community. A preliminary step towards achieving decision-making for catchment management has been the increasing recognition of the role of SDI to generate knowledge, identify problems, propose alternatives and define future courses of action (Paudyal and McDougall 2008). In recent years, many countries have spent considerable resources on developing their own National Spatial Data Infrastructure (NSDI) to manage and utilise their spatial data assets more efficiently, reduce the costs of data production and eliminate the duplication of data acquisition efforts (Masser 2005; Rajabifard et al 2003a).

These initiatives have traditionally been highly government dominated and generally based on the administrative/political hierarchy of the country's government. However, catchment management issues cut across political/administrative boundaries and do not follow the rules of political/administrative hierarchies. Hence, there is a need to consider SDI development across catchments differently, particularly understanding the catchment management hierarchy and the needs of the various stakeholders.

3.4.2. Catchment Management Issues and Spatial Information Requirements

Spatial information plays an important role for catchment management. Spatial information is regarded as a powerful management tool for many catchment decisions. The key catchment management issues/problems and the spatial applications/processes identified by Paudyal et al (2009b) in Condamine Catchment of Queensland are shown in Table 3.4. Although there are disparities among regional NRM bodies regarding catchment management issues, Table 3.4 demonstrates the major catchment management issues and the spatial data requirements to address various catchment management issues for better catchment outcomes.

Table 3.4: Catchment management key issues and application of spatial data

Catchment Management Issues	Application of Spatial Data
Biodiversity, Fewer Native Plants	Biodiversity Mapping, Spatial Decision Making
Community Capacity Building	Community Awareness, Education Materials etc
Climate Change	Assessment of Vulnerability and Adaptation
Floodplains, Land Erosion and Land Degradation	Flood Modelling, Erosion Zoning, Emergency Management, Future Forecasting
Land Use Planning and Soil Conservation	Land Use Mapping, Soil Mapping
Mining (gas, coal etc)	Mineral Mapping, Geological Mapping
Pest Animal and Weed Management	Weed Mapping, Habitat Mapping
Water Resource Management (including water quality and availability)	Mapping and Modelling of Water Resources, Environmental Impact Assessment (EIA)

The identification of spatial information for catchment management is also very important for building SDI or any decision-making tools. Authoritative spatial information which is necessary for catchment management activities are located at different government levels. State government organisations are the main custodians of spatial information necessary for catchment management. Table 3.5 illustrates the complexities of sources of spatial information at different government levels. The access and sharing of disparate spatial information for catchment decisions is a challenge.

Table 3.5: Main spatial datasets and spatial data providers for catchment management (Paudyal et al 2011)

Spatial information	Sources (Jurisdictions)		
	Local Govt.	**State Govt.**	**National Govt.**
Vegetation		X	X
Cadastral		X	
Watershed/Catchment boundary data	X	X	
Land use/ Land cover		X	
Topographic base		X	
DEM/ Aerial Photography	X	X	
Satellite Imagery and LIDAR		X	
Administrative boundary		X	
Infrastructure and utilities data (building, transportation etc)	X	X	
Locally gathered data (GPS mainly) and Land holder data	X		
Spatial project specific data	X	X	
Geology and Soil		X	X
Mineral resources		X	X
Atmospheric			X
Demography/Population distribution	X	X	
Water quality	X	X	
Protected areas	X	X	X
Sources of pollution	X	X	
Ecosystem zones	X	X	

The advent of spatial technology and web services has provided a mechanism for farmers and community groups, with no prior experience in spatial technology, to use spatial information for catchment management activities. Community groups and regional NRM bodies are also collecting large scale spatial information and government agencies are interested in gaining access to this spatial data/information.

3.4.3. Hierarchy of Catchment Management and Spatial Data Infrastructure

It is assumed that there are two broad groups of stakeholders in catchment management, namely government and the community. Activities undertaken by land care groups or property owners at the grass-root level will impact on broader environmental and societal issues such as climate change, land use change, and ecological system change, and finally affect sustainable development.

As Figure 3.4 illustrates, the four management hierarchies in catchment management are farms, sub-catchments, catchments and basins. The landcare groups, indigenous community members and individual land owners are the main stakeholders at the farm level which have horizontal relationships with local government and can share property-related spatial information in the form of farm level SDI. A farm level SDI may facilitate the access and sharing of spatial information to the farmers and more widely to contribute for the development of higher level SDIs.

The sub-catchment authorities and other community groups share water, land and nature data with local government and sometimes other levels of government to build sub-catchment SDI. Catchment authorities work towards the ecological sustainability of catchments. They share catchment data with state government and other levels of government. They work towards the broad vision of natural resource management and building catchment level SDI.

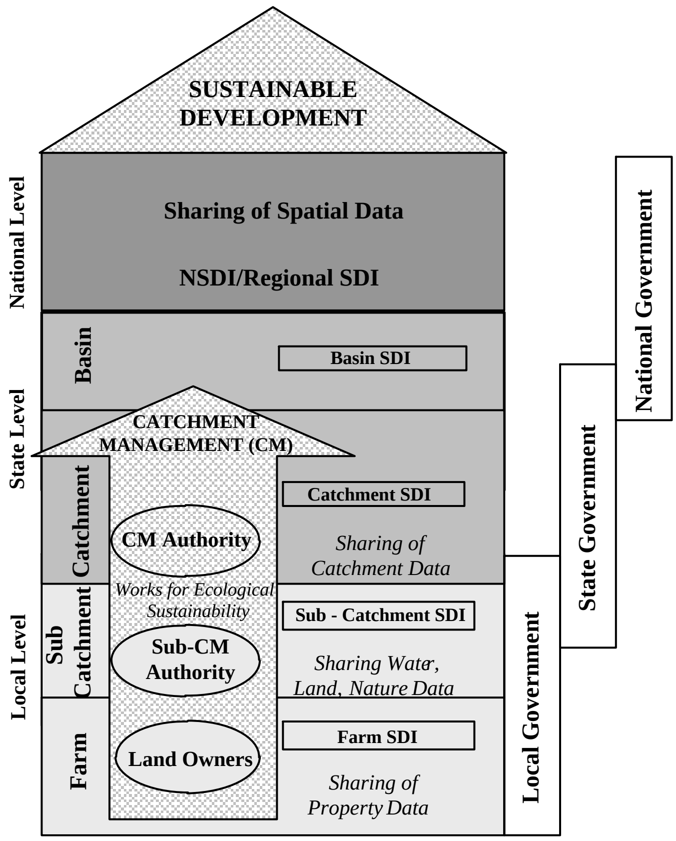

Figure 3.4: The relationship between catchment and administrative hierarchy

The Basin SDI is the highest level of SDI hierarchy within the catchment management framework. In countries like Australia, a Basin SDI covers the whole country or part of the country. For example, the Murray-Darling Catchment which stretches across four states (Queensland, Victoria, New South Wales and South Australia) and one territory (Australian Capital Territory). The Spatial Data Infrastructure (SDI) established by Murray Darling Basin Authority which aims to improve the basin-wide access, use, management, sharing and custodianship of spatial information is an example of a Basin SDI. In some countries, a basin may cross international boundaries and the catchment management issues may become far more complex. The Danube Basin (covers 19 European countries), The Nile Basin (Tanzania, Uganda, Rwanda, Burundi, Zaire, Kenya, Ethiopia, Sudan and Egypt), Indus Basin (China, India, Pakistan and Afghanistan), the Mekong Basin (Cambodia, Laos, Thailand and Vietnam) and Uruguay Basin (Brazil, Argentina and Uruguay) are examples of river basins which cross international boundaries (Frederick 2002). The Basin SDI provides a potential contribution to the nation for the spatial decision-making in the global issues like climate change, land use change and sustainable development.

Rajabifard (2002) argued that a model of SDI hierarchy that includes SDIs developed at different political-administrative levels is an effective tool for the better management and utilisation of spatial data assets. This SDI hierarchy is made up of inter-connected SDIs at corporate, local, state/provincial, national, regional (multi-national) and global levels. The relationship between different levels of SDIs is complex due to the dynamic, inter- and intra-jurisdictional nature of SDIs (Rajabifard et al 2003a). However, the hierarchical concept of SDI does not fully recognise inter- and intra-jurisdictional issues which can cross administrative boundaries..

Many countries are developing SDI at different levels ranging from corporate, local, state, national and regional to a global level, to better manage and utilise spatial data assets. Each SDI, at the local level or above, is primarily formed by the integration of spatial datasets originally developed for use in corporations operating at that level and below (Rajabifard et al 2003a). However in practice, the integration of spatial information from one level to the other follows in a sequential or well-structured pattern.

As demonstrated in Figure 3.5, the catchment hierarchy is somewhat different from this administrative hierarchy. In catchment environments, the hierarchy begins from farm enterprises, sub catchment, catchment, and extends up to the basin level.

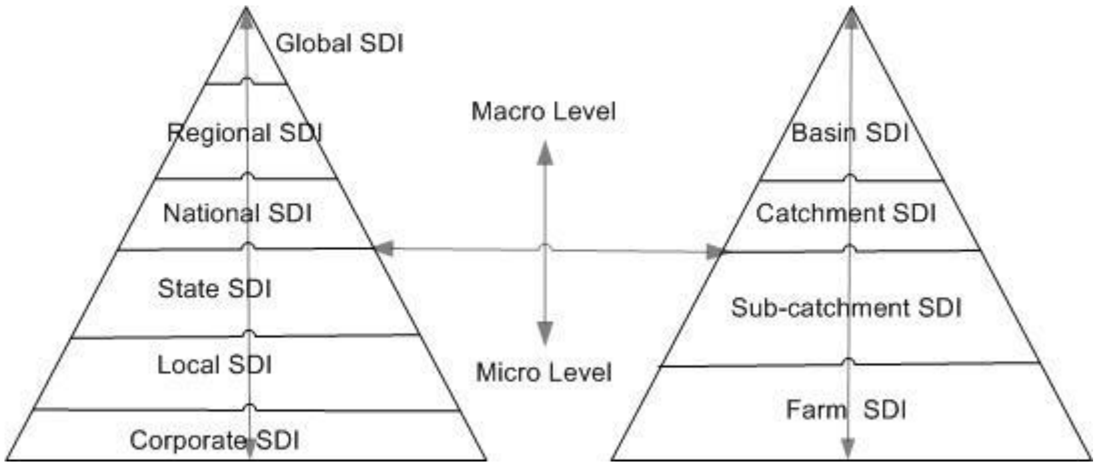

Figure 3.5: Interrelation between administrative and catchment hierarchy

The proposed SDI hierarchy for SDI development does not fit neatly for catchment management as the catchment management issues extend beyond the jurisdiction of administrative/political boundaries and can often cross the territorial boundaries of several countries. The hierarchical concept of SDI may not be a suitable model for the purpose of catchment management as these issues cut across jurisdictional and administrative/political boundaries. The hierarchical model for SDI development therefore needs to be re-examined for the purpose of catchment management.

SDI practitioners (Crompvoets et al 2010; Omran 2007; van Oort et al 2010; Vancauwenberghe et al 2009) have started to examine SDI from network perspectives. Onsrud (2011) defined SDI as a network-based solution to provide easy, consistent, and effective access to geographic information and services to improve decision-making in the real world in which we live and interact. Therefore, it is important to explore the network perspectives of SDI for the purpose of catchment management.

3.5. Spatial Portals and NRM Tools for Catchment Management

There are many spatial data directories, portals and decision support tools available to support access, sharing, and use of spatial information for catchment decisions. Government agencies are the custodians of large amounts of spatial information necessary for the catchment decisions. Now, community groups and the private sector are also collecting a significant amount of large scale spatial information and other catchment stakeholders are interested in gaining access to this spatial data/information. Both top-down as well as bottom-up activities are happening from a national level to grass-roots level.

The NRM Navigator (http://nrmnavigator.net.au) is an initiative of Land and Water Australia's Knowledge for Regional NRM Program, funded by the Australian Government. The NRM Navigator is a set of online tools and databases that make it easier for catchment communities to access, use and share NRM information. It searches four large metadata databases, ie Australian Agricultural and Natural Resources Online (AANRO), The Australian Spatial Data Directory (ASDD), The Australian Bibliographic Database (ANBD), and The NRM Toolbar databases, and more than one hundred NRM related websites in Australia. The Environmental Resources Information Network (ERIN), National Vegetation Information System (NVIS), Australian Agriculture and Natural Resources Online (AANRO), Australian Spatial Data Directory (ASDD) are a few examples of national level spatial information portals where the catchment related spatial information can be accessed and shared at a national level.

The Environmental Resources Information Network (ERIN) (http://www.environment.gov.au/erin/about.html) is coordinated by the Department of Sustainability, Environment, Water, Population and Communities and provides online spatial information and documents related to environment themes at national level. ERIN aims to improve environmental outcomes by developing and managing a comprehensive, accurate and accessible information base for environmental decisions. The National Vegetation Information System (NVIS) (http://www.environment.gov.au/erin/nvis/about.html) is a collaborative initiative between the Australian and state and territory governments to manage national vegetation information to improve vegetation planning and management within Australia. The NVIS was developed to assist in managing a range of ecosystem services and catchment management practices such as biodiversity conservation, salinity control, and improving water quality. The Australian Natural Resources Data Library provides the gateway for downloadable spatial data available from the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES).

The Australian Spatial Data Directory (ASDD) (http://asdd.ga.gov.au/asdd/) is a national initiative supported by all governments under the auspices of the Spatial Information Council (ANZLIC) and the gateway to key sources of spatial information (ANZLIC 2003). The ASDD aims to improve access to Australian spatial data for industry, government, education and the general community through effective documentation, advertisement and distribution. The directory is a distributed system of links between government and commercial nodes in each state/territory as well as spatial data agencies within the federal government. The directory incorporates information about datasets (metadata) from all jurisdictions and is thus a key component linking local, state and national SDIs (Feeney 2003).

Each state has its own spatial data directories and/or portals. The New South Wales (NSW) Natural Resources Data Directory (http://www.canri.nsw.gov.au/nrdd); QLD Government Information Service (http://dds.information.qld.gov.au/dds/); Victorian Resources Online (VRO) (http://www.dpi.vic.gov.au/vro/); the Western Australian Shared Land Information Platform (https://www2.landgate.wa.gov.au/web/guest/about-slip); NT Land Information System (http://www.nt.gov.au/ntlis/), The Atlas of South Australia (SA) (http://www.atlas.sa.gov.au), and Land Information System Tasmania (http://www.thelist.tas.gov.au/) are several examples. Basically, these spatial data directories are primarily services for distributed data discovery using metadata. They may be extended to form the basis of a clearinghouse, which is a distributed model for data access. In principle, a clearinghouse is developed from the building block of a spatial data directory through the addition of several new metadata elements (Feeney and Williamson 2002).

At the catchment level, a number of spatial information portals and collaboration activities are operating to support access, use and sharing of spatial information and knowledge for better catchment outcomes. The Herbert Resource Information Centre (http://www.hric.org.au/home/Default.aspx), Queensland Knowledge and Information Network Project (Sinclair and Kenyon 2009), WA Weed Watcher portal (http://spatial.agric.wa.gov.au/weedsWA/), VIC Waterwatch Data (http://www.vic.waterwatch.org.au), and Sydney Metropolitan Catchment Management Authority GIS portal (http://www.sydney.cma.nsw.gov.au/our-projects/downloadable-gis-project-data.html) are five examples where community and grass-root groups are utilising spatial information for different catchment management activities.

3.5.1. SDI Initiatives for Catchment Management

There are many initiatives for the development of an Australia-wide information infrastructure to better support natural resource management policy, planning and decision-making. Recent environmental challenges have encouraged a national approach to meet the challenges of immediate and emerging whole-of-Australia and international issues such as the current water crisis, climate change, and environment degradation. A road map of Australian Natural Resource Information Infrastructure (ANRII) has been developed to facilitate access and integration of NRM information to support decision-making for sustainable natural resource management. The main components of the ANRII roadmap include partnerships, people, governance, information, standards, agreements and technology. The guiding principles include importance, accessibility, availability, standardisation, reciprocity, responsibility and priority (National Land and Water Resources Audit 2007).

Likewise, at the state level a whole-of-state approach has been used to integrate local NRM activities and contribute to a whole-of-Australia approach for natural resource management activities. There are many successful initiatives in natural resource management sectors and both top-down as well as bottom-up approaches exist to improve the natural resource outcomes. The following section describes some Spatial Data Infrastructure (SDI) initiatives at state and catchment levels in Australia where the prime purpose is to improve access and sharing of spatial information among catchment communities.

3.5.1.1. QLD Regional NRM Data Hub Pilot

The QLD Regional NRM Data Hub study commenced in December 2007 and was completed in May 2008. The objective of the study was to evaluate the business needs for data sharing between regional NRM bodies, local government organisations and government agencies (both state and Australian Government agencies), and to construct a business case for a project to improve NRM information sharing (Jones and Norman 2008). The basic objective of this project was to investigate the further development of regional collaborative networks to implement new functions and structures to improve NRM knowledge and information exchange. The pilot of this project was undertaken over two pilot areas; south western and northern regions of Queensland. The project was sponsored by the Regional Groups Collective (RGC) and Department of Environment and Resource Management (DERM). The Queensland Murray Darling Committee (QMDC) facilitated the pilot in the south west, covering the NRM regions of Condamine Alliance, QMDC, and South West NRM. The north pilot area was coordinated by Terrain NRM and the other participating regional NRM bodies included the Torres Strait, Cape York, Northern Gulf Resource Management Group, Southern Gulf Catchments, and North QLD Dry Topics NRM Regions (Sinclair and Kenyon 2009).

It was considered that a technical solution such as a data portal might be useful in facilitating spatial information access and sharing between regional NRM bodies and government agencies. The study identified that the real need was not a technical component of data access and sharing, but a ‘people part’: how could people be put in place to improve the brokering of spatial information for access and sharing? It identified that librarians should be installed as knowledge brokers to bridge the gap between DERM and regional NRM bodies. Moreover, it was found that they should go beyond the regional boundaries for natural resource management and adopt a state-wide approach. It was found from the study that data was not the only concern, knowledge and information sharing was also an issue.

The pilot identified that collaboration with respect to spatial information and knowledge sharing was desired by regional NRM bodies, and so the QLD Regional NRM Data Hub project evolved into the NRM Knowledge and Information Network (KIN) project. The main objective of the KIN project was to improve access and sharing of NRM information between regional NRM bodies and DERM (Queensland Regional NRM Groups Collective 2010). A framework was endorsed by RGC and the project is now in its implementation phase.

3.5.1.2. NSW NRAtlas

NSW Natural Resource Atlas (http://www.nratlas.nsw.gov.au) is a state initiative to access all New South Wales (NSW) natural resources spatial information through a single gateway. The previous Community Access to Natural Resources Information (CANRI) program evolved into the NSW Natural Resource Atlas and aligned with the policy framework of Australian Spatial Data Infrastructure (ASDI), and the NSW Spatial Data Infrastructure (NSW SDI). This is a collaborative initiative between state government organisations and community organisations in New South Wales (Department of Natural Resources 2011). The Department of Infrastructure, Planning and Natural Resources is the lead agency, with contributing agencies including the Department of Environment and Conservation, Department of Lands, NSW Agriculture, Department of Mineral Resources, Australian Museum, NSW Fisheries and State Forests. This is an outstanding model for community participation, where the community is able to make informed decisions based on government controlled spatial information.

NRAtlas is built on an open technology framework that consists of a suite of applications, catalogues and data repositories. The NRAtlas provides easy access to over 5,000 data records (metadata), 200 datasets and 20 websites, managed by more than a dozen organisations. The main spatial information includes maps and data for biodiversity, water quality/quantity, satellite imagery, major roads and infrastructure, natural resources administrative boundaries, and salinity.

3.5.1.3. Herbert Resource Information Centre (HRIC)

The Herbert Resource Information Centre (HRIC) (http://www.hric.org.au) is a Geographic Information System (GIS) web service infrastructure that supports real time access to data and spatial functionality, and efficient acquisition, management and dissemination of information for the Lower Herbert River Catchment (De Lai and Packer 2010). It is service oriented, where neutrality, objectivity and collaborative capacity transcend the interest of any individual and which creates a culture of willingness to support the whole community. The House of Representatives Standing Committee on Environment and Heritage believed that the HRIC should be used as a model for the development of a nationwide network (Commonwealth of Australia 2000). The HRIC was established in 1996 and evolved from the Herbert River Mapping Project, which began in 1994. It was formed to facilitate the collection and sharing of data between eleven agencies from industry, community and the three tiers of government (local, state and federal) (Walker et al 1999). In 2009, HRIC was established as a web-based information portal and centre of expertise for GIS services to the Herbert River community. It currently involves an unincorporated joint venture between Hinchinbrook Shire Council, Sucrogen, Herbert Cane Productivity Service Ltd (HCPSL), Canegrowers, BSES Ltd and Terrain NRM (De Lai and Packer 2010).

HRIC's vision is to support the balanced and sustainable development of the Lower Herbert River Catchment. HRIC plays a significant role in economic, environmental and social development through capacity building, sustainable development of the catchment and facilitating improvements in the sugar industry value-chain. Further, it aims to be recognised as a centre of excellence in spatial information management through collaboration and facilitation and building networks between industry, community and government. It also provides leadership and high level technical advice to make productive use of spatial technologies and improve communication and collaborative processes between members and within the wider community (De Lai and Packer 2010). HRIC is funded through annual cash and in-kind contributions from the Joint Venture Partners and other project funding acquired during its operation.

3.5.1.4. WA Shared Land Information Platform

The Shared Land Information Platform (SLIP) is a shared information delivery system which provides efficient access to WA's Government spatial information and based on an enabling framework of connected servers to deliver real time spatial data, provides the infrastructure to access spatial information (Armstrong 2009). The SLIP enabling framework, known as SLIP Enabler, provides the infrastructure required to enable access to the government's spatial information. The SLIP Enabler adopts an approach which uses contemporary internet technology, based on a Services Oriented Architecture, to provide a common approach across government. This provides a single point for applications (web browsers, GIS applications or other business applications) to gain access to spatial information distributed across many government agencies (Landgate 2011).

Presently, there are four focus areas of SLIP which includes emergency management, natural resource management, electronic land development, and interest enquiry. State NRM agencies and the WA NRM Regions have been funded by the Australian and Western Australian Governments through the SLIP NRM focus area to deliver systems for accessing a range of spatial data and information products sourced from the Department of Agriculture and Food (DAF), Department of Environment and Conservation (DEC) and Department of Water (DoW); and a range of other organisations including Landgate and the regional NRM bodies (Landgate 2011).

The lead agency for this programme is the Department of Agriculture and Food (DAF) which is working collaboratively with other state government agencies and the regional NRM bodies to deliver the outcomes of this program. The NRM online system (NRM Info) provides a mechanism for regionally collected data to be integrated with other key natural resource databases and ensure regionally collected data and derived information is readily available to all stakeholders through SLIP. Under SLIP, a number of mapping portals are available for users to interactively view live spatial information which contain a number of WA state government spatial datasets.

SLIP also has local level spatial portals. The Weed Watcher portal is a very good example. It provides a home for information on the distribution and abundance of major weed species in Western Australia, which information is collected by members of the public and community groups with an interest in weed management. This information is intended to augment other information collected by Government agencies and specialist research organisations in Australia to support the management of significant weeds in Australia (Bruce 2011).

3.5.1.5. iMAP (Victoria)

The iMap portal was developed by the North Central Catchment Management Authority which is located in Northern Victoria. iMap is an interactive mapping system, which displays key regional spatial information which can be used for strategic natural resource management planning on a property, community group and regional scale. The user is able to produce and download a map which contains the spatial data of interest, including the latest aerial imagery.

A key feature of iMAP is the ability to link from the map interface through a series of spatial layers and display associated geo-referenced documents. The documents are held in the Authority's Document Management System, 80-20. Documents include emails, reports and images in a variety of formats. Conversely, users of 80-20 can also link from a document to the spatial location via web mapping (Francis 2011).

3.6. Chapter Summary

Catchment based management is the approach used to manage land and water resources in Australia. This management is implemented through collaboration and partnerships between different levels of government, community groups, industry groups, and academia.

This chapter has reviewed the catchment management concept and its historical development in Australia. It discussed the current catchment management practices and institutional arrangements. Three tiers of government exist in Australia and influence catchment management activities. However, the role of state government and community groups are very important in the achievement of sustainable catchment outcomes. The catchment management practices in each of the states were briefly examined and some variations among states were found. The jurisdictional models in the states are either statutory (New South Wales, South Australia, and Victoria) or non-statutory (Western Australia, Queensland, Tasmania, Australian Capital Territory, and Northern Territory). The sources of spatial information necessary for catchment management were identified and it was found that most of the spatial information is held by state government organisations.

The participation and engagement community groups for natural resource management have a long history in Australia. Regional NRM bodies in Australia have made significant progress in improving sustainability of activities within catchments. Some of these contributions include reduction on soil salinity and soil erosion, pest animal and weed management, re-establishment of native flora and fauna, etc which all contributes towards sustainability of catchments.

There are significant institutional complexities for spatial information sharing and building SDI for catchment management requires a high level of collaboration of community organisations and different levels of government. The examination of the hierarchy of catchment management and the administrative hierarchy identified that catchment hierarchy is somewhat different from administrative hierarchy and we may require a network approach to bridge the two hierarchies and develop SDI for catchment management. There are a number of spatial portals and NRM tools for catchment management emerging.

The next chapter discusses the research design and methodology that has been adopted to address the research problem and research aim.

Chapter 4

Research Design and Methods

4.1. Introduction

The previous chapters of this dissertation examined the spatial data infrastructure (SDI) concept and its theoretical foundation, the context of the research in relation to SDI and catchment management. This chapter describes the research design and methods which were used to answer the research questions and to achieve the research objectives. The first part of the chapter investigates the conceptual research design framework by exploring the research gaps, examining the research questions and developing the research design framework. The second part of the chapter examines the possible strategies of enquiry (research methods) and justifies the mixed method approach. The third part of the chapter discusses the research methods including the data collection strategy, data collection methods and data analysis processes and the synthesis of research findings including connecting, interpreting and validation. Finally, the ethical considerations related to the research are described, and the chapter concludes with a summary.

4.2. Conceptual Design Framework

4.2.1. Gaps in Research

In Chapters Two and Three, the theory and practice across the areas of spatial data infrastructure (SDI), catchment management, and spatial data sharing were reviewed. It was found that there are various perspectives and understanding on SDI definitions and components. The institutional and administrative components of SDI continue to be problematic and less explored by SDI practitioners. SDI involves complex, intra- and inter-jurisdictional stakeholder interactions that span all sectors of society including tiers of government, industry, academia and community. Various applications for SDIs continue to emerge with the application of SDI to catchment management being a relatively new domain with little theoretical research.

Most of the current SDI research is focussed on the existing hierarchical government environments; however, there has been little research on the impact within natural boundaries such as catchments. In Chapter Two, theoretical foundations to SDI development were studied and their contributions to catchment SDI development were examined. It was found that Hierarchical Theory is useful to understand the complex relationships between catchment hierarchy and the administrative hierarchy. The Principal-Agent (P-A) theory proved useful for gaining a better understanding of the relationships in the sharing of spatial information and partnerships and collaboration for catchment management. The Actor-Network Theory (ANT) examines and explains the interaction between information technology and society and helps to understand the spatial enablement of society whilst the Social Network Theory can help explain the roles and relationships of stakeholders during spatial information sharing. Social network theory and actor-network theory have been utilised to identify the roles and relationships between organisations for spatial information sharing and catchment SDI development. Within the SDI community there are differences in the understanding of SDI and its potential benefits (Grus et al 2007). Current progress of SDI initiatives shows that SDI is viewed, defined and interpreted differently by different practitioners. Traditionally, SDI were considered in a hierarchical context in which high levels of SDI (global, regional, national) build upon lower levels (state, local) (Rajabifard et al 2003a). This hierarchical concept came with the top-down government approach where custodians of spatial data were mapping agencies and led the building of SDI. Now, the concept of more open and inclusive SDI where users play a vital role in spatial information management and SDI development is emerging (Budhathoki et al 2008; Paudyal et al 2009a). The custodianship of spatial data is also no longer totally controlled by mapping agencies.

Another approach is to view SDIs from a network perspective. Two theories which are relevant to the network perspective of SDI development are the Actor-Network Theory and Social Network Theory. In order to examine the contribution of the network approach of SDI development for catchment management, it was considered important that the measurement of these components in the spatial information sharing and collaboration be considered during the research design.

4.2.2. Research Design Framework

The research questions described in Chapter One are both qualitative and quantitative in nature. The first, second, and fourth research questions are primarily qualitative in nature and investigation through literature review and an in-depth study such as case study are appropriate. Question three is more quantitative in nature and seeks to identify and measure a number of issues or factors. The final research question requires the combination of both qualitative and quantitative approaches. The next section illustrates the research design framework to examine the research methods which are suitable for addressing all research questions. Figure 4.1 illustrates the four stages of the conceptual research design framework for data collection, data analysis and synthesis.

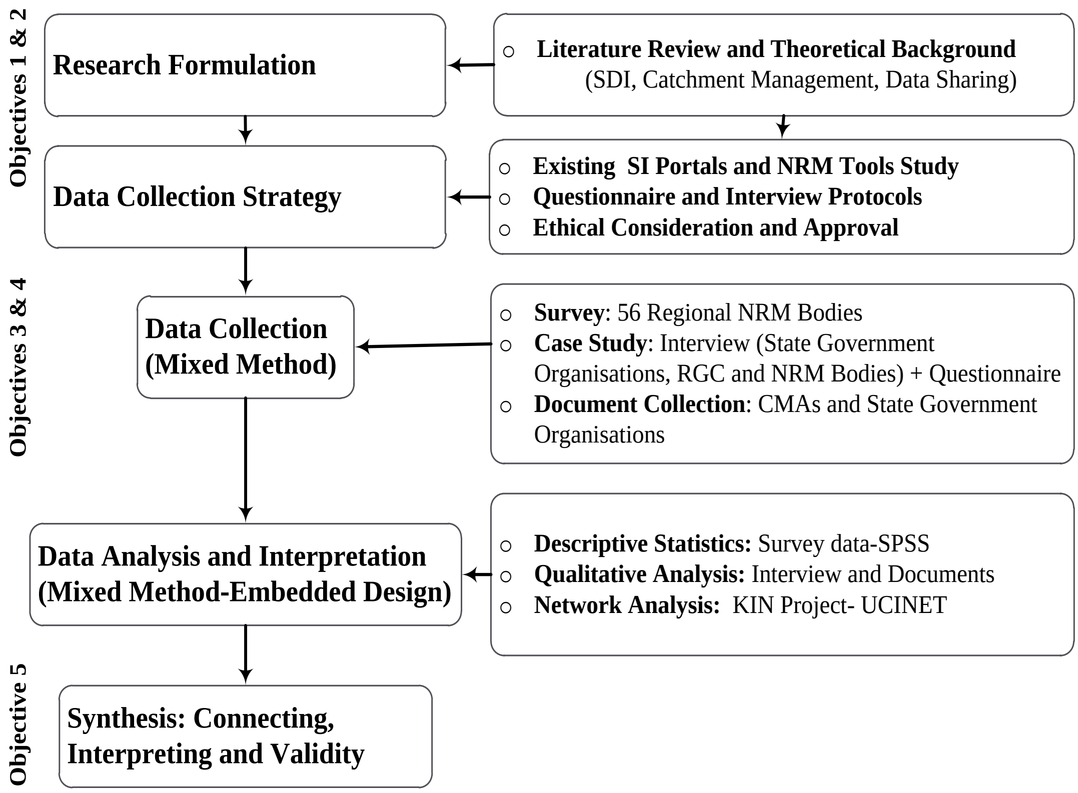

Figure 4.1: Conceptual design framework

4.3. Strategies of Enquiry and Research Design

This section examines the strategies of enquiry that provide specific processes in this research design. The strategy of enquiry is also called approaches to enquiry (Creswell and Plano Clark 2007) or research methodologies (Mertens et al 2010). The three main strategies of enquiry are the quantitative approach, qualitative approach and mixed methods approach (Creswell 2009) as shown in Table 4.1.

Table 4.1: Strategies of enquiry (Creswell 2009)

Quantitative	Qualitative	Mixed Methods
Experimental design	Narrative research	Sequential
Survey	Phenomenology	Concurrent
	Ethnographies	Transformative
	Grounded theory studies	
	Case study	
	Action research	

This section examines the context of all three strategies of enquiry: qualitative, quantitative, and mixed methods and their relationships to the research problem and questions which have been formulated. As the research questions are both qualitative and quantitative in nature, a mixed method approach is proposed as suitable strategies of enquiry to answer the research questions and to achieve the research aim. The mixed method research design types are presented, and the selection of the particular design type is justified.

4.3.1. Quantitative Strategies

Quantitative research allows the researcher to present the research outputs in terms of statistical methods and numbers to explain and validate phenomena. Creswell (2003) notes that quantitative methods are used chiefly to test or verify theories or explanations, identify variables to study, relate variables in questions or hypotheses, establish statistical standards of validity and reliability, and employ statistical procedures for analysis. Copper and Schindler (2011) suggests that a quantitative approach tends to answer questions related to how much, how many and how often. This design allows flexibility in the treatment of data, in terms of comparative analyses, statistical analyses, and repeatability of data collection in order to verify reliability, however, it fails to provide any explanation or analysis beyond the descriptive level.

According to Thomas (2003) quantitative methods focus on measurements and amounts (more or less, larger or smaller, often or seldom, similar or different) of the characteristics displayed by people and events that the researcher studies. Two main quantitative strategies of enquiry are survey and experimental design (Creswell

2009). A survey provides a quantitative or numeric description of trends, attitudes, or opinions of a population by studying a sample of that population. From sample results, the researcher generalises or makes claims about the population (Creswell 2009). Experiments consist of treating objects in a defined way and then determining how the treatment is influenced under a variety of conditions (Thomas 2003).

The strength of quantitative strategies lies in their ability to efficiently include a large number of participants through instruments such as surveys, and then the ability to analyse those variables comprehensively and quickly using computing methods (McDougall 2006). In the context of this research, the use of the survey approach was considered to be the suitable approach to investigate the attitudes and trends in the access, sharing and use of spatial information for catchment management activities.

4.3.2. Qualitative Strategies

Qualitative research examines the social phenomena where principles are not true all of the time and in all conditions, to explain how and why things actually happen in a complex world (Dalrymple 2005). Qualitative methods involve a researcher describing the characteristics of people and events without comparing events in terms of measurements or amounts (Thomas 2003). Qualitative research is criticised for being a “soft” social science approach as opposed to quantitative research that is considered hard-nosed, data driven, outcome orientated and truly scientific (Yin 2009a). However, the strength of the qualitative methodology lies in its focus on specific situations or people, and its emphasis on words rather than numbers (Maxwell 1996). It enables a much richer understanding of people, individual events and the contexts in which they occur and typically includes, but is not limited to, discerning the perspectives of people (Sandelowski, 2007). Most common qualitative research methods include case study, narrative research, ethnographic research, phenomenology, grounded theory studies, and action research.

The most common method among the qualitative approaches is case study research. A case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin 1994). According to Yin (2009a) there are four basic types of case studies (single-holistic case study, single-embedded case study, multiple-holistic case study and multiple-embedded case study) as illustrated in Figure 4.2. The holistic and embedded case study research design depends upon the number of units of analysis. As shown in the Figure 4.2, the holistic design consists of single unit of analysis and the embedded design consists of multiple unit of analysis. Each type of case study can be adopted in accordance with the nature of the research.

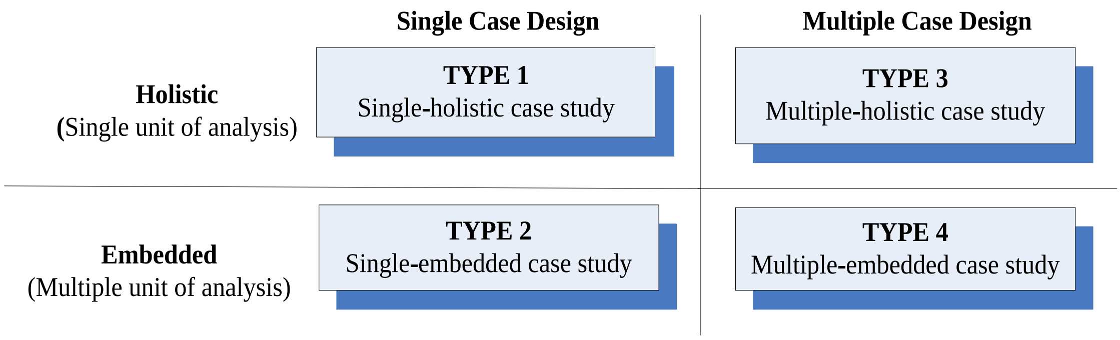

Figure 4.2: Basic types of design for case studies (Yin 2009a)

The selection between single-case design and multiple-case designs depends upon several situations and factors. Both approaches have advantages and disadvantages. The important thing to be considered is the ability to assess the availability, relevance, and usefulness of the case and its scope to address the research question (Yin 2009b). This study has adopted a single-holistic case study (TYPE 1). One of the frequently asked questions about a single case is "How can you generalise your results from a single case?" However, one could ask the same question about an experiment, "How can you generalise from a single experiment?" (Kennedy 1976). Like experiments, the case study's goal is to expand and generalise theories (analytic generalisation) and not to enumerate frequencies (Yin 2009a).

It has also been argued that the single case study is an appropriate design for several circumstances. The five rationales given are the critical case, an extreme or unique case, representative or typical case, and the revelatory case (Yin 1994). The critical case can be used by researchers to challenge, confirm, test and extend a well-formulated theory. In the extreme or unique case, researches can be focussed on studying a specific case. It is, for example, a unique situation in clinical psychology where a specific injury or mortal illness might be so rare that a single case study can be selected for documenting and analysing it. In a representative or typical case, the case study may represent a typical project among many different projects. In the revelatory case, a researcher, for example, has an opportunity to explore, observe and analyse a phenomenon previously inaccessible to scientific investigation (Yin 2009a).

4.3.3. Mixed Methods Strategies

Mixed methods strategies are less well known than either the qualitative or quantitative approaches. However, in recent times there has been a growing recognition of collecting and analysing both qualitative and quantitative data in a research study and mixing them. It has been argued that the overall strength of mixed method in a study is greater than either qualitative or quantitative research (Creswell and Plano Clark 2007). Blending both qualitative and quantitative research methods can create an optimal design although both single methodology approaches (qualitative only and quantitative only) have strengths and weaknesses. The combination of methodologies can focus on their relevant strengths.

Different scholars have used different terms (e g integrative, combined, blended, mixed methods, multi-method, multi-strategy) to identify studies that attempt such mixing (Collins et al 2007; Creswell and Plano Clark 2007; Tashakkori and Teddlie 2007). However, the term *mixed methods* seems to be accepted by most scholars. It has also been argued that qualitative method often needs to be supplemented with quantitative methods, and vice versa (Baran 2010), and go hand in hand.

Baran (2010) reviewed 57 mixed methods studies, and summarised five main purposes for the mixed method studies:

1 **Triangulation**: seeking convergence of results;

2 **Complementary**: examining overlapping and different facets of a phenomenon;

3 **Initiation:** discovering paradoxes, contradictions, or fresh perspectives which may stimulate new research questions;

4 **Development:** using results from one method to shape subsequent methods or steps in the research process; and

5 **Expansion:** providing richness and detail to the study exploring specific features of each method.

There are a number of dynamic ongoing debates within the mixed methods research over issues such as basic definitions, research design, and how to draw inferences (Tashakkori and Teddlie 2009). Tashakkori and Teddlie (2007) categorised mixed designs into five families (sequential, parallel, conversion, multi-level, and fully integrated) based on three dimensions (number of strands in the research design, type of implementation process, and stage of integration).

Tashakkori and Teddlie (2003) noted that they found nearly 40 different types of mixed method designs in the literature. Creswell (2003) summarised the range of these and classified them into twelve groups. Creswell and Plano Clark (2011) again classified the groups into six categories as shown in Table 4.2. The differences are in terms of variants, timing, weighting, mixing, and theoretical perspectives.

Table 4.2: Mixed method design types

Design Type	Variants	Timing	Weighting	Mixing	Theoretical perspective
Triangulation	-Convergence -Data Transformation -Validating -Quantitative data Multilevel	Concurrent: quantitative and qualitative at same time	Usually equal	Merge the data during the interpretation or analysis	May be present
Embedded	-Embedded experimental -Embedded correlational -Mixed methods case study/narrative research	Concurrent or sequential	Unequal	Embed one type of data within a larger design using the other type of data	May be present
Explanatory	-Follow-up Explanations -Participant selection	Sequential: Quantitative followed by qualitative	Usually quantitative	Connect the data between the two phases	May be present
Exploratory	-Instrument Development -Taxonomy development	Sequential: Qualitative followed by quantitative	Usually qualitative	Connect the data between the two phases	May be present
Transformative	-Feminist lens transformative variant -Disability lens transformative variant -The socioeconomic class lens transformative variant	Concurrent or sequential collection of quantitative or qualitative data	Usually equal	Analysis or interpretation phase	Definitely present
Multi-phase design	-Large scale projects -Multilevel state-wide study	Concurrent or sequential collection of quantitative or qualitative data	Unequal	Analysis or interpretation phase	May be present

4.3.3.1. Triangulation

Triangulation design is the most common and well-known design approach to mixed methods (Creswell 2003). This design is also called convergent parallel design

(Creswell and Plano Clark 2011). The purpose of this design is "to obtain different but complementary data on the same topic" (Morse 1991) to best understand the research problem. The intent in using this design is to bring together the differing strengths and non-overlapping weaknesses of quantitative methods (large sample size, trends, generalisation) with those of qualitative methods (small sample size, details, in depth) (Creswell and Plano Clark 2011).

4.3.3.2. The Embedded Design

The embedded design is a mixed methods design in which one data set provides a supportive, secondary role in a study based primarily on the other data type (Creswell 2003). In an embedded design, the researcher may add a qualitative strand within a quantitative design, or add a quantitative strand within a qualitative design (Creswell and Plano Clark 2011). In the embedded design, the supplemental strand is added to enhance the overall design. The premise of this design is that a single data set is not sufficient, that different questions need to be answered, and that each type of question requires different types of data (Creswell and Plano Clark 2011).

This design is particularly useful when a researcher needs to embed a qualitative component within a quantitative design, as in the case of survey design and to enhance the application of a quantitative or qualitative design to address the primary purpose of the study. The qualitative and quantitative data can be collected either sequentially, concurrently or both.

4.3.3.3. The Explanatory Design

The explanatory design is a two-phase mixed methods design. The overall purpose of this design is to use a qualitative strand to explain initial quantitative results (Creswell 2003). This design can also be used when a researcher wants to form groups based on quantitative results and follow up with the groups through subsequent qualitative research (Morse 1991; Tashakkori and Teddlie 2003), or to use quantitative participant characteristics to guide purposeful sampling for a qualitative phase (Creswell 2003). This design is well suited to a study in which a researcher needs qualitative data to explain significant (or non-significant) results, outlier results, or surprising results (Morse 1991).

4.3.3.4. The Exploratory Design

The exploratory design is also a two-phase sequential design, normally qualitative design followed by quantitative design. The intent of exploratory design is that the results of qualitative findings based on a few individuals from the first phase can help to generalise to a large sample gathered during the second phase (Creswell and Plano Clark 2011). This design is particularly suitable for exploring a phenomenon in depth (Creswell 2003), when a researcher needs to develop and test an instrument because one is not available (Creswell and Plano Clark 2007), identify important variables to study quantitatively when the variables are unknown, or a researcher wants to generalise results to different groups (Morse 1991).

4.3.3.5. The Transformative Design

The transformative design is based on a theoretical-based framework for advancing the need of under-represented or marginalised populations. The theoretical framework of the feminist theory, the racial or ethnic theory, the sexual orientation theory, the disability theory are a few examples where the transformative design is utilised (Mertens et al 2010). The purpose of this design is to conduct research that is change-oriented and seeks to advance social justice causes by identifying power imbalances and empowering individuals and/or communities (Creswell and Plano Clark 2011).

4.3.3.6. The Multiphase Design

The purpose of this design is to address a set of incremental research questions that all advance one programmatic research objective. It provides an overarching methodological framework to a multi-year project that calls for multiple phases to develop an overall program of research or evaluation. The multiphase design occurs when an individual researcher or team of investigators examines a problem or topic through an iteration of connected quantitative and qualitative studies that are sequentially aligned, with each new approach building on what was learned previously to address a central programme objective (Creswell and Plano Clark 2011).

This research has selected the embedded design with sequential timing. The national survey data and case study data were collected and analysed in two phases. The case study component was the supportive component of the survey design as different research questions were addressed in the survey and case study to achieve the primary aim of this research.

4.3.4. Use of Mixed Method Research in SDI Related Research

The use of qualitative and quantitative research in land administration and SDI related research is not a new approach. Cagdas and Stubkjar (2009) analysed ten doctoral dissertations on cadastral development from the methodological point of view and found that case study research was favoured in all the reviewed research. Researchers collected both qualitative and quantitative data within the case study research design framework. Several doctoral dissertations related to the SDI field (Chan 1998; Davies 2003; McDougall 2006; Mohammadi 2008; Rajabifard 2002; Warnest 2005) used both qualitative and quantitative strands in their PhD studies. However, except for McDougall, all others did not use a mixed method design framework when combined with both qualitative and quantitative strands.

Smith et al (2003) utilised the mixed method approach to GIS analysis. They asserted that a mixed-method would provide a more comprehensive analysis of the use of GIS within the National Health Service (NHS). The extensive questionnaire-based survey identified the best practice examples of the use of GIS within the NHS which could then be explored more fully via face to face qualitative interview. Further, they argued that combining survey results and interview data within mixed method design framework enhanced the research findings.

Another significant use of the mixed-method in GIS research was by Nedovic-Budic (Unpublished) who explored the utility of mixed method research in GIS (cited in McDougall, 2006). Wehn de Montalvo (2003) also used the mixed-method in her study, however her design frameworks were based on theoretical grounding (theory of planned behaviour) rather than on a mixed method design framework as suggested by mixed methods researchers (Creswell and Plano Clark 2011; Tashakkori and Teddlie 2003; Tashakkori and Teddlie 2009).

McDougall (2006) utilised the mixed method design framework during his SDI research and advocated it as the best of both qualitative and quantitative worlds. His study provided a very structured approach to combine both qualitative and quantitative data. The structure of this study has largely been influenced by the mixed method design framework suggested in McDougall's (2003) study, however, this study utilises the embedded research design framework as suggested by Creswell and Plano Clark (2011).

4.4. Research Methods

This research has utilised survey and case study as the main research methods.

4.4.1. Survey

Within the mixed method strategy, a national survey of regional NRM bodies was considered to be the most appropriate method to investigate the spatial information access, use, and sharing between regional NRM bodies and state government organisations, and to explore the current status of SDI development for catchment management activities in Australia.

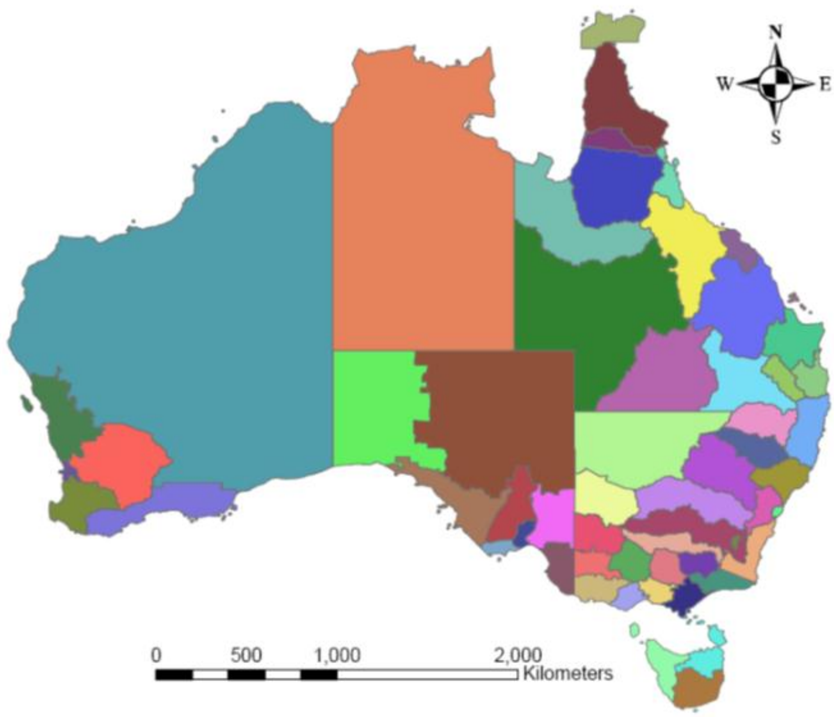

Figure 4.3: Survey location of NRM regions

The survey was conducted with all 56 regional NRM bodies responsible for catchment management in Australia. As illustrated in Figure 4.3, there are 14 regional NRM bodies in Queensland (QLD), 13 in New South Wales (NSW), eight in Victoria (VIC), eight in South Australia (SA), six in Western Australia (WA), three in Tasmania (TAS), one in the Australian Capital Territory (ACT) and one in the Northern Territory (NT).

The questionnaire consisted of seven parts and included questions related to the spatial capacity of regional NRM bodies and GIS activities; catchment management issues and role of spatial information; information policy and funding; spatial information requirements; spatial information flow, data access and pricing; data sharing, collaboration and networking, and emerging spatial information management model as summarised in Table 4.3. The questionnaire also covered the main SDI components as discussed in Chapter Two and answers research question Three. A total of 36 questions were asked comprising three to five questions in each part as shown in the Appendix 1.

Table 4.3: Structure of questionnaire

Main parts	Topics covered
Part 1: Spatial capacity of Regional NRM Bodies and GIS activities	Organisation type, capacity of staff, GIS maturity level, GIS activities
Part 2: Catchment management issues and role of spatial information	Catchment management issues, role of spatial information, volunteer initiatives and motivation factors, suitable spatial scale
Part 3: Information policy and funding	Spatial information policy, funding mechanism
Part 4: Spatial data requirements	Importance of spatial data, spatial data locating tools, importance of spatial data provider
Part 5: Information flow, data access and pricing	Access mechanism and easiness, information flow, restriction, integration of spatial information, pricing arrangement
Part 6: Data sharing, collaboration and networking	Collaborative arrangement and areas of collaboration, main partners for collaboration, spatial information sharing factors, spatial information sharing mode
Part 7: Emerging model of spatial information management	Awareness, frequency of use and applicability of open source products, awareness of social networking activities and its applicability for SDI development

The majority of questions were closed and categorical type and were measured on a five point Likert scale. The categorical descriptive data were converted to five point

Likert scale before statistical analysis. In a number of the questions, a comment space was provided for respondents to place additional comments.

The questionnaire was undertaken between June 2010 and September 2010. Before the questionnaire was finalised, the draft questionnaire was tested with Queensland Murray Darling Committee (QMDC), one of the regional NRM bodies in Queensland. Comments were incorporated and the final questionnaire was then developed to a web form. The quality of the online questionnaire was also tested before distribution. The questionnaire was distributed in two stages and targeted for two groups of regional NRM bodies. The questionnaire was distributed to regional NRM bodies which belong to Murray Darling Basin Authority (MDBA) and later distributed to the remaining NRM bodies. The feedback and experience from the first stage was used to assist in the second stage of the survey and the high response rate.

The support of regional NRM bodies was critical. The contact address of regional NRM bodies was collected through website/yellow pages and telephone directory. The targeted respondent in each of the regional NRM bodies was identified by contacting customer service staff and a contact e-mail address was collected. After identifying the respondent in each of the regional NRM body, a supporting e-mail with brief background about the research work and the survey link was sent through the principal supervisor. The approach achieved a response rate of 100 per cent. The sample e-mail is contained in Appendix 2. More than 40 per cent of responses were returned in the two week period after the e-mail was sent. A follow-up e-mail was sent after three weeks and five weeks and a diary was maintained.

The online questionnaire was designed such that the data from the questionnaires was automatically collected into an Excel spreadsheet via the web server. This eliminated the possibility of errors in coding and transcription and accelerated transferring data into the data analysis software. A notification was obtained via e-mail when the online survey was submitted by the respondent. This enabled me to administer and collect the survey responses. For quality control purposes, the raw data were reviewed and cleaned before inputting into the statistical software. The results of the survey are presented in Chapter Five.

4.4.2. Case study

The case study approach was considered to be the most suitable approach for understanding the spatial information sharing process between regional NRM bodies and state government organisations, and developing a deeper understanding of the issues related to spatial information management which were identified during the survey. It also offered the opportunity to cross-check some of the issues identified during the survey.

The Knowledge and Information Network (KIN) project was selected as a representative or typical case to investigate spatial information and knowledge sharing process for catchment management. However, in the whole research design, this case study is a part of a larger, mixed methods study.

The KIN project was selected as the case study for four main reasons. Firstly, the KIN project is a representative case and one of the projects suggested during the national survey of 56 regional NRM bodies. One of the open questions asked was, "*If you are aware of social networking activities and/or data sharing projects for improved catchment outcomes within your catchment areas, please provide details*." A number of Queensland regional NRM bodies suggested this project. Secondly, this project was a community-led and state-wide project funded through the Queensland and Commonwealth Governments. All the regional NRM bodies of Queensland participated in this project and it gained both community support (bottom-up) and government support (top-down). Thirdly, Queensland has a long tradition of utilising spatial information management in NRM sector. The Queensland case has not been previously examined by previous SDI practitioners. Finally, it was easily readily accessible the researcher to undertake an in-depth study.

The case study location of the Knowledge and Information Network (KIN) project location is the state of Queensland Australia as illustrated in Figure 4.4. Queensland (QLD) has 14 regional NRM bodies and 74 local authorities spread from the far-northern region of Torres Strait to the New South Wales (NSW) border to the south. The QLD regional NRM bodies also have common boundaries with Northern Territory (NT) regional NRM bodies, South Australian regional NRM bodies and Victorian catchment management authorities (CMAs).

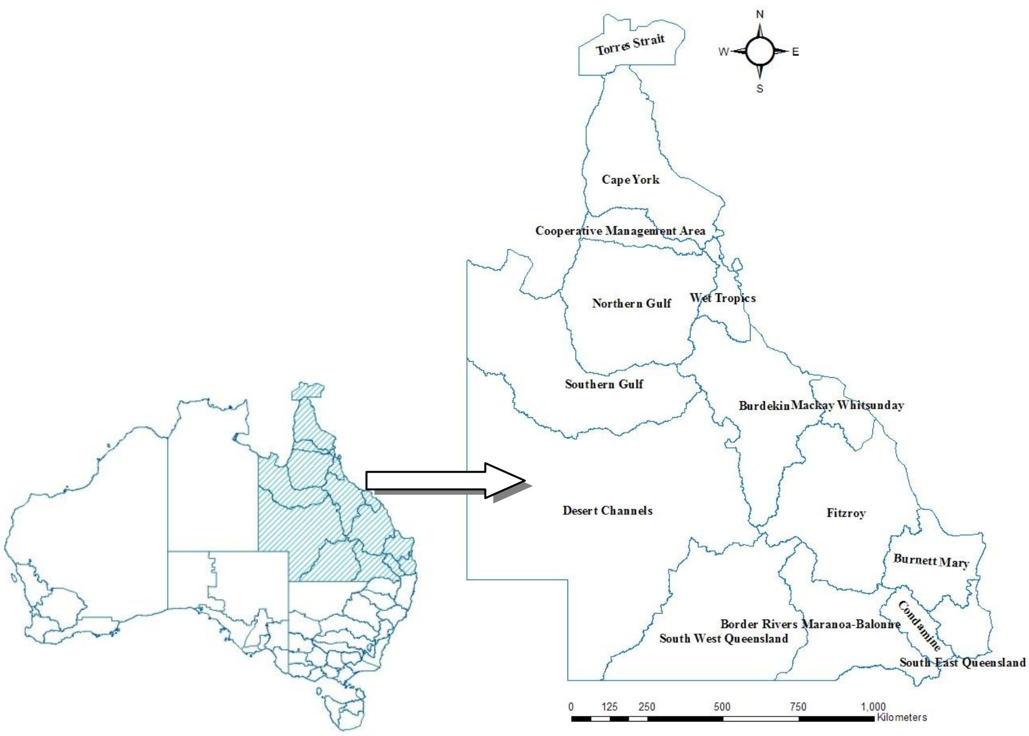

Figure 4.4: Location map of KIN project areas

The regional NRM bodies in Queensland differ in terms of size, location, corporate structure and stakeholder interests, and their stage of planning and implementation of natural resource management activities (Queensland Regional NRM Groups Collective 2010). Regional NRM bodies develop regional NRM plans and deliver sustainable catchment outcomes at grass-root level. The size of Queensland regional NRM bodies vary from 24,000 km^2 (Reef Catchments/Mackay Whitsunday) to 500,000 km^2 (Desert Channels). The majority (10 out of 14) of the regional NRM bodies include both land and coastal water. The catchment management issues relate to land, water, biodiversity, coast and marine themes in Queensland and the institutional arrangements for catchment management are complex.

In the research methodology, it has been argued by a number of researchers that the selection and use of appropriate data collection and analysis techniques are very important to the success of research (de Vaus 2001; Marshall 2006; Yin 2009b).

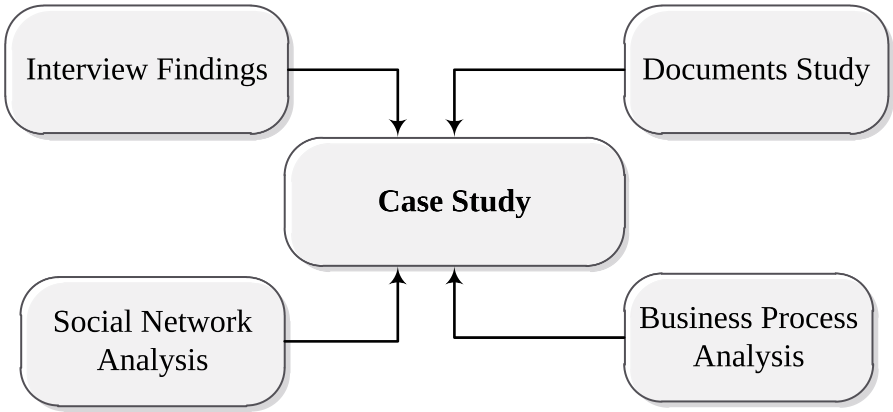

Figure 4.5: Case study framework

Figure 4.5 illustrates the case study framework for this study. Four forms of data were collected and analysed to investigate the spatial information sharing arrangements between regional NRM bodies and state government organisations. Firstly, existing project documents/reports, data sharing agreements and published papers were collected and studied for background information and to understand the history and context of NRM KIN project.

Secondly, semi-structured interviews were conducted with all 14 regional NRM bodies, state government representatives and Queensland Regional NRM Groups Collective (RGC) which provided an in-depth understanding about NRM KIN project and its working principles. In total, 19 interviews were conducted; 15 from regional NRM bodies, two from state government organisations and two from the RGC. The staff involved in the KIN project experienced in spatial and knowledge management activities were, interviewed. Both telephone and face-to-face interview methods were used. As the respondents were scattered throughout state, the majority of interviews were carried out by telephone. Interviewees were contacted by email and phone with a description of the research objectives. The recording of interviews was voluntary. The average length of interviews was between 45 minutes to one hour.

The list of questions for the semi-structured interview is given in Appendix 3. The structure of the interviews broadly covers the following the areas:

1 Historical context and institutional setting;

2 Motivation factors for collaboration;

3 Constraints (policy, technological, organisational, culture and economic) managing this project;

4 Scope of emerging technologies and social media;

5 Knowledge and spatial information sharing characteristics and process; and

6 Key factors for the success of the project.

Thirdly, a brief questionnaire (see Appendix 4) was constructed to specifically target and measure relationships and interactions with other stakeholders. The targeted population for this network analysis was 18 stakeholders consisting of six categories or organisations/professionals including state government, RGC, regional NRM bodies, Landcare groups, landholders/farmers, and knowledge coordinators. The questionnaire was distributed to a non-random and purposive sample of representatives from project stakeholders to quantify the frequency of interaction, exchange of spatial information, and role of organisation in achieving the KIN goal. The data collected through the questionnaire was analysed using social network analysis software.

Fourthly, the unified modelling language (UML) which is based on the object oriented (OO) concept and standardised by the object management group (OMG) was used to understand the spatial information sharing process. A UML use-case diagram was used to explore and demonstrate the spatial information sharing process. Six main actors and nine use-cases were identified for spatial information sharing process and business process analysis of the spatial information sharing in the KIN project.

The results of this case study are presented in Chapter Six.

4.4.3. Synthesis: Connecting, Interpreting and Validity

The embedded design framework suggested by Creswell and Plano Clark (2011) is utilised for the synthesis and interpretation of the results as illustrated in Figure 4.6. The national survey investigated the current status of spatial information access, use and sharing for catchment management in Australia and provided the overall landscape. Within national survey, there was an embedded case study of the KIN project which was further explored through in-depth study.

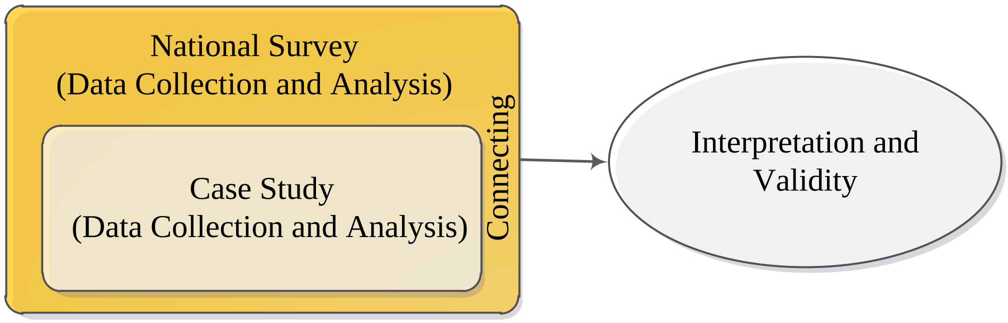

Figure 4.6: The embedded design

The national survey data and case study data were collected and analysed sequentially (ie in two phases). The results are connected and presented in Chapter Seven. The case study component was the supplementary component of the survey design. Different research questions were addressed in the survey and case study design and the two results were connected in the design phase.

One of the evaluation criterion for the quality of research findings is the validity of the findings. Validity is the extent to which the research can be said to produce an accurate version of the world (Bloor and Wood 2006). When considering the validity of the conclusions of research, two types of inferences are involved. The first of these is the internal validity of the study. This is the degree to which the investigator's conclusions correctly portray the data collected. Internal validation can be completed by testing the significance of results statistically or by testing their models or results through a subsequent case. The other inference concerns external validity (also referred to as generalisability). This is the degree to which conclusions are appropriate to similar populations and locations outside of the study area (Bloor and Wood 2006). The internal validity of the study was examined through embedded design where both the case study and the survey supported the findings. Due to the specific nature of the study, the external validity of the study is the supportive evidence from other studies in data sharing.

4.5. Ethical Considerations

Before commencing the survey and interviews, ethical approval (see Appendix 5) was gained through the USQ Human Research Ethics Committee. The information from the case studies and survey remains confidential. The survey and interview participation was voluntary and agreement to participate was recorded. Participants were initially contacted by phone regarding their involvement and then an email was sent with the web survey.

The questionnaires were carefully designed and pre-tested before distribution. Participants were informed and assured through a statement on the cover page of the protection and confidentiality of data/information. The participants were also informed that only consolidated data would be published. The survey was conducted online and the data was directly stored on the USQ web server (which had high security standards). All data was aggregated and processed using software tools and participants were assured that the individual participant's response would not be made public. The semi-structured interview questions were provided to participants before the interview and participants' consent was taken before recording the interview.

A number of official documents and data sharing agreements were studied and care was taken that confidentiality would be protected during the analysis in this thesis.

4.6. Chapter Summary

This chapter presented the research design framework for this research. The gaps in research were identified through a literature review in Chapters Two and Three and the research questions subsequently framed/refined. The research questions were both qualitative and quantitative in nature so strategies of enquiry were examined to answer the identified research questions. It was found that a mixed method strategy was the most suitable approach to collect and analyse both qualitative and quantitative data and blend them. It was assumed that blending both qualitative and quantitative research methods created an optimal design. The study utilised a quantitative priority where a greater emphasis was placed on the quantitative strands and the qualitative strands were used in a secondary role. The embedded mixed method design with sequential timing was used and the mixing was done at the level of design and interpretation. The case study was embedded within a larger survey design.

The results from surveying 56 regional NRM bodies provided a national perspective of spatial information access, use, and sharing for catchment management from the NRM groups/communities' perspectives. The similarities and differences that exist between states, statutory arrangements, association with a basin authority regarding the access, use, and sharing of spatial information by regional NRM bodies provided a secondary level of analysis. The results of the survey are reported in detail in Chapter Five. From the responses of the survey, Queensland Knowledge and Information Network (KIN) Project was selected as a representative case and the case study approach enabled an in-depth study of knowledge and information sharing initiatives through a scientifically rigorous process. Further, the supplemental case study analysis embedded within a larger national survey supported the results obtained from the national survey. The results of the case study are reported in Chapter Six. The mixing strategies and collective interpretation of both qualitative and quantitative outputs is described in Chapter Seven.

Chapter 5

Assessment of Spatial Information Management of NRM Bodies in Australia

5.1. Introduction

The previous chapters of this dissertation discussed the relevant literature and research design and methods which were used to answer the research questions and to achieve the research objectives. The results of the qualitative and quantitative analysis of NRM bodies and case study investigations are presented over the next two chapters. This chapter presents the results of the questionnaire survey which was conducted across 56 regional NRM bodies throughout Australia. The main objective of this survey was to assess the current status of spatial information access, use and sharing for catchment management from the NRM groups'/communities' perspectives and explore the SDI development activities in the natural resource management sector in Australia. Furthermore, this chapter examines the variations between Australian states, different jurisdictional environments (statutory versus non-statutory regional NRM bodies) and regional NRM bodies associated with dedicated basin authorities (managed by the Murray Darling Basin Authority and others). The chapter begins with a description of the survey results and explores the differences between various states. The key factors that influence data sharing across catchment management areas are examined and the chapter concludes with a summary.

5.2. Questionnaire Survey Overview

The questionnaire (see Appendix 1) was arranged into seven parts and included questions on the spatial capacity of regional NRM bodies, catchment management issues, information policy and funding, information flow, data access and pricing, data sharing, collaboration and networking mechanism and emerging SDI models.

5.2.1. Profile of Responses

A total of 56 valid responses were received to the on-line questionnaire giving an overall response rate of 100%. A statistical analysis of the survey results was undertaken in the SPSS Statistics package. The survey was undertaken from 15 June 2010 to 9 September 2010. The questionnaire survey was distributed in two stages. Initially, the questionaries were distributed to regional NRM bodies which belong to the Murray Darling Basin Authority (MDBA) and later to the remaining NRM bodies around Australia. The feedback and experience from the first distribution assisted in the second stage of the survey and assisted in achieving the high response rate. The largest group of respondents was identified as GIS officers, while other respondents were the staff directly or indirectly involved with spatial information management or the GIS operations of that regional NRM body. The responses were provided from their organisational point of view. The majority of the respondents were full-time staff. The profile of respondents has been tabulated in Figure 5.1.

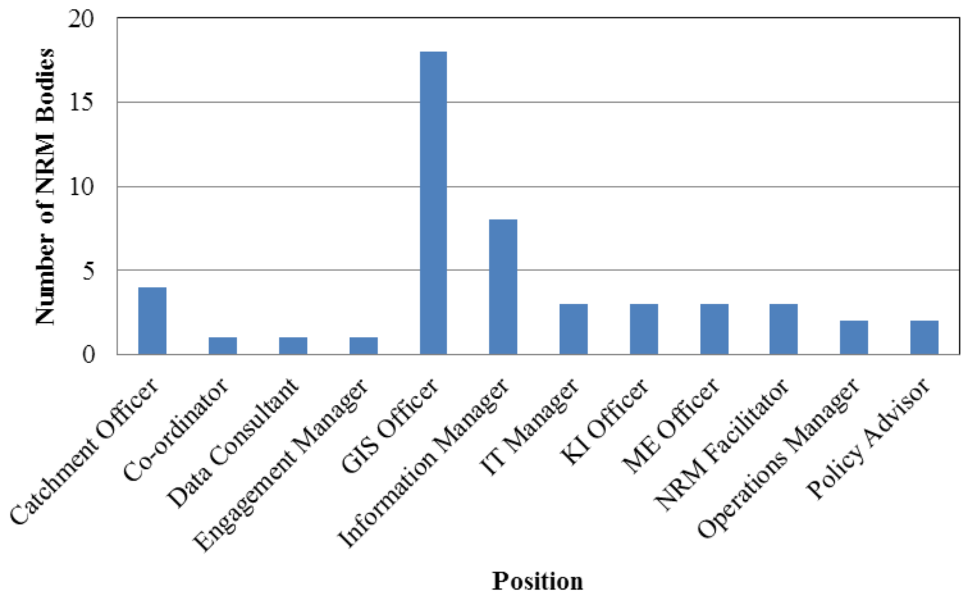

Figure 5.1: Profile of respondent (by position)

5.3. Descriptive Statistics

5.3.1. Spatial Capacity of Regional NRM Bodies and GIS Activities

The first part of the questionnaire examined the spatial capacity of regional NRM bodies. Four questions explored the organisation type, capacity of staff, GIS maturity level and GIS activities of regional NRM bodies and their GIS activities. The majority (approximately 70%) of regional NRM bodies identified themselves as being both a user and provider of spatial information and the remainder as being a user (Figure 5.3). This response demonstrates that the regional NRM bodies not only use spatial information but also produce spatial information. This provides a strong base for developing spatial data infrastructure (SDI) in the catchment management sector.

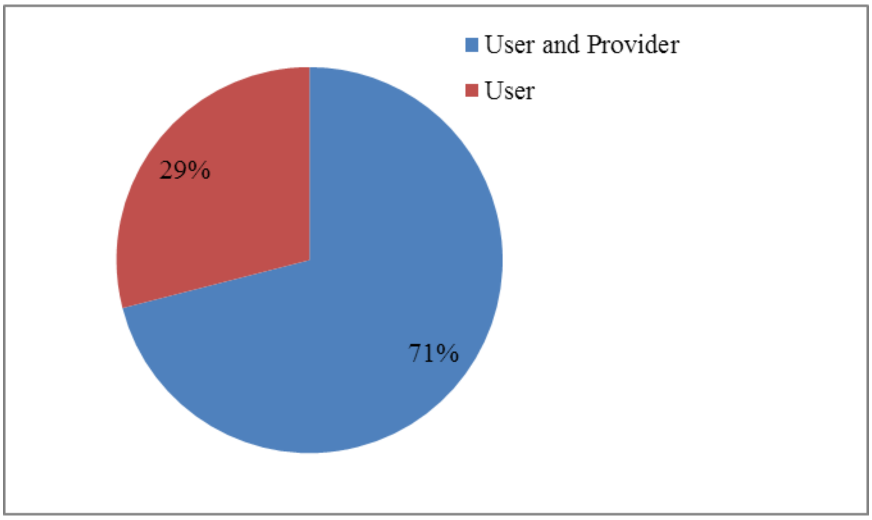

Figure 5.2: Breakdown of user/provider of spatial information

With respect to the use of spatial information by regional NRM bodies staff, 40 out of 56 regional NRM bodies indicated that over 40% of their staff use spatial information. In contrast, only 7 out of 56 regional NRM bodies indicated that less than 20% of their staff utilise spatial information. This result indicates that there is a strong spatial information awareness and use among regional NRM staff.

The GIS activities are also not new for regional NRM bodies. 26 out of 56 regional NRM bodies have been using GIS/spatial information for five or more years and only three NRM bodies have been using spatial information for less than two years (as illustrated in Figure 5.3). This illustrates that the majority of regional NRM bodies in Australia are quite mature with respect to using spatial information as part of their catchment decision-making processes.

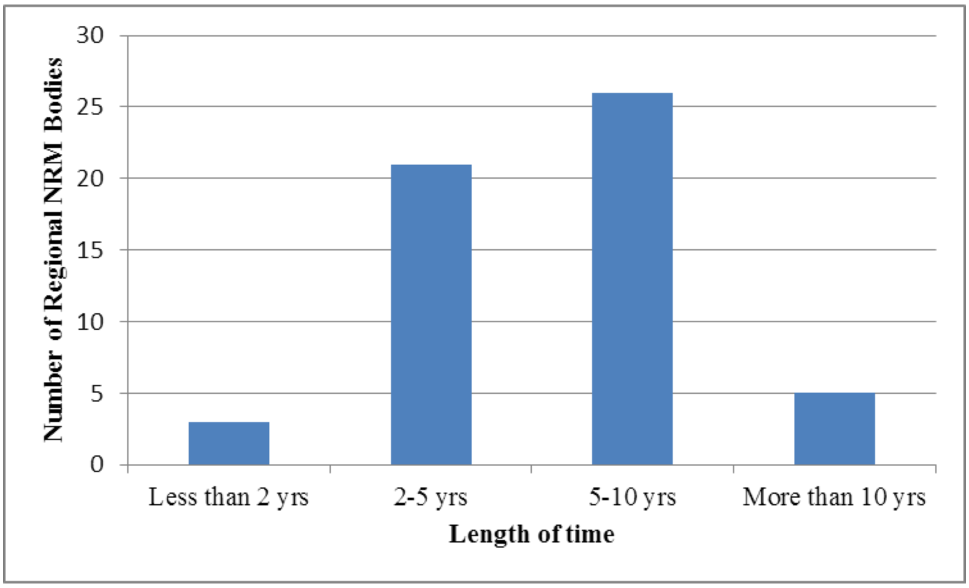

Figure 5.3: Length of time using GIS

Likewise, the majority (72%) of regional NRM bodies indicated that they use a combination of in-house and outsourced GIS activities. However, only 21% of regional NRM bodies undertake their GIS activities completely in-house. The remaining 3% of regional NRM bodies outsource all of their GIS activities. This response indicates that the majority of organisations work with other external organisations for spatial information use and management which provides the opportunity for collaboration and partnership.

5.3.2. Catchment Management Issues and the Role of Spatial Information

The second part of the questionnaire explored catchment management issues, the role of spatial information, spatial scale, volunteer activities and motivational factors for volunteer activities.

The regional NRM bodies' perception regarding the statement "Catchments cross over a number of local as well as state government boundaries and create administrative and political difficulties" varied. Approximately 20% of the total regional NRM bodies disagreed with this statement. However, about 45% were in favour of this statement and about 35% neither agreed nor disagreed with this statement (Figure 5.4). The trend in the responses to this part of the questionnaire is also summarised in Appendix 6 Case 3.

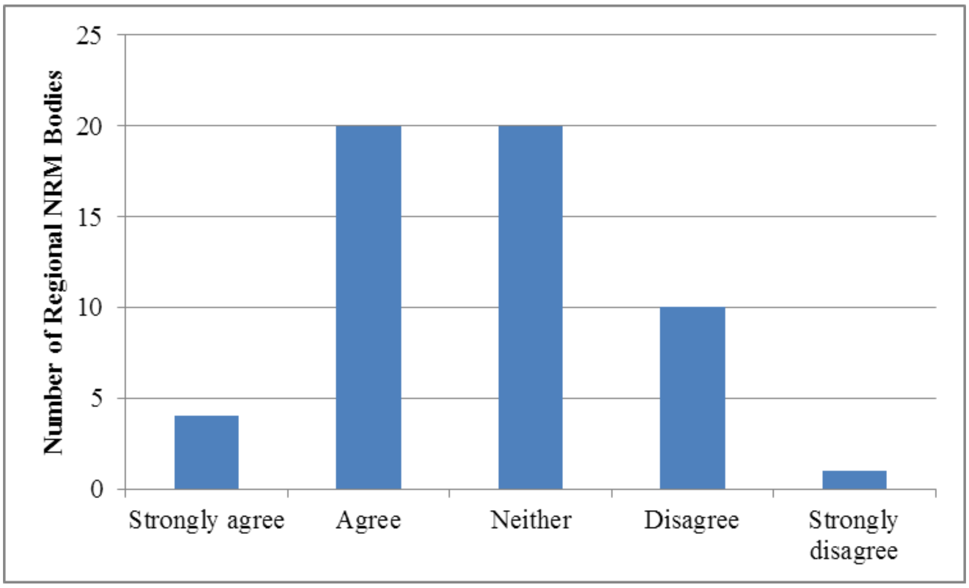

Figure 5.4: Responses to statements regarding difficulties with respect to catchment and administrative boundaries

Regional NRM bodies were also asked if any catchment boundaries overlap or if there is boundary confusion with adjoining regional NRM bodies in their areas. A total of 39 out of 56 organisations answered this question. Twenty regional NRM bodies advised that they have boundary overlap or boundary confusion and 19 regional NRM bodies advised that there were no boundary issues. It was identified that operational arrangements were in place to deal with the management difficulties due to catchment boundary overlap or confusion.

The questionnaire found that there are disparities among regional NRM bodies regarding the catchment management issues on which they focus. Table 5.1 shows the top ten catchment management issues identified by NRM bodies. The highest priorities include healthy habitat and biodiversity conservation, pest animal and weed management and community capacity building and indigenous engagement.

Table 5.1: Main catchment management issues

Rank	Catchment Management Issues	Frequency
1	Healthy Habitat and Biodiversity Conservation	38
2	Pest Animal and Weed Management	29
3	Community Capacity Building and Indigenous Engagement	27
4	Disaster Management (Fire Mapping, Floodplain, Land erosion, etc)	24
5	Water Resource Management	23
6	Land Use Planning and Soil Conservation	19
7	Climate Change	7
8	Coastal and Marine Management (estuarine and near shore)	5
9	Grazing Land and Property Management	4
10	Aboriginal NRM and Cultural Heritage	3

When asked to identify the role that spatial information can play in addressing the catchment management issues listed in Table 5.1, it was interesting to observe that approximately 60% of the regional NRM bodies responded that spatial information can play a very significant role, with the remaining 40% of the organisations responding that it can play a significant role (Figure 5.5). Not a single organisation responded that it was not aware of the role of spatial information in addressing catchment management issues. This response indicates the importance of spatial information in supporting the development of SDI at the regional level (catchment level).

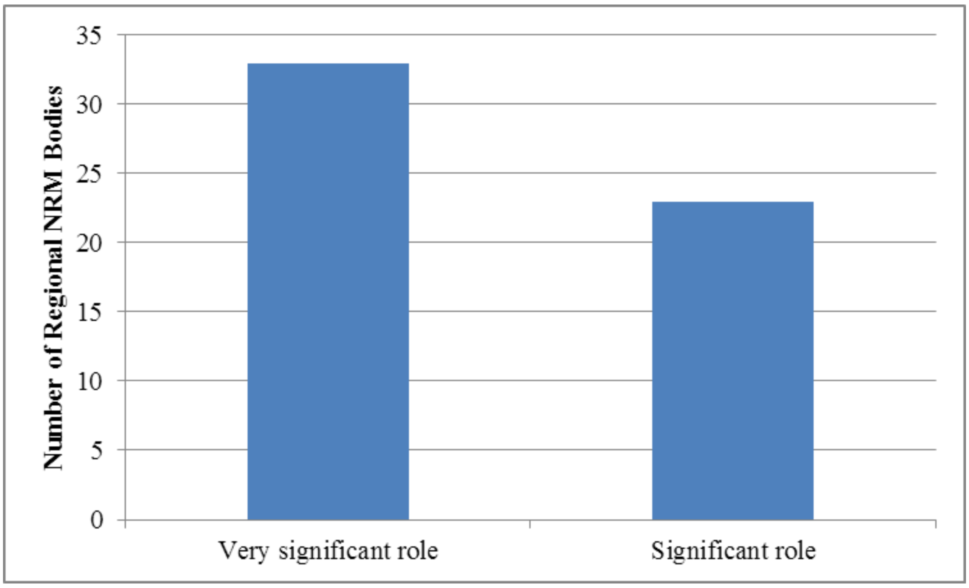

Figure 5.5: Role of spatial data to address catchment management issues

The survey also identified the major volunteer initiatives associated with catchment management. There were more than 20 volunteer activities for catchment management identified including Landcare, Waterwatch, Birdwatch, Vegewatch, Land for Wildlife, Coastcare and Parkcare.

The motivational factors for these volunteer activities were identified and ranked as shown in Table 5.2. The top three motivation factors were awareness and concern for environmental benefits, long standing love of the land and/or water, and social interactions/benefits.

Table 5.2: Motivational factors for volunteer activities

Rank	Motivational Factors
1	Awareness and concern regarding environmental benefits
2	Long standing love of the land and/or water
3	Social interactions/benefits
4	Self-esteem/desire to serve community
5	Personal benefits
6	Having fun/getting hands dirty
7	Cultural obligation/spiritual connectivity

The most suitable scale for spatial information management for catchment planning and decision-making was also examined. The majority (65%) of regional NRM bodies were in favour of a multi-scale approach, namely the ability to utilise data at property, sub-catchment, and catchment scales. However, 18% were in favour of sub-catchment scale and 9% were in favour of property scale. This indicates that catchment-planning and decision-making processes require multi-scale spatial information ranging from the paddock to catchment scale. However, the most suitable scale is dependent upon the particular application of spatial data for catchment management activities.

5.3.3. Information Policy and Funding

The third part of the questionnaire examined spatial information policy and funding mechanisms of the regional NRM bodies. Five aspects of spatial information policy including spatial information management, spatial information use and re-use, data custodianship, pricing and access, and value adding were examined. The details of responses are provided in Appendix 6.

Approximately 80% of the total regional NRM bodies had limited or no information policies/guidelines to manage spatial information. The rest of the regional NRM bodies have some form of spatial information policy such as in-house spatial information standards, guidelines and procedures. However, most indicated that these need to be revisited, updated and formalised.

Approximately 63% of regional NRM bodies indicated that they have a policy on spatial information use and re-use. In most cases, the spatial information use and re-use policies were incorporated in data sharing agreements with various data providers.

It was found that 65% of regional NRM bodies included data custodianship as part of their spatial information policies. Custodianship is also covered through service level agreements and memoranda of understanding (MOUs) or licence agreements with state custodians which clarify the position of data ownership. A few regional NRM bodies also showed interest in sharing data under the creative commons framework and Intellectual Property Rights (IPR). Creative commons licenses are designed to facilitate and encourage greater flexibility in copyright.

Approximately 35% of regional NRM bodies advised that they have a policy for pricing and access to spatial information. The access is generally free to project partners and covered by the data sharing agreements. Only 18% of the regional NRM bodies advised that they have value adding policies and were usually covered under the agreements for use and licencing of spatial data. The value adding issues were not exclusively covered under the data share agreements. Most of the organisations advised that they value-added their spatial products, however they had no guidelines or policies.

The majority of funding for regional NRM bodies comes from the Commonwealth Government, followed by the State Government. The landowner "in-kind" contribution is comparable to local government’s funding support. NRM bodies are also funded from private industry. The funds they received from different sources contribute to community activities (eg Landcare, Waterwatch, Birdwatch, etc), land holders and their project delivery partners (private/public consultants and academia).

5.3.4. Spatial Data Requirements

The fourth part of the questionnaire investigated the spatial information requirements, spatial data discovery tools, the importance of spatial data and the importance of spatial data providers.

As spatial information is a critical component of SDI, the identification of the spatial information requirements is fundamental to building SDI for catchment management. Table 5.3 ranks the importance of spatial information for catchment management activities as identified by the NRM bodies.

Table 5.3: Spatial information needs for catchment management

Rank	Spatial information
1	Vegetation data
2	Cadastral data
3	Watershed/catchment boundary data
4	Land use/land cover data
5	Topography data
6	Aerial Photography and DEM
7	Satellite Imagery and LIDAR
8	Administrative boundary data
9	Infrastructure and utilities data (building, transportation etc)
10	Locally gathered data (GPS mainly) and Landholder data
11	Spatial project specific data
12	Geology and soil data
13	Open source data (Google Maps, OpenStreetMap, WikiMapia etc)
14	Mineral resources

Table 5.3 identifies that vegetation, cadastral and catchment boundary/watershed boundary, and land use/land cover data are the highest priority spatial data for catchment decisions. The regional NRM bodies were less concerned with geology and soil data, open source data or mineral resources data.

Most of the regional NRM bodies access their spatial information through data sharing agreements. For example, in Queensland all regional NRM bodies have a single data usage agreement with the state government managed through the

Regional Groups Collective (RGC). The main mechanisms for finding their spatial information are via telephone, e-mail, personal contact and website (internet and intranet). The majority of regional NRM bodies source their spatial data through e-mail and websites.

The main spatial information providers to regional NRM bodies are the state government organisations. The majority (86%) of regional NRM bodies rated state government organisations as of high importance, whilst only 28% of regional NRM bodies rated commonwealth government organisations (eg Geoscience Australia, Bureau of Rural Sciences, etc) as of high importance. Local government organisations and private industries were identified as being of limited importance as a source of data.

5.3.5. Information Flow, Data Access and Pricing

The fifth part of the questionnaire explored the access mechanisms, information flow, integration of spatial information and pricing arrangements.

It examined the effectiveness of access to spatial data from data providers. Approximately half (48%) of the regional NRM bodies indicated that access was neither easy or difficult, 18% indicated that it was easily accessible and 11% indicated that it was very accessible. A minority (23%) of regional NRM bodies indicated that it was difficult (Figure 5.6). In regards to the effectiveness of access to spatial data from spatial data providers, the response did not indicate any strong trends or issues for regional NRM bodies in accessing spatial information from spatial data providers.

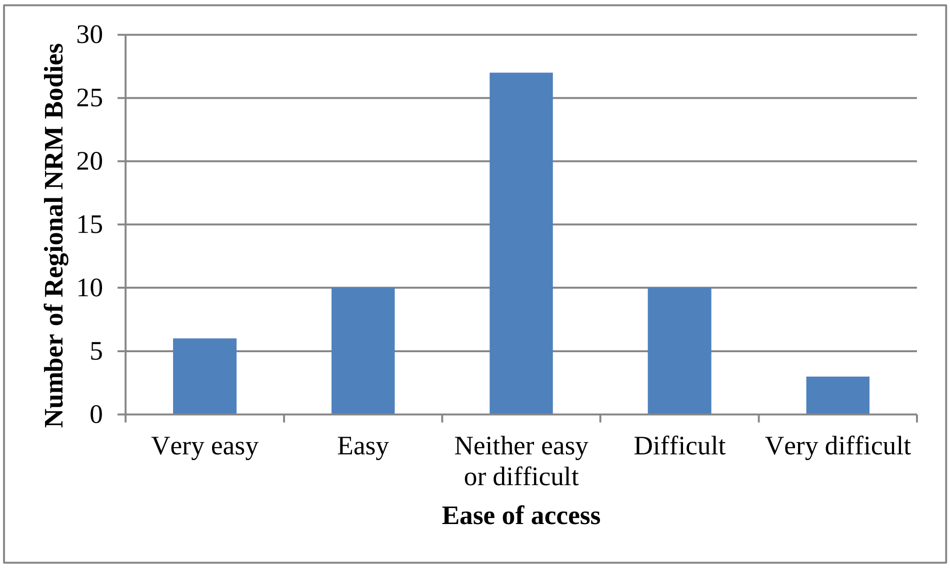

Figure 5.6: Ease of access to spatial information

The majority of organisations (77%) indicated that they also supplied spatial information. The main users of spatial information that was generated or value-added by regional NRM bodies were the community organisations such as Landcare, Watercare, Birdwatch, landowners and indigenous groups. Government organisations, the private sector and academic research institutions utilised spatial information managed by regional NRM bodies less frequently. It was also evident that there is a two-way information flow between regional NRM bodies and government organisations. As a result of this mutual interest, government organisations are interested in collaborating and networking with regional NRM bodies via data sharing agreements.

The most common ways of receiving spatial information from other organisations were by paper maps, CDROM or other portable digital media, digital download (eg enterprise server, internet, FTP, data directory, etc) and e-mail. Only 18% of regional NRM bodies receive spatial information in the form of paper maps. The majority of regional NRM bodies received their spatial information using ICT technology and digital media.

Restrictions on the use of the spatial information placed by the spatial data providers, and the impact of these on the ability for NRM bodies to undertake GIS activities, were also investigated. The majority (62%) of regional NRM bodies advised that there were restrictions on the use of spatial information provided by spatial data providers, and only 4% of the regional NRM bodies advised that there are no usage restrictions.

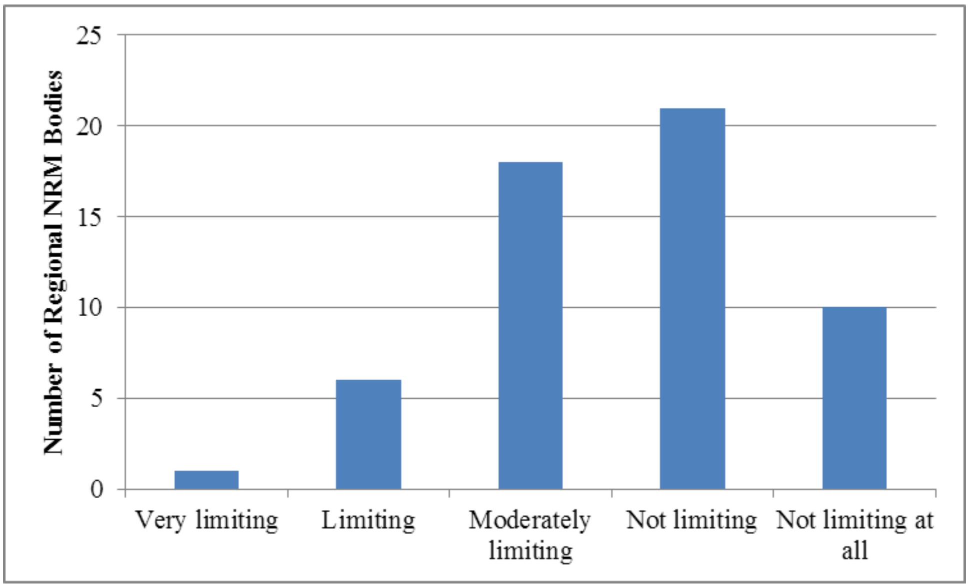

Figure 5.7: Impact of restriction to undertake GIS activities

While assessing the impacts of the restrictions to undertake GIS activities, more than half (54%) of the regional NRM bodies advised that the restrictions placed on them by the spatial data provider did not limit their ability to undertake their GIS activities (Figure 5.7).

With respect to integrating externally obtained spatial data into GIS, approximately half of the regional NRM bodies advised that there were problems. The main problems were related to standards and the format of the data. Only 9% of regional NRM bodies advised that it was related to scale. This indicates that interoperability continues to be an issue in integrating externally obtained spatial data into their GIS systems.

The majority (60%) of the regional NRM bodies advised that the pricing of spatial information is affordable for their organisation. Forty two per cent accepted a pricing arrangement for spatial data based on the cost of transferring data, whilst 33% indicated that the spatial information should be free. Only 7% of regional NRM bodies were in favour of full cost recovery (Figure 5.8). Seventy five per cent argued that the foundation data should be free.

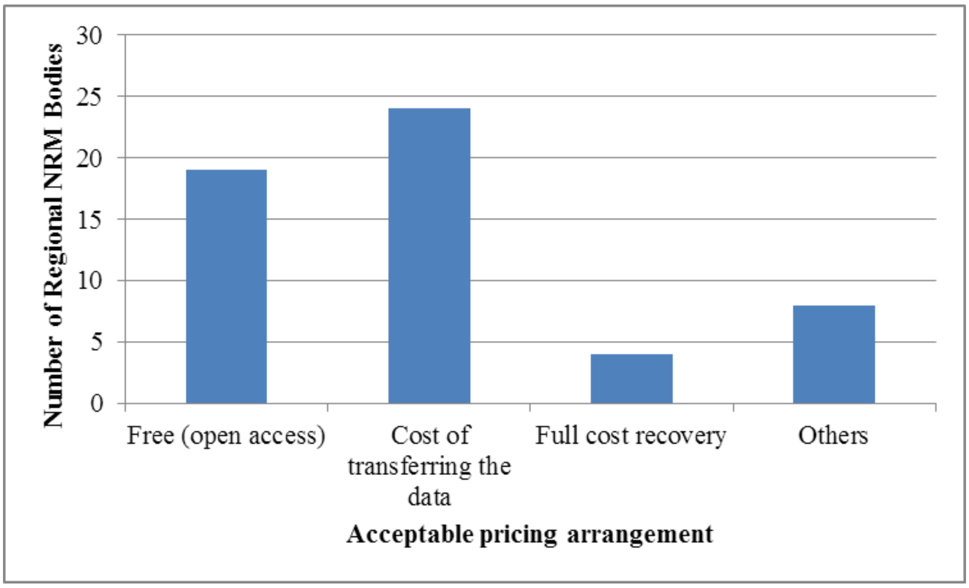

Figure 5.8: Pricing arrangement

Many regional NRM bodies also supply spatial information and this may explain why they are seeking an acceptable pricing arrangement. A few regional NRM bodies also advised that the pricing was dependent upon the type of spatial information and data users. Other specific responses include "*the government spatial data should be free and a reasonable cost should be placed for private and community owned spatial data*" and *"the best way of distributing spatial information could be under creative commons*."

5.3.6. Data Sharing, Collaboration and Networking

The sixth part of the questionnaire investigated data sharing, collaboration and networking activities for catchment management.

The collaborative arrangements of regional NRM bodies with other organisations with respect to the exchange of resources, skills and technology were examined. The majority (83%) of the regional NRM bodies advised that they have a collaborative arrangement with other organisations. After investigation, it was found that data sharing and spatial information management were the main areas of collaboration. However, it was identified that the majority of regional NRM bodies had a silo approach to the spatial information management which did not encourage to spatial information sharing. The next most important area of collaboration was knowledge transfer (as illustrated in Figure 5.9).

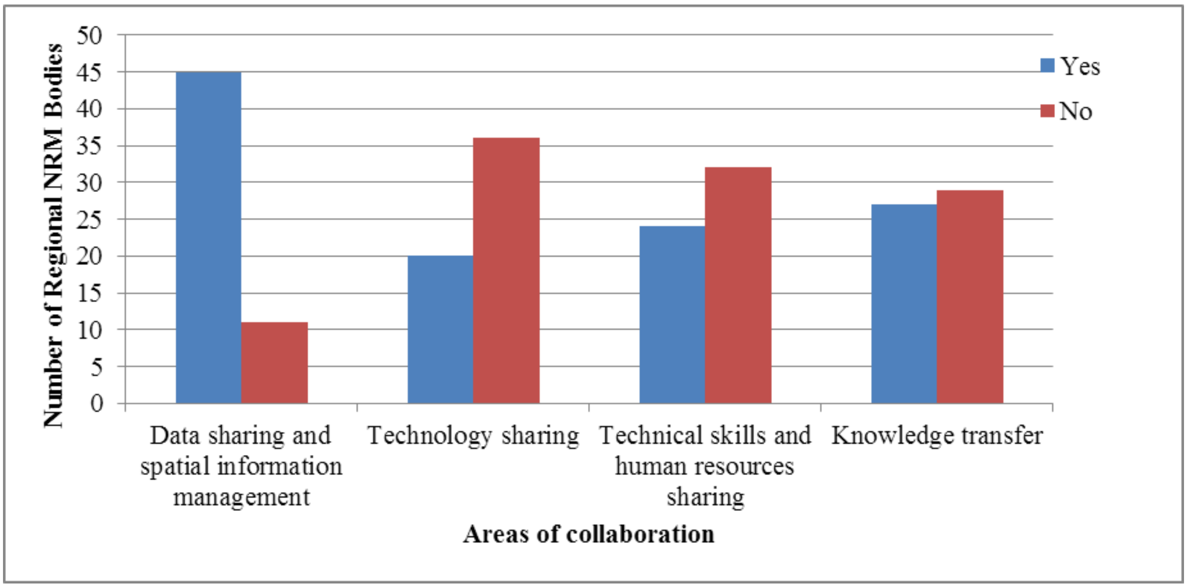

Figure 5.9: Areas of collaboration

The main partners for these collaboration and networking activities were state government organisations with community organisations, including other regional NRM bodies, the next most common.

Spatial information sharing factors were identified and their importance in facilitating information sharing with other organisations was examined. Having a formal agreement, organisational attitude to sharing, individual attitude, ability and willingness to share, and leadership were found most important. Table 5.4 lists the spatial information sharing factors and their importance as rated by regional NRM bodies.

Table 5.4: Spatial information sharing factors and their importance

Spatial Information Sharing Factors	Importance
Formal agreement	Very High
Organisational attitude to sharing	Very high
Individual attitude, ability and willingness	Very High
Leadership	Very High
Networking and contacts	High
IT system and technical tools	High

5.3.7. Emerging Models of Spatial Information Management

The last part of the questionnaire explored the emerging spatial information management models and freely available/accessible spatial products (eg Google Maps, OpenstreetMap, WikiMapia, etc) and their potential application to catchment management activities.

The majority (95%) of the regional NRM bodies advised that they were aware of freely available/accessible spatial products for their work needs. However, the utilisation of these products for catchment management activities was infrequent. About 35% of the regional NRM bodies advised that they used these products a few times in a year. However, the level of applicability of these open source products to various catchment management issues is very high. Exchanging feedback through portals such as *Webblogs, Facebook, Flickr and Twitter* will be increasingly useful for community networking and the exchange of ideas/knowledge. Approximately 45% of regional NRM bodies were neutral with this statement whilst 32% of NRM bodies agreed with this statement. This tends to show that there is a growing recognition of the utilisation of these new web tools and social media for spatial information sharing and exchange. The regional NRM bodies were also aware of various social networking activities and/or data sharing projects for improved catchment managements within their catchment areas. The comments on social networking activities and/or data sharing projects are listed in Appendix 6.

5.3.8. Summary of Findings

The majority of regional NRM bodies identified themselves as spatial information users and providers and there is a strong spatial information awareness among regional NRM staff. The introduction of GIS activities in most of the regional NRM bodies appears to be quite mature with dedicated spatial sections/staff within their organisations. The organisations are also actively working with other external organisations for spatial information management and use. This demonstrates a strong spatial capacity of regional NRM bodies and the need for a coordinated approach for building SDI at the catchment/regional scale. Some regional NRM bodies have in-house spatial standards, policies and guidelines, however these need to be revisited, updated and formalised.

The main funding source for regional NRM bodies is the Commonwealth Government whilst the main spatial information providers are the state government organisations. Vegetation, cadastral data, catchment boundaries, and land use/land cover data were identified as the most important spatial datasets for catchment decisions. Most of the regional NRM bodies acquire their spatial information via a data sharing agreement and use e-mail, internet and other web based tools to locate their data. Some restrictions are placed by spatial data providers on the use of spatial data, however the impact of these restrictions does not appear to limit regional NRM bodies' ability to undertake their work. The access to spatial information by spatial data providers is reasonable, however, there is difficulty identifying which organisation holds each type of data and how to access these datasets. Often, there are problems in integrating externally obtained spatial data into GIS systems due to standards and formats. The pricing arrangements are generally affordable, with the most acceptable pricing arrangement being the cost of transferring data. To protect intellectual property and copyright, regional NRM bodies suggested the distribution of spatial data under a creative common licence.

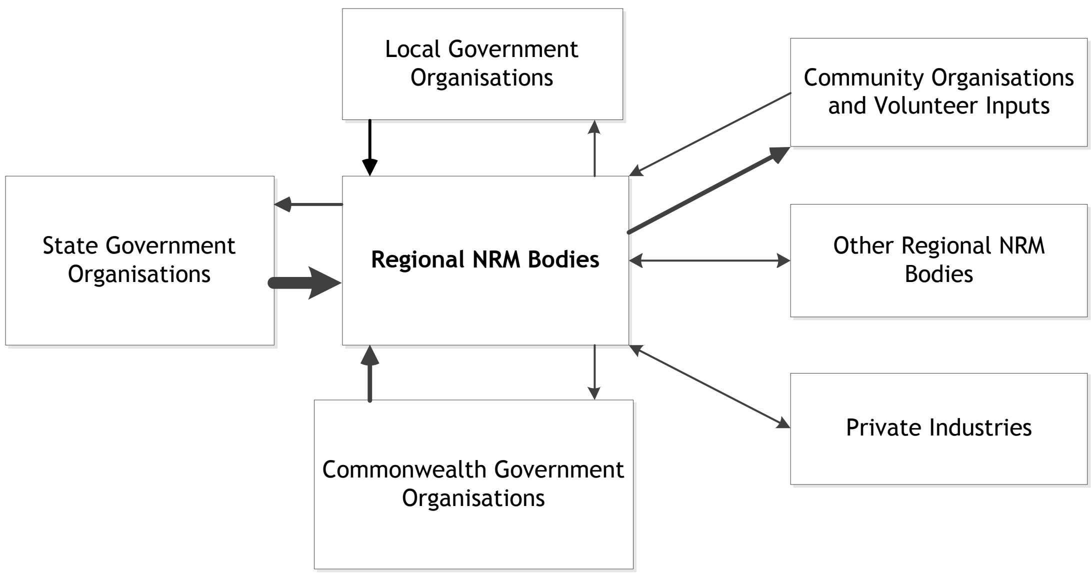

Figure 5.10: Flow of spatial information between regional NRM bodies and other organisations

Figure 5.10 shows that there is a two-way spatial information flow between regional NRM bodies and other organisations. The main spatial information providers to regional NRM bodies are the state government organisations followed by commonwealth government organisations. The main users of spatial information that is generated or value-added by regional NRM bodies are the community organisations such as Landcare, Watercare, Birdwatch, landowners and indigenous groups. The Local government organisations and private industries are identified as being of limited importance as a source of data.

Data sharing and spatial information management is a key area of collaboration which is based on the partnerships with state government organisations or community organisations. An emerging area for collaboration in the NRM sector is knowledge sharing. Regional NRM bodies are aware of freely available/accessible spatial products and there is a growing recognition of web tools and social media for spatial information sharing and management in the NRM sector.

5.4. Similarities and Differences between Regional NRM Bodies/CMAs

The descriptive statistics discussed in Section 5.3 provided a national perspective of the spatial information use, access and sharing for catchment management activities for NRM bodies at the regional scale. This section describes the similarities and differences that exist between states, varying statutory arrangements (statutory or non-statutory groups) and the association with a basin authority (eg Murray Darling Basin Authority).

Though there are different views regarding the definition and the components of spatial data infrastructure (SDI), the common view is that SDI is an infrastructure to facilitate spatial information access, use and sharing (EU 2006; Rajabifard et al 2003a; UN Geospatial Information Working Group 2007). These three areas (spatial information access, use and sharing) were selected and the variables contributing towards these areas were identified to explore the similarities and differences between regional NRM bodies. The three key areas and the contributing factors are provided in Table 5.5.

Table 5.5: Areas and contributing factors for SDI development

Areas	Contributing factors
Spatial Information Access	Ease of access, restriction, impact of restriction, affordability of current pricing, spatial information access medium
Spatial Information Use	Type of organisation, spatial information used by staff, GIS maturity, GIS activities, spatial information receiving medium
Spatial Information Sharing	Collaborative arrangement, networking, use of open source models and social media, spatial policy, cost of spatial data, funding sources, importance of spatial data provider, spatial information integration issues, data sharing agreement

5.4.1. Comparison between States

As described in Chapter Three, there are 14 regional NRM bodies in Queensland (QLD), 13 in New South Wales (NSW), eight in Victoria (VIC), eight in South Australia (SA), six in Western Australia (WA), three in Tasmania (TAS), one in the Australian Capital Territory (ACT) and one in the Northern Territory (NT). The comments on spatial information policy are provided in Appendix 6. The similarities amongst and differences between Australian states regarding spatial information access, use, and sharing among Australian States is discussed in the following section.

5.4.1.1. Spatial Information Access

In respect to the ease of accessing spatial data, about half (48%) the organisations responded that it was moderately easy to access. However, in NSW, the majority of organisations advised that it was more difficult to access spatial information. It was likely that this was due to the restrictions placed by the spatial data provider on their use of spatial data (Figure 5.11).

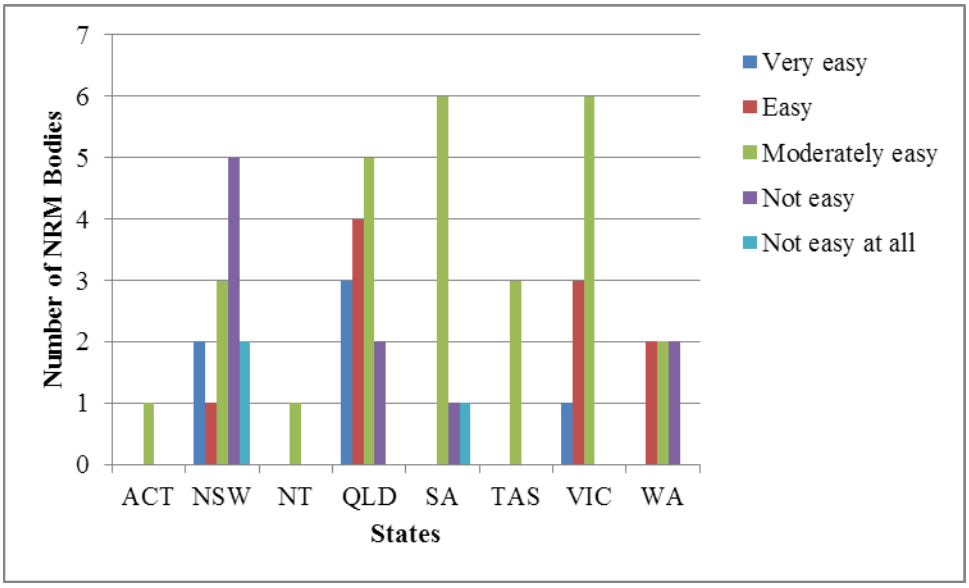

Figure 5.11: Ease of access to obtain spatial data from spatial data provider

Six out of 13 NSW NRM bodies advised that there were always restrictions on the use of spatial information provided by spatial data providers which limited their ability to undertake GIS activities. However, the majority of regional NRM bodies located in Queensland, South Australia, Victoria and Northern Territory advised that the restrictions did not limit their GIS activities. The majority of regional NRM bodies of Tasmania and Western Australia advised that the restrictions impacted on their ability to undertake GIS activities. With respect to the pricing of spatial data, 60% of the organisations advised that the pricing of spatial information was affordable and the most accepted was the pricing arrangement as the cost of transferring data. Most regional NRM bodies received their spatial information using ICT technology and digital media.

5.4.1.2. Spatial Information Use

The regional NRM bodies also produce spatial information which provides a strong base from which to develop spatial data infrastructure (SDI) at the catchment level. Most regional NRM bodies including Queensland (93%), New South Wales (85%), Victoria (80%), Western Australia (67%), Northern Territory (100%), and Tasmania (100%) identified themselves as both spatial information providers and users. However, half of regional NRM bodies in South Australia and regional NRM body of Australian Capital Territory identified themselves as spatial information users only. With respect to the use of spatial information by regional NRM bodies' staff, 40-60% of the total staff in New South Wales, Queensland, Victoria and Western Australia used spatial information for catchment management activities. However, 60-80% of total staff in Tasmania and South Australia used spatial information for catchment management activities.

Figure 5.12: Length of time using GIS

The regional NRM bodies in Queensland, New South Wales and Victoria identified themselves as mature GIS organisations using spatial information for 5-10 years or more. However, the regional NRM bodies of Tasmania and the Australian Capital Territory indicated limited experience in their use of spatial information (as shown in Figure 5.12).

The majority of regional NRM bodies in New South Wales, Queensland, South Australia, Victoria, Northern Territory and Tasmania outsource some of their GIS activities. However, about half of the regional NRM bodies in Western Australia are undertaking GIS activities completely in-house. The Western Australian Land Information System (WALIS) appears to have significantly influenced WA regional NRM bodies in building in-house GIS capacity.

5.4.1.3. Spatial Information Sharing and Networking

The collaborative arrangements with other organisations with respect to the exchange of resources, skills and technology were examined. Regional NRM bodies of QLD identified themselves having a high level of collaboration (Figure 5.13).

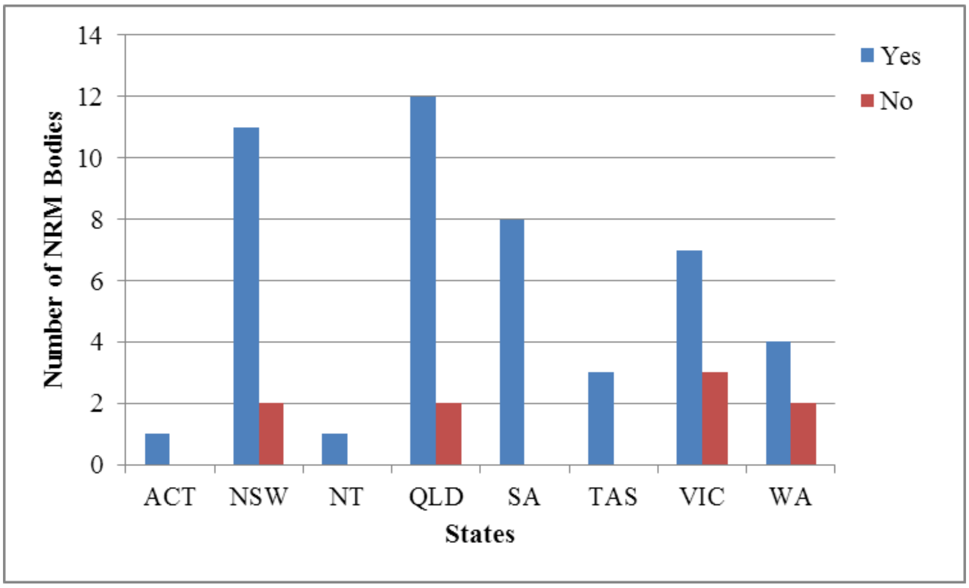

Figure 5.13: Collaborative arrangements

There are some variations in the type of collaboration amongst the regional NRM bodies. It was found that data sharing was the main area of collaboration in most of the states. However, in Tasmania, the main area of collaboration was knowledge transfer. Knowledge transfer was the second most important area of collaboration in most of the other states.

The main partners for these collaboration and networking activities were state government organisations. Community organisations, including other regional NRM bodies, were the second most common.

Approximately 95% of the regional NRM bodies advised that they were aware of freely available/accessible spatial products such as Google Maps, OpenStreetMap, Wikimapia for their work needs. However, the utilisation of these products for catchment management activities is infrequent. Most NRM bodies of the Australian Capital Territory, South Australia and Western Australia were in favour of using social media and open models for spatial information management. However, the other states were neutral on this issue (Figure 5.14). There is a growing utilisation of these new open models and social media for spatial information sharing and exchange in the community. However, due to the security, privacy and confidentiality, the regional NRM bodies are not very comfortable using these products at this stage.

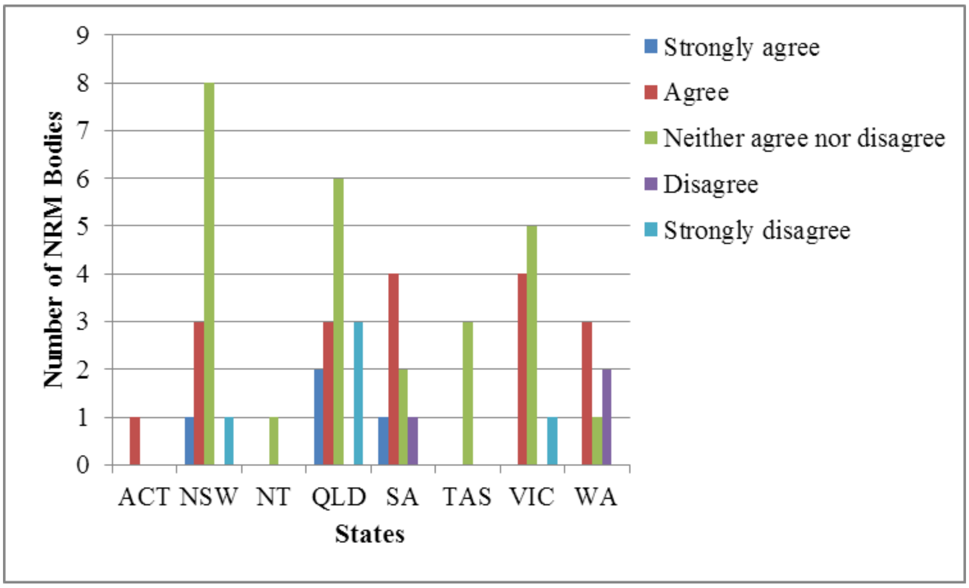

Figure 5.14: Exchanging feedback through portals using social media

5.4.2. Comparison Between Statutory and Non-Statutory NRM Bodies

In this section, the similarities and differences that exist between statutory (established by the state government) and non-statutory (community based) regional NRM bodies in spatial information access, use, and sharing for catchment management activities are discussed. As discussed in Chapter Three, the regional NRM bodies in New South Wales, Victoria, South Australia and Australian Capital Territory are statutory (defined by legislation) whilst the regional NRM bodies in Queensland, Western Australia, Tasmania and Northern Territory are non-statutory. Amongst the 56 regional NRM bodies, 24 are statutory and the remaining 32 are non-statutory. The main purpose of this comparison is to explore whether any trends and significant variations exist due to statutory arrangements.

5.4.2.1. Spatial Information Access

With respect to accessing spatial data, there were no significant differences between statutory and non-statutory regional NRM bodies, although some variations were noted. Only 17% of non-statutory NRM bodies indicated that it was difficult to access spatial information whilst 28% of statutory NRM bodies indicated difficulty in accessing spatial information from spatial data providers (Figure 5.15).

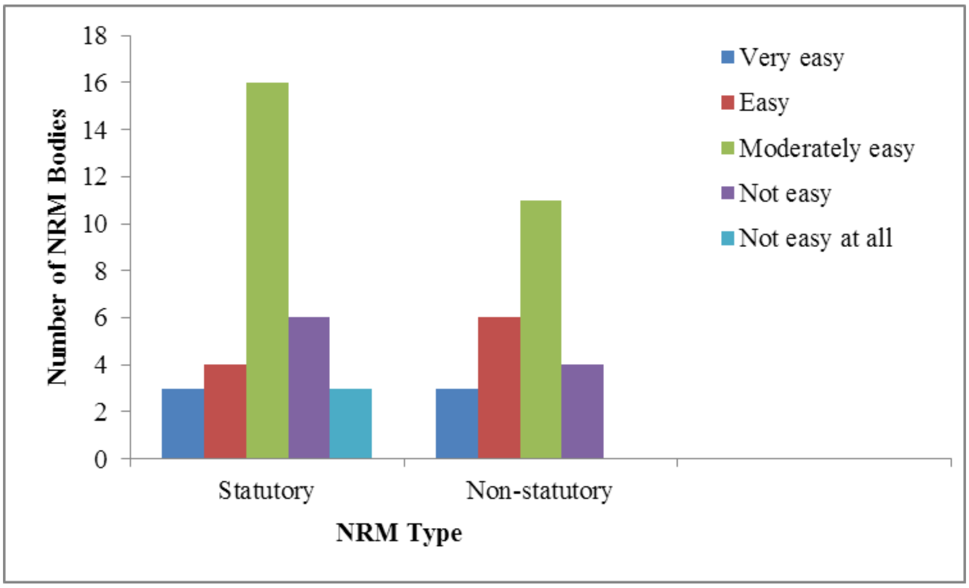

Figure 5.15: Ease of access and obtain spatial data from spatial data providers

Approximately 42% of non-statutory and 28% of statutory regional NRM bodies advised that restrictions were placed (by the spatial data providers) on the use of spatial information, however, these did not limit their ability to undertake GIS activities. With respect to current pricing of spatial data, the non-statutory NRM bodies were more satisfied than statutory NRM bodies. This finding is interesting given that statutory NRM bodies are usually considered to be closely aligned with the state government. The most accepted pricing arrangement for the statutory group was the cost of transferring data, and for non-statutory group, it was free access. However, both groups agreed that the pricing depends upon the data type, and that foundation data should be free. This indicates that statutory bodies operate in a similar way to government organisations.

5.4.2.2. Spatial Information Use

The majority (92%) of non-statutory organisations advised that they also supply spatial information and identified themselves as both spatial information providers and users. The number of statutory organisations that supply spatial information is relatively low (69%) in comparison with the non-statutory group. This indicates that non-statutory organisations are more dynamic and proficient in spatial information management.

With respect to the use of spatial information by regional NRM staff, 40-60% of staff in both of the groups used spatial information for catchment management activities. Approximately half (48%) of the regional NRM bodies in both of the groups identified themselves as mature GIS organisations using spatial information for 5-10 years or more. There are some variations regarding the mode of undertaking GIS activities. Ten out of 24 non-statutory organisations advised that they were undertaking GIS activities completely in-house. However, only two out of 36 statutory organisations advised that they were undertaking GIS activities completely in-house (Figure 5.16). This indicates that statutory organisations are more dependent on other organisations, especially state government organisations and have perhaps less resources to undertake in-house GIS activities. In contrast, non-statutory organisations appear to be more flexible and self-sufficient in undertaking GIS activities.

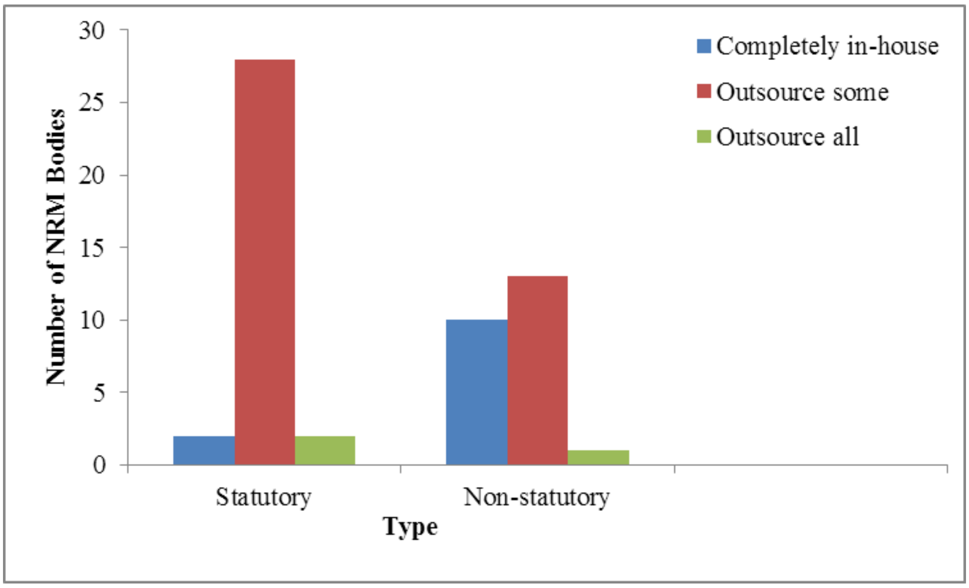

Figure 5.16: Mode of undertaking GIS activities

5.4.2.3. Spatial Information Sharing and Networking

Almost 84% of the regional NRM bodies in both statutory and non-statutory groups indicated that they have some form of collaboration or networking activities with other organisations for spatial information management (Figure 5.17).

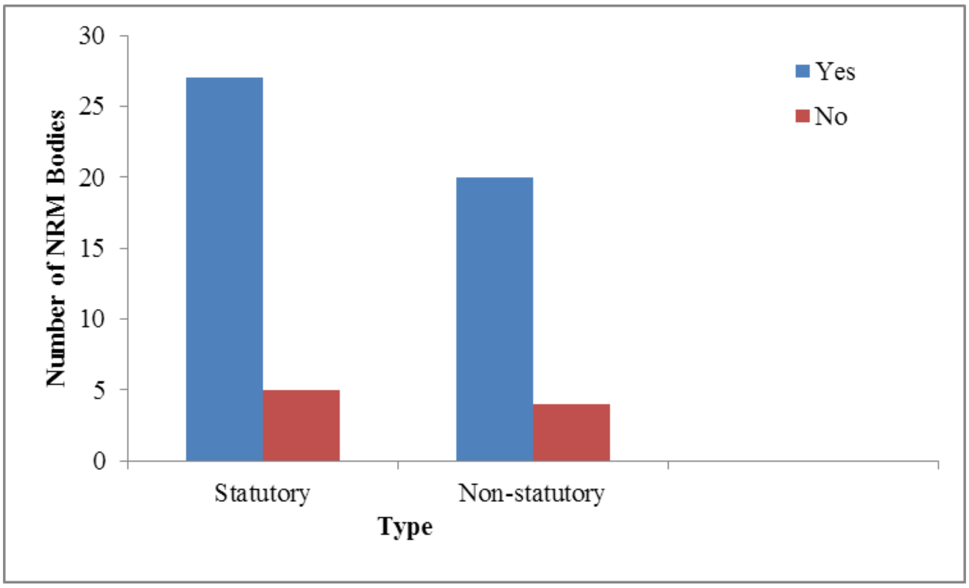

Figure 5.17: Collaborative arrangements

It was found that data sharing and spatial information management were the main areas of collaboration in both of the groups. However, there were some variations in the next most important area of collaboration. Statutory regional NRM bodies advised that the next most important area of collaboration related to technical skills and human resources sharing. The non-statutory regional NRM bodies advised that the next most important area of collaboration was knowledge transfer (Figure 5.18).

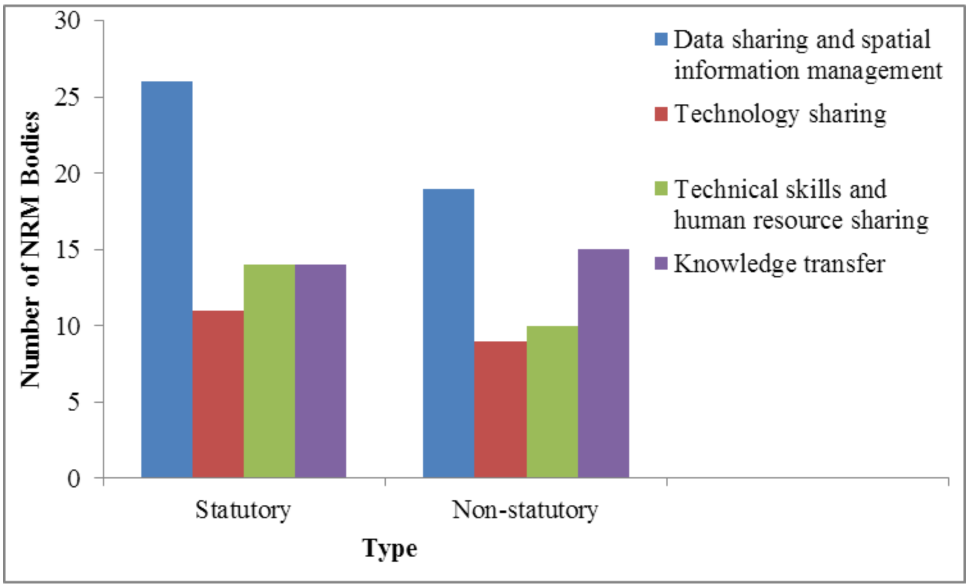

Figure 5.18: Area of collaboration

Again, this indicates that statutory organisations lack resources or the capacity for GIS activities and so collaborate in technical skills and human resources sharing.

In the majority of statutory regional NRM bodies data sharing was undertaken through formal processes. However, in non-statutory groups, data sharing was done through both formal as well as informal processes. This indicates non-statutory regional NRM bodies are more dynamic and flexible in spatial information sharing.

5.4.3. Comparison between MDBA and Non-MDBA NRM Bodies

As discussed earlier in Chapter Three, the Murray Darling Basin Authority (MDBA) of Australia is one of the major basin authorities for natural resource management. It covers four states (Queensland, New South Wales, Victoria, and South Australia) and one territory (Australian Capital Territory). In this section, the similarities and differences that exist between regional NRM bodies which are associated with the MDBA are explored. The number of regional NRM bodies which fall under MDBA and non-MDBA in each of the states is illustrated in Table 5.6.

Table 5.6: The number of MDBA and Non-MDBA NRM bodies in each state

Regional NRM bodies	States					
	QLD	**NSW**	**VIC**	**SA**	**ACT**	**Total**
MDBA	3	8	5	3	1	20
Non-MDBA	11	5	5	5	0	26
Total	14	13	10	8	1	46

There are 20 MDBA NRM bodies and 26 non-MDBA regional NRM bodies. The NRM bodies of Western Australia, Tasmania and Northern Territory were excluded in this analysis. The jurisdiction of the MDBA covers one-seventh of the Australian mainland, including three-quarters of New South Wales, more than half of Victoria, significant portions of Queensland and South Australia, and all of the Australian Capital Territory. Figure 5.19 illustrates the MDBA areas and non-MDBA areas.

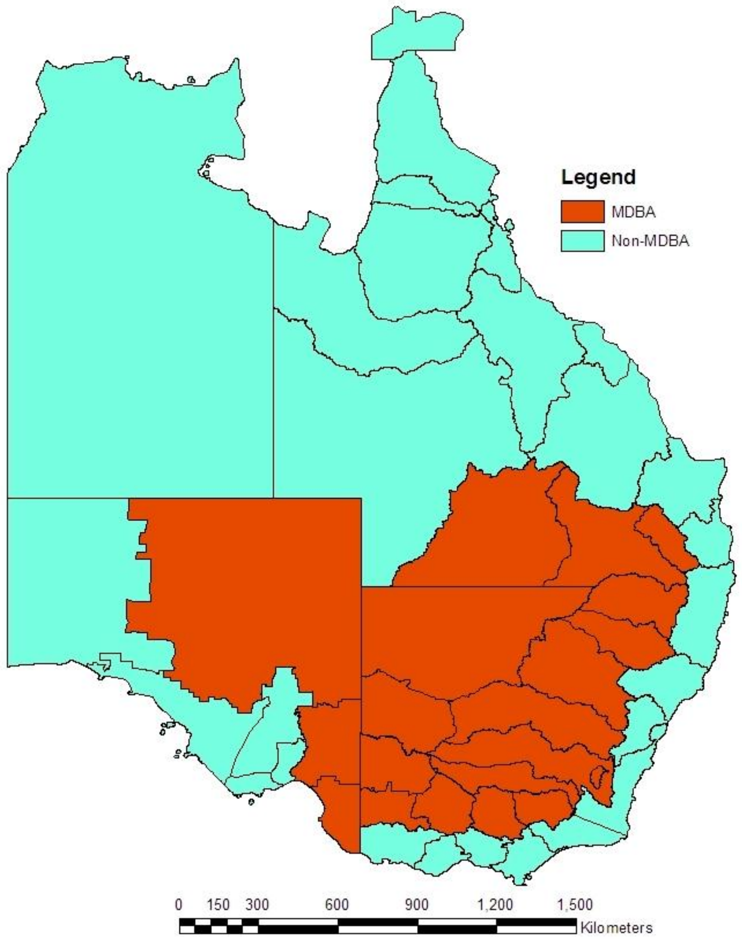

Figure 5.19: MDBA and Non-MDBA regional NRM bodies

5.4.3.1. Spatial Information Access

With respect to the ease of accessing spatial data, more than half (53%) the MDBA regional NRM bodies responded that it was easy to access spatial data from spatial data providers, whilst only 38% of non-MDBA regional NRM bodies indicated that this was the case. Spatial information access was found to be easier in the regional NRM bodies which are associated with the MDBA in comparison with non-MDBA groups (Figure 5.20).

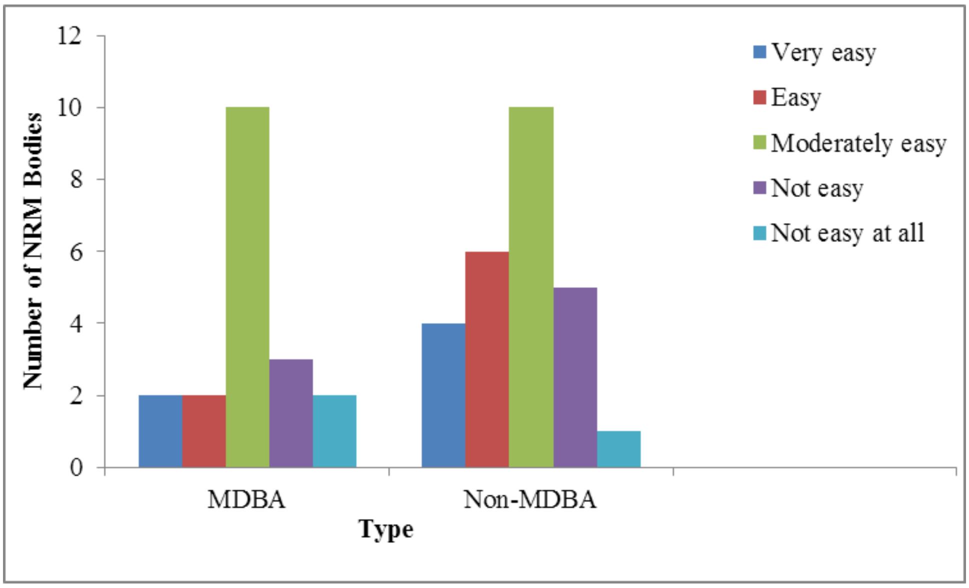

Figure 5.20: Ease of access to obtain spatial data from spatial data provider

Twenty out of 26 non-MDBA regional NRM bodies advised that, while spatial data providers placed restrictions on the use of their spatial information most of the time, the restrictions were not limiting to their GIS activities. The MDBA regional NRM bodies advised that in their case the restrictions were moderately limiting to their GIS activities (Figure 5.21).

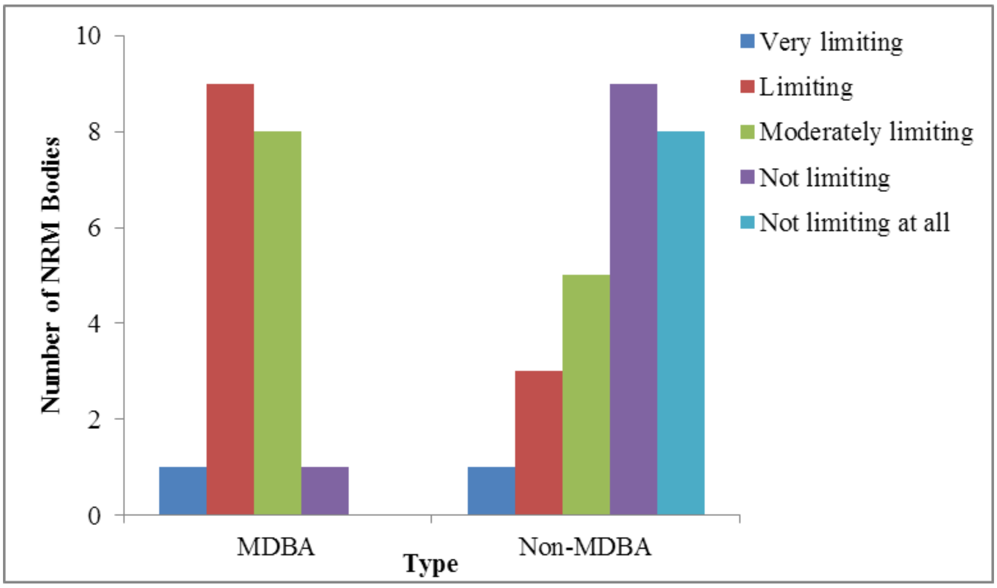

Figure 5.21: Impact of restrictions to undertake GIS activities

With respect to the pricing of spatial data, about half (52%) of MDBA regional NRM bodies advised that the pricing of spatial information was affordable and the most acceptable pricing arrangement was the cost of transferring data. The majority (65%) of non-MDBA regional NRM bodies responded that the current pricing was also affordable but the most acceptable pricing arrangement was the provision of cost of transfer. Both groups of regional NRM bodies acknowledged the impact of ICT tools and digital media on spatial information access.

5.4.3.2. Spatial Information Use

In both of the groups, the majority of regional NRM bodies identified themselves as both spatial information users and providers. Both groups also identified themselves as mature GIS organisations using spatial information for 5-10 years or more. With respect to the use of spatial information by regional NRM bodies, 40-60% of the total staff in both groups were identified as utilising spatial information for catchment management activities (Figure 5.22).

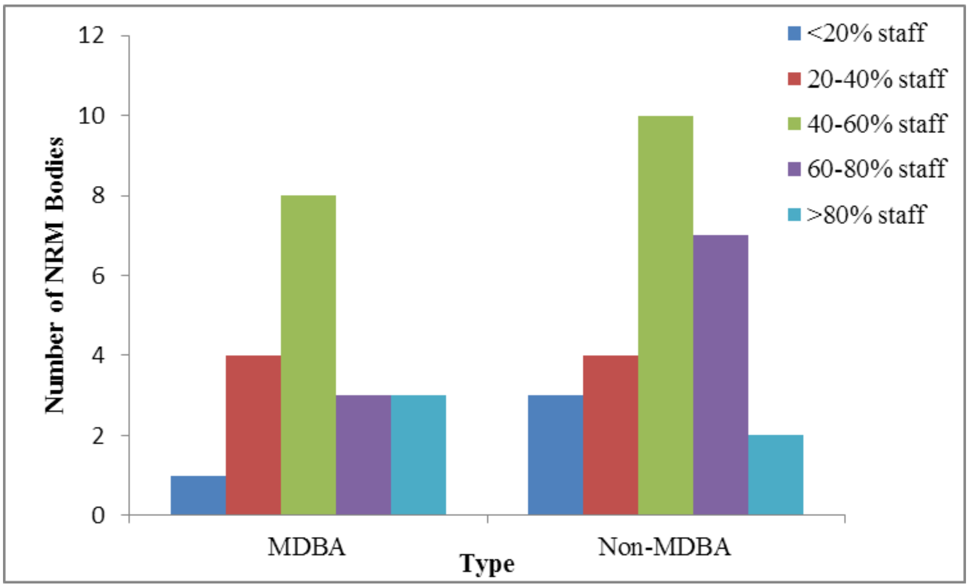

Figure 5.22: Use of spatial information by CMA staff

There were no discernible differences between the groups with respect to GIS capacity, with each group using a combination of in-house and outsourced GIS and having sufficient resources to undertake GIS activities.

5.4.3.3. Spatial Information Sharing and Networking

Regarding the collaborative arrangement with other organisations with respect to the exchange of resources, skills, and technology, the majority (84%) of the organisations in both of the groups indicated that they have a collaborative arrangement with other organisations. It was found that data sharing and spatial information management were the main areas of collaboration for both groups. However, there were some variations in the next most important areas of collaboration between two groups. MDBA regional NRM bodies advised that technical skills and human resources sharing were the second highest areas of collaboration, whilst non-MDBA regional NRM bodies indicated that collaboration in the area of knowledge transfer was the next most important (Figure 5.23). Spatial information sharing was undertaken through both formal and informal agreement. More than half (65%) of the non-MDBA regional NRM bodies favoured informal mechanisms of spatial information sharing. This indicates non-MDBA regional NRM bodies may be more willing to explore options for spatial information sharing.

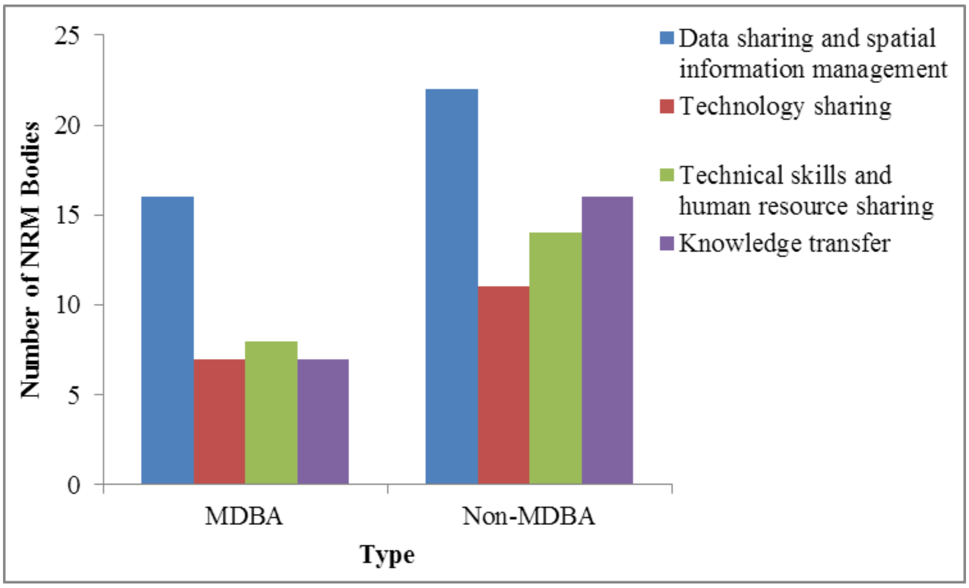

Figure 5.23: Main areas of collaboration for catchment management activities

In both groups, the main partners for this collaboration and networking activities were the state government organisations followed by community organisations (including other regional NRM bodies).

Regarding the awareness of freely available/accessible spatial products such as Google Maps, OpenstreetMap and Wikimapia for their work needs, almost all of the regional NRM bodies were aware of these products. When examining the scope of utilisation of these products for spatial information management, MDBA regional NRM bodies were in the favour of using these options.

5.4.3.4. Summary of Findings

The similarities and differences that exist between states, varying statutory arrangements (statutory or non-statutory groups), and the association with a basin authority (eg Murray Darling Basin Authority) provided an insight into the varying institutional arrangements.

Regional NRM bodies most commonly obtain spatial information from state government agencies; however, the access mechanisms vary between the Australian states. The access policy of state government organisations has impacted on spatial information access for the NRM bodies. The regional NRM bodies of New South Wales, Queensland, Victoria and Western Australia are quite mature in comparison with other states. This indicates that the state government organisations appear to have significantly influenced regional NRM bodies in building their capacity for spatial information management. The Western Australian Land Information System (WALIS) is a very good example of an organisation that has influenced the building of GIS capacity in WA regional NRM bodies. Data sharing and spatial information management were the main areas of collaboration in most of the states. Knowledge management and knowledge sharing is well-practised in the NRM sector and knowledge sharing was identified as an emerging area for collaboration.

It was found that there were limited differences between statutory and non-statutory regional NRM bodies regarding spatial information access. Statutory regional NRM bodies operate more like government organisations. The most acceptable pricing arrangement for the statutory group was the cost of transferring data, and for the non-statutory group it was free access. Approximately half of the regional NRM bodies in both of the groups identified themselves as mature GIS organisations using spatial information for 5-10 years or more. The non-statutory group was found to undertake more in-house GIS activities. Data sharing and spatial information management were the main areas of collaboration in both of the groups. The next most important area of collaboration for statutory regional NRM groups was technical skills and human resource sharing, and for non-statutory regional NRM bodies it was knowledge transfer. So, the non-statutory group appears to be more flexible and self-sufficient whilst statutory regional NRM bodies may lack flexibility in their spatial information management practices.

The spatial information access arrangements of MDBA regional NRM bodies were found to be better than non-MDBA regional NRM bodies. The MDBA is a peak body that works directly with regional NRM bodies and government agencies and therefore appears to have had a positive influence on the spatial information access and sharing. The spatial data collected by the MDBA is available under the Australian Governments Open Access and Licencing Framework (AusGOAL).

The majority of non-MDBA regional NRM bodies indicated that spatial data providers placed restrictions on the use of their spatial information most of the time. Regarding spatial information use, there were no significant variations between the two groups. Data sharing and spatial information management were also the main areas of collaboration for both of the groups. Similar to the statutory/non-statutory NRM bodies, the MDBA regional NRM bodies indicated that technical skills and human resources sharing were the second highest areas, whilst the non-MDBA regional NRM bodies indicated that knowledge transfer was the second highest priority. Non-MDBA regional NRM bodies also favoured informal processes for spatial information sharing.

5.5. Key Factors That Influence Data Sharing Across Catchment Management Areas and Facilitate SDI Development

In this section, the conditions which influence data sharing across catchments were examined. Broadly, the conditions for sharing can be categorised into five groups, namely sharing environment, rules for sharing, capacity to enable sharing, will to share and the value of sharing. The descriptive statistics in Section 5.3 and similarities and differences in descriptive statistics Section 5.4 were used to identify the importance of these factors for spatial information sharing. The factors which were rated above 70% importance were classified as high, 50-70% are medium and less than 50% are low. The factors are shown in Table 5.7

From the below table, the 21 factors were then reduced into five broad groups: sharing environment (governance), rules for sharing (policy), capacity to enable sharing (technology), willingness to share (culture) and value of sharing (economics). These five broad groups were identified during literature review (see Chapter 2, Table 2.7). The factors indicating the spatial capacity of the organisation, spatial information policies and data share arrangements, spatial data requirements, access mechanisms, collaborative arrangements and willingness to provide data were the main factors which impacted on spatial information sharing between the regional NRM bodies and government agencies. The sharing environment, rules for sharing and willingness to share were the most important conditions for spatial information sharing.

Table 5.7: Factors that influence spatial information sharing

Individual Factors	Conditions for sharing	Importance
Organisation type	Sharing environment	High
Spatial information use by staff	Sharing environment	High
GIS maturity	Sharing environment	High
Organisational capacity	Sharing environment	High
Volunteer activities	Will to share	Low
Scale of spatial data	Sharing environment	Low
Spatial information policy	Rules for sharing	High
Funding sources	Value of sharing	Medium
Spatial data requirements	Value of sharing	High
Spatial information access medium	Rules for sharing	Medium
Importance of spatial information providers	Sharing environment	High
Ease of access to spatial information	Rules for sharing	High
Frequency of supply	Capacity to enable sharing	Low
Spatial information receiving medium	Capacity to enable sharing	Medium
Restrictions on spatial information	Rules for sharing	Medium
Integration issues	Capacity to enable sharing	Low
Pricing of spatial data	Value of sharing	Low
Collaborative arrangements	Sharing environment	High
Data sharing agreement	Rules for sharing	High
Social media, Web 2.0 technology	Capacity to enable sharing	Medium
Willingness to provide spatial data	Will to share	High

A framework was developed from this output and is shown in Figure 5.24.

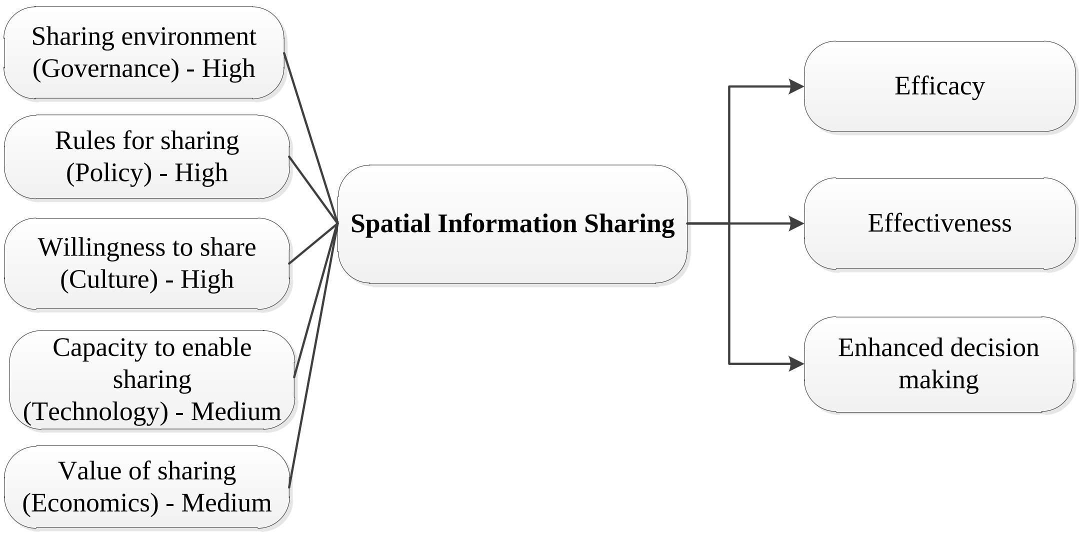

Figure 5.24: Cause and effects of spatial information sharing

The open ended responses (see Appendix 6) of the questionnaire provided another valuable source of information.

5.6. Concluding Remarks

This chapter has undertaken a comprehensive analysis of the current status of spatial information access, use and sharing of catchment management across the natural resource management sector in Australia. A number of significant trends and differences were identified between Australian states, jurisdictional environments and regional NRM bodies associated with a basin authority. The key factors that influence the data sharing across catchment management areas were identified and categorised into five spatial information sharing groups: sharing environment, rules for sharing, capability to enable sharing, willingness to share and value of sharing. The three groups appear to be important are sharing environment (governance), rule for sharing (policy), and willingness to share (culture). The factors such as the spatial capability of an organisation, spatial information policies and data sharing arrangements, spatial data requirements, access mechanisms, collaborative arrangements and willingness to provide data were found to be the main factors that impact spatial information sharing between regional NRM bodies and state government agencies.

Chapter Six examines the Knowledge and Information Network (KIN) project and explores the current spatial information sharing mechanisms between regional NRM bodies and state government organisations.

Chapter 6

Case Study – KIN Project

6.1. Introduction

In Chapter Five, the current status of spatial information access, use and sharing for catchment management was examined. Spatial information sharing was identified as a very important component for catchment management and spatial data infrastructure (SDI) development. The Knowledge and Information Network (KIN) project was identified as a representative case for further investigation. This chapter documents the case study of the KIN project. The case study enabled the author to undertake an in-depth analysis of the spatial information and knowledge sharing arrangements between regional NRM bodies and state government organisations. The overall goal of this case study was to investigate the effectiveness of the KIN project in promoting spatial information sharing arrangements between regional NRM bodies and state government organisations. Three objectives were formulated to achieve the overall goal. Figure 6.1 illustrates the case study framework.

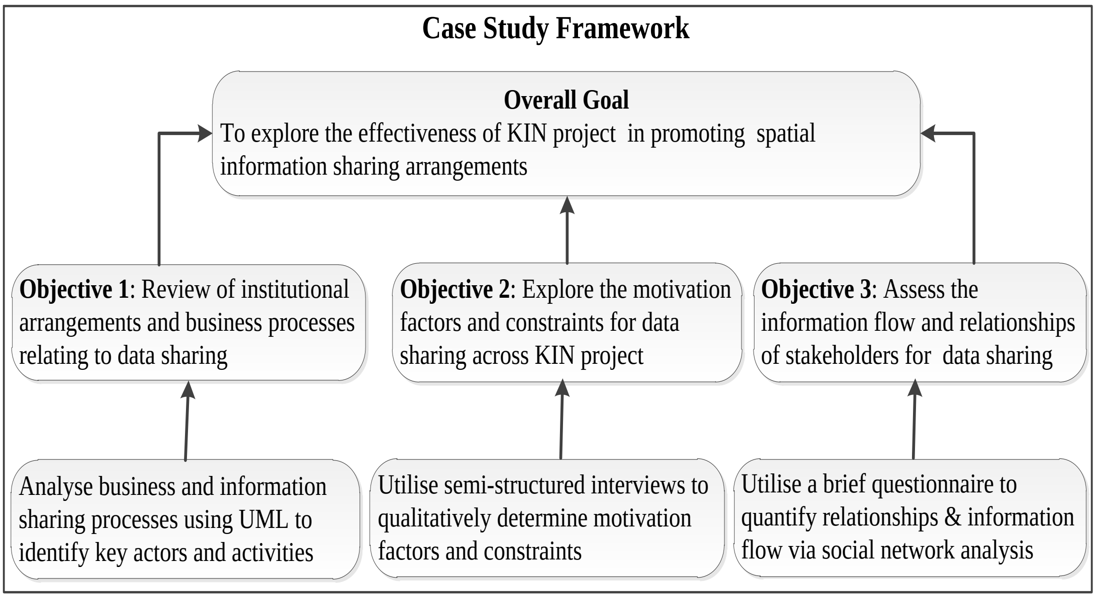

Figure 6.1: Relationships between data collection strategy and objectives

As described in Chapter Four, three forms of data were collected and analysed to investigate the spatial information and knowledge sharing arrangements between regional NRM bodies and state government organisations. The existing project documents/reports, data sharing agreements and published papers provided background information (including history and context of NRM KIN project) and assisted in understanding the institutional arrangements and objectives of the KIN project. The qualitative data were used to analyse spatial information sharing processes using UML and identify key actors and activities. The semi-structured interview with stakeholders explored the motivational factors and constraints for data sharing. Finally, a brief questionnaire measured the relationships and interactions of stakeholders for spatial information sharing.

This chapter consists of five main sections. Section 6.2 provides case study overview which includes the background information about the KIN project, institutional arrangements and objectives. Section 6.3 reviews institutional arrangements and business processes relating to data sharing. A UML use-case diagram was used to explore and demonstrate the spatial information sharing process. Section 6.4 describes the interview findings and explores motivational factors and constraints for spatial information and knowledge sharing. Section 6.5 quantifies the role, relationships and interactions of stakeholders for spatial information and knowledge sharing and mapped through the social network analysis. The last section draws the conclusions from the case study.

6.2. Case Study Overview

6.2.1. History and Context

Many attempts have been made to improve the NRM information access and sharing between NRM bodies and government agencies (Queensland Regional NRM Groups Collective 2009). The Queensland spatial information group has a long tradition of professional networking and trust in spatial information access and management. In early 2000, a project (funded under the Natural Heritage Trust Phase 1-NHT1) was formulated by the then Department of Natural Resources and Water (DNRW) to identify and organise all spatial and non-spatial information which could be useful for NRM activities. The primary purpose of that project was to capture, catalogue and develop metadata. In that process, trust and communication between state agencies and regional NRM bodies was difficult to achieve between the 14 regional NRM bodies and state agencies. In 2002, the Queensland Regional NRM Groups Collective (RGC) was formed to act as a peak body for natural resource management and to improve the state-wide delivery of regional NRM outcomes in Queensland. Being a non-government organisation, RGC provided the opportunity to establish trust between Department of Environment and Resource Management (DERM) and regional NRM bodies, and its popularity grew in a very short period of time. The RGC identified the lack of coordination in information access and cataloguing and made the resolving of these issues a priority.

In 2007, the NRM Data Hub project was scoped and led by the RGC partnership with DERM (Jones and Norman 2008). The main objectives of the NRM Data Hub project were to evaluate the business needs for data sharing and construct a business case to improve data sharing between regional NRM bodies, government agencies and industry stakeholders (Queensland Regional NRM Groups Collective 2009). Initially, it was identified that a technical solution such as data portal might be useful in facilitating spatial information access and sharing between regional NRM bodies and state agencies. However, the study found that the real issues were not technical, but moreover were the institutional arrangements for data access and data sharing. How could people be put in place to improve the brokering of spatial information for access and sharing? The study identified that the traditional librarian could be put in place as knowledge brokers or a focal person to bridge the gap between DERM and regional NRM bodies. The librarian should not be housed in any regional NRM body but should be independent.

In 2009, two NRM data hub projects, namely the Northern Region NRM Data Hub Project and the Southern Region NRM Data Hub Project, were conducted with Terrain NRM, the Queensland Murray-Darling Committee (QMDC) and DERM to test the use of knowledge librarians/brokers. The outputs from this pilot enabled the expansion of the project concept across the whole of Queensland to better support information and knowledge management.

The data hub project evolved into the Knowledge and Information Network (KIN) project with the main objective being improved access and sharing of NRM information between regional NRM bodies and DERM (Queensland Regional NRM Groups Collective 2010).

6.2.2. Institutional Arrangement and Objectives

The main stakeholders of the KIN project were Queensland Regional Group Collectives (RGC), 14 regional NRM bodies and Department of Environment and Resource Management (DERM) (as shown in Figure 6.2).

The project was managed by the RGC and four knowledge coordinators. The four knowledge coordinators were working with three NRMs and DERM. A state steering committee was made up of state government and regional NRM bodies' representatives. As well as these organisations/professionals, there were about 300 Landcare groups which were not formally involved in the KIN project; however regional NRM bodies also shared spatial information with these groups. The Landcare groups (including other community organisations) often create spatial data for their own use by utilising both government data (authoritative data) and freely accessible spatial products (eg Google Maps) for grass-roots catchment management activities. The funding for this project was supported by both Commonwealth and state governments.

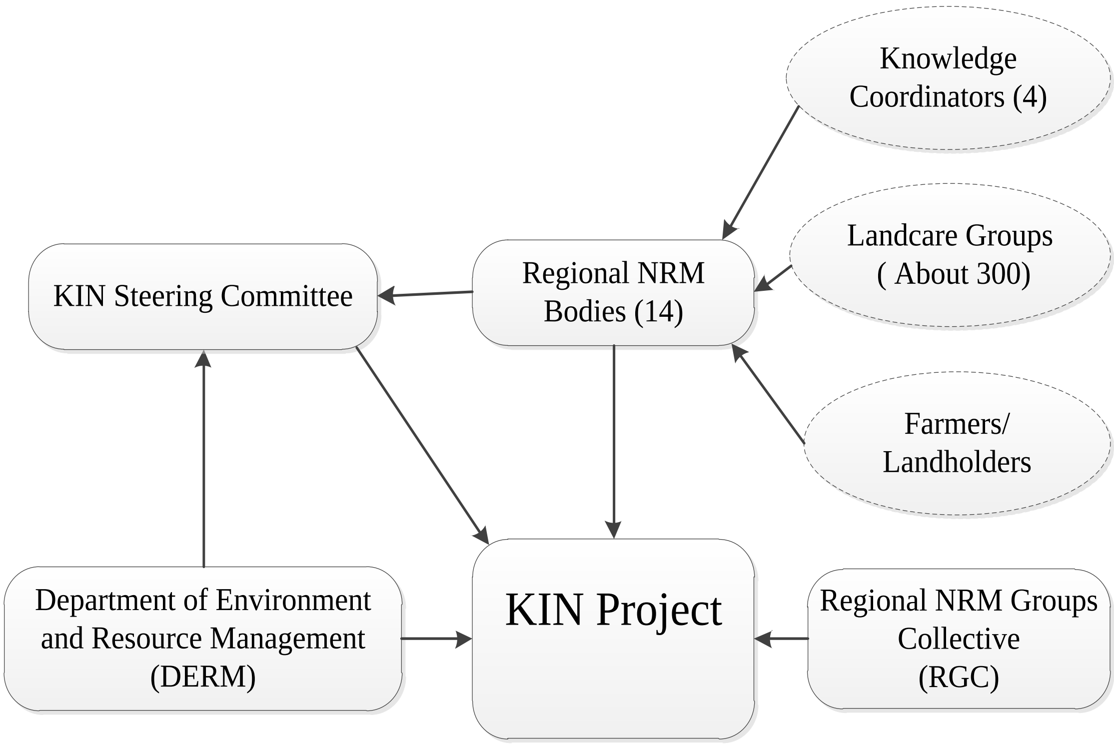

Figure 6.2: Institutional settings

The overall aim of the KIN project was to understand how regional NRM knowledge and spatial information management responsibilities could be better shared across Queensland for improved NRM decisions (Queensland Regional NRM Groups Collective 2010).

6.3. Objective 1: Mapping of institutional arrangements and business processes relating to spatial information sharing

The unified modelling language (UML) was used to formally describe and understand the spatial information sharing processes. The unified modelling language (UML) is an object oriented modelling tool for specifying, visualizing, constructing, and documenting the artefacts of a system-intensive process (Radwan et al 2001). A UML use-case diagram was used to explore and demonstrate the spatial information sharing process. Basically, the use-case lists the actors and activities and consists of three elements; the actors, use-cases and the system boundary. In UML, the relationships between actors and use-cases can be shown using the concepts such as ‘generalisation’, ‘uses’ and ‘extents’. Six main actors and twelve use-cases were identified for the spatial information sharing process.

As shown in Figure 6.3, six actors are interacting with nine use-cases in a system whose system boundary is defined by the ‘Spatial Information Sharing Process’.

The six main actors and spatial information sharing process include:

KIN representative/knowledge coordinators: The KIN representative or knowledge coordinators (KC) identify the spatial information needs for catchment management and advise regional NRM bodies to make requests for the particular spatial information.

Regional NRM bodies: Regional NRM bodies request spatial information, imagery, metadata and/or any spatial information services via the RGC’s spatial manager.

Farmers/Landholders: Farmers/landholders receive spatial information through the RGC’s spatial manager. They also collect large scale spatial information and provide this to regional NRM bodies through the RGC’s spatial manager. The RGC’s spatial manager checks the request and facilitates the access of community owned spatial information to government agencies and other external bodies.

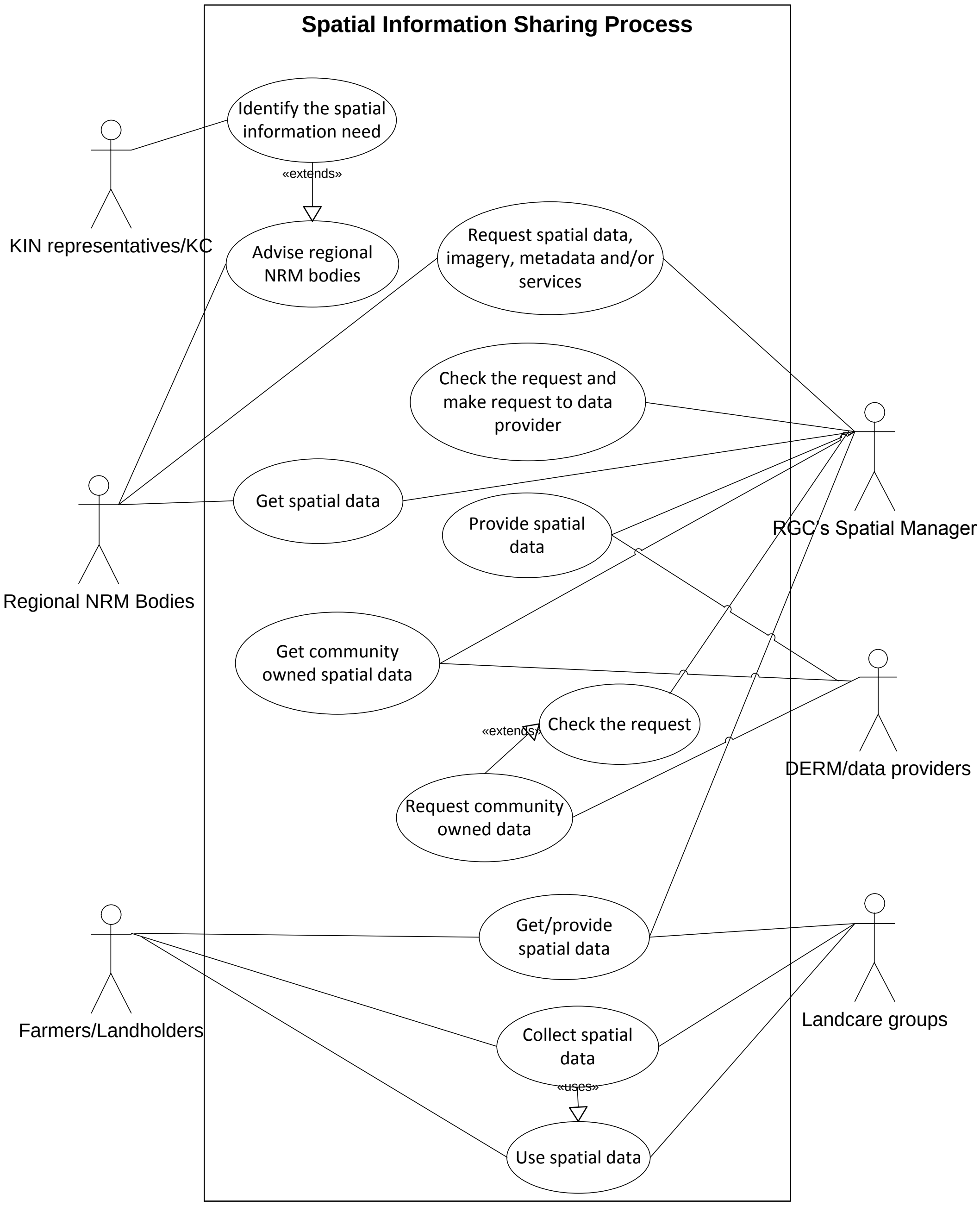

Figure 6.3: Use-case diagram of spatial information sharing process

RGC's spatial manager: RGC's spatial manager checks the request from regional NRM bodies and makes requests to a spatial information provider. RGC's spatial manager knows who to approach to access particular spatial information.

DERM/Spatial information provider: DERM provides spatial information to the RGC's spatial manager. If DERM or other government agencies need community owned spatial data, they request the data through the RGC's spatial manager.

Landcare groups: Landcare groups also receive spatial information through the RGC's spatial manager from the spatial information providers. They also collect large scale spatial information and make this data available to regional NRM bodies through the RGC's spatial manager. The RGC spatial manager makes this community owned spatial information available to government agencies and other external bodies.

6.4. Objective 2: Explore motivational factors and constraints for collaborating and information sharing across the KIN project

6.4.1. Motivational Factors for Collaborating in the KIN Project

The motivational factors for collaborating in the KIN project were determined through a semi-structured interview with all 14 regional NRM bodies, state government representatives and Queensland Regional NRM Groups Collective (RGC). As shown in Appendix 3, one of the questions asked was "what are the motivational factors for your organisation to collaborate in the NRM KIN project?" The responses were transcribed, analysed and the factors were determined.

The motivation for collaborating in the KIN project was to better organise information and knowledge, to reduce cost, avoid duplication, and to enhance better collaboration and networking. However, the motivational factors varied between stakeholders. Basically, three types of organisations were involved in the KIN project and the motivations for these organisations to be involved with the KIN project are discussed in the following section.

6.4.1.1. Motivational Factors for Regional NRM Bodies

The staff who were experienced in spatial and knowledge management activities were targeted for interview. A total of 15 staff were interviewed from 14 regional NRM bodies. The responses were transcribed and analysed and the main factors were determined. The following were the five main motivational factors identified for regional NRM bodies to collaborate in the KIN project.

1 State-wide project: This was a state-wide project and all regional NRM bodies received funding support from state and commonwealth governments to develop regional NRM plans and deliver sustainable catchment outcomes. All regional NRM bodies were encouraged to participate in this project and to include this project as part of their regional plans. The regional NRM bodies were seeking to improve knowledge and information sharing across their regions through their involvement in this state-wide project.

2 To enhance collaboration and networking: The spatial group of regional NRM bodies has a tradition of collaboration and networking for spatial information management and to reduce isolation. However, collaboration and networking activities have traditionally been informal. Regional NRM bodies saw the opportunity to formalise their good practice and became involved in this project.

3 To better organise knowledge and information: The regional NRM bodies also collect a significant amount of spatial information, and other agencies, particularly state agencies, are interested in gaining access to this spatial information. Further, a significant amount of 'grey' data (published or uncatalogued) exists within regional NRM bodies and could be very useful for NRM decision-making processes. In some cases, even people inside the department do not know what spatial information exists within their department. Regional NRM bodies saw the project as an opportunity to better organise knowledge and information. There was a silo approach to the spatial information management and this hindered spatial data sharing process. Through the KIN project, the 'silos' of information and knowledge were consolidated and better organised. When asked about this motivational factor, one NRM respondent answered:

There is a lot of information within regional NRM bodies and it is hard to know who to contact and where to go.

4 An Improved Information Portal: The KIN project was inspired by the improved knowledge and information management practices that were happening around the region. The Knowledge for Regional NRM Program of Land and Water Australia (LWA) was an example of a project that inspired regional NRM bodies to participate in this project. The outcomes from this project included a Regional Knowledge Resource Kit and NRM Navigator. It included a comprehensive guide to developing information and knowledge strategies and an online resource library covering a wide range of information and knowledge.

The NRM Navigator provided a set of online tools and databases that made it easier for NRM professionals to access and share information. It resulted in significant financial savings which were achieved primarily through preventing duplication of effort, eliminating software licence costs and reducing the time taken to find relevant authoritative information in the NRM sector. These improved practices for information and knowledge sharing at the national level have inspired similar activities at regional level.

5 To reduce cost, avoid duplication and optimise the use of resources: One of the motivations for regional NRM bodies to participate in the KIN project was to reduce cost, avoid duplication and optimise the use of resources.

6.4.1.2. Motivational Factors for State Government Organisation

The responses from executive level and operational level were collated and analysed to determine the motivational factors. For the Department of Environment and Resource Management (DERM), the motivational factors identified were:

1 To maximise the use of spatial information: Regional NRM bodies are the main users of spatial information in the NRM sector and DERM is the primary spatial information provider. The spatial information generated by DERM could be channelled to community NRM groups through regional NRM bodies and maximise the use of spatial information through this project. This will also reduce the need for DERM to negotiate with multiple NRM bodies and hence save time and effort.

2 Collaboration and networking: At present, regional NRM bodies are collecting a significant amount of spatial information. State agencies are interested in accessing this spatial data/information and DERM saw the opportunity to build a partnership with regional NRM bodies through this project. For regional NRM bodies, DERM is an important partner for the access and sharing of spatial information. One comment from a respondent identified:

State government works on various projects with regional bodies. By sharing information, it helps to build the partnerships with regional bodies.

3 Better regional NRM outcomes: DERM works with regional NRM bodies to facilitate the integrated delivery of natural resource management programs and better natural resource management outcomes. Regional NRM bodies develop NRM plans to improve the sustainable management of natural resources. Regional NRM bodies are funded primarily by the Australian and Queensland governments to implement these plans. Spatial information is a critical component for developing and implementing plans. This project has developed a better process to exchange data, information and knowledge at regional and state level and promote better regional NRM outcomes. One of the state government executives working in the spatial information policy team advised the benefits as:

By sharing spatial information, regional NRM bodies can use the information for regional NRM outcomes and state government benefits from the utilisation of this data.

6.4.1.3. Motivational Factors for the RGC

The Queensland Regional Natural Resource Management Groups Collective (RGC) is the lead body and represents the interests of 14 regional NRM bodies in Queensland. It is funded through Queensland's regional NRM bodies, the Queensland Government and the Commonwealth Government.

Two staff were interviewed from RGC to determine the motivational factors. For the RGC, the motivational factors are to avoid duplication, save time and resources and to encourage collaboration and networking. However, the additional motivational factor for RGC was that the project was aligned with the organisational mandate and strategic goal of RGC. One of the strategic goals of the RGC is to lead and bring all the regional NRM bodies together to improve NRM outcomes.

6.4.2. Constraints in Managing the Project

There were a number of constraints in managing this project. The constraints were categorised into five different areas as policy, technological, governance, cultural and economic.

6.4.2.1. Policy

A large amount of NRM-related spatial information has been collected by regional NRM bodies, however, the spatial information collected has different scales, contents and qualities and does not match with state government standards. Though the state government organisations realised the value of the spatial information collected by regional NRM bodies, there was no policy to include the spatial information back into the state repository or to utilise that spatial information for updating state-wide NRM data. There are also issues regarding pricing and access policies including licencing arrangements. However, the single data share agreement between regional NRM bodies and state government organisations covered the interests of all regional NRM bodies and facilitated spatial information sharing.

6.4.2.2. Technology

There was a lack of common standards or specifications during data collection. The national standards developed by Geoscience Australia are suitable for the national level but not suitable for catchment or property level data. This created technical difficulties in integrating the spatial information with state spatial information. Another technical problem was the lack of a single gateway to access NRM related spatial information.

6.4.2.3. Governance

Organisational issues are often more complex than technical issues. Institutional and legal issues in managing this project and sharing spatial information were significant governance issues. People in state government organisations were concerned that they might lose their power and control in providing access to their spatial data.

6.4.2.4. Cultural

The landholders' information contained a number of privacy issues and could not be shared with state government organisations and so a condition was specified during data collection that the spatial information would not be shared with government organisations. This was primarily because the landholders did not trust government agencies, specifically identifying that collected spatial information might be used against them by government agencies. One example was weed information collected by landholders. They feared that government agencies might accuse them of not maintaining their properties in good condition. When asked about the cultural issues, one specific comment was:

In the scientific realm people still fear the misuse of data so it is hard to motivate people to share and collaborate.

6.4.2.5. Economic

This project received financial support from both the state and commonwealth governments. The project funding has been extended and the project is now in the implementation phase. It is now the responsibility of regional NRM bodies to implement the KIN framework. Implementing the KIN framework involves significant costs for regional NRM bodies and requires continued funding support from the state and commonwealth governments. When asked about the economic issues the comments included:

It is a significant cost to put metadata into Australian Natural Resource Online.

Another constraint could be the costs involved. The spatial information should be provided freely and Queensland Government is working towards this.

6.5. Objective 3: Assessment of relationships and information flow using social network analysis

The primary reason for undertaking the social network analysis was to measure the relationships between the KIN project stakeholders. This research measured three types of relationships namely: transactional relations, communication relations and authority-power relations. The reasons for measuring relationships were to quantify the frequency of interaction, exchange of spatial information and the role of organisation in achieving the KIN goal.

The targeted population for this network analysis was 18 stakeholders consisting of six categories of organisations/professionals including DERM, RGC, regional NRM bodies, Landcare groups, landholders/farmers, and knowledge coordinators. An online questionnaire (see Appendix 4) was designed and questions were framed in order to specifically target and measure responses to other stakeholders. The questionnaires were distributed to a non-random and purposive sample of representatives from regional NRM bodies, DERM and RGC. Three questions were asked to quantify the frequency of interaction, exchange of spatial information, and role of organisation in achieving the KIN goal.

Data were analysed using the UCINET (Borgatti et al 2002) and NetDraw program (Borgatti 2002). First, the numerical data were entered into the UCINET program and visualised through NetDraw. The value of InDegree centrality was used to measure the relationships between project participants. The three variables which were used for this analysis were: frequency of interaction, rate of flow of spatial information and role of organisation (as shown in Table 6.1). The consolidated data (Freeman's degree centrality measures and descriptive statistics value) used for social network analysis is given in Appendix 7.

Table 6.1: Relationship and variables used for social network analysis

Level of Analysis	Measure	Relationship	Variable used
Network Analysis	InDegree Centrality	Communication	Frequency of interaction
	InDegree Centrality	Transactional	Rate of flow of spatial information
	InDegree Centrality	Authority-power	Role of organisation

The organisations were differentiated in the diagram by different node colours, node position, node size and line width to show the interaction between organisations in network. The results from social network analysis of the KIN project are described in the following sections.

6.5.1.1. Frequency of Interaction

The frequency of interaction was used to measure the communication relationship between catchment communities and state government organisations. The organisations were asked to rate the frequency of interaction with other organisations and their responses were measured on a five point Likert scale (from very frequently to rarely) as shown in Appendix 4 (Q1).

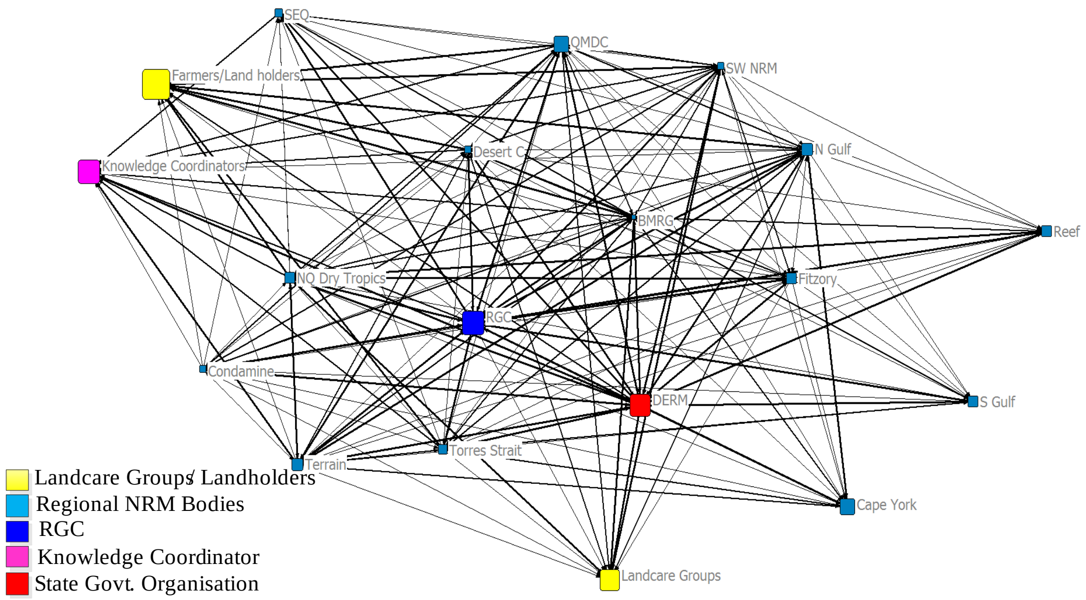

Figure 6.4: Frequency of interaction

Figure 6.4 shows the frequency of interaction between regional NRM bodies and other organisations. Five types of organisations directly or indirectly contributed to the KIN project. The different colour nodes represent the organisation type. The size of the node represents the value of InDegree centrality and the rate of frequency of interaction with other organisations. The thickness of lines depicts the frequency of communication. The larger the node size, the greater the frequency of interaction and the value of InDegree centrality. The network position shows the importance of each organisation with respect to the communication.

It was observed that regional NRM bodies had frequent interactions with farmers/land holders and landcare groups, though these groups were not directly involved in the KIN project. Regional NRM bodies also communicated frequently with knowledge coordinators, RGC and DERM. RGC appeared at the centre of the network with a high InDegree centrality value in communication and could be viewed as a good mediator in the process of spatial information sharing. There was little communication between DERM and the Landcare groups/farmers. The communication between regional NRM bodies also varied. There were greater levels of communication between adjacent regional NRM bodies compared with geographically distant bodies. However, it was found that if groups had common environmental concerns and good professional relationships they had a greater number of interactions. Further, the regional NRM groups had more frequent communication with external organisations (DERM, Landcare groups, etc) in comparison with internal regional NRM bodies. RGC and DERM both appear at the centre of the network. The organisations which appear at the centre of the network diagram indicate the importance of their role to maintaining communication relationships.

6.5.1.2. Rate of flow of spatial information

The flow of spatial information was used as a unit to measure transactional relationships between organisations. Participants were asked to rate the flow of spatial information between their organisation and other organisations. Their responses were measured on a five point Likert scale (from more to less) as shown in Appendix 4 (Q2).

Figure 6.5 shows the flow of spatial information and spatial information exchange between regional NRM bodies and other organisations. There were four different categories of organisations involved in spatial information sharing and the organisations are differentiated by node colours. The variations in line weights represent the rate of flow of spatial information between organisations. The thicker the line weight the greater the flow of information. The size of the node represents the value of InDegree centrality. As discussed earlier, there were both spatial information providers and users in the network and they had varying capacities for spatial information collection and management. NRM bodies provide spatial information to community groups like Landcare groups and farmers/land holders. The community owned spatial information is also provided to government (namely DERM). RGC is at the centre of the network so again it could be perceived that RGC is a key mediator and facilitator of the spatial information sharing process. Further, it was found that the flow of spatial information with adjacent regional NRM bodies is higher than with those that are more distant.

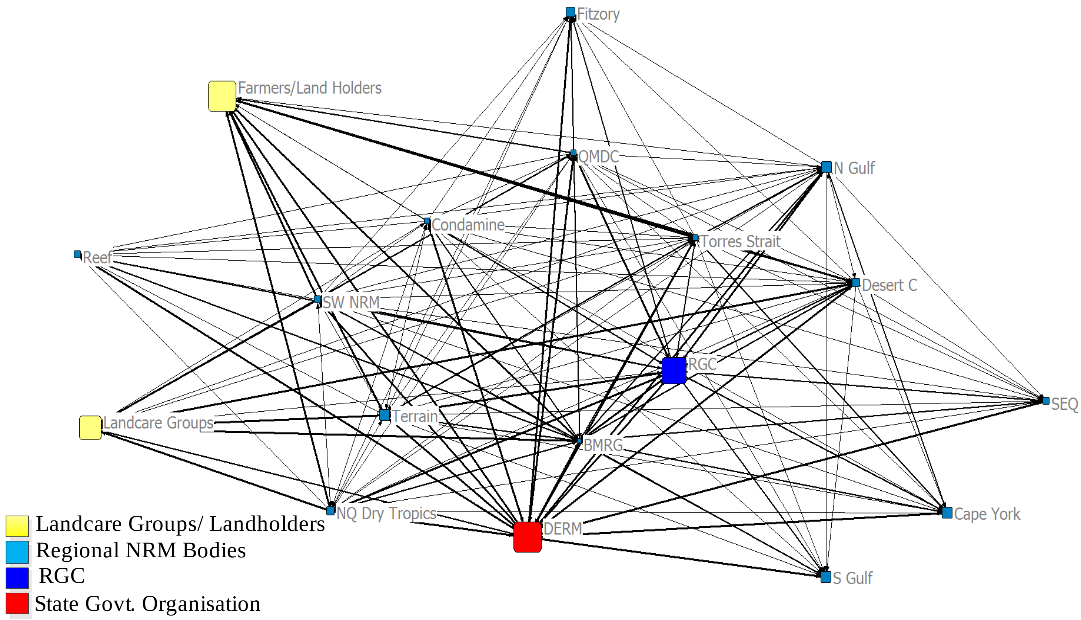

Figure 6.5: Flow of spatial information

6.5.1.3. Role of organisations in achieving the KIN Goal

The value of InDegree centrality was used to measure the role of an organisation in achieving the KIN goal. Participants were asked to rate the importance of the role of organisations/professionals in achieving the KIN goal. Participants rated each of the organisations on a five point Likert scale (from highest to lowest) as shown in Appendix 4 (Q3) and their responses were recorded and used for social network analysis.

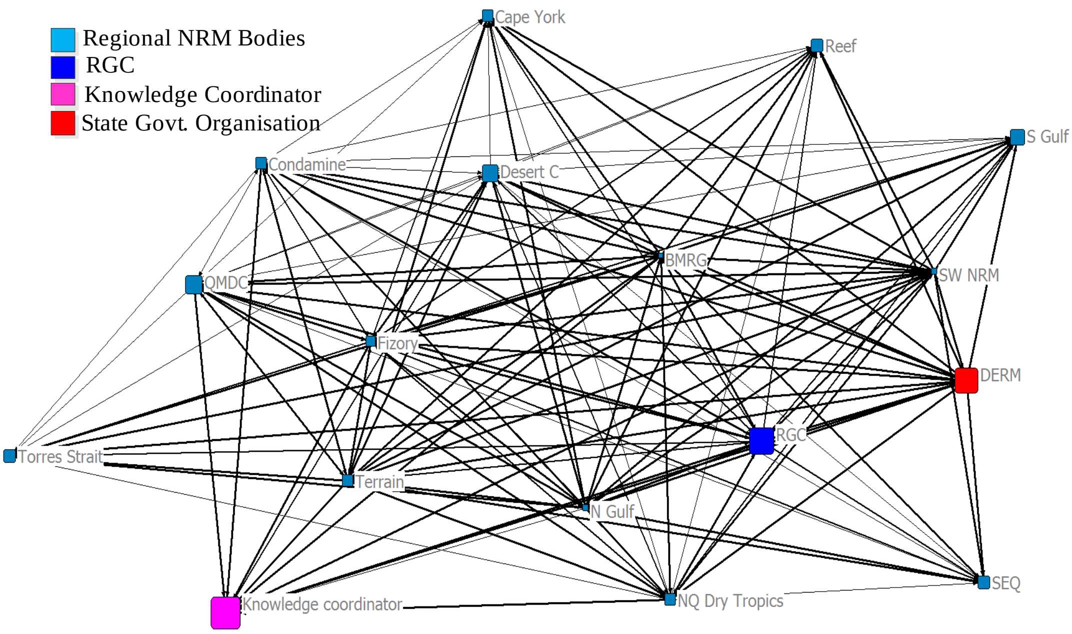

Figure 6.6: Role of organisations in achieving the KIN goal

Figure 6.6 shows the role of organisations in achieving the KIN goal. The importance of the role is demonstrated by the size of the node and the size of the node represents the value of InDegree centrality. The larger the node size, the greater the importance of the role of organisation. The organisations which appear at the centre of the network diagram indicate the importance of their role in achieving the KIN goal. Three organisations were identified as having important roles in achieving the KIN goal. As RGC is at the centre of the network, it has one of the strongest roles. Knowledge coordinators also have very important roles. The role of regional NRM bodies varies, however, RGC could be seen as having a coordination role in bringing all the regional NRM bodies together. This is a state-wide project and DERM has provided the funding, so it also has an important role in the network. This network analysis demonstrated that intermediary organisations and professionals play a very important role in achieving the KIN's goal.

6.6. Conclusions

This chapter presented a comprehensive case study analysis of the Knowledge and Information Network (KIN) project. The existing project documents/reports, data sharing agreements and workshop visits provided a detailed understanding of the historical context and institutional arrangements. The qualitative data collected from the interview helped to explore the stakeholders' motivation for participating in and the main constraints in managing this project. The spatial information sharing process which was modelled using object oriented use-case process identified the role of spatial manager as very important to facilitate spatial information sharing between regional NRM bodies and other organisations.

The main motivational factors for collaborating in the KIN project were to better organise information and knowledge, to reduce cost and avoid duplication, and to enhance better collaboration and networking. The major issues related to managing this project were categorised into policy, technology, organisational, cultural and economic.. The state government agencies were interested in using the spatial information collected by regional NRM bodies and other community groups. However, there was a lack of policy for depositing the spatial information back to the state repository. Without adequate policy or institutional support the spatial information sharing and exchange was found to be problematic. State government agencies were the main spatial information providers; however, they were reluctant to provide suitable access to their spatial information. One of their fears was the loss of power/control. The spatial information collected by landholders contains privacy issues and there was a reluctance to share data with government agencies. The continuity of funding for the KIN framework implementation was also identified as another issue. Without adequate funding and resources the KIN framework is unlikely to be sustained. The technological capacity to share spatial information was available, however, the policy, organisational, cultural and economic issues need to be addressed to improve spatial information sharing. Therefore, the policy, organisational, cultural and economic issues were found to be more important in comparison to the technological issues.

The social network analysis measured the rate of spatial information flow, frequency of interaction and the role of organisations. RGC was found to be a key mediator and facilitator of the spatial information sharing process and brought together the regional NRM bodies. It was found that intermediary organisations and professionals play a very important role in achieving the KIN's goal. From network analysis, it was found that there is a strong relationship and trend between frequency of interaction and spatial information exchange. The communication relationship was found to be important to improving spatial information and knowledge sharing. The organisations that were instrumental in improving the communication relationship and information exchange also had a positive influence towards achieving the KIN’s goal.

The outcomes from the case study and survey are analysed and integrated in Chapter Seven.

Chapter 7

Synthesis

7.1. Introduction

In Chapters Five and Six, the results from the national survey and case-study were discussed. The purpose of this chapter is to present a summary of the findings from Chapters Five and Six and integrate the findings to present the key factors influencing spatial information sharing among regional NRM bodies and state government organisations. Based upon these key factors, major strategies are then formulated to improve spatial information sharing.

This chapter consists of four sections. The chapter starts with a summary of findings from the previous chapters. The results are synthesised through the integration and interpretation of findings. Strategies are then developed to consolidate the issues related to spatial information sharing in catchment management and facilitate catchment SDI development in Australia. The final section provides discussion on the significance of the findings to other research.

7.2. Summary of Findings

7.2.1. National Survey of NRM Bodies

The overall aim of the national survey was to assess the current status of spatial information access, use and sharing for catchment management and identify key factors that influence spatial information sharing in catchment management and facilitate sub-national SDI development. The findings from the national survey are discussed briefly in this section.

Importantly, the majority of regional NRM bodies identified themselves as being both a user and provider of spatial information which provides a strong base to develop spatial data infrastructure (SDI) in the catchment management sector. Spatial information is heavily utilised for catchment management decisions and there is strong spatial information awareness and use among NRM staff. The role of users to the management of spatial information and future SDI was also highlighted by previous studies (Budhathoki et al 2008; Goodchild 2007; Mooney and Corcoran 2011).

There are many community-driven volunteer initiatives such as Landcare, Watercare, Bushcare, and Coastcare which exist for catchment management. The top three motivational factors for volunteers were awareness and concern regarding environmental benefits, long standing love with the land and water, and social interactions/benefits. These were similar to the motivational factors for community-driven volunteer initiatives and VGI application as identified by Coleman et al (2009). This indicates an opportunity to utilise the networks and the enthusiasm of community volunteers for spatial information collection and validation for the purpose of catchment management.

It was found that the majority of regional NRM bodies had limited spatial information policies/guidelines and the existing policies also needed to be updated and formalised. Regional NRM bodies also utilise various arrangements for access and pricing to spatial information. In most of the cases, the access is free to project partners and covered by a data sharing agreement. No significant problems for regional NRM bodies to access of spatial information from spatial data providers were identified.

The main spatial information providers for regional NRM bodies are state government organisations, whilst the main users of spatial information generated or value-added by regional NRM bodies are the community organisations (Landcare, Watercare, Birdwatch), land owners and indigenous groups. There is a two-way spatial information flow between regional NRM bodies and government organisations and government organisations have an interest in accessing the spatial information managed by regional NRM bodies via data sharing agreements.

The majority of regional NRM bodies utilise ICT technology and digital media to receive spatial information from spatial information providers. There are restrictions on the use of spatial information; however, it did not appear to limit their ability to undertake GIS activities. Interoperability continues to be a key issue in integrating externally obtained spatial data into GIS systems. The majority of organisations are satisfied with the current pricing of spatial information for their organisation with the most accepted pricing arrangement based on the cost of transferring data. However, there is debate on whether the spatial information should be free or based on cost recovery.

The majority of the regional NRM bodies have collaborative arrangements with other organisations. State government organisations were the main partners for this collaboration and community organisations including other NRM bodies were the second most common.

The spatial information sharing factors were identified and categorised into two levels as illustrated in Figure 7.1.

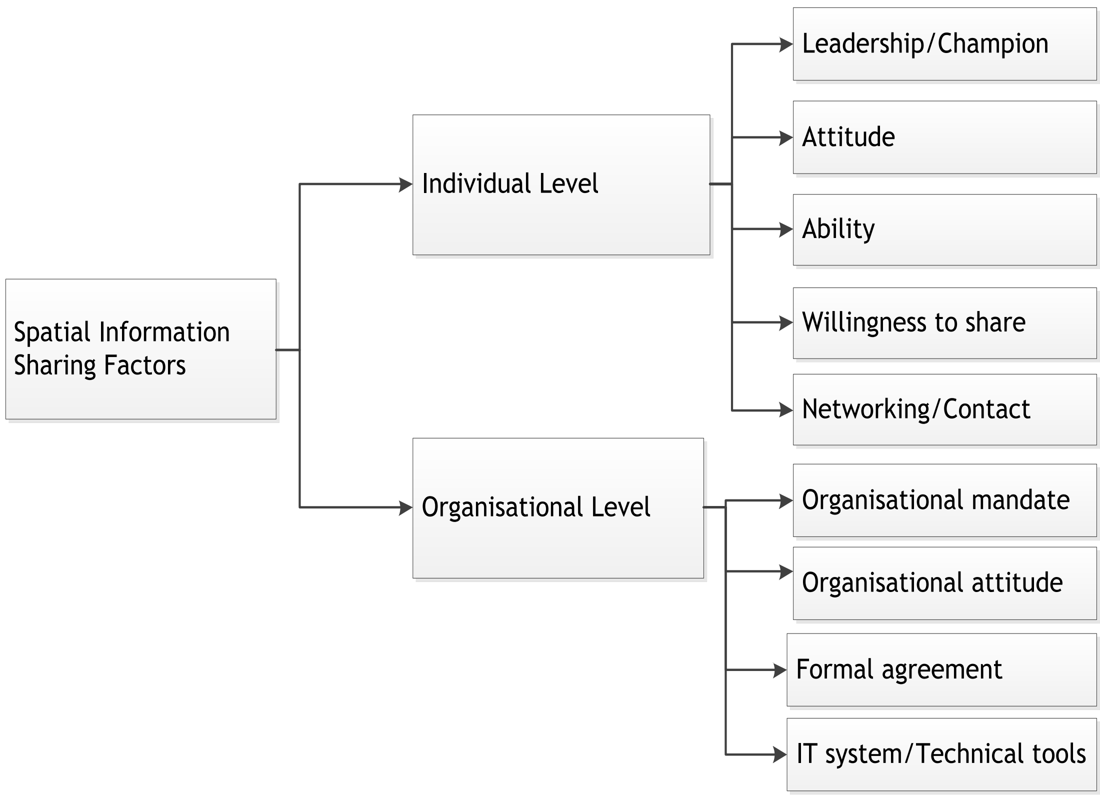

Figure 7.1: Spatial information sharing factors

Both individual and organisational levels of spatial information sharing factors were found important for spatial information sharing and catchment SDI development. As identified by regional NRM bodies, attitude, leadership/champion, and willingness to share were found to be the most important at the individual level, whilst organisational mandate, organisational attitude and formal agreement were found to be most important at the organisational level.

Vegetation, cadastral, catchment boundary and land use information were the most highly used spatial data by regional NRM bodies for catchment decisions. Most of the regional NRM bodies access their spatial information through a data sharing agreement. The awareness and applicability of freely available/accessible spatial products such as Google Maps, OpenStreetMap, Wikimapia for catchment management activities is very high although the utilisation of these products for catchment management activities is limited. Further, there is growing utilisation of web tools and social media for community networking and information exchange at the catchment level.

There were minor differences in spatial information access, use and sharing due to varying jurisdictional arrangements (being in different states), institutional environment (statutory vs non-statutory) and association with basin authority (MDBA vs non-MDBA). The results show the current statutory and administrative arrangements and regional focus for natural resource management is reasonable from a spatial information management perspective and provides an opportunity for building spatial data infrastructure (SDI) at the catchment scale. However, effective institutional arrangements should better align catchment SDI development activities.

7.2.2. Case Study: Knowledge and Information Network Project

The overall aim of the case study was to explore the effectiveness of KIN project in promoting spatial information sharing arrangements. Before the KIN project, the spatial information sharing process between NRM communities and state government organisations was very complicated due to complex institutional arrangements and lack of trust. Each organisation was working separately with state government organisations for data access and sharing. The KIN project was initiated to improve access and sharing of NRM information between regional NRM bodies and state government. The main stakeholders of the KIN project were RGC, regional NRM bodies and the Department of Environment and Resource Management (DERM).

The spatial information sharing review demonstrated that the main concerns were related to the institutional and cultural issues of data sharing and not the technical areas. The KIN study identified the importance of improving the institutional and cultural component of the data sharing mechanism. Six main actors and nine use-cases were identified for the spatial information sharing process via modelling using the object oriented use-case process. The six main actors include the KIN representative/knowledge coordinators, regional NRM bodies, RGC spatial manager, state government organisations, farmers/landholders and Landcare groups. The role of the KIN representative or knowledge coordinators (KC) and RGC's spatial manager was found to be very important in identifying spatial information requirements and for facilitating spatial information sharing.

The main motivational factors for collaborating in the KIN project were to organise information and knowledge better, to reduce cost, avoid duplication, and to enhance better collaboration and networking. These motivational factors are also supported by previous research (Harvey 2001; Harvey and Tulloch 2006; McDougall 2006; Nedovic-Budic and Pinto 2000; Nedovic-Budic et al 2011; Omran 2007; Onsrud and Rushton 1995; Wehn de Montalvo 2003). There were a number of constraints in managing the KIN project and the spatial information sharing. The constraints were categorised into five broad areas as policy issues, organisational issues, cultural issues, economic issues and technical issues. The main organisational issues included concern about losing authority, and data sharing not being an organisational priority. The policy issues included the lack of spatial policy, pricing issues, and the lack of policies to return the data to the state repository. The legal issues included the licencing arrangements and privacy/confidentiality. The continuity of funding and incentives for sharing were identified as the key economic issues, whilst lack of trust and confidentiality were identified as cultural issues. Finally, lack of metadata and no single gateway to access spatial data were the main technical issues. From case study, it has been identified that the non-technical issues such as policy, governance, cultural and economic issues were found to be more significant for the success of the KIN project in comparison with the technical issues.

The assessment of relationships and information flow was performed using social network analysis. It was observed that the regional NRM bodies had frequent interactions and information exchanges with landholders and Landcare groups. The inclusion of these groups within the institutional framework was important in achieving the KIN's goal and to facilitate knowledge and information sharing. It was found that the spatial information flows were mainly between regional NRM bodies and state government organisations. The flow of spatial information between adjacent regional NRM bodies was found to be higher than those that were more distant. This appeared to be driven by common environmental concerns and the close professional relationships. Being at the centre of the network, RGC was identified as a key mediator and facilitator of the spatial information sharing process. The significant role of mediator/intermediary organisations to facilitate spatial information sharing is also supported by previous studies (Omran 2007; van Oort et al 2010). The communication relationship was found to be important for improving spatial information and knowledge sharing. The organisations that were instrumental in improving the communication relationship and information exchange also had a positive influence towards achieving the KIN's goal

7.3. Synthesis: Integrating, Interpreting and Validity

This research follows the embedded design framework suggested by Creswell and Plano Clark (2011) (Figure 7.2). The framework is utilised for the synthesis of findings from survey and case studies which includes integration, interpreting and validity.

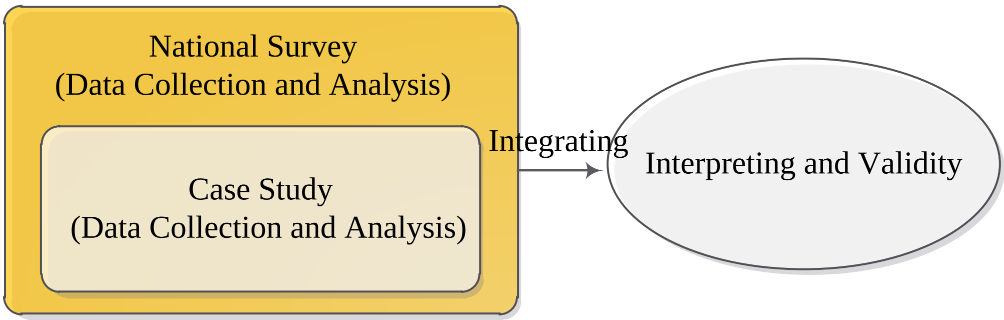

Figure 7.2: The embedded design

The national survey data and case study data were collected and analysed sequentially (ie in two phases) with the outputs from the two methods integrated. The case study component was the supplementary component of the survey design and different research questions were addressed in the survey and case study design to achieve the main aim of this research. After the integration, the common findings were interpreted. The quality of the output was examined through the validity of the findings.

7.3.1. Integrating

This research followed the embedded mixed method design. In the embedded mixed method design, different datasets are connected within the methodology framed by other datasets at design phase to help in interpretation of the results (Creswell and Plano Clark 2011). The case study results provided a supportive role and enhanced the findings from the national survey. A summary of the spatial information sharing issues identified during the survey and case study are presented in Table 7.1. A number of issues were also supported from the review of literature in Chapters Two and Three. Table 2.7 and Figure 5.23 were used to classify the factors into five broad groups. The factors which were identified during survey or case study were indicated by (√).

Table 7.1: Factors that influence spatial information sharing

Spatial Information Sharing Factors	Survey	Case study	Factor's group/Class
Organisation type	√		Governance
Spatial information use by staff	√		Governance
GIS maturity	√		Governance
Organisational capacity	√		Governance
Spatial information policy	√	√	Policy
Data custodianship	√	√	Governance
Funding	√	√	Economic
Incentives	√	√	Economic
Spatial data requirements	√		Governance
Spatial information access medium	√		Technical
Importance of spatial information providers	√		Governance
Ease of access spatial information	√		Policy
Spatial information receiving medium	√		Technical
Restrictions on spatial information	√		Legal
Collaborative arrangements	√	√	Governance
Data sharing agreement		√	Legal
Licencing		√	Legal
Social media, web 2.0/3.0 technology	√	√	Technical
Willingness to provide spatial data	√	√	Governance
Trust		√	Cultural
Willingness to share spatial data	√	√	Cultural
Data integration	√	√	Technical
Data portal	√		Technical
Networking/contact	√	√	Governance
Leadership/champion	√		Governance

7.3.2. Interpreting

This section documents the key factors influencing spatial information sharing between regional NRM bodies and state government organisations. The common findings from the survey and case study are interpreted and classified into six classes. Finally, major strategies to promote spatial information sharing are presented.

7.3.2.1. Key Factors Influencing Spatial Information Sharing and Catchment SDI Development

Section 7.3.1 identified a list of factors which influence or contribute to the spatial information sharing between regional NRM bodies and state government organisations. Following the national survey of regional NRM bodies and the case study, this list of factors has been classified into six major classes which are influencing, or contributing to spatial information sharing, and the development of catchment SDI. These classes of factors are: governance, policy, economic, legal, cultural and technical. The first five classes of factors are non-technical factors and the last is a technical factor. These six classes of identified factors have been also supported by the review of literature which was discussed in Chapter Two.

Figure 7.3 identifies the six classes of factors that affect the spatial information sharing and catchment SDI development.

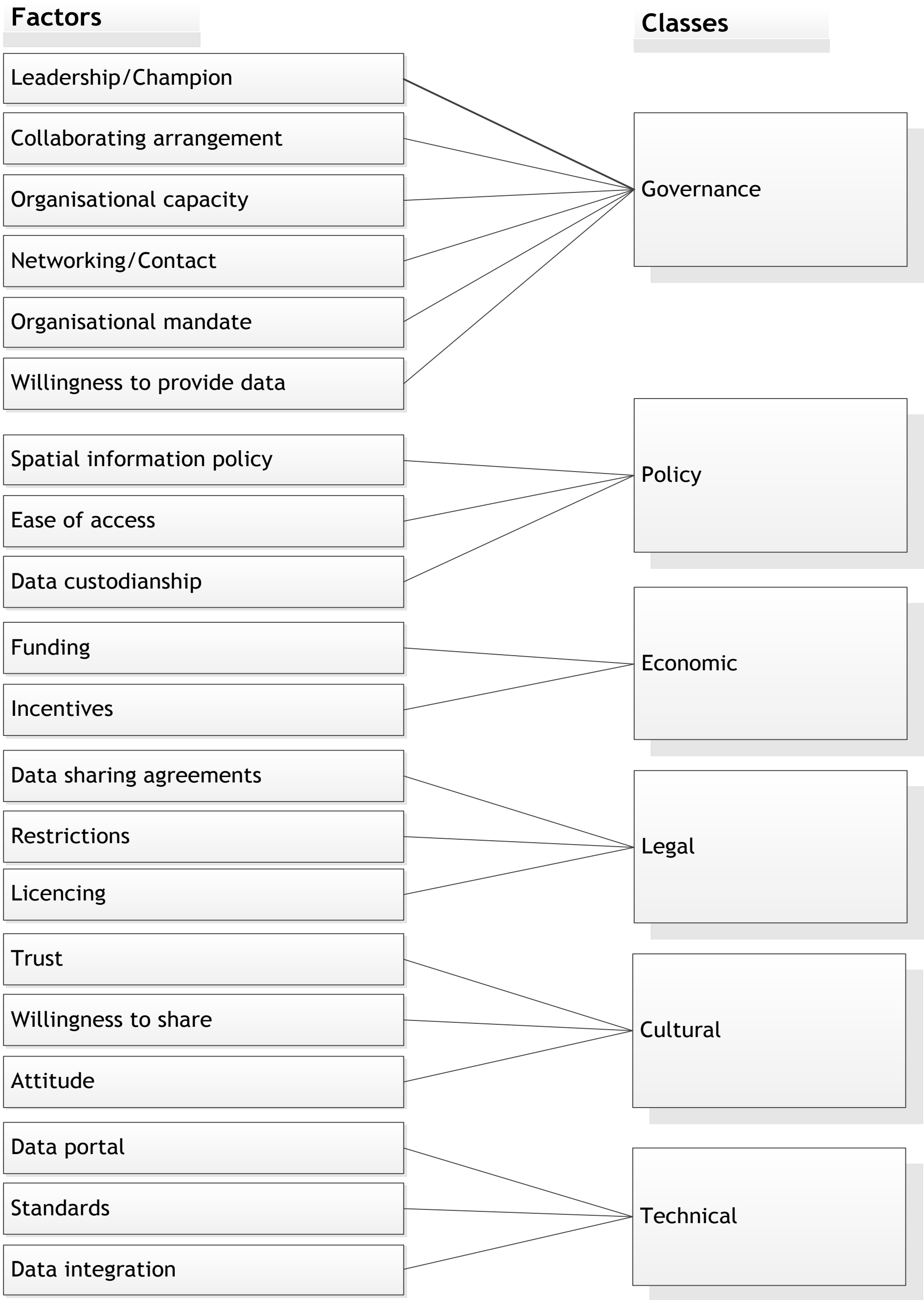

Figure 7.3: Factors influencing the spatial information sharing

In the following section, each class is discussed more fully.

Governance Factors

The six main governance factors that influence the spatial information sharing between regional NRM bodies and state government organisations include leadership/champion, collaboration arrangement, organisational capacity, networking/contact, organisational mandate and willingness to provide spatial data.

Both formal and informal relationships exist with spatial data providers and influence spatial information sharing. The collaboration arrangements bring stakeholders to one place and improve the relationship. The organisational capacity includes spatial information use by staff and GIS maturity. The willingness to provide spatial data can be improved through networking and contact.

Policy Factors

The three main policy factors identified were availability of spatial information policy, data custodianship and ease of access. There was no policy or limited polices/guidelines in regional NRM bodies to manage spatial information. There was no policy to return the spatial information collected by regional NRM bodies to the state repositories or to utilise that spatial information for updating state-wide NRM databases. As a large amount of spatial information is collected or value-added by regional NRM bodies, the data custodianship also becomes an issue. Due to the restrictions on the use of the spatial information placed by the spatial data providers, the access to data was problematic.

Economic Factors

Two economic factors include the continuity of funding and incentives for spatial information sharing activities. The key funding sources for regional NRM bodies are the commonwealth government, state government, land owner’s “in-kind” contribution and local government. Spatial data sharing was not considered a part of the organisational mandate and therefore was always considered a lower priority.

Legal Factors

The data sharing agreements, licencing and restrictions were identified as the legal factors. Regional NRM bodies also showed interest in sharing data under the Creative Commons Framework.

Cultural Factors

Trust, willingness to share and attitude were the cultural factors. The landholders’ data contained information that was considered private and they feared that their information may be used against them by the government. One example was weed information collected by landholders. They feared that government agencies might accuse them of not maintaining their properties in good condition. Additionally, the spatial information related to cultural heritage and traditional owners could not be placed on the public domain.

Technical Factors

The data portal, standards and data integration were identified as technical factors. There was a lack of common standards or specifications during data collection as the data were collected for different purposes. This created technical difficulties in integrating the spatial information. Many spatial information portals were available, however, there was a lack of a single gateway to access NRM related spatial information.

7.3.2.2. Information Sharing Strategies

The findings from Chapters Five and Six were used to formulate the strategies illustrated in Figure 7.4.

Figure 7.4: Spatial information sharing strategies

The strategies were developed to address the spatial information sharing factors. The adoption and implementation of these strategies can assist to improve spatial data sharing. Further, these strategies can accelerate the progress in the development of catchment SDI initiatives. Each strategy will be discussed and presented in more detail below.

1 Collaboration and networking

Collaboration and networking was identified as an important strategy to improve spatial information sharing. A particular issue that was identified was the poor relationship between regional NRM bodies and state government organisations in the provision of data. Various regional collaboration and networking activities already exist for natural resource management and lessons from their development can be gleaned and transplanted for spatial information sharing.

2 Promote knowledge sharing

Knowledge sharing is one activity where community organisations such as Landcare, Watercare, Bushcare, and Coastcare are achieving better natural resource management outcomes. The current focus of regional NRM bodies is for spatial data and information sharing. The raw spatial data can be translated into meaningful knowledge resources for the wider benefits of society using spatial technology and web tools. Therefore, knowledge sharing is an emerging area to be considered when developing spatial data infrastructure (SDI).

3 Place people at the front and empower brokering

There are many technical solutions in place and it was found that a technology based approach was not likely to make a significant difference for spatial information access and sharing. The real need was to place people at the front. The people part of SDI was found to be critical for sharing spatial information. It was found from the case study that the role of the classic librarian should be formalised and placed at the front within the institutional framework either as a knowledge broker or a focal person. The role of librarian will provide both energy and focus to enable better cataloguing, indexing, interpretation and publication of NRM information. It was also found from the case study that the function of the librarian should not be housed in any regional NRM body but should be independent.

4 Prioritise spatial data sharing as an organisational activity

Spatial information sharing is not an organisational mandate for regional NRM bodies. The organisational mandate should be revised and spatial data sharing should be included as a priority area.

5 Create awareness

There is a need to create awareness regarding spatial data sharing. Awareness is not simply the knowledge about spatial information sharing benefits; it also involves the appreciation, recognition and engagement of regional NRM bodies and other community organisations for spatial information management. The organisational attitudes and individual willingness to share data can be improved through improved awareness.

6 Make foundation data free

There is growing pressure for state government organisations to make foundation data free. Seventy five per cent of regional NRM bodies argue that foundation data should be made free as it is a public good and paid for by the public through their taxes. This will also maximise the use of spatial information. Additionally, private organisations such as Google Earth and OpenStreetMaps have already placed their spatial products free in the market place. In this competitive market, there is pressure on state government organisations and mapping agencies to make foundation data free. The Commonwealth Government and the Victorian Government have already recognised the benefits of improved access and availability of public sector information (PSI). The findings from case study showed that making foundation data free will also encourage regional NRM bodies to utilise foundation data and to better organise their data.

7 Establish and harmonise information policy

It was found that there was a lack of information policy in regional NRM bodies and so it is important to establish an appropriate information policy in these bodies. The main areas for the preparation of spatial information policy include spatial information access, pricing, data custodianship, licencing arrangements, utilisation of open source information and social media, and should include an arrangement for the spatial information collected by regional NRM bodies to be returned to the state repositories.

8 Continuous funding and provide incentives for information sharing

One of the major constraints for spatial information sharing and SDI development for catchment management activities was funding. The key funding sources for regional NRM bodies are the commonwealth government, state government, land owner's "in-kind" contribution and local government. There is a need for more reliable and continuing funding for spatial information management area for NRM bodies.

Spatial information sharing is not the core business of regional NRM bodies. There is little motivation for regional NRM bodies to share spatial information as they are busy with their core business. Incentives should be put in place to encourage further sharing of spatial information. The incentives could be economic incentives or some form of acknowledgment, recognition or appreciation so that the individual's willingness to share spatial information will be increased.

9 Improved licencing arrangements

It is recommended that regional NRM bodies use a single licencing arrangement rather than multiple licencing with state government organisations. The Queensland licencing framework used by the RGC when sharing spatial information between regional NRM bodies and state government organisations is a useful model to follow for other states. This could be facilitated through utilising the Creative Commons licencing framework or the Australian Government Open and Access Licensing (AusGOAL) framework. Creative Commons licences are designed to facilitate and encourage greater flexibility in copyright. A single licencing arrangement will improve efficiency in accessing and sharing of spatial information between regional NRM bodies and government agencies.

10 Respect privacy and build trust

The data which is collected by Landcare groups and landholders often have privacy/confidentiality issues. It is necessary to respect the privacy of spatial information during data sharing. The community groups and farmers should be assured that the collected data regarding their properties will not be misused. This will also help to build trust and enhance collaboration in the future.

11 Promote volunteerism

The volunteer participation and engagement of community groups and citizens for natural resource management has a long history in Australia. These community volunteer activities have been successful in achieving improved environmental outcomes and are acknowledged by government agencies. The local environmental knowledge of these groups can also be used for spatial information collection and management. Recent developments in ICT tools and spatial technology have provided community groups with a new opportunity to collect and manage the spatial data and facilitate spatial information access, sharing and SDI development.

12 Utilising a single gateway for access

Many IT solutions and spatial portals exist; however, NRM bodies are confused about where to go and how to access the data they need. It was identified by regional NRM bodies that a single gateway (access point) for natural resource information would improve discovery and access to spatial data.

13 Use of open standards

A continuing technical difficulty for spatial information sharing and spatial data infrastructure development at sub-national level is interoperability. The spatial information collected or generated by regional NRM bodies are generally local and have various standards and formats. Because it is very difficult to integrate and utilise spatial data gathered from different sources, spatial portals need to be built using open source and OGC standards to encourage interoperability. If open standards are embraced, the integration, access and sharing of spatial data can be improved.

14 An enterprise approach

The regional NRM bodies have a silo approach to spatial data management. The silo approach does not encourage the sharing of spatial data. The enterprise approach is more reliable and stable. It consolidates ‘silos’ of information, standardises existing technologies, and minimises the duplication of information services. As catchment management issues cross the administrative boundaries the adoption of an enterprise approach for data management is recommended.

7.3.3. Roadmap for Implementing Spatial Information Sharing Strategies

A roadmap can serve as a starting point for implementation of comprehensive SDI program (The National Academy of Sciences 2012). In this study, the roadmap sets out the approach that will be adopted for the implementation of improved spatial information sharing arrangements between regional NRM bodies and state government organisations in Australia. Specifically, it provides specific guidelines on how spatial information sharing strategies (section 7.3.2.2) can be adopted and used in practice, provides support to address spatial information sharing issues, and improves spatial information sharing arrangements in catchment management sector. In particular, this roadmap supports the test of hypothesis which was discussed in Chapter 1, section 1.2.2. A five-point action plan is suggested for the implementation of these strategies. The first four are institutional considerations and the last one is a technical consideration.

1 Establish a formal knowledge and information network (KIN) between state government organisations and regional NRM bodies

Collaboration and networking was identified as an important strategy to improve spatial information and knowledge sharing between regional NRM bodies and government organisations. It is proposed that a formal knowledge and information network (KIN) be established throughout the states, similar to Queensland KIN. The institutional arrangements of this network should include spatial data managers, knowledge coordinators, communication officers and representatives from community volunteer organisations and government agencies. The knowledge coordinator and spatial data manager should be a focal position to promote spatial information and knowledge sharing. The communication officer should establish communication channels and improve the communication between regional NRM bodies, community volunteer organisations and government agencies. This will also help to build trust for collaboration. The communication officer should also create awareness for the prioritisation of spatial information sharing as part of each organisation’s goal. The collaboration arrangements will bring all stakeholders together to pursue an appropriate data licensing agreement with government and community partner agencies. This arrangement should support the preparation of an appropriate information policy.

This action incorporates the strategies 1, 2, 3, 4, 5, 7 and 10 as described in section 7.3.2.2.

2 Ensure an effective governance arrangement for catchment management

The Australia New Zealand Land Information Council (ANZLIC) is Australia's peak spatial information council, responsible for developing "best practice" guidelines for the use and sharing of spatial information in Australia and New Zealand. In most of the states there are spatial councils which are responsible for spatial policy and strategic direction for the use of spatial information. The NSW Spatial Council (NSC), Victorian Spatial Council (VSC), Queensland Spatial Information Council (QSIC) and Western Australian Land Information System (WALIS) are examples of formal state spatial information councils. It is important to formalise some formal spatial council in each of the states to support ANZLIC and to promote spatial information within their state jurisdictions. Similarly, an effective governance arrangement should be established to ensure that NRM bodies are represented on the state spatial information council. This will ensure a strong stakeholder voice in the development of spatial information policy and improve the access and availability of public sector information (PSI). The Commonwealth Government and the Victorian Government have already recognised the benefits of improved access and availability of PSI and other states should follow. With this arrangement, the regional NRM bodies will have an opportunity to be the member of the Open Geospatial Consortium (OGC) and the issue of data interoperability can be addressed using open standards. This effective governance arrangement will bind together technology, organisations and information. This will constitute the enabling platform for effective spatial information sharing.

This action incorporates strategies 6, 7, 9, 10, 13 and 14 as described in section 7.3.2.2.

3 Communicate the work of regional NRM bodies for a strong voice to government

Adequate resources, time and effort are needed to develop catchment SDI and facilitate spatial information sharing. Regional NRM bodies need to influence and lobby government agencies to support their activities by utilising their collective energy or power. Regional NRM bodies need to align their business with government priority areas to obtain funding as state and federal government funding is highly competitive. They need to convince government agencies about the importance of their work so that their collective voice will be accepted and their program will be prioritised. For example, the Murray Darling Basin Authority (MDBA) was able to convince federal government to provide funding by demonstrating their achievements on the ground. The federal government has provided funding to develop the basin plan knowledge and information directory (BPKID) as part of their information sharing strategy. The MDBA has been pursuing appropriate data-licensing agreements with state and federal partner agencies to improve spatial information access and sharing. Likewise, regional NRM bodies should highlight the critical catchment management issues and identify how improved spatial information sharing arrangements will help to address these issues.

This action incorporates the strategies 1, 4, 5, 8 and 9 as described in section 7.3.2.2.

4 Continue to encourage the community volunteer activities

There is a need to create a formal mechanism to continue and encourage community volunteer initiatives such as Landcare, Birdwatch, Waterwatch, Coastcare and Bushcare and to utilise these volunteer inputs for spatial information collection and management. These groups are not a formal part of the knowledge and information network. The involvement of grass-root level community groups for natural resource management has a long tradition in Australia. These community volunteer activities have been very successful in achieving better environmental outcomes and their volunteer inputs are widely acknowledged by government agencies. Recent developments in ICT tools and spatial technology have provided these groups with a new opportunity to manage the natural resource data utilising their volunteer synergy.

Mechanisms should be established to systematically collect and validate data that is collected locally so that it can be utilised as a regional resource. These groups are also key users of spatial information collected by regional NRM bodies and therefore the access to spatial data should be facilitated to support their volunteer initiatives. These actions will ensure that the local environmental and spatial knowledge of these groups can be utilised to achieve better natural resource management outcomes.

This action incorporates the strategies 2, 5 and 11 as described in section 7.3.2.2.

5 Develop appropriate spatial and ICT tools for spatial information management

The development of appropriate spatial technology and ICT tools and existing infrastructure to enable volunteers to submit data via smart phones and other mobile devices should be a priority. This should be coordinated through a KIN type model or by creating a representative body similar to regional groups collective (RGC) in Queensland. It was found that some form of collective or representative organisation is desirable in each of the states to provide a single, strong voice for regional NRM bodies to improve the state-wide delivery of regional NRM outcomes. This organisation should be funded by regional NRM bodies and the state and federal governments. The website of the representative organisation should be utilised as a single gateway for access and use of spatial information. The OGC open standard should be used to address the issues of interoperability. This will assist in integrating authoritative spatial data and volunteered geographic information (VGI).

This action incorporates strategies 11, 12, 13 and 14 as described in section 7.3.2.2.

7.3.4. Validity/Evaluation

As discussed in Chapter Four, section 4.4.3, one of the evaluation criterion for the quality of research findings is their validity. Even though different terms are utilised in the mixed methods literature to discuss the quality of findings, the term “validity” has the widest acceptance by both qualitative and quantitative researchers (Creswell 2009). In most of the mixed methods books (Axinn and Pearce 2006; Creswell and Plano Clark 2011; Mertens et al 2010; Tashakkori and Teddlie 2009) and articles (Collins et al 2007; Smith et al 2003), the guidelines for validity focus on the "correctness" of design procedures. Tashakkori and Teddlie (2009) suggested two areas to be examined with respect to validity as design quality (rigour of procedures, consistency across all aspects of the study, etc) and interpretive rigour (consistency with findings, consistency with theory, etc). This research followed the guidelines for validity focus on the design quality and examined the internal and external validity as shown in Figure 7.5.

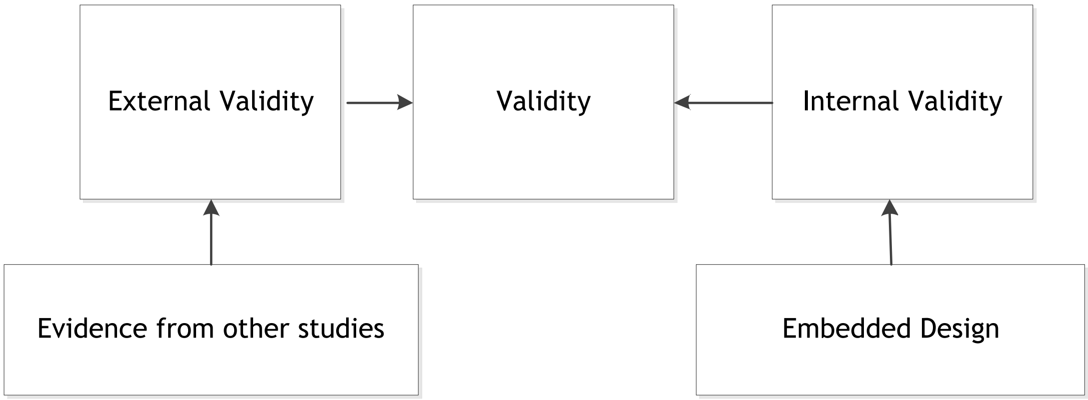

Figure 7.5: Validity of findings

This research followed the mixed methods embedded design approach which consists of two distinct phases: survey followed by case study as suggested by Creswell (2003). In the first phase, quantitative data were collected and analysed through a national survey of regional NRM bodies. This provided a more detailed understanding of the research problem. From the national survey of regional NRM bodies, spatial information sharing was identified as a key component of catchment management and SDI development. The results from the national survey also identified that the Knowledge and Information Network (KIN) Project was a representative case for further investigation. In the second phase, the case study data were collected and analysed, which helped to explain and corroborate the results obtained through the survey. Therefore, the internal validity of the study was examined through an embedded design where the findings of the case study provided a supportive role in the survey study. An initial summary of the issues identified during the survey and case study (Table 7.1) shows that approximately half of the 25 spatial information sharing factors/issues were identified by both the survey and case study. The remaining issues were also supported by the body of knowledge which has been discussed in Chapter Two.

In this study, the emphasis has been on ensuring that there is high level of internal validity through the design process and both the case study and survey support and triangulate the findings. The external validity of the findings is supported by evidence from other studies in data sharing (Harvey 2001; Harvey and Tulloch 2006; McDougall 2006; Nedovic-Budic and Pinto 2000; Nedovic-Budic et al 2011; Omran 2007; Onsrud and Rushton 1995; Wehn de Montalvo 2003).

7.4. Significance of Findings to Other Research

This study produced results which corroborate the findings from previous work in this field. The results of the questionnaire indicated that the regional NRM bodies were both users and providers of spatial information. The custodianship of spatial information necessary for catchment management was not only held by government agencies but also by regional NRM bodies and community organisations. The changing role of users for spatial information management was also supported by previous studies. Budhathoki et al (2008) and McDougall (2010) argued that the distinction between users and producers was blurring as both are involved in spatial data collection and management. Harvey et al (2012) suggested that the next development of SDIs around the world point to new types of hybridism with non-governmental data providers and semi-public partnerships in complex networks.

The results of this study (see Table 5.2) indicated that the motivation for community-driven volunteer activities and VGI application have similarities. The top three motivation factors for community-driven volunteer initiatives identified from this study were awareness and concern regarding environmental benefits, long standing love with land and water and social interactions/benefits which also accords with earlier findings (Coleman 2010; Connors et al 2011; Thompson et al 2011).

The findings of the case study social network analysis identified the roles and relationships of regional NRM bodies with the state government organisations and community groups. Regional NRM bodies are positioned between government organisations and community groups and can facilitate improved flow of spatial information between community groups and government organisations. They can work as an intermediary organisation between government organisations and community groups for spatial information sharing. For both top-down and bottom-up, they can work as intermediary organisations. The crucial role of mediator/intermediary organisations to facilitate spatial information sharing was also supported by previous study (Omran 2007; van Oort et al 2010).

The motivational factors for collaborating in the knowledge sharing project were to better organise information, to reduce cost, avoid duplication, and to enhance better collaboration and networking. The additional motivational factors identified were to maximise the use of spatial information and knowledge. These motivational factors were supported by previous research in spatial data sharing area (Harvey 2001; Harvey and Tulloch 2006; McDougall 2006; Nedovic-Budic and Pinto 2000; Nedovic-Budic et al 2011; Omran 2007; Onsrud and Rushton 1995; Wehn de Montalvo 2003).

This study identified 20 key factors that influence spatial information sharing between regional NRM bodies and government organisations. The six broad areas were organisational, policy, economic, legal, cultural and technical. The majority of these individual factors were similar to Kevany (1995) nine broad areas, Pinto and Onsrud (1995) six antecedents, and various spatial information sharing institutional issues identified by Nedovic-Budic and Pinto (2000) and McDougall (2006). This research identified that non-technical factors were more important than technical factors, which was also supported by previous research (de Man 2011; McDougall 2006; Mohammadi 2008; Nedovic-Budic and Pinto 2000).

7.5. Conclusions

This chapter discussed and presented the summary of findings from the national survey and the case study. The findings from two studies were integrated to identify key factors which influence spatial information sharing across the natural resource management sector. The chapter presented and discussed six major classes of factors namely organisational, policy, economic, legal, cultural and technical, and then argued that these six classes of factors influence spatial information sharing and catchment SDI development. Sixteen major strategies were then formulated from a consideration of the six key classes of factors to the improve data sharing and catchment SDI development. The significance of the findings to other research was also discussed.

The final chapter will conclude this research by firstly reviewing the initial research questions and stated objectives. The contribution to the original body of knowledge will be presented and recommendations for further research will be outlined.

Chapter 8

Conclusions and Future Research

8.1. Introduction

Effective spatial information sharing is important for SDI development and improved natural resource management. In Australia, state and territory governments have the legislated responsibility for natural resource management within their boundaries. Regional NRM bodies/catchment management authorities have the responsibility for developing and implementing regional catchment strategies and action plans to achieve sustainable catchment outcomes. The shift to a regional model for NRM was driven by a desire to provide local communities with a greater role in natural resource management. As the state agencies are the custodians of spatial information, it is important to understand the spatial information sharing mechanisms between regional NRM bodies and the state government organisations.

This research investigated the catchment management issues and spatial data requirements at the national and state levels which assist the Australian and state governments in making better decisions for optimal natural resource management. Further, it identified the key factors that influence spatial information sharing across catchment management areas and formulated strategies for improved catchment outcomes.

This chapter examines the outcomes achieved during this research, highlights the significance of the research to theory and practice, reflects on the original research problem and suggests directions for future research efforts.

8.2. Achievement of Research Aim and Objectives

As highlighted in the first chapter, the central aim of this research was:

"To identify key factors influencing spatial information sharing between state government organisations and regional NRM bodies/catchment management authorities within Australia, and to formulate appropriate strategies to facilitate spatial information sharing and hence contribute to SDI development".

In order to achieve the aim of the research, Chapter Four outlined the embedded mixed methods design framework and the research approach which was then successfully utilised in Chapters Five, Six and Seven. Within the embedded mixed method design framework, Chapter Five presented the results of the national survey of regional NRM bodies. The national survey assessed the current status of spatial information access, use and sharing for catchment management and determined the spatial information sharing factors which contributed to SDI development activities in the natural resource management sector in Australia. Chapter Six reported on the Knowledge and Information Network (KIN) project as a representative case to investigate spatial information and knowledge sharing arrangements across a number of regional NRM bodies. The findings from the survey and case study were integrated and interpreted in Chapter Seven.

The achievements of the objectives of the research are now reviewed and discussed.

8.2.1. Objective 1: Review the SDI theoretical foundations to develop a conceptual framework

This research has reviewed SDI theoretical foundations and found five theories which were relevant to SDI development. Each theory has its strength and limitations and can be utilised to support various areas of SDI development. Hierarchical spatial theory is useful in describing the vertical (inter) and horizontal (intra) relationships between different levels of SDIs and assists the modelling and understanding of SDI relationships. The diffusion theory describes SDI diffusion and is applicable for catchment SDI development as new ideas are spread to the community and stakeholders though diffusion. The Principal-Agent (P-A) theory was found to be an appropriate theory for gaining a better understanding of the relationships in sharing spatial information and partnership/collaboration. Actor-network theory (ANT) explores society-technology interactions and provides an understanding of spatial enablement of society. Social network theory views the network perspectives of SDI and is useful in relating volunteered geographical information (VGI) and spatial information sharing.

This research utilised social network theory to explore spatial information sharing arrangements between regional NRM bodies and state government organisations in Australia and examined SDI from a network perspective.

8.2.2. Objective 2: Description of institutional and jurisdictional dimensions of catchment management and key catchment management issues

In Chapter Three, the existing institutional and jurisdictional dimensions of catchment management in Australia were reviewed. Catchment management arrangements in Australia are implemented through the partnerships of government, community groups, private sector and academia. Three tiers of government exist and influence catchment management activities and create institutional complexities. It requires a high level of collaboration by community organisations and different levels of government. The role of state government and community organisations in association with regional NRM bodies is very important in the achievement of sustainable catchment outcomes. State government organisations are largely responsible for catchment management activities with varying jurisdictional models namely statutory (New South Wales, South Australia and Victoria) and non-statutory (community based) (Western Australia, Queensland and Tasmania).

There are also disparities between regional NRM bodies regarding the catchment management issues on which they focus. It was identified that spatial information plays a very significant role in addressing catchment management issues. The identification of spatial information for catchment management is also very important for building SDI. Authoritative spatial information which is necessary for catchment management activities is located within different levels of government which create challenges for accessing and sharing of data. State government organisations are the main custodians of the spatial information necessary for catchment management. However, the advent of spatial technology and web services has afforded a mechanism for farmers and community groups, with no prior experience in spatial technology, to access spatial information for catchment management activities.

8.2.3. Objective 3: Assessment of spatial information access, use and sharing mechanisms and SDI development in NRM bodies/CMAs

In Chapter Five, the results of the questionnaire were presented, which assessed the current status of spatial information access, use and sharing for catchment management activities in Australia.

Regional NRM bodies identified a significant need and capacity for spatial information. Regional NRM bodies are not only spatial information users, they are also spatial information providers. The main users of spatial information generated or value-added by regional NRM bodies are the community organisations. Government organisations, private sectors and academia/research institutions less frequently utilise spatial information acquired by regional NRM bodies. However, there was a significant interest by state government organisations in having access to community generated spatial information. This finding provided a new perspective on the management of spatial information and the development of spatial data infrastructure (SDI) in the natural resource management sector.

Spatial information and knowledge sharing were identified as the main areas of collaboration with the main collaboration partners being state government agencies and community organisations. Interoperability was found to be a key issue in integrating externally obtained spatial data into the GIS system. The survey (see Section 5.4) identified subtle variations in spatial information access, use and sharing due to varying institutional, jurisdictional and association arrangements. The regional NRM bodies of NSW, QLD, VIC and WA were well advanced in comparison with other states. The non-statutory regional NRM bodies also appeared to be more flexible and self-sufficient whilst statutory regional NRM bodies were more dependent on government assistance and lacked resources for spatial information management. The regional NRM bodies associated with MDBA had better spatial information access arrangements in comparison with other groups. The MDBA approach may therefore be useful for other regional NRM groups.

8.2.4. Objective 4: Exploring the effectiveness of spatial information sharing arrangements across catchment management authorities

In Chapter Six, the effectiveness of spatial information sharing arrangements across catchment management authorities was explored through an in-depth case study analysis of the Knowledge and Information Network (KIN) project in Queensland.

The use-case modelling revealed that the role of RGC spatial manager was significant in facilitating spatial information sharing among regional NRM bodies and state government organisations. The model also demonstrated that regional NRM bodies are receiving and providing spatial information and play a significant role in developing and supporting catchment SDI.

The main motivational factors for collaboration were to better organise information and knowledge, to reduce cost/resources, to avoid duplication, to maximise the use of spatial information and to achieve better regional NRM outcomes. These motivational factors are also supported by previous research. Various issues such as lack of spatial policy, lack of trust, privacy/confidentiality, and continuity of funding for the KIN framework implementation were identified.

The social network analysis highlighted the role and relationships of various stakeholders involved in spatial information and knowledge sharing across catchments. The role of intermediary organisations and professionals such as the regional groups collective and knowledge coordinator was found to be important in improving the communication and spatial information sharing across catchments. The communication and flow of spatial information was higher with external organisations (DERM, Landcare groups, etc) in comparison with internal organisation (regional NRM bodies). However, when the groups had common environmental concerns or close professional relationships (both formal and informal), they had higher levels of communication and hence sharing of spatial information.

The sharing of spatial information in the case of the KIN project was found effective because it had increased knowledge and access to spatial information by reducing barriers and making access more timely”.

8.2.5. Objective 5: Identification of key spatial information sharing factors and formulate spatial information sharing strategies

In Chapter Seven, the critical factors for improving data sharing across catchment management authorities were identified through triangulating the findings from the literature review, the results of the national survey of regional NRM bodies and the KIN project case study. Eighteen issues were identified as being highly significant and classified into the six major classes of organisational, policy, economic, legal, cultural and technical. The non-technical factors (organisational, policy, economic, legal and cultural) were found to be more significant in comparison with the technical factor. Based on these findings, information sharing strategies were developed.

Fourteen major strategies were formulated from the findings from Chapters Five, Six and Seven. A five-point road map was suggested and the adoption and implementation of this road map can assist in overcoming the spatial information sharing issues and will contribute to the development of catchment SDI.

The internal validity of the study was examined through the embedded design process where the findings from the case study provide a supporting role in the survey study. The case study was the representative case from survey findings.

Finally, this research achieved its aim and objectives which were stated in Chapter One.

8.3. Contribution to Original Knowledge

This research has contributed to the body of knowledge in the areas of theory, methodology and practice.

There has been limited previous research on spatial data infrastructure and data sharing in catchment management. This research identified five main SDI theories and their characteristics. With the increasing role of users and applicability of spatial information to the wider society, the social network theory was utilised to gain a better understanding of the relationships in sharing spatial information in catchment communities and the future SDI development in natural resource management sector.

The previous research on spatial data sharing and SDI development has mainly used either qualitative or quantitative research approaches. In some cases, researchers have collected both qualitative and quantitative data within the case study research design framework. However, with a few exceptions they have not utilised a mixed method designed framework or explored the strength of the mixed method research design framework. The single approach lacks the triangulation of multiple sources of evidence although it has other strengths. It has been argued that the overall strength of a mixed method in a study is greater than either qualitative or quantitative research approaches (Creswell and Plano Clark 2007). This research applied a mixed method research design framework as suggested by Creswell and Plano Clark (2011) and provided the capacity to examine the research problem in both depth and breadth. The method of integration of the national survey (quantitative study) and the case study (mainly a qualitative study) was clearly explained in the design phase. Within the case study, social network analysis was introduced for analysing data sharing and provides a new perspective on assessing spatial data sharing relationships.

The national survey provides a unique nation-wide perspective on the spatial information access, use and sharing for catchment management. The outputs from the survey will help to identify priority catchment management issues, national NRM datasets and information infrastructure in Australia. The case study identified the crucial role of intermediary organisations and professionals to improve the communication and spatial information across catchments. The results from the case study identify the roles and relationships of the various stakeholders in improving spatial information sharing and building effective institutional arrangements. With the growing number of users now influencing the design and development of SDI, users will play an increasingly important role in the next generation of spatial data infrastructure (SDI) design and development.

8.4. Avenues for Further Research

The outcomes of this research identified further avenues that could be explored, hence, future research investigation could be directed in the following areas.

8.4.1. Emerging Spatial Technologies, Social Media and VGI

The regional NRM bodies are increasingly aware of the freely available/accessible spatial products (eg Google Maps, OpenStreetMap, Wikimapia) and the potential for utilising social media, Web 2.0/3.0 technologies and more flexible models of spatial services. The KIN project partners, including regional NRM bodies and DERM, identified the significant potential of these products/services to information and knowledge sharing. The Australian Government and state government agencies have introduced Government 2.0 approaches and promoted open collaboration models for spatial services. A significant amount of spatial information is already under Creative Commons licences that allow users to freely use and remix it. Likewise, regional NRM bodies have already been using some of the Web 2.0 technologies like blogs and wikis to share information and knowledge at an organisational level. However, there are important issues such as quality, confidentiality, and trust regarding the use of these technologies with external organisations. These issues need to be explored further.

8.4.2. Network Components of SDI and Data Sharing

The conceptualisation of SDIs has evolved over time, resulting in different approaches. The hierarchical approach conceptualised SDIs as a link across different levels (local to global) (Rajabifard et al 2000). The concept came with the top-down government approach where custodians of spatial data were the mapping agencies which led the building of SDI. Other researchers have examined SDI from network perspectives. However, the existing studies on network perspective of SDI have focussed on the spatial enablement of organisations with less emphasis on the user's perspectives. The users play a vital role in spatial information management and contribute to SDI design and development. The network component of SDI from users' perspectives should be further explored.

8.4.3. Spatial Enablement and its Contribution to Address Global Issues

According to Steudler and Rajabifard (2012) "spatial enablement" is a concept that adds location to existing information and thereby unlocks the wealth of existing knowledge about land and water, its legal and economic status, its resources, potential use and hazards. Land and water information is a crucial component for facilitating decision-making to address global issues. They argued that such information must be available in a free, efficient, and comprehensive way in order to support the sustainable development of society. Masser et al (2007) believe that the next significant step in SDI development is the spatial enablement of the government and society. They also urge that the future of SDIs is reliant on the ever-increasing involvement of the data producer and users in SDI development.

This research has acknowledged the evolving concept of SDI for the spatial enablement of society through a networked model based on the common goal of data sharing. However, the realisation of spatial enablement and a spatially enabled society is dependent upon the real time access and sharing of spatial information to support more effective cross-jurisdictional and inter-agency decision-making in priority areas such as emergency management, disaster relief and natural resource management. SDIs have become a key infrastructure in realising a spatially enabled society. Therefore, there is a need to explore further the components of SDI and the economic, social and environmental drivers to support spatial enablement.

8.4.4. Knowledge Sharing and Spatial Knowledge Infrastructure

The data, information and knowledge hierarchy demonstrates the interdependence of data, information and knowledge. Spatial Knowledge Infrastructure is an emerging area to be considered when exploring next generation spatial data infrastructures (SDIs). This research work identified the importance of spatial knowledge sharing for building SDI. Further research is necessary to understand spatial knowledge infrastructure and its contribution to decision-making processes and SDI development.

8.5. Final Remarks

Traditionally, government organisations and mapping agencies were the custodians of spatial information and the development of SDI was dominated by mapping agencies and spatial professionals. Readily accessible and available spatial technologies such as Google Earth, hand-held navigation systems, Web 2.0/3.0 technologies, and social media provide the opportunity for grass-root citizens and community groups with no prior experience in spatial technology to engage in spatial information capture and SDI development. It has the potential to revolutionise the concept of SDI as all sectors of society increasingly becoming spatially enabled and contribute towards the next generation of SDI development. The original concept of SDIs was to view SDI in a hierarchical context where the higher levels of SDI (global, regional, national) build upon lower levels (regional, local).. This research has examined SDIs from a network perspective and identified that the contribution of both spatial information providers and users are important to the effective access and sharing of spatial information to improve decision making. The findings and strategies from this research have the potential to improve spatial information sharing between regional NRM bodies and government organisations to support better catchment management decisions.

References

Ackoff, R 1989, 'From Data to Wisdom', *Journal of Applied Systems Analysis*, vol 16, pp 3-9.

Agriculture Forests and Fisheries Australia AFFA 2002, '*Scientific Advice to the Parliament of the Commonwealth of Australia, Submission no 142, pp 2-4'*, The Department of Agriculture, Fisheries and Forestry, Australia.

ANZLIC 1992, '*Land Information Management in Australasia 1990-1992 '*, Australia Government Publishing Service, Canberra, ACT.

ANZLIC 2003, '*Implementing the Australian Spatial Data Infrastructure: Action Plan 2003-2004'*, ANZLIC, Canberra, ACT.

ANZLIC 2010, *Spatial Information Related Terms*. Available: http://www.anzlic.org.au/glossary_terms.html, accessed 10 January 2010.

Armstrong, K 2009, '*SLIP Enabler: Leveraging Public/Private Partnerships'*, Paper presented at the the Spatial@gov Conference - Location as an Enabler for Government Business, 15-16 June 2009, Canberra, ACT.

Australian Government Information Management Office 2009, *National Government Information Sharing Strategy: Unlocking Government information assets to benefit the broader community*. Australian Government Information Management Office (AGIMO). Available: http://www.finance.gov.au/publications/national-government-information-sharing-strategy/docs/ngiss.pdf, accessed 20 October 2012.

Australian Local Government Association 2011, '*Submission to the Expert Panel on Constitutional Recognition of Local Government'*, Deakin, ACT.

Azad, B and Wiggins, LL 1995, 'Dynamics of Inter-organisational Data Sharing: A Conceptual Framework for Research' In *Sharing Geographic Information* (Eds, Onsrud, HJ and Rushton, G), Centre for Urban Policy Research, New Brunswick, pp. 22-43.

Baran, M 2010, 'Teaching Multi-methodology Research Courses to Doctoral Students', *International Journal of Multiple Research Approaches*, vol 4, no 1, pp 19-27.

Bellamy, J, Ross, H, Ewing, S and Meppem, T 2002, '*Integrated Catchment Management:Learning from the Australian Experience for the Murray-Darling Basin'*, CSIRO Sustainable Ecosystems, Canberra, ACT.

Bellinger, G, Castro, D and Mills, A 2004, *Data, Information, Knowledge, and Wisdom*. Available: http://www.systems-thinking.org/dikw/dikw.htm, accessed 10 February 2010.

Bloor, M and Wood, F 2006, *Keywords in Qualitative Methods: A Vocabulary of Research Concepts*, Sage Publication, London.

Borgatti, P 2002, *NetDraw: Graph Visualization Software,* Analytic Technologies, Harvard, MA.

Borgatti, P, Everett, G and Freeman, C 2002, *Ucinet for Windows: Software for Social Network Analysis,* Analytic Technologies, Harvard, MA.

Borgman, CL 2000, *From Gutenberg to the Global Information Infrastructure: Access to Information in the Networked World,* MIT Press, Cambridge, MA.

Brand, M 1998, *Global Spatial Data Infrastructure: Policy and Organisational Issues* (November). Available: http://gsdidocs.org/docs1998/canberra/theme.html, accessed 5 April 2009.

Branscomb, AW 1982, 'Beyond Deregulation: Designing the Information Infrastructure', *The Information Society*, vol 1, no 3, pp 167-190.

Brass, DJ 1992, 'Power in Organisation: A Social Network Perspective' In *Research in Politics and Society* (Eds, Moore, G and Whitt, JA), JAI Press, Greenwich, pp. 295-323.

Bregt, AK 2011, 'Building European Spatial Data Infrastructures, by Ian Masser', *International Journal of Geographical Information Science*, vol 25, no 11, pp 1-1.

Bruce, J 2011, Weed Watcher, Paudyal, DR, Geraldton WA, (Personal communication) 17 November 2011

Budhathoki, N, Bruce, B and Nedovic-Budic, Z 2008, 'Reconceptualising the Role of the User of Spatial Data Infrastructure', *GeoJournal*, vol 72, no 3, pp 149-160.

Cagdas, V and Stubkjar, E 2009, 'Doctoral Research on Cadastral Development', *Land Use Policy*, vol 26, no 4, pp 869-889.

Calkins, HW and Weatherbe, R 1995, 'Taxonomy of Spatial Data Sharing' In *Sharing Geographic Information* (Eds, Onsrud, HJ and Rushton, G), Center for Urban Policy Research, New Brunswick, New Jersey, pp. 65-100.

Callon, M 1986, 'Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieuc Bay' In *In Power, Action, and Belief: A New Sociology of Knowledge?* (Ed, Law, J), London, Routledge & Kegan Paul.

Campbell, A 1994, *Landcare: Communities shaping the land and the future*, Allen & Unwin, St Leonards, NSW.

Canadian Government 1986, '*Management of Government: A Study Team Report to the Task Force Program Review'*, Canadian Government Publishing Center, Ottawa.

Car, A, Taylor, G and Brunsdon, C 2000, 'An Analysis of the Performance of a Hierarchical Way Finding Computational Model Using Synthetic Graphs', *Computers, Environment and Urban Systems*, vol 25, no 1, pp 69-88.

Carr, A 2002, *Grass Roots and Green Tape : Principles and Practices of Environmental Stewardship*, Federation Press, Annandale NSW, Australia.

CCMA 2001, '*Condamine Catchment Strategic Plan* ', Condamine Catchment Management Association Inc, Toowoomba, QLD.

Central Coast Regional Catchment Committee 1999, *A Submission to the Standing Committee's Inquiry into Catchment Management*. Available: www.aph.gov.au/house/committee/environ/cminq/sub115-e.pdf, accessed 15 September 2011.

Chan, TO 1998, '*The Dynamics of Diffusion of Corporate GIS* ', Doctor of Philosophy, The University of Melbourne, Australia.

Chan, TO and Williamson, IP 1999, 'The different identities of GIS and GIS diffusion', *International Journal of Geographical Information Science*, pp 267-281.

Clark, R 2006, *Roger Clarke's Information Infrastructure Home-Page* Available: http://www.rogerclarke.com/II/, accessed 30 September 2011.

Cleveland, H 1982, 'Information as Resource', *The Futurist*, vol 16, no 6, pp 34-39.

Clinton, WJ 1994, *Coordinating Geographic Data Acquisition and Access to the National Spatial Data Infrastructure. Executive Order 12096*. Available: http://govinfo.library.unt.edu/npr/library/direct/orders/20fa.html, accessed 15 September 2011.

Cockfield, G 2010, '*Between Markets and the State: Natural Resources Management Policy in Australia* ', Paper presented at the APSA Conference 2010- Connected Globe: Conflicting Worlds, 27-29 September 2010, University of Melbourne, Australia.

Coleman, D 2010, 'Volunteered Geographic Information in Spatial Data Infrastructure: An early look at opportunities and constraints' In *Spatially Enabling Society: Research, Emerging Trends and Critical Assessment* (Eds, Rajabifard, A, Crompvoets, J, Kanantari, M and Kok, B), Leuven University Press, Belgium.

Coleman, DJ and McLaughlin, JD 1998, 'Defining Global Geospatial Data Infrastructure (GGDI): components, stakeholders and interfaces', *Geomatica*, vol 52, no 2, pp 129-143.

Collins, KM, Onwuegbuzie, AJ and Jiao, QG 2007, 'A Mixed Methods Investigation of Mixed Methods Sampling Designs in Social and Health Science Research', *Journal of Mixed Methods Research*, vol 1, no 3, pp 267-294.

Commonwealth of Australia 2000, '*Co-ordinating Catchment Management: Report of the Inquiry into Catchment Management'*, House of Representatives Standing Committee on Environment and Heritage, Canberra.

Connors, JP, Lei, S and Kelly, M 2011, 'Citizen Science in the Age of Neogeography: Utilizing Volunteered Geographic Information for Environmental Monitoring', *Annals of the Association of American Geographers*, pp 1-24.

Cooper, DR and Schindler, PS 2011, *Business Research Methods*, 11th edn, McGraw-Hill/Irwin Series Operations and Decision Sciences, McGraw-Hill/Irwin, New York.

Creswell, JW 2003, *Research Design : qualitative, quantitative, and mixed methods approaches*, 2nd edn, Sage Publications, Thousand Oaks, CA.

Creswell, JW 2009, *Research Design : qualitative, quantitative, and mixed methods approaches,* 3rd edn, Sage Publications, Thousand Oaks, CA.

Creswell, JW and Plano Clark, VL 2007, *Designing and Conducting Mixed Methods Research,* Sage Publications, Thousand Oaks, CA.

Creswell, JW and Plano Clark, VL 2011, *Designing and Conducting Mixed Methods Research,* 2nd edn, Sage Publications, LA.

Crompvoets, J 2006, '*National Spatial Data Clearinghouses: Worldwide Development and Impact',* Doctor of Philosophy, Wageningen University, Wageningen, The Netherlands.

Crompvoets, J, de Man, WHE and Macharis, C 2010, 'Value of Spatial Data: Networked Performance beyond Economic Rhetoric', *International Journal of Spatial Data Infrastructures Research,* vol 5, pp 96-119.

Cunningham, GM 1986, 'Total Catchment Management, Resource Management for the Future', *Journal on Soil Conservation,* vol N.S.W. Special Edition: Total Catchment Management, 42, no 1, pp 4-5.

Curtin, GG 2008, 'E-Governance' In *Encyclopedia of Political Communications,* Vol. 1 (Eds, Kaid, LL and Holtz-Bacha, C), Sage Publications, pp. 14.

Dalrymple, K 2005, '*Expanding Rural Land Tenures to Alleviate Poverty',* Doctor of Philosophy, The University of Melbourne, Australia.

Davidson, J, Lockwood, M, Curtis, A, Stratford, E and Griffith, R 2007, '*NRM Governance in Australia: NRM Programs and Governance Structures',* University of Tasmania, Australia.

Davies, J 2003, '*Expanding the Spatial Data Infrastructure Model to Support Spatial Wireless Applications',* Doctor of Philosophy, The University of Melbourne, Australia.

De Lai, R and Packer, G 2010, '*Enterprise GIS: Herbert Resource Information Centre',* Paper presented at the ESRI International User Conference, 12-16 July, 2010, San Diego, CA.

de Man, WHE 2006, 'Understanding SDI : Complexity and institutionalisation', *International Journal of Geographical Information Science (IJGIS),* vol 20 no 3, pp 329-343.

de Man, WHE 2008, 'The multi-faceted nature of SDIs and their assessment-dealing with dilemmas' In *A multi-view framework to assess spatial data infrastructures* (Eds, Crompvoets, J, Rajabifard, A, Van Loenen, B and Fernández, TD), Melbourne University Press, Melbourne, pp. 23–49.

de Man, WHE 2011, 'Spatial Data Infrastructuring: Praxis between Dilemmas', *International Journal of Spatial Data Infrastructures Research (IJSDIR),* vol 6, pp 261-289.

de Vaus, DA 2001, *Research Design in Social Research*, Sage Publications, London.

Department of Natural Resources 2011, *About the NRAtlas*. Available: http://www.nratlas.nsw.gov.au/wmc/custom/popups/aboutatlas.html, accessed 1 December 2011.

Department of Sustainability and Environment Victoria 2012, *Notification for Editing Service Department Sustainability and Environment Version 1.7*. Available: http://nes.land.vic.gov.au/WebSite/help/NES_User_Manual_V1.7.pdf, accessed 29 October 2012.

Department of the Environment 1987, '*Handling Geographic Information: Report of the Committee of Enquiry Chaired by Lord Chorley'*, HMSO, London.

Eelderink, L, Crompvoets, J and de Man, WHE 2008, 'Towards Key Variables to Assess National Spatial Data Infrastructures (NSDIs) in Developing Countries' (Eds, Crompvoets, J, Rajabifard, A, Van Loenen, B and Fernandez, TD), The Melbourne University Press, Australia.

Elwood, S 2008, 'Volunteered Geographic Information: Key questions, concepts and methods to guide emerging research and practice', *GeoJournal*, vol 72, no 3, pp 133-135.

ERIN 2010 Environmental Resources Information Network, Department of Sustainability Environment Water Population and Communities, Australia.

EU 2006, '*Assessing the Impacts of Spatial Data Infrastructure'*, Joint Research Centre EU, Brussels.

European Commission 2004, '*Proposal for a Directive of the European Parliament and the Council Establishing an Infrastructure for Spatial Information in the Community (INSPIRE)'*, Brussels.

European Commission 2007, *Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007: Establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)*. Available: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:108:0001:0014:EN:PDF accessed 2 October 2011.

Executive Office of the President 1994a, *Coordinating Geographic Data Acquisition and Access to the National Spatial Data Infrastructure. Executive Order 12096*. Executive Office of the President. Available: http://govinfo.library.unt.edu/npr/library/direct/orders/20fa.html, accessed 15 September 2011.

Executive Office of the President 1994b, *The National Information Infrastructure: Agenda for Action*. Available: http://www.ibiblio.org/nii/toc.html, accessed 23 February 2009.

Executive Office of the President 2002, *Circular No A-16 Revised*. Available: http://www.whitehouse.gov/omb/circulars_a016_rev, accessed 3 October 2011.

Feeney, M-EF 2003, 'SDIs and Decision Support' In *Developing Spatial Data Infrastructures From Concept to Reality* (Eds, Williamson, IP, Rajabifard, A and Feeney, M-EF), Taylor & Francis, London and New York, pp. 195-210.

Feeney, M-EF, Rajabifard, A and Williamson, IP 2001 In *5th Global Spatial Data Infrastructure Conference*Cartagena de Indias, Columbia, pp. 14.

Feeney, M-EF and Williamson, IP 2000, '*Researching Framework for Evolving Spatial Data Infrastructure'*, Spatial Data Infrastructure and Cadastral Research Group, Melbourne, Australia.

Feeney, M-EF and Williamson, IP 2002, '*The Role of Institutional Mechanisms in Spatial Data Infrastructure Development that Supports Decision-Making',* Paper presented at the Proceedings of MSIA 50th Anniversary Conference, 12-15 May 2002, Melbourne, Australia.

FGDC 1997, *A Strategy for the NSDI*. Available: http://www.fgdc.gov/nsdi/policyandplanning/nsdi-strategic-plans, accessed 2 October 2011.

FGDC 2011, *The Federal Geographic Data Committee* Available: http://www.fgdc.gov/, accessed 2 October 2011.

Francis, C 2011, '*Implementing an Enterprise Catchment Information Service '*, Spatial Vision, Australia.

Frederick, KD 2002, 'Water Resources and Climate Change' An Elgar Reference Collection, MA, USA.

Gattiker, UE 1990, *Technology Management in Organizations,* Sage Publications, Newbury Park.

GeoConnections 2004, *A Developers' Guide to the CGDI: Developing and publishing geographic information, data and associated services* Available: http://www.geoconnections.org/publications/Technical_Manual/html_e/toc.html accessed 2 October 2011.

GeoConnections 2012, *Key Facts*. Available: http://geoconnections.nrcan.gc.ca/6, accessed 5 October, 2012.

Godden, D 2006, *Agricultural and Resource Policy: Principles and Practice*, Oxford University Press, Melbourne, Australia.

Goodchild, MF 2007, 'Citizens as Voluntary Sensors: Spatial Data Infrastructures in the World of Web 2.0', *International Journal of Spatial Data Infrastructure Research*, vol 2, pp 24–32.

Goodchild, MF 2008, 'Commentary: whither VGI?', *GeoJournal*, vol 72, no 3, pp 239–244.

Goodchild, MF, Fu, P and Rich, P 2007, 'Sharing Geographic Information: An Assessment of the Geospatial One-Stop', *Annals of the Association of American Geographers*, vol 97, no 2, pp 249–265.

Gore, A 1998, *The Digital Earth: Understanding our planet in the 21st century*. Digital Earth, Wikipedia. Available: http://www.isde5.org/al_gore_speech.htm#, accessed 15 September 2011.

Grant, DM 1999, '*Spatial Data Infrastructures: Vision for the future and the role of government in underpinning future land administration systems'*, Paper presented at the Proceedings of UN-FIG International Conference on Land Tenure and Cadastral Infrastructures for Sustainable Development, 24-27 October, Melbourne, Australia, pp. pp. 94-109.

Groot, R and McLaughlin, J 2000, *Geospatial Data Infrastructure: Concepts, Cases and Good Practice*, Oxford University Press, Oxford, UK.

Grus, L, Crompvoets, J and Bregt, A 2007, 'Multi-view SDI Assessment Framework', *International Journal of SDI Research*, vol 2, pp 33-53.

Hanseth, O and Lyytinen, K 2010, 'Design Theory for Dynamic Complexity in Information Infrastructures: The Case of Building Internet', *Journal of Information Technology*, vol 25, pp 1–19.

Hanseth, O and Monteiro, E 1998, *Understanding Information Infrastructure*. Manuscript 27 August 1998. Available: http://heim.ifi.uio.no/~oleha/Publications/bok.html, accessed 22 November 2011.

Harvey, F 2000, 'The Social Construction of Geographic Information Systems', *International Journal of GIS*, vol 14, no 8, pp 711-713.

Harvey, F 2001, *Constructing GIS: Actor Networks of Collaboration*. Available: http://www.urisa.org/files/HarveyVol13no1-3.pdf, accessed 4 October 2011.

Harvey, F, Iwaniak, A, Coetzee, S and Cooper, AK 2012, 'SDI Past, Present and Future: A Review and Status Assessment' In *Spatially Enabling Government, Industry and Citizens: Research and Development Perspectives* (Eds, Coleman, D and Rajabifard, A), GSDI Association, Canada.

Harvey, F and Tulloch, D 2004, '*How do Governments Share and Coordinate Geographic Information? Issues in the United States'*, Paper presented at the 10th EC & GIS Workshop, 23-25 June 2004, Warsaw, Poland.

Harvey, F and Tulloch, D 2006, 'Loca lgovernment data sharing: Evaluating the foundations of spatial data infrastructures', *International Journal of Geographical Information Science*, vol 20, no 7, pp 743-768.

Hendriks, PHJ, Dessers, E and van Hootegem, G 2012, 'Reconsidering the definition of a spatial data infrastructure', *International Journal of Geographical Information Science*, vol 26, no 8, pp 1479-1494.

Hofstede, G and Hofstede, GJ 2005, *Cultures and organizations : software of the mind,* McGraw-Hill New York

Holland, P 2006, '*Report on UNRCC-AP and PCGIAP meeting in Thailand, September 2006'*.

Intergovernmental Committee on Surveying and Mapping (ICSM) 2008, '*Spatially Enabling Australia Recommendations'*, ICSM ASDI Consultancy, Australia.

Johnson, AKL, Walker, DH, O'Brien, A and Cottrell, A 1997, '*The Herbert Resource Information Centre: Collaborative GIS in a Rural Catchment',* Paper presented at the AURISA 97 - The 25th Annual Conference of the Australasian Urban and Regional Information Systems Association, 19-21 November 1997, Christchurch, New Zealand.

Jones, A and Norman, P 2008, '*NRM Data Hub Scoping Project'*, Queenslands NRM Science Panel, Queensland, Australia.

Kadushin, C 2004 'Chapter 2: Some basic network concepts and propositions, Introduction to social network theory' unpublished.

Keast, R and Brown, K 2005, '*The network approach to evaluation: Uncovering patterns, possibilities and pitfalls ',* Paper presented at the the Australasian evaluation society international conference, 10-12 October 2005, South Bank, Brisbane.

Kelly, PC 1986, '*A Revolution in the Provision of Cadastral Data in Australia : Implications at federal level',* Paper presented at the XVIII FIG Congress, 1-11 June 1986, Toronto, Canada pp. 190-196.

Kevany, MJ 1995, 'A Proposed Structure for Observing Data Sharing' In *Sharing Geographic Information* (Eds, Onsrud, HJ and Rushton, G), Center for Urban Policy Research, New Brunswick, pp. 76-100

Klinkenberg, B 2003, 'The True Cost of Spatial Data in Canada', *The Canadian Geographer*, vol 47, no 1, pp 37-49.

Kuhn, W 2007, '*Volunteered Geographic Information and GIScience',* Paper presented at the The NCGIA and Vespucci Workshop on Volunteered Geographic Information, 13-14 December 2007, Santa Barbara, CA.

Landgate 2011. *About SLIP Enabler*. Landgate. Available: https://www2.landgate.wa.gov.au/web/guest/about-slip.

Last, R and Rojas, P 2007, '*Performance Evaluation for GeoConnections and the Canadian Geospatial Data Infrastructure',* Paper presented at the Multi-view Framework to Assess Spatial Data Infrastructures Workshop, 23-25 May 2007, Wageningen, The Netherlands.

Latour, B 1987, *Science in Action: How to Follow Scientists and Engineers through Society,* Harvard University Press, MA.

Laut, P and Taplin, BJ 1989, *Catchment Management in Australia in the 1980s,* CSIRO Institute of Natural Resources and Environment Division of Water Resources, Canberra.

Law, J 1992, *Notes on the Theory of Actor-Network: Ordering, Strategy and Heterogeneity,* The Centre for Science Studies, Lancaster University, Lancaster, UK.

Longley, PA, Goodchild, MF, D.J., M and Rhind, DW 1999, *Geographical Information Systems: Principles and Technical Issues*, 2nd edn, John Wiley & Sons, New York.

Love, S, Paine, M, Melland, A and Gourley, C 2006, '*Research or Extension? Scientists Participating in Collaborative Catchment Management'*, Paper presented at the APEN International Conference, 6-8 March 2006, Beechworth, Victoria, Australia.

Marshall, C 2006, *Designing qualitative research,* 4th edn, Sage Publications, Thousands Oaks Calif.

Marshall, GR 2001, '*Crafting Cooperation in the Commons: An Economic Analysis of Prospects for Collaborative Environmental Governance',* Doctor of Philosophy, University of New England, Armidale, Australia.

Masser, I 1998, '*The First Generation of National Geographic Information Strategies',* Paper presented at the The 3rd Global Spatial Data Infrastructure Conference, 17-19 November 1998, Canberra, Australia.

Masser, I 2005, 'GIS Worlds, Creating Spatial Data Infrastructures' ESRI Press, Redlands, CA.

Masser, I 2006, 'What's Special about SDI Related Research?', *International Journal of Spatial Data Infrastructures Research*, vol 1, pp 14-23.

Masser, I 2009, 'Changing Notions of Spatial Data Infrastructures' In *SDI Convergence: Research, Emerging Trends, and Critical Assessment* (Eds, Van Loenen, B, Bessemer, JWJ and Zevenbergen, JA), Netherlands Geodetic Commission, Delft, The Netherlands.

Masser, I 2010, *Building European Spatial Data Infrastructures,* Esri Press.

Masser, I 2011, 'Emerging Frameworks in the Information Age: The Spatial Data Infrastructure Phenomenon' In *The SAGE Handbook of GIS and Society* (Eds, Nyerges, TL, Couclelis, H and McMaster, R), Sage Publications, London.

Masser, I, Rajabifard, A and Williamson, IP 2008, 'Spatially Enabling Governments through SDI Implementation', *International Journal of Geographical Information Science*, vol 22, no 1, pp 5-20.

Maxwell, JA 1996, *Qualitative Research Design: An iterative approach, Applied social research methods series,* Sage Publications, Thousand Oaks.

McDougall, K 2006, '*A Local-State Government Spatial Data Sharing Partnership Model to Facilitate SDI Development'*, Doctor of Philosophy, The University of Melbourne, Australia.

McDougall, K 2010, '*From Silos to Networks - Will Users Drive Spatial Data Infrastructures in the Future?'*, Paper presented at the XXIV FIG Congress, Facing the Challenges - Building the Capacity, 11-16 April 2010, Sydney, Australia.

McDougall, K, Rajabifard, A and Williamson, IP 2007, 'A Mixed-Method Approach for Evaluating Spatial Data Sharing Partnerships for Spatial Data Infrastructure

Development' In *Research and Theory in Advancing Spatial Data Infrastructure Concepts* (Ed, Onsrud, H), ESRI Press Redlands, CA, pp. 55-73.

McLaughlin, JD 1991, '*Towards National Spatial Data Infrastructure'*, Paper presented at the Canadian Conference on GIS, March, Ottawa, Canada, pp. 1-5.

Mertens, DM, Bledsoe, KL, Sullivan, M and Wilson, A 2010, *Sage Handbook of Mixed Methods in Social and Behavioral Research,* 2nd edn, Sage Publications, LA.

Millar, J 2007, '*Extension for Natural Resource Management: Changing roles, approaches, methods and theories'*, Paper presented at the 2007 APEN Forum, 12-13 November 2007, Canberra, Australia.

Mohammadi, H 2008, '*The Integration of Multi-source Spatial Datasets in the Context of SDI Initiatives'*, Doctor of Philosophy, The University of Melbourne, Australia.

Mooney, P and Corcoran, P 2011, 'Can Volunteered Geographic Information be a Participant in eEnvironment and SDI?' In *Environmental Software Systems. Frameworks of eEnvironment*, Vol. 359 (Eds, Hrebicek, J, Schimak, G and Denzer, R), Springer Berlin Heidelberg, pp. 115-122.

Morse, JM 1991, 'Approaches to Qualitative-Quantitative Methodological Triangulation', *Nursing Research*, vol 40, no 2, pp 120-123.

National Research Council 1993, '*Toward a Coordinated Spatial Data Infrastructure for the Nation'*, Mapping Science Committee, National Academy Press, Washington DC.

Nebert, D 2010, *National Spatial Data Infrastructure Concepts and Tutorial* US Federal Geographic Data Committee Secretariat. Available: http://www.fgdc.gov/library/presentations-list, accessed 22 November 2011.

Nedovic-Budic, Z Unpublished, 'Exploring the Utility of Mixed Method Research in GIS',

Nedovic-Budic, Z, Feeny, M-EF, Rajabifard, A and Williamson, IP 2004, 'Are SDIs Serving the Needs of Local Planning? Case study of Victoria, Australia and Illinois, USA', *Computers, Environment and Urban Systems*, vol 28, no 2, pp 329-51.

Nedovic-Budic, Z and Pinto, JK 1999, 'Understanding Interorganisational GIS Activities: A Conceptual Framework', *Journal of Urban and Regional Information Systems Association*, vol 11, no 1, pp 53-64.

Nedovic-Budic, Z and Pinto, JK 2000, 'Information Sharing in an Interorganisational GIS Environment', *Environment and Planning B: Planning and Design*, vol 27, no 3, pp 455-474.

Nedovic-Budic, Z, Pinto, JK and Warnecke, L 2011, 'GIS Database Development and Exchange: Interaction Mechanisms and Motivations' In *Spatial Data Infrastructures in Context: North and South* (Eds, Nedovic-Budic, Z, Crompvoets, J and Georgiadou, Y), CRS Press, Taylor & Francis Group, Boca Raton, London, New York.

North, DC 1990, *Institutions, institutional change and economic behaviour*, Cambridge University Press.

Office of the Director of National Intelligence 2008, '*Information Sharing Strategy'*, Director of National Intelligence, Washington DC, USA.

Oliver, C 1990, 'Determinants of Inter-organizational Relationships: Integration and Future Directions', *Academy of Management Review*, vol 15, no 2, pp 241-65.

Omran, EE 2007, '*Spatial Data Sharing: From Theory to Practice'*, Doctor of Philosophy, Wageningen University, The Netherlands.

Onsrud, HJ 2011, 'Afterword' In *Spatial Data Infrastructure in Context: North and South* (Eds, Nedovic-Budic, Z, Crompvoets, J and Georgiadou, Y), Taylor & Francis, CRC Press, London.

Onsrud, HJ, Poore, B, Rugg, R, Taupier, R and Wiggins, L 2004, 'The Future of the Spatial Information Infrastructure,' In *A Research Agenda for Geographic Information Science* (Eds, McMaster, RB and Usery, EL), CRC Press, Boca Raton, FL, pp. 225-255.

Onsrud, HJ and Rushton, G 1995, *Sharing Geographic Information*, Centre for Urban Policy Research, Urban Policy Research, New Brunswick, New Jersey.

Pannell, DJ, Ridley, A, Seymour, E, Regan, P and Gale, G 2008, '*Regional Natural Resource Management Arrangements for Australian States: Structures, Legislation and Relationships to Government Agencies, SIF3 Working Paper 0809'*, Paper presented at the CRC for Plant-Based Management of Dryland Salinity, Perth.

Paudyal, DR and McDougall, K 2008, '*Building Spatial Data Infrastructure to Support Sustainable Catchment Management'*, Paper presented at the Queensland Spatial Conference 2008, 17-19 July 2008, Gold Coast, Queensland.

Paudyal, DR, McDougall, K and Apan, A 2009a, 'Building SDI Bridges for Catchment Management' In *Spatial Data Infrastructure Convergence: Research, Emerging Trends, and Critical Assessment* (Eds, Van Loenen, B, Besemer, JWJ and Zevenbergen, JA), Netherland Geodetic Commission (NGC), Delft, The Netherlands, pp. 265-279.

Paudyal, DR, McDougall, K and Apan, A 2009b, 'Spatial Data Infrastructure for Catchment Management: A Case study of Condamine Catchment, Australia', *Indian Cartographer, Journal of the Indian National Cartographic Association (INCA)*, vol 38, pp 439-444.

Paudyal, DR, McDougall, K and Apan, A 2010, '*A Regional Collaborative Network to Improve Spatial Information Sharing in Australia.'*, Paper presented at the 12th Global Spatial Data Infrastructure Association World Conference (GSDI 12), 19-22 October, 2010, Singapore.

Paudyal, DR, McDougall, K and Apan, A 2011, 'Spatial Data Infrastructure Convergence: Building Spatial Data Infrastructure Bridges to Address Climate Change' In *Geoinformatics for Climate Change Studies* (Eds, Joshi, PK and Singh, TP), The Energy and Resourcecs Institute (TERI), New Delhi, India, pp. 377-392.

Paudyal, DR, McDougall, K and Apan, A 2012, 'Exploring the Application of Volunteered Geographic Information to Catchment Management: A Survey Approach', *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.*, vol I-4, pp 275-280.

Pigram, JJ 2006, *Australia's Water Resources: From use to management*, CSIRO Pubishing, Collingwood, Victoria.

Pinto, JK and Onsrud, HJ 1993, 'Correlating Adoption Factors and Adopter Characteristics with Successful Use of Geographic Information Systems' In *Diffusion and Use of Geographic Information Technologies* (Eds, Masser, I and Onsrud, HJ), Kluwer Academic Publishers, Dordrecht/Boston/London, pp. 165-194.

Pinto, JK and Onsrud, HJ 1995, 'Sharing Geographic Information Across Organisational Boundaries: A Research Framework' In *Sharing Geographic Information* (Eds, Onsrud, HJ and Rushton, G), Centre for Urban Policy Research, New Brunswick, New Jersey, pp. 45-64.

Pironti, JP 2006, 'Key Elements of a Threat and Vulnerability Management Program', *Information Systems Audit and Control Association Member Journal*, pp 1-5.

Pollard, PA 2006, '*Co-ordinating the Sharing of Spatial Data in the UK'*, Doctor of Philosophy, University of the West of England, Bristol.

Queensland Regional NRM Groups Collective 2009, '*NRM Data and Knowledge Hub Pilot Project (Data Hub) Phase 1- Findings and Recommendations'*, Queensland Regional NRM Groups Collective, Queensland, Australia.

Queensland Regional NRM Groups Collective 2010, *Knowledge and Information Framework for Queensland regional NRM bodies*. Queensland Regional NRM Groups Collective. Available: http://www.rgc.org.au/collective-projects accessed 2 September 2011.

Radwan, MM, Onchaga, R and Morales, J 2001, '*A Structural Approach to the Management and Optimisation of Geoinformation Processes'*, European Organisation for Experimental Photogrammetric Research (OEEPE), Paris.

Rajabifard, A 2002, '*Diffusion of Regional Spatial Data Infrastructures: with particular reference to Asia and the Pacific'*, Doctor of Philosophy, The University of Melbourne, Australia.

Rajabifard, A 2007, 'SDI Design to Facilitate Spatially Enabled Society' In *Towards a Spatially Enabled Society* (Ed, Rajabifard, A), The University of Melbourne, Australia, Melbourne, pp. 219-231.

Rajabifard, A, Crompvoets, J, Kalantari, M and Kok, B 2010, 'Spatially Enabled Societies' In *Spatially Enabling Society Research, Emerging Trends and Critical Assessment* (Eds, Rajabifard, A, Crompvoets, J, Kalantari, M and Kok, B), GSDI Association and Leuven University Press, Leuven Belgium.

Rajabifard, A, Escobar, F and Williamson, IP 2000, 'Hierarchical Spatial Reasoning Applied to Spatial Data Infrastructures', *Cartography Journal Australia*, vol 29, no 2, Rajabifard, A, Feeney, M-EF and Williamson, IP 2003a, 'Spatial Data Infrastructures: Concept, Nature and SDI Hierarchy' In *Developing Spatial Data Infrastructures: From Concept to Reality* (Eds, Williamson, IP, Rajabifard, A and Feeney, M-EF), Taylor & Francis, London, UK, pp. 17-40.

Rajabifard, A, Feeney, M-EF, Williamson, IP and Masser, I 2003b, 'National SDI Initiatives' In *Developing Spatial Data Infrastructures: From Concept to Reality* (Eds, Williamson, IP, Rajabifard, A and Feeney, M-EF), Taylor & Francis, London, UK, pp. 94-110.

Rajabifard, A and Williamson, IP 2001, '*Spatial Data Infrastructures: Concepts, SDI Hierarchy and Future Directions* ', Paper presented at the Geomatics' 80 Conference, Tehran, Iran.

Rajabifard, A, Williamson, IP, Wallace, J and Bennett, R 2011, '*Spatially Enabled Society'*, Paper presented at the FIG Working Week 2011, 18-22 May 2011, Marrakech, Morocco.

RAVI 1995, '*The National Geographic Information Infrastructure NGII* ', Netherlands Council for Geographic Information (RAVI), Amersfoort, The Netherlands.

Reeve, DE and Petch, JR 1999, *GIS Organisations and People: A Socio-technical Approach*, Taylor and Francis, London.

Roberts, BR 1990, *The Birth of Land Care: Collected papers on land use*, University College of Southern Queensland Press, Toowoomba, Australia.

Rogers, EM 1971, *Diffusion of Innovations,* The Free Press, New York.

Rogers, EM 1983, *Diffusion of Innovations,* The Free Press, New York.

Rogers, EM 1995, *Diffusion of Innovations,* The Free Press, New York.

Ryan, S, Broderick, K, Sneddon, Y and Andrews, K (Eds.) (2010) *Australia's NRM Governance System: Foundations and Principles for Meeting Future Challenges*, Australian Regional NRM Chairs,Canberra.

Ryttersgaard, J 2001, '*Spatial Data Infrastructure-Developing Trends and Challenges'*, Paper presented at the CODI-2, 4–7 September 2001, Addis Ababa, Ethiopia.

Salleh, N 2010, '*Sharing Spatial Data at Government Departments in Brunei'*, Doctor of Philosophy, Salford University, UK.

Salleh, N and Khosrowshani, F 2010, '*A preliminary framework for research in spatial data sharing'*, Paper presented at the Proceedings of the International Conference in Computing in Civil and Building Engineering, 30 June-2 July, 2010, Nottingham, UK, pp. 33.

Scott, J 2000, *Social Network Analysis: A Handbook,* 2nd edn, Sage Publications, London.

SEDAC 2006, *Metadata Review*. Available: http://sedac.ciesin.org/metadata/overview.html, accessed 3 October 2011.

Shedroff, N 2001, 'Information interaction design: A unified field theory of design An Overview of Understanding' In *Information Design* (Ed, Jackon, R), The MIT Press, Cambridge, pp. 267-292.

Shi, Y 2008, '*Virtual Organisation Based Distributed Environmetal Decision Support Systems: Applications in Watershed Management'*, Doctor of Philosophy, Michigan State University.

Sinclair, R and Kenyon, K 2009, '*Queensland NRM Data and Knowledge Hub Pilot Project Northern Pilot Report'*, Queensland, Australia.

Smith, DP, Higgs, G and Gould, MI 2003, 'Using a Mixed Method Approach to Investigate the Use of GIS Within the UK National Health Service' In *Socio-economic Applications of Geographic Information Science* (Eds, Kidner, DB, Higgs, G and White, S), Taylor and Francis, London.

Spence, WR 1994, *Innovation: The Communication of Change in Ideas, Practices and Products* Chapman and Hall, London, Glasgow, Weinheim, New York, Tokyo, Melbourne, Madras.

Steudler, D and Rajabifard, A 2012, '*Key Elements for a Spatially Enabled Society'*, Joint publication of FIG-Task Force on "Spatially Enabled Society" in cooperation with GSDI Association and with the support of Working Group 3 of the PCGIAP.

Tashakkori, A and Teddlie, C 2003, *Handbook of Mixed Methods in Social and Behavioral Research,* Sage Publications, Thousand Oaks, CA.

Tashakkori, A and Teddlie, C 2007, *Foundations of Mixed Methods Research : Integrating quantitative and qualitative techniques in the social and behavioral sciences,* Sage Publications, Thousand Oaks, CA.

Tashakkori, A and Teddlie, C 2009, 'Mixed Methods' In *The SAGE Handbook of Applied Social Research Methods* (Eds, Bickman, L and Rog, DJ), Sage Publications, LA, pp. 283-317.

The National Academy of Sciences 2012, '*Advancing Strategic Science: A Spatial Data Infrastructure Roadmap for the U.S. Geological Survey'*, Committee on Spatial Data Enabling USG Strategic Science in the 21st Century, Mapping Science Committee, Board on Earth Sciences and Resources, Division on Earth and Life Studies, National Research Council, National Research Council, the National Academy of Sciences, Washington.

Thomas, RM 2003, *Blending Qualitative and Quantitative Research Methods in Theses and Dissertations,* Corwin Press, Thousand Oaks, CA.

Thompson, AW, Prokopy, LS, Floress, K and Weinkauf, DC 2011, 'A Method for Incorporating Community Priorities into GIS: Challenges, Choices, and Directions for Landscape Planners', *Landscape Journal*, vol 30, no 2, pp 299-312.

Tichy, NM, Tushman, ML and Fombrun, C 1979, 'Social Network Analysis for Organisations', *Academy of Management Review*, vol 4, no 4, pp 507-519.

Timpf, S and Frank, AU 1997, '*Using Hierarchical Spatial Data Structures for Hierarchical Spatial Reasoning'*, Paper presented at the International Conference COSIT'97, 15-18 October 1997, Laurel Highlands, Pennsylvania, USA, pp. 69-83.

Timpf, S, Volta, GS, Pollock, DW and Egenhofer, MJ 1992, 'A Conceptual Model of Wayfinding Using Multiple Levels of Abstractions' In *Theories and Methods of Spatio-Temporal Reasoning in Geographic Space* (Eds, Frank, AU and Campari, I), Springer Verlag, Heidelberg-Berlin.

Tulloch, DL and Harvey, F 2008, 'When Data Sharing Becomes Institutionalized: Best Practices in Local Government Geographic Information Relationships', *URISA Journal*, vol 19, no 2, pp 51-59.

UN Geospatial Information Working Group 2007, '*Strategy for Developing and Implementing a UN Spatial Data Infrastructure'*, United Nations, New York.

Vaez, SS 2010, '*Building a Seamless SDI Model for Land and Marine Environments'*, The University of Melbourne, Australia.

Van Loenen, B 2006, '*Developing Geographic Information Infrastructures: The Role of Information Policies'*, Doctor of Philosophy, Delft University of Technology, The Netherlands.

van Oort, P, Hazeu, G, Kramer, H, Bregt, A and Rip, F 2010, 'Social Networks in Spatial Data Infrastructures', *GeoJournal*, vol 75, no 1, pp 105-118.

Vancauwenberghe, G, Crompvoets, J, Bouckaert, G and Vandenbroucke, D 2009, '*A Network Perspective on Spatial Data Infrastructures: SDI as support to e-government'*, Paper presented at the GSDI11, 15-19 June 2009, Rotterdam, The Netherlands.

Vancauwenberghe, G, Crompvoets, J, Bouckaert, G and Vandenbroucke, D 2011, 'Social Network Analysis of the SDI in Flanders' In *Spatial Data Infrastructures in Context: North and South* (Eds, Nedovic-Budic, Z, Crompvoets, J and Georgiadou, Y), Taylor and Francis Group, CRC Press, Boca Raton, London, New York.

Vandenbroucke, D, Crompvoets, J, Vancauwenberghe, G, Dessers, E and Van Orshoven, J 2009, 'A Network Perspective on Spatial Data Infrastructures: Application to the Sub-national SDI of Flanders (Belgium)', *Transactions in GIS*, vol 13, no 1, pp 105-122.

VROM 2008, *GIDEON - Key Geo-information Facility for the Netherlands*. VROM, The Netherlands. Available: http://inspire-forum.jrc.ec.europa.eu/pg/file/read/1388/gideon-key-geo-information-facility-for-the-netherlands, accessed 2 October 2011.

Walker, D, De Lai, R, Johnson, A and Leitch, A 1999, '*Collaborative GIS in a Rural Catchment: History and achievements of the Herbert River Information Centre'*, Information Kit, Herbert River Information Centre and CSIRO, Australia.

Wallace, J, Williamson, IP and Rajabifard, A 2006, 'Spatial information opportunities for Government', *Journal of Spatial Science*, vol 51, no 1, Warnest, M 2005, '*A Collaboration Model for National Spatial Data Infrastructure in Federated Countries'*, Doctor of Philosophy, The University of Melbourne, Australia.

Wasserman, S and Faust, K 1994, *Social Network Analysis: Methods and Applications* Cambridge University Press, Cambridge, UK.

Wasserman, S and Faust, K 2008, *Social Network Analysis: Methods and Applications* Cambridge University Press, Cambridge, UK.

Webster's Online Dictionary 2008, *Definition: Infrastructure*. Webster's Online Dictionary. Available: http://www.websters-online-dictionary.org/definitions/Infrastructure, accessed 22 November, 2008.

Wehn de Montalvo, U 2003, *Mapping the Determinants of Spatial Data Sharing*, Ashgate Publishing Ltd, Aldershot, UK.

Western Australian Land Information System 2011, *About WALIS*. Government of Western Australia, WALIS. Available: http://www.walis.wa.gov.au/about-us, accessed 1 December 2011.

Whinnen, MF 1988, 'Technology and land information systems ', *Land and Minerals Surveying, Australia*, vol 6, no 10, pp 505-509.

Williamson, IP, Fauzi, A and Rajabifard, A 2007, '*Report of Working Group 3 Meeting to the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP)'*, Seol, South Korea.

Williamson, IP, Holland, P and Rajabifard, A 2010, '*Spatially Enabled Society'*, Paper presented at the The XXIV FIG Congress, Facing the Challenges - Building the Capacity, 11-16 April 2010, Sydney, Australia.

Williamson, IP, Rajabifard, A and Binns, A 2006a, 'Challenges and Issues for SDI Development', *International Journal of Spatial Data Infrastructures Research*, vol 1, no 1, pp 24-35.

Williamson, IP, Rajabifard, A and Feeney, M-EF 2003, *Developing Spatial Data Infrastructures: From Concept to Reality*, Taylor & Francis, New York.

Williamson, IP, Wallace, J and Rajabifard, A 2006b, '*Spatially Enabling Governments: A New Vision for Spatial Information'*, Paper presented at the Seventeenth United Nations Regional Cartographic Conference for Asia and the Pacific, 18-22 September 2006, Bangkok, Thailand.

World Bank 2011, *Definition of E-Government*. World Bank. Available: http://go.worldbank.org/M1JHE0Z280, accessed 8 November 2011.

Yildiz, M 2007, 'E-government Research: Reviewing the literature, limitations, and ways forward', *Government Information Quarterly*, vol 24, no 3, pp 646-665.

Yin, RK 1994, *Case Study Research Design and Methods* Sage Publications, Thousand Oaks, London, New Delhi.

Yin, RK 2009a, *Case Study Research Design and Methods,* 4th edn, Sage Publications, Los Angeles, London, New Delhi, Singapore, Washington DC.

Yin, RK 2009b, 'How to Do Better Case Studies' In *The SAGE handbook of applied social research methods* (Eds, Bickman, L and Rog, DJ), SAGE, Los Angeles, pp. 254-282.

Zaltman, G, Duncan, R and Holbeck, J 1973, *Innovations and Organisations,* John Wiley & Son, NY.

Appendix 1

Questionnaire to Regional NRM Bodies in Australia

Dear Sir/Madam,

Re: Assessment of the Status of Spatial Data Access, Sharing and Use for Catchment Management – Communities' Perspectives

My name is Dev Raj Paudyal and I am currently a PhD Candidate at University of Southern Queensland and conducting a research entitled "Facilitating Sustainable Catchment Management through Spatial Data Infrastructure Design and Development".

Spatial information plays an important role in many social, environmental, economic and political decisions and is increasingly acknowledged a national resource essential for sustainable development. Accurate, up-to-date, relevant and accessible spatial information is essential in addressing various global issues like climate change, urban change, land use change, poverty reduction, environmental protection and sustainable development. One of the potential areas where spatial information can make a positive impact is for improved decision-making to support catchment management. Reliable information infrastructure are needed to record the social, environmental, economic and political dimensions of natural resource management and to support appropriate decision-making and conflict resolution. However, the integration of spatial data in such environments has been problematic as the available data often have different scale, content and formats. By building an appropriate Spatial Data Infrastructure (SDI), disparate spatial data can be accessed and utilised to facilitate the access, sharing and use of spatial data between stakeholders across catchment communities.

The aim of this questionaries is to assess current status of spatial data access, sharing and use for catchment management from NRM groups/Communities' perspectives. This questionnaire focuses on the six main themes and contains a total of 39 questions. It should take 20 minutes to complete this survey.

I kindly request you to complete this online and send it back. Confidentiality of individuals will be fully preserved in the collection and reporting of the results. The results will be made available to survey participants upon request and distributed through the research publications.

Thank you in advance for your kind cooperation.

Sincerely,

Dev Raj Paudyal, PhD Candidate
Faculty of Engineering and Surveying
University of Southern Queensland
Phone: 0746312633 (Tel), Fax: 0746312526
E-mail: paudyal@usq.edu.au

Faculty of Engineering and Surveying

University of Southern Queensland
West Street, Toowoomba QLD

Chief Investigator's Name: Dev Raj Paudyal, B.Sc. (Surveying), M.Sc (ITC, the Netherlands)
PhD Candidate
Supervisors' Name: A/Prof. Kevin McDougall, BSurv (Hons) MSurv&MapSc (UQ) PhD Melb
MISAust MSSI
Head of Surveying and Spatial Science
Faculty of Engineering and Surveying
&
A/Prof. Armando Apan, B.S. (*Forestry*), MSc (AIT), PhD (Monash)
Deputy Head of Surveying and Spatial Science
Faculty of Engineering and Surveying

PARTICIPANT CONSENT FORM

By the act of submitting this survey, I hereby give my consent to participate in this study.

Title: Facilitating Sustainable Catchment Management through Spatial Data Infrastructure Design and Development

In giving my consent I acknowledge that:

1) The procedures required for the project and the time involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.
2) I have read the Participation Information Statement and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.
3) I understand that my involvement is strictly confidential and no information about me will be used in anyway that reveals my identity.
4) I understand that being in this study is completely voluntary – I am not under any obligation to consent.

I AGREE

SURVEY OF STATUS OF SPATIAL DATA ACCESS, SHARING AND USE FOR CATCHMENT MANAGEMENT

IDENTIFICATION

Position: ____________

(Eg. GIS Officer, IT Manager, Technical Officer, etc.)

Department or Section: ____________

Employee Type: Full Time

(Eg. Full time, Part time, Casual, Contract etc.)

INTRODUCTION

1. Do you consider your organisation as a

- ☐ Spatial information provider
- ☐ Spatial information user
- ☐ Spatial information provider and user (both)

2. How widely is spatial information used by staff within your organisation?

- ☐ <20% staff
- ☐ 20-40% staff
- ☐ 40-60% staff
- ☐ 60-80% staff
- ☐ >80% staff

3. How long has your organisation been using GIS/spatial information for catchment management activities?

- ☐ Less than 2 years
- ☐ 2-5 years
- ☐ 5-10 years
- ☐ More than 10 years

4. How do you undertake all your GIS activities

- ☐ Completely in-house
- ☐ Outsource some
- ☐ Outsource all

CATCHMENT MANAGEMENT ISSUES

5. Catchments cross over a number of local as well as state government boundaries. Does this create administrative and political difficulties for your organisation? (Tick the appropriate one).

- ☐ Strongly agree
- ☐ Agree
- ☐ Neither
- ☐ Disagree
- ☐ Strongly disagree

6. What are the main catchment management issues focussed on by your organisation? Rate them in order of priority (Tick 1 for highest priority, and 5 for lowest priority).

	Priority: Highest……………………………Lowest				
	1	2	3	4	5
Biodiversity Conservation	1	2	3	4	5
Community Capacity Building	1	2	3	4	5
Climate Change	1	2	3	4	5
Floodplains, Land Erosion & Land Degradation	1	2	3	4	5
Land Use Planning and Soil Conservation	1	2	3	4	5
Pest Animal and Weed Management	1	2	3	4	5
Water Resource Management (including water quality and availability)	1	2	3	4	5
Other (please specify)	1	2	3	4	5
Other (please specify	1	2	3	4	5
Other (please specify	1	2	3	4	5

7. Do you think that spatial data can play a role in addressing the above issues?

- Not at all
- Minor role
- Significant role
- Very significant role
- Not Aware

8. In your areas, do any catchment boundaries overlap or is there boundary confusion with adjoining NRM groups/CMAs? Please specify.

9. Which of the following community-driven/ volunteer initiatives do you have in your catchment? Tick all applicable.

- Landcare
- Waterwatch
- Birdwatch
- Land for Wildlife
- Coastcare
- Other (please specify)
- Other (please specify
- Other (please specify)

10. What do you think is the motivation for these volunteer initiatives? (Tick those that are appropriate).

- Having fun
- Social interaction/benefits
- Personal benefits
- Long standing love of the land and/ or water
- Self esteem/ Desire to serve community

- ☐ Awareness and concern regarding environmental benefits
- ☐ Spiritual connectivity
- ☐ Other ______

11. Which of the following scale is most suitable for spatial information management for catchment planning and decision making in your catchment?

- ○ Property scale
- ○ Sub-catchment scale
- ○ Catchment scale
- ○ All of the above

INFORMATION POLICY AND FUNDING

12. Does your organisation have policies or guidelines for the following aspects of spatial information? Please specify.

- ☐ Management ______
- ☐ Data use and Re-use ______
- ☐ Custodianship ______
- ☐ Pricing and Access ______
- ☐ Value adding ______
- ☐ No policies/guidelines ______

13. What are the key funding sources in your NRM group/CMA?

Rate your level of funding from each source (Tick 1 for highest level, and 5 for lowest level)

Highest……………………………………………Lowest

	1	2	3	4	5
Commonwealth Government	○1	○2	○3	○4	○5
State Government	○1	○2	○3	○4	○5
Local Government	○1	○2	○3	○4	○5
Private Sector/Industry	○1	○2	○3	○4	○5
Land Owners/Individuals	○1	○2	○3	○4	○5
Other (please specify) ______	○1	○2	○3	○4	○5
Other (please specify) ______	○1	○2	○3	○4	○5

14. Does your organisation provide funding to any of the following organisations?

Rate them by your level of funding support (Tick 1 for highest amount, and 5 for lowest amount)

Highest……………………………………………Lowest

	1	2	3	4	5
Community Organisations (e.g. landcare, waterwatch, birdwatch etc.)	○1	○2	○3	○4	○5
Academia/Research Institution	○1	○2	○3	○4	○5
Indigenous Groups	○1	○2	○3	○4	○5
Land Owners/Individuals	○1	○2	○3	○4	○5
Other (please specify) ______	○1	○2	○3	○4	○5
Other (please specify) ______	○1	○2	○3	○4	○5

SPATIAL DATA REQUIREMENTS

15. Please rate the following spatial data according to their importance to your organisation.

Type of spatial data	Importance of data High……Low				
	1	2	3	4	5
Cadastral data	☐1	☐2	☐3	☐4	☐5
Topography	☐1	☐2	☐3	☐4	☐5
Geology	☐1	☐2	☐3	☐4	☐5
Watershed/Catchment boundary data	☐1	☐2	☐3	☐4	☐5
Administrative boundary data	☐1	☐2	☐3	☐4	☐5
Infrastructure and utilities data (building, transportation etc.)	☐1	☐2	☐3	☐4	☐5
Digital elevation model (DEM)	☐1	☐2	☐3	☐4	☐5
Land use/Land cover data	☐1	☐2	☐3	☐4	☐5
Vegetation	☐1	☐2	☐3	☐4	☐5
Weather data	☐1	☐2	☐3	☐4	☐5
Mineral resources	☐1	☐2	☐3	☐4	☐5
Open source data (Google Maps, OpenStreetMap, WikiMapia etc.)	☐1	☐2	☐3	☐4	☐5
Other ______	☐1	☐2	☐3	☐4	☐5

16. How do you locate this spatial data from the data provider? Tick all applicable.

☐ Telephone

☐ E-mail

☐ Personal contact

☐ Website

☐ Others (please specify) ______

17. Please rate the importance of following group of spatial data providers for your GIS activities.

	High……Low				
	1	2	3	4	5
o Commonwealth Government (e.g. Geoscience Australia, BRS, etc.)	☐1	☐2	☐3	☐4	☐5
o State Government (e.g. DERM, DNR, DSE, DAF, DWLBC, etc.)	☐1	☐2	☐3	☐4	☐5
o Local Government	☐1	☐2	☐3	☐4	☐5
o Private Sector/Industry	☐1	☐2	☐3	☐4	☐5

INFORMATION FLOW, DATA ACCESS AND PRICING

18. In your experience, how easy is it to access and obtain the spatial data you need?

☐ Very easy

☐ Easy

☐ Moderately easy

☐ Not easy

☐ Not easy at all

19. Does your organisation also supply spatial information?

☐ Yes ☐ No (go to 21)

20. Who do you provide data to?

Frequency of supply

Very frequently……………...Rarely

	1	2	3	4	5
○ Commonwealth Government	☐1	☐2	☐3	☐4	☐5
○ State Government	☐1	☐2	☐3	☐4	☐5
○ Local Government	☐1	☐2	☐3	☐4	☐5
○ Private Sector/Industry	☐1	☐2	☐3	☐4	☐5
○ Academia/ Research Institution	☐1	☐2	☐3	☐4	☐5
○ Community Organisations (e.g. landcare, watercare, birdwatch etc.)	☐1	☐2	☐3	☐4	☐5
○ Land owners/Individuals	☐1	☐2	☐3	☐4	☐5
○ Indigenous groups	☐1	☐2	☐3	☐4	☐5
○ Other ______	☐1	☐2	☐3	☐4	☐5
○ Other ______	☐1	☐2	☐3	☐4	☐5

21. What are the most common ways you receive spatial information from other organisation?

- ☐ Paper maps (hard copy)
- ☐ CDROM or other portable digital media
- ☐ Digital download (i.e. internet, data directory/data atlas/map viewer, FTP etc.)
- ☐ Emailed
- ☐ Others (please specify) ______

22. Are there any restrictions placed on you by the spatial data provider on your use of their spatial information?

- ○ Always
- ○ Most of the time
- ○ Sometimes
- ○ Infrequently
- ○ Not at all

23. Do restrictions on the use of spatial data impact on your ability to undertake your work?

- ○ Very limiting
- ○ Limiting
- ○ Moderately limiting
- ○ Not limiting
- ○ Not limiting at all

24. Do you have any problems in integrating externally obtained spatial data into your GIS system?

- ☐ Yes – due to scale
- ☐ Yes- due to standards (projection, contents, etc.)
- ☐ Yes – due to format
- ☐ No
- ☐ Not applicable

25. Is the pricing of spatial data affordable to your organisation?

☐ Yes ☐ No

26. What would be an acceptable pricing arrangement for spatial data for your organisation?

☐ Free (open access)

☐ Cost of transferring the data

☐ Full cost recovery (cost of transfer plus cost of creation, updating, etc.)

☐ Others (please specify) ______

DATA SHARING, COLLABORATION AND NETWORKING

27. Do you have any collaborative arrangements with other organisations with respect to the exchange of resources, skills or technology?

☐ Yes ☐ No (go to question 30)

28. If yes, please identify the areas of collaboration.

☐ Data sharing and spatial information management

☐ Technology sharing

☐ Technical skills and human resources sharing

☐ Knowledge transfer

☐ Others (please specify) ______

29. Who are your main partners for this collaboration? (Tick 1 for highest importance and 5 for lowest importance).

	Partnership importance				
	Highest……………lowest				
	1	2	3	4	5
o Commonwealth Government	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o State Government	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o Local Government	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o Private Sector/Industry	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o Academia/ Research Institution	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o Community Organisations (e.g. landcare, watercare, birdwatch etc.)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o Land owners/Individuals	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o Indigenous groups	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o Other ______	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o Other ______	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

30. Rate the importance of the following factors for sharing spatial data with other organisations?

	Influencing factor				
	Strong……………Weak				
	1	2	3	4	5
o The existence of a formal agreement	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o Organisational attitude to sharing	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o Individual attitude, ability and willingness of your staff	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o Networking and contact	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
o Leadership	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

- Good IT system and technical tools ☐1 ☐2 ☐3 ☐4 ☐5

31. What percentage of your spatial data sharing is done by

☐ Formal agreement ______ %

☐ Informal agreement ______ %

☐ Others (please specify) ______ %

VOLUNTEERED GEOGRAPHIC INFORMATION (VGI), WEB 2.0, SOCIAL NETWORKING AND OTHER EMERGING MODELS OF SPATIAL INFORMATION MANAGEMENT

32. Are you aware of freely available/accessible spatial products e.g. Google Maps, OpenStreetMap, Wikimapia, etc. for your work needs?

☐ Yes ☐ No (go to question 34)

33. How often you use these products?

☐ Daily

☐ Weekly

☐ Fortnightly

☐ Monthly

☐ A few times a year

34. How applicable are these open source products in your organisation?

Level of applicability

Highly………….................................Not applicable

	1	2	3	4	5
Biodiversity Conservation	☐1	☐2	☐3	☐4	☐5
Community Capacity Building	☐1	☐2	☐3	☐4	☐5
Climate Change	☐1	☐2	☐3	☐4	☐5
Floodplains, Land Erosion & Land Degradation	☐1	☐2	☐3	☐4	☐5
Land Use Planning and Soil Conservation	☐1	☐2	☐3	☐4	☐5
Pest Animal and Weed Management	☐1	☐2	☐3	☐4	☐5
Water Resource Management (including water quality and availability)	☐1	☐2	☐3	☐4	☐5
Other (please specify) ______	☐1	☐2	☐3	☐4	☐5
Other (please specify ______	☐1	☐2	☐3	☐4	☐5
Other (please specify ______	☐1	☐2	☐3	☐4	☐5

35. Exchanging feedback through portals such as webblog, facebook, flickr, twitter, hyves, linkedIn etc. will be increasingly helpful for community networking and information exchange.

☐ Strongly agree

☐ Agree

☐ Neither

☐ Disagree

☐ Strongly disagree

36. If you are aware of social networking activities and/or data sharing projects for improved catchment outcomes within your catchment areas, please provide details?

Thank you.

For your time and assistance in completing this questionnaire is greatly appreciated.

If you would like to receive a copy of the consolidated data please provide your details.

Name:

E-mail:

Mailing Address:

Should you have any concern about the conduct of this research project, please contact the USQ Ethics Officer, Office of Research & Higher Degrees, University of Southern Queensland, West Street, Toowoomba QLD 4350, Telephone (07) 4631 2690, email: ethics@usq.edu.au

Submit Reset

Appendix 2

Sample Letter of Supporting e-Mail Sent through Supervisor

Dev Raj Paudyal

From: Dev Raj Paudyal
Sent: Tuesday, 15 June 2010 5:50 PM
To: [redacted]
Subject: Seeking your assistance in a research study

Dear [redacted],

I am writing to seek your assistance in a research study on the "Access and Sharing of Spatial Information for Catchment Management" which is being undertaken by my research student Mr Dev Raj Paudyal.

As part of the study we are looking for your assistance to answer a brief on-line questionnaire on your experiences with using GIS and spatial information for your catchment management.

The survey should take no more than 15min and will provide some very important information for Dev as part of his study.

To commence the survey simply click the following link: http://www.usq.edu.au/users/paudyal/NRM_Survey/Introduction.htm

If you have any questions either Dev or myself can be contacted on the details below.

Thank you in advance for your assistance in this research work.

Kind regards

Kevin

Associate Professor Kevin McDougall
Head, Surveying and Spatial Science
Faculty of Engineering and Surveying
University of Southern Queensland
Surveying
West Street, Toowoomba, Queensland 4350 Australia
Queensland 4350 Australia
Tel: 617 4631 2545
Fax: 617 4631 2526
Email: mcdougak@usq.edu.au
Web: www.usq.edu.au/users/mcdougall

Dev

Mr Dev Raj Paudyal
PhD Candidate
Surveying and Spatial Science
Faculty of Engineering and

University of Southern Queensland,

Tel: 617 4631 2633; 0412163217
Fax: 617 4631 2526
Email: paudyal@usq.edu.au

Appendix 3

Semi-structured Interview Protocol and Questions

(Case Study –KIN Project)

Semi-structured Interview Questions – NRM KIN Project

The interview investigates your role and the role of your organisation for NRM Knowledge and Information Network (KIN) Project in Queensland. The questions should be answered from the perspective of your particular organisation. The interview is comprised of sixteen questions.

Any information supplied is for research purposes only. The researcher is obliged not to disclose the names of people and organisations interviewed. The data collected through this interview is confidential, and reference to responses will be anonymous. Your opinion is important to rich a full understanding of this phenomenon, and I would like to ask for your permission to record the interview.

The researcher thanks you for your time.

Dev Raj Paudyal
PhD Candidate
Faculty of Engineering and Surveying
University of Southern Queensland
Phone: 0746312633 (Tel), 0412163217 (Cell)
Fax: 0746312526
E-mail: paudyal@usq.edu.au

Semi-structured Interview Questions: NRM KIN Project

Organisation/Agency:

Interviewer:

Position:

Date: **Time:**

---

1 Could you please explain to me your role and your organisational role in the NRM KIN project?

2 What is the current status of NRM KIN project? Could you please explain the history of your organisation's involvement?

3 What are the motivations factors for your organisation to collaborate in the NRM KIN project?

4 Is this project based on other similar initiatives in Australia or elsewhere? Is the intension to share existing data or to collect new data?

5 SDI portals exist at national level, state level and local level to utilise and share spatial information. Why are these initiatives not sufficient to share/ utilise spatial information for catchment decisions? Why do you need another information portal like data hub/KIN then?

6 What are the main spatial information themes that are you planning to share through this NRM KIN?

7 Are there any constraints (policy, technological, organisational, cultural, and economic) to link NRM KIN project with state/local level SDI activities? Are the project participants satisfied with the way the NRM KIN project is managed or governed?

8 What are the biggest issues or barriers you are facing managing this project?

9 How could this KIN project and existing SDI activities be linked?

10 Are the project participants satisfied with the way the NRM KIN project is managed /governed?

11 How do you communicate with your project partners and what is the frequency of the communication?

12 The NRM KIN project is a fixed term project. What could be done for the sustainability of these project/initiatives to facilitate spatial information sharing?

13 There could be a lot of spatial information collected/generated by land care groups, land holders and other community groups at grass-root level. Is there any mechanism to share this information through NRM KIN project?

14 Is it possible to utilise social media (face book, twister, etc) web 2.0 technology (wiki, etc) and volunteered geographical information (VGI) (open street map, etc) through the NRM KIN project? If yes, how?

15 Have you measured the benefits of this project to justify the investment? What could be the mechanism?

16 I would like to request you for your consent to perform Network Analysis of KIN project. The analysis will give me the idea about the frequency of interaction and flow of spatial information between project partners and their role in achieving the goal of KIN project.

Comments:

Appendix 4

Network Analysis Questionnaire

(KIN Project Participants)

Questionnaire for Network Analysis

Organisation/Agency: **Date:**

1. Please rate your frequency of interaction with the following organisations.

	Very frequently ….…………….				Rarely
	1	2	3	4	5
State Govt - DERM	1	2	3	4	5
QLD Regional Group Collective (RGC)	1	2	3	4	5
Northern Gulf RMG	1	2	3	4	5
Southern Gulf Catchment	1	2	3	4	5
NQ Dry Tropics	1	2	3	4	5
Burnett Mary Regional Group	1	2	3	4	5
South West NRM LTD	1	2	3	4	5
QMDC	1	2	3	4	5
Condamine Alliance	1	2	3	4	5
SEQ Catchments	1	2	3	4	5
Terrain NRM	1	2	3	4	5
Cape York PDA	1	2	3	4	5
Fitzroy Basin Association	1	2	3	4	5
Desert Channels	1	2	3	4	5
Reef Catchments Mackay Whitsunday	1	2	3	4	5
Torres Strait Regional Authority	1	2	3	4	5
Knowledge coordinators	1	2	3	4	5
Landcare Groups	1	2	3	4	5
Farmers/Landholders/Land Managers	1	2	3	4	5

2. Please rate the flow of spatial information between your organisation and the following organisations.

	More ……………………………….				Less
	1	2	3	4	5
State Govt - DERM	1	2	3	4	5
QLD Regional Group Collective (RGC)	1	2	3	4	5
Northern Gulf RMG	1	2	3	4	5
Southern Gulf Catchment	1	2	3	4	5
NQ Dry Tropics	1	2	3	4	5
Burnett Mary Regional Group	1	2	3	4	5
South West NRM LTD	1	2	3	4	5
QMDC	1	2	3	4	5
Condamine Alliance	1	2	3	4	5
SEQ Catchments	1	2	3	4	5
Terrain NRM	1	2	3	4	5
Cape York PDA	1	2	3	4	5
Fitzroy Basin Association	1	2	3	4	5
Desert Channels	1	2	3	4	5
Reef Catchments Mackay Whitsunday	1	2	3	4	5
Torres Strait Regional Authority	1	2	3	4	5
Knowledge coordinators	1	2	3	4	5
Landcare Groups	1	2	3	4	5
Farmers/Landholders/Land Managers	1	2	3	4	5

3. Please rate the role of following organisations/professionals for better NRM outcomes.

	Highest…. 1	2	3	4	………lowest 5
State Govt - DERM	1	2	3	4	5
QLD Regional Group Collective (RGC)	1	2	3	4	5
Northern Gulf RMG	1	2	3	4	5
Southern Gulf Catchment	1	2	3	4	5
NQ Dry Tropics	1	2	3	4	5
Burnett Mary Regional Group	1	2	3	4	5
South West NRM LTD	1	2	3	4	5
QMDC	1	2	3	4	5
Condamine Alliance	1	2	3	4	5
SEQ Catchments	1	2	3	4	5
Terrain NRM	1	2	3	4	5
Cape York PDA	1	2	3	4	5
Fitzroy Basin Association	1	2	3	4	5
Desert Channels	1	2	3	4	5
Reef Catchments Mackay Whitsunday	1	2	3	4	5
Torres Strait Regional Authority	1	2	3	4	5
Knowledge coordinators	1	2	3	4	5
Landcare Groups	1	2	3	4	5
Farmers/Landholders/Land Managers	1	2	3	4	5

4. Please rate the level of trust in working together (sharing information, etc) of your organisation with others in this KIN project?

	Most … 1	2	3	4	..Least 5
State Govt - DERM	1	2	3	4	5
QLD Regional Group Collective (RGC)	1	2	3	4	5
Northern Gulf RMG	1	2	3	4	5
Southern Gulf Catchment	1	2	3	4	5
NQ Dry Tropics	1	2	3	4	5
Burnett Mary Regional Group	1	2	3	4	5
South West NRM LTD	1	2	3	4	5
QMDC	1	2	3	4	5
Condamine Alliance	1	2	3	4	5
SEQ Catchments	1	2	3	4	5
Terrain NRM	1	2	3	4	5
Cape York PDA	1	2	3	4	5
Fitzroy Basin Association	1	2	3	4	5
Desert Channels	1	2	3	4	5
Reef Catchments Mackay Whitsunday	1	2	3	4	5
Torres Strait Regional Authority	1	2	3	4	5
Knowledge coordinators	1	2	3	4	5
Landcare Groups	1	2	3	4	5
Farmers/Landholders/Land Managers	1	2	3	4	5

Thank you very much for your time

Appendix 5

Ethics Approval Letter

TOOWOOMBA QUEENSLAND 4350
AUSTRALIA
TELEPHONE +61 7 4631 2300

CRICOS: QLD 00244B NSW 02225M

www.usq.edu.au

OFFICE OF RESEARCH AND HIGHER DEGREES
William Farmer
Ethics Officer
PHONE (07) 4631 2690 | FAX (07) 46311995
EMAIL will.farmer@usq.edu.au

Friday, 12 March 2010

Dev Raj Paudyal
Faculty of Engineering
USQ Toowoomba Campus

Dear Dev,

Thankyou for submitting your project below for human ethics clearance. The Chair of the USQ Fast Track Human Research Ethics Committee (FTHREC) recently reviewed your responses to the FTHREC's conditions placed upon the ethical approval for the above project. Your proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research* and full ethics approval has been granted.

Project Title	Facilitating Sustainable Catchment Management through Spatial Data Infrastructure Design and Development
Approval no	H09REA129
Period of Approval	20/11/2009 – 20/11/2010
FTHREC Decision	**Approved**

The standard conditions of this approval are:

(a) conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal required by the HREC;
(b) advise the HREC (email: ethics@usq.edu.au) immediately if any complaints or expressions of concern are raised, or any other issue in relation to the project which may warrant review of ethics approval of the project;
(c) make submission to the HREC for approval of any amendments, or modifications to the approved project before implementing such changes;
(d) in the event you require an extension of ethics approval for this project, please make written application in advance of the end-date of this approval;
(e) provide the HREC with a written "Annual Progress Report" for every year of approval. The first progress report is due 12 months after the start date of this approval (by **20/01/2010**);
(f) provide the HREC with a written "Final Report" when the project is complete;
(g) if the project is discontinued, advise the HREC in writing of the discontinuation.

For (c) to (f) proformas are available on the USQ ethics website: http://www.usq.edu.au/research/ethicsbio/human

Please note that failure to comply with the conditions of approval and the *National Statement on Ethical Conduct in Human Research* may result in withdrawal of approval for the project.

You may now commence your project. I wish you all the best for the conduct of the project

Yours sincerely

William Farmer
Ethics Officer
Office of Research and Higher Degrees

Appendix 6

Open Ended Questionnaire Responses

(Regional NRM Bodies)

Case Summarises (1) – Comments on Spatial Information Policy

1. Spatial Information Management

Queensland

- CRIS manual
- Currently being re-vamped
- Have a corporate guideline in place
- Data Management Standards
- Documented procedures
- Informal database of Software and Data Register
- Internal Guidelines
- Privacy Issues
- Spatial Data Management Plan
- Still learning the details
- Have a guideline but it needs to be revisited, updated and formalised

New South Wales

- Data drive is read only
- GIS Standard Operating Procedures and MOU agreements for use and licence of spatial data
- NSW state government has the guidelines
- Still in the process of development
- Firm in-house spatial standards, policies and procedures
- Spatial attribution guidelines for collecting data to be stored in the Land Management Database

Victoria

- Currently having a GIS audit as a component of an SDI
- Information management policy
- Documentation around the storage and use of spatial data.
- Focus in the near future on data creation and acquisition to ensure standards are known and described in metadata and format is suitable

South Australia

- General guidelines exist but not kept up to date
- Outsourced to SAMRIC

Western Australia

- The regional spatial information management toolkit
- Follow the WALIS guidelines

Tasmania

- Draft document

2. <u>Data use and Reuse</u>

Queensland

- According to data-share agreements with various stakeholders and where the data originated from
- Benchmark Atlas incorporating metadata
- Documented procedures
- RGC data-share agreement
- Roles and responsibilities - GIS data management
- Still learning the details
- Tied to NRM requirements for shared data
- Usage agreement for whoever uses data that we provide

New South Wales

- Data licence agreement
- DECCW disclaimers and policies
- Metadata statements and data use licensing
- MOU agreements for use and licence of spatial data
- NSW state government
- Firm in-house spatial standards, policies and procedures

Victoria

- Currently having a GIS audit as a component of an SDI
- GIS user procedure

South Australia

- No policy

Western Australia

- Developed through SLIP and the NACC Regional Spatial Information Toolkit
- Follow the WALIS guidelines

Tasmania

- Distribution licenses
- Draft policy

3. <u>Custodianship</u>

Queensland

- Regional NRM bodies are the custodians of most of the NRM data

- As per data share agreements
- Considerable interest in sharing data under creative commons
- Intellectual property policy
- Metadata incorporates the custodianship
- Tied to NRM requirements for shared data
- Follow clear statement of all custodians of different spatial information

New South Wales

- Data licence agreement
- MOU agreements for use and licence of spatial data
- NSW state government
- Firm in-house spatial standards, policies and procedures

Victoria

- As per contractual obligations
- Currently having a GIS as a component of an SDI

South Australia

- All data is available to state government agencies and departments
- Most spatial information is held by a specialist partner organisations
- Outsourced to SAMRIC (South Australian Murray Darling Basin Resource Information Centre)

Western Australia

- SLIP and the Regional Spatial Information Toolkit

Tasmania

- Draft policy
- Service level agreement with state custodians, clarifies position of data ownership

4. <u>Pricing and Access</u>

Queensland

- Internal guidelines
- Pricing only relates to map production and not to any spatial information
- Policies and process for data and hard copy supply
- Quotes provided using approved (SWIFT)
- Fixed through data sharing/data agreements.
- No charge for data access and usually free to project partners
- Pricing if applied is at a cost recovery

- Follow clear statement of all custodians of different spatial information
- The government spatial data should be free and the reasonable cost should be placed for private and community owned spatial data.

New South Wales
- Data licensing
- MOU agreements for use and licence of spatial data
- No charge, access to all for anything CMA produces
- NSW state government

Victoria
- Currently working on this in GIS strategy

South Australia
- No policy

Western Australia
- Developed through SLIP and the Regional Spatial Information Toolkit
- WALIS guidelines

Tasmania
- Draft policy
- Service level agreement with state custodians, clarifies position of data ownership

5. **Value adding**

Queensland
- Required under most of the data share agreements
- Under development

New South Wales
- Value add is in practice, but have no guidelines or policy
- MOU agreements for use and licence of spatial data
- NSW state government

Victoria
- GIS User Procedures

South Australia
- No policy

Western Australia

- WALIS guidelines
- Part of the guidelines in written in our contracts with the project deliveries

Tasmania

- Draft policy

Case Summarises (2) – Comments on social networking activities for improved catchment outcomes

Case #	Comments
1	I have been involved in the SLIP Project in WA. I think this project really increased access and awareness of spatial data available in the NRM sector. We have got a good working relationship with the Dept. of Agriculture and Food (mainly through SLIP) and try to exchange/update property data as often as possible. NACC has also developed a social networking site called Banjar but other than a town name we don't ask for any spatial data. We have asked ESRI to develop a toolbar that captures all our on-ground works we fund through CFOC projects.
	Regional Coordination Group - assisting with planning (and data) coordination in South East Queensland Catchments - consolidating spatial data in the region and distribution to partners/stakeholders for improved natural resource management
2	Significant amounts of work is being undertaken state-wide (across all three Tasmanian regions) though various projects, including: purchase of state-wide satellite imagery; development of on-ground works and outcome mapping tool (PDA), associated geo-databases, processes and training; various mapping projects (university reports, CERF hub participation, land use mapping in conjunction with State Government); arrangement of research framework with three regions and UTas
3	The Land Management Database is being used by all 13 CMAs in NSW to capture information about all NRM investment on ground
11	We are primarily using a WIKI (http://wiki.bdtnrm.org.au) and YouTube We have dabbled in Facebook and Twitter
15	Our organisation has just instituted Facebook. We're always trying to be involving in spatial data sharing initiatives that occur between us and state government agencies (in particular)
27	Regional Groups Collective - assisting with data sharing across the state
30	Not quite aware of that
36	I am aware of these but never use them
41	Anti-mining is about it at this point as far as I'm aware

42	No
46	I am slightly aware of networking activities and data sharing
52	DSE run a CIP program
55	eFarmer - www.spatialvision.com.au/efarmer Connecting Country - http://cwmp.spatialvision.com.au/svcwmp/ - web2

Case Summarises (3) – Comments on boundaries overlap or confusion with adjoining CMAs

Case #	Comments
1	Yes, there is some overlap with our Southern NRM groups but there are no issues
2	NRM/CMA boundaries are Local Government area based, rather than catchment based, making managing catchments administratively difficult (This is consistent across Tasmania)
3	All CMAs have access to similar state wide data. The extent of some spatial layers is isolated to small parts of individual CMAs, whilst many layers overlap multiple CMAs.
4	No, boundaries are determined by Basins
5	Our region is very dry with very little permanent surface water areas.
6	No
7	No, there is a clear delineation between areas NRM groups. There is some joint work undertaken via MOU
8	Northern Ag region to our north uses local government boundaries as regional boundary which overlaps our catchment boundary. Our catchment drains into the neighbouring catchment therefore we contribute to issues experienced in neighbouring catchment
9	Yes, they overlap, but no issues with that.
10	No, there are no boundary confusions between our neighbouring regional bodies. There has been considerable effort for collaborative efforts and sharing (especially with spatial skills and knowledge).
11	Yes - number of catchments cross boundaries with neighbouring CMA's - does not really create a management issue between the organisations - operational arrangements in place to deal with
12	No overlap. Some confusion between boundaries between the Regional body, Regional Councils, and some sub-catchments....the boundaries are close. No confusion, we just verbally agree on areas that we will manage with other Regional Groups.
13	No

14	No, I think the NRM boundaries have been sorted now. In earlier days perhaps but haven't heard much around the place with regards to boundary confusion with adjoining NRM regions. Pretty sure our catchments don't overlap either.
17	There are three NRM regions in Tasmania, for which there is no overlap. Within the southern region there are several 'sub regional' NRM groups some focussing on different areas of interest such as whole catchments others on municipal areas and there is confusion.
19	NRM boundaries are clearly define and it's not really an issue, even working across groups is not a problem as long as it's clearly define and transparent.
20	Yes, not a major issue
21	Yes, we have a shared catchment
22	None
23	Nil, Catchment Management Authority Boundaries are catchment based
24	No
25	No
27	Yes ongoing issues. Planning boundaries overlap catchment boundaries. eg overlap with other adjoining Regional Group, Council of Mayors, and Department of Infrastructure and Planning Regional boundary.
30	Yes, the catchment boundaries overlap and we are aware of that. Therefore, we are quite careful when using the boundaries to prevent confusion.
31	Yes, with other two adjoining catchments
33	No
34	No
35	No- Catchment boundaries seem straight forward. With the merger we are joining with another CMA so our boundary with them will be erased.
36	There are at least 5 active Landcare and an unknown number of Rivercare and other Community Groups overlapping with our boundaries.
37	Our land parcel sizes are very large in comparison to other parts

	of the state, therefore confusion is minimal.
38	Yes, we share boundaries with 5 other CMA's
40	No
41	Some area of shared interest and conflict
42	No being an Island our region is very distinct.
43	Just Landcare boundaries
44	We usually request data for all of Queensland, or all of southern Queensland. Some minor issues when obtaining information from NSW
45	No
46	There is no boundary overlap or confusion with adjoining groups; however, a small section of our catchment does cross over into the Northern Territory.
47	No
48	Often boundary confusion with customers - unaware of what catchment they belong to
49	We have a number of catchment areas that extend into other states and other NRM boards
50	No, Boundaries are Gazetted and there is no overlap
51	Cross-border catchment with South-western Victoria. We have a MOU in place to manage catchment cooperatively
52	In our catchment there are a few different boundaries for different functions eg waterway management, irrigation area all have slightly different boundaries and there is confusion
53	Nil
54	Due to relatively large property size, many landholdings straddle two catchments. Catchment boundaries are often arbitrary rather than following natural features or divides and landholders have difficulty in recognising their CMA
55	We have boundaries on the eastern and western boundaries which do not reflect the actual river catchments
56	Some issues on eastern side with adjoining NRM body

Appendix 7

Sample Social Network Analysis Data

(KIN Project Participants)

Q1.txt

FREEMAN'S DEGREE CENTRALITY MEASURES

Diagonal valid? NO
Model: ASYMMETRIC
Input dataset: Frequency of Interactions
(C:\Users\paudyal\Desktop\Chapter 6\Network Analysis\Analysis\Q1\Frequency of Interactions)

		1 OutDegree	2 InDegree	3 NrmOutDeg	4 NrmInDeg
1	DERM	73.000	36.000	81.111	40.000
2	RGC	66.000	38.000	73.333	42.222
11	BMRG	60.000	21.000	66.667	23.333
8	NQ Dry Tropics	53.000	26.000	58.889	28.889
7	Terrain	51.000	28.000	56.667	31.111
13	SW NRM	49.000	23.000	54.444	25.556
5	N Gulf	45.000	27.000	50.000	30.000
12	Desert C	44.000	23.000	48.889	25.556
3	Torres Strait	37.000	25.000	41.111	27.778
14	QMDC	31.000	29.000	34.444	32.222
10	Fitzory	21.000	26.000	23.333	28.889
16	Condamine	21.000	23.000	23.333	25.556
15	SEQ	3.000	25.000	3.333	27.778
9	Reef	0.000	28.000	0.000	31.111
4	Cape York	0.000	31.000	0.000	34.444
6	S Gulf	0.000	27.000	0.000	30.000
17	Landcare Groups	0.000	37.000	0.000	41.111
18	Farmers/Land Holders	0.000	45.000	0.000	50.000
19	Knowledge Coordinators	0.000	36.000	0.000	40.000

DESCRIPTIVE STATISTICS

		1 OutDegree	2 InDegree	3 NrmOutDeg	4 NrmInDeg
1	Mean	29.158	29.158	32.398	32.398
2	Std Dev	25.261	6.218	28.068	6.909
3	Sum	554.000	554.000	615.556	615.556
4	Variance	638.133	38.659	787.818	47.728
5	SSQ	28278.000	16888.000	34911.113	20849.383
6	MCSSQ	12124.526	734.526	14968.552	906.823
7	Euc Norm	168.161	129.954	186.845	144.393
8	Minimum	0.000	21.000	0.000	23.333
9	Maximum	73.000	45.000	81.111	50.000
10	N of Obs	19.000	19.000	19.000	19.000

Network Centralization (Outdegree) = 51.420%
Network Centralization (Indegree) = 18.580%

Note: For valued data, the normalized centrality may be larger than 100.
Also, the centralization statistic is divided by the maximum value in the input dataset.

Actor-by-centrality matrix saved as dataset FreemanDegree

Running time: 00:00:01
Output generated: 02 Jun 11 11:52:28

FREEMAN'S DEGREE CENTRALITY MEASURES.txt

FREEMAN'S DEGREE CENTRALITY MEASURES

Diagonal valid? NO
Model: ASYMMETRIC
Input dataset: Rate of Flow of Spatial Information_Matrix (C:\Users\paudyal\Desktop\Chapter 6\Network Analysis\Analysis\Q2\Rate of Flow of Spatial Information_Matrix)

		1 OutDegree	2 InDegree	3 NrmOutDeg	4 NrmInDeg
1	DERM	41.000	38.000	82.000	76.000
7	BMRG	34.000	16.000	68.000	32.000
2	RGC	30.000	35.000	60.000	70.000
6	NQ Dry Tropics	20.000	19.000	40.000	38.000
3	Torres Strait	20.000	17.000	40.000	34.000
5	Terrain	19.000	21.000	38.000	42.000
4	N Gulf	17.000	21.000	34.000	42.000
10	QMDC	16.000	17.000	32.000	34.000
8	Desert C	15.000	19.000	30.000	38.000
9	SW NRM	13.000	18.000	26.000	36.000
11	Condamine	13.000	17.000	26.000	34.000

DESCRIPTIVE STATISTICS

		1 OutDegree	2 InDegree	3 NrmOutDeg	4 NrmInDeg
1	Mean	21.636	21.636	43.273	43.273
2	Std Dev	8.824	7.202	17.649	14.404
3	Sum	238.000	238.000	476.000	476.000
4	Variance	77.868	51.868	311.471	207.471
5	SSQ	6006.000	5720.000	24024.000	22880.000
6	MCSSQ	856.545	570.545	3426.182	2282.182
7	Euc Norm	77.498	75.631	154.997	151.261
8	Minimum	13.000	16.000	26.000	32.000
9	Maximum	41.000	38.000	82.000	76.000
10	N of Obs	11.000	11.000	11.000	11.000

Network Centralization (Outdegree) = 42.600%
Network Centralization (Indegree) = 36.000%

Note: For valued data, the normalized centrality may be larger than 100. Also, the centralization statistic is divided by the maximum value in the input dataset.

Actor-by-centrality matrix saved as dataset FreemanDegree

Running time: 00:00:01
Output generated: 02 Jun 11 16:49:14

FREEMAN'S DEGREE CENTRALITY MEASURES.txt

FREEMAN'S DEGREE CENTRALITY MEASURES

Diagonal valid? NO
Model: ASYMMETRIC
Input dataset: Level of Trust_matrix
(C:\Users\paudyal\Desktop\Chapter 6\Network Analysis\Analysis\Q4\Level of Trust_matrix)

		1 OutDegree	2 InDegree	3 NrmOutDeg	4 NrmInDeg
5	Fitzory	45.000	31.000	100.000	68.889
6	BMRG	36.000	30.000	80.000	66.667
1	RGC	36.000	38.000	80.000	84.444
8	SW NRM	33.000	30.000	73.333	66.667
3	Terrain	29.000	33.000	64.444	73.333
2	N Gulf	28.000	32.000	62.222	71.111
9	QMDC	28.000	26.000	62.222	57.778
4	NQ Dry Tropics	28.000	33.000	62.222	73.333
10	Condamine	27.000	30.000	60.000	66.667
7	Desert C	26.000	33.000	57.778	73.333

DESCRIPTIVE STATISTICS

		1 OutDegree	2 InDegree	3 NrmOutDeg	4 NrmInDeg
1	Mean	31.600	31.600	70.222	70.222
2	Std Dev	5.643	2.939	12.539	6.532
3	Sum	316.000	316.000	702.222	702.222
4	Variance	31.840	8.640	157.235	42.667
5	SSQ	10304.000	10072.000	50883.949	49738.273
6	MCSSQ	318.400	86.400	1572.346	426.667
7	Euc Norm	101.509	100.359	225.575	223.021
8	Minimum	26.000	26.000	57.778	57.778
9	Maximum	45.000	38.000	100.000	84.444
10	N of Obs	10.000	10.000	10.000	10.000

Network Centralization (Outdegree) = 33.086%
Network Centralization (Indegree) = 15.802%

Note: For valued data, the normalized centrality may be larger than 100.
Also, the centralization statistic is divided by the maximum value in the input dataset.

Actor-by-centrality matrix saved as dataset C:\Users\paudyal\Desktop\Chapter 6\Network Analysis\Analysis\Q3\Centrality and Power\FreemanDegree

---

Running time: 00:00:01
Output generated: 03 Jun 11 22:26:55

```
                                          ucinetlog31.txt
DENSITY / AVERAGE MATRIX VALUE
--------------------------------------------------------------------------------

Input dataset:                          Frequency of Interactions
(C:\Users\paudyal\Desktop\Chapter 6\Network Analysis\Analysis\Q1\Frequency of
Interactions)
Output dataset:                         Frequency of Interactions-density
(C:\Users\paudyal\Desktop\Chapter 6\Network Analysis\Analysis\Frequency of
Interactions-density)


                                     Avg Value        Std Dev
                                -------------- --------------
    Frequency of Interactions          2.5530         1.2693


----------------------------------------
Running time:  00:00:01
Output generated:  02 Jun 11 11:40:57
UCINET 6.339 Copyright (c) 1992-2011 Analytic Technologies
```

Appendix 7: Sample Social Network Analysis Data (KIN Project Participants)

```
                      Rate of Flow of Spatial Information_Matrix.txt
DENSITY / AVERAGE MATRIX VALUE
--------------------------------------------------------------------------------

Input dataset:                          Rate of Flow of Spatial Information_Matrix
(C:\Users\paudyal\Desktop\Chapter 6\Network Analysis\Analysis\Q2\Rate of Flow of Spatial
Information_Matrix)
Output dataset:                         Rate of Flow of Spatial
Information_Matrix-density (C:\Users\paudyal\Desktop\Chapter 6\Network
Analysis\Analysis\Rate of Flow of Spatial Information_Matrix-density)


                                                     Avg Value        Std Dev
                                                -------------- --------------
    Rate of Flow of Spatial Information_Matrix          2.1636         1.3110


----------------------------------------
Running time:  00:00:01
Output generated:  02 Jun 11 16:30:14
UCINET 6.339 Copyright (c) 1992-2011 Analytic Technologies
```

```
                              DENSITY_AVERAGE MATRIX VALUE.txt
DENSITY / AVERAGE MATRIX VALUE
--------------------------------------------------------------------------------

Input dataset:                          Rate of Flow of Spatial Information_Matrix
(C:\Users\paudyal\Desktop\Chapter 6\Network Analysis\Analysis\Q3\Rate of Flow of Spatial
Information_Matrix)
Output dataset:                         Rate of Flow of Spatial
Information_Matrix-density (C:\Users\paudyal\Desktop\Chapter 6\Network
Analysis\Analysis\Rate of Flow of Spatial Information_Matrix-density)


                                                     Avg Value        Std Dev
                                                  -------------- --------------
    Rate of Flow of Spatial Information_Matrix          3.4818         1.1734


----------------------------------------
Running time:  00:00:01
Output generated:  03 Jun 11 16:46:17
UCINET 6.339 Copyright (c) 1992-2011 Analytic Technologies
```