Building SDI Bridges for Catchment Management

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Abstract

This research paper discusses the importance of spatial data and Spatial Data Infrastructure (SDI) for catchment management. It reviews four SDI theories including hierarchical spatial theory, diffusion theory, evolution theory and principal-agent (P-A) theory and discusses their characteristics and potential utilisation for catchment management. As catchment management issues are characterised by multi-level stakeholder participation in SDI implementation, the theory of hierarchy and the P-A theory may assist in exploring in greater depth the context of building SDI at the catchment level. Based upon existing SDI theory, it explores a conceptual framework and its implications for more effective development of catchment-based SDI. The framework which is based upon hierarchical theory, investigates the community-government interaction between various catchment and administrative/political levels for developing SDI. Such a framework is complex and potentially has many levels. Additionally, the cross-jurisdictional linkages required to implement this framework within the existing administrative/political SDI framework also need to be carefully examined. The framework is explored through a case study of the Murray-Darling Basin in Australia, one of the world's largest catchments. The challenges for developing an SDI which effectively supports the decision making within and across this catchment will be discussed and the potential strengths and weakness of the proposed framework identified in the context of this case study.

Keywords: spatial data infrastructure (SDI), catchment management, spatial data, natural resource management, SDI Theory.

1. INTRODUCTION

Spatial data plays an important role in many social, environmental, economic and political decisions (McDougall and Rajabifard, 2007) and is increasingly acknowledged as a national resource essential for sustainable development (Warnest, 2005). Accurate, up-to-date, relevant and accessible spatial data is essential in addressing various global issues such as climate change, urban change, land use change, poverty reduction, environmental protection and sustainable development. One of the potential areas where spatial data can make a positive impact is for improved decision making to support catchment management. Reliable spatial data infrastructure (SDI) is needed to record the environmental, social and economic 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 spatial data often have different scale, content and formats. By building an appropriate SDI, disparate spatial data can be accessed and utilised to facilitate the exchange and sharing of spatial data between stakeholders across catchment communities.

SDI is a dynamic, hierarchic and multi disciplinary concept that encompasses policies, organisational remits, data, technologies, standards, delivery mechanisms and human resource dimensions (Rajabifard, 2007). SDI can also be viewed as a portal where

each stakeholder can access, use, and exchange spatial data for social, economic and environmental well-being (Feeney et al., 2001; McDougall, 2006). In many countries, SDI is regarded as a necessary component of the basic infrastructure required to efficiently support the operations and economic development of the nation. SDIs have been developed to manage and better utilise our spatial data assets by considering the needs and information flows from the local level, up through state, national and regional levels and finally to the global (GSDI) level. This has resulted in the emergence of varying forms of SDI at, and between, these levels (Hjelmager et al., 2008).

Although Australia is recognised internationally as a leader in SDI development and spatial information management, current SDI initiatives are more heavily dominated by national mapping agencies and state government organisations (Warnest, 2005). Currently, this SDI hierarchy is focused on SDI development at different political-administrative levels, ranging from local to state/provincial, national, regional and global levels (Chan and Williamson, 2001; Rajabifard and Williamson, 2001). However, catchment management issues cut across political-administrative boundaries and do not follow the rules of political-administrative hierarchies. Catchments have their own socio-spatial extents and coverage and could be considered to be community centric in nature and therefore more closely aligned to local government. Although local government has extensive local knowledge and experience in catchment management, an integrated management approach with a greater emphasis on community involvement is required to achieve sustainable catchment outcomes. Government organisations, business and community groups are the main stakeholders in catchment management. Unfortunately, the sharing of spatial data among these groups is generally characterised by a one way flow of spatial data. The majority of catchment data is government managed and there is limited spatial capacity within the many catchment groups. 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).

The aim of this research paper is to explore a conceptual or theoretical framework for building or developing SDI from a catchment management perspective. The framework is then explored through a case study of the Murray-Darling Basin in Australia, one of the world's largest catchments. The challenges for developing an SDI to effectively support the decision making within and across this catchment will be discussed and the potential strengths and weakness of the proposed framework are identified.

2. CATCHMENT MANAGEMENT AND SDI

A catchment can be defined as a natural collection area where all rainfall and run-off water eventually flows to a creek, river, lake, ocean or into the groundwater system. Natural and human systems such as rivers, bush land, farms, dams, buildings, infrastructures, plants, animals and people co-exist in a catchment (Sydney Catchment Authority, 2008). Catchment management involves consideration of land use and land use change in relation to the land and water resources and the consequential effects on runoff and groundwater, as well as the effects of changes on land use (Laut and Taplin, 1989).

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 co-ordinated 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.

On the other hand, ICM has a philosophy for achieving the long-term sustainable use of land, water and related biological resources. It aims to coordinate the activities of landholders, community groups, industry groups and all spheres of government within the river catchment (CCMA, 2001). ICM 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 jurisdictions in Australia.

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.

SDI can facilitate access to the spatial data and services through improving the existing complex and multi-stakeholder decision-making process (Feeney, 2003; McDougall and Rajabifard, 2007). Moreover, it can facilitate (and coordinate) the exchange and sharing of spatial data between stakeholders within the spatial data community. A preliminary step toward 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 duplication of data acquisition efforts (Masser, 2005; Rajabifard et al., 2003a).

Various researchers (Rajabifard et al., 2000; Rajabifard et al., 2002; Rajabifard and Williamson, 2001) argue 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 among different levels of SDIs is complex due to the dynamic, inter- and intra-jurisdictional nature of SDIs (Rajabifard et al., 2003a). However, this perspective, although useful, does not encompass the many complex relationships that operate between jurisdictions nor does it recognise the varying institutional objectives. The hierarchical model for SDI development therefore needs to be re-examined for the purpose of catchment management as catchment issues cut across jurisdictional and administrative/political 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, the catchment hierarchy is somewhat different to this administrative hierarchy. In catchment environments, the hierarchy begins from farm level and extends to the sub-catchment, catchment up to the basin level (see Figure 1).

Figure 1: Interrelation between administrative hierarchy and catchment hierarchy.
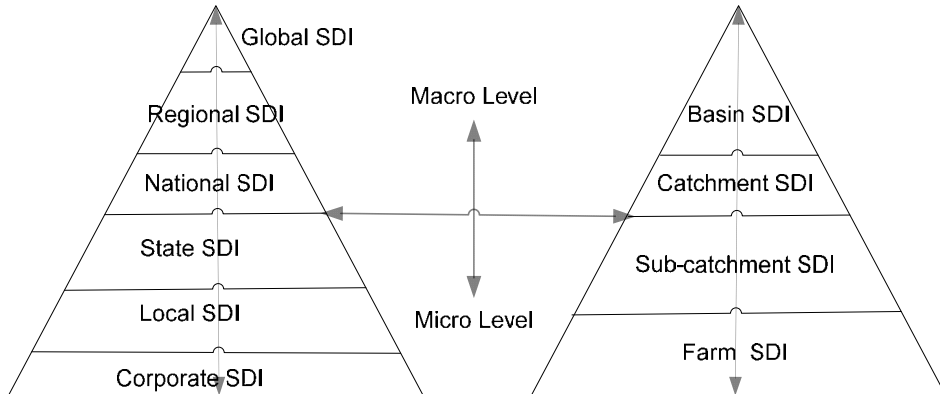
The existing SDI hierarchy for SDI development does not readily fit neatly with catchment management as their issues extend beyond the jurisdiction of administrative/political boundaries and can often cross the territorial boundaries of several countries. Therefore, it is important to explore the extent to which hierarchical government environments contribute to the various components of SDI development and which SDI framework might be suitable for achieving catchment management objectives.

3. SDI THEORETICAL FOUNDATION

Many countries are developing SDI from the local to global level to better manage and utilise their spatial data for promoting economic development, to support better government and to foster environmental sustainability (Masser, 1998). SDI development is supported by various theoretical backgrounds. The following section describes some of the important theories relevant to the development of SDI for catchment management.

3.1 Hierarchical Spatial Theory and SDI Hierarchy

In the past much 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., 2001; Timpf and Frank, 1997). Examples of hierarchical applications include classification of road networks (Car et al., 2000), 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 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 (i.e. national, regional) with their spatial data needs. Rajabifard (2002) made use of hierarchical reasoning in his work on SDI structures in which a 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.

3.2 Diffusion Theory and SDI Diffusion

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 relation 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, which has constituted 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 (2001) means that some degree of uncertainly is involved in diffusion.

The theory of diffusion as an innovation model (Rogers, 1995) is appropriate for the study of SDI diffusion, though the diffusion of innovations model has been criticised for its pro-innovation bias. This can be seen in the statements that are made in connection with SDI development which constantly stress its positive impacts in terms of promoting economic growth, better government and improved environmental sustainability (Masser, 1998). 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 a 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.

3.3 Evolution Theory and SDI Evolution

The creation of SDIs is a long term task that may take years or even decades in some cases before they are fully operational. This process is likely to be an evolving one that will also reflect the extent to which the organisations that are involved re-invent themselves over time (Masser, 2006). Rogers (1995) defines reinvention as 'the degree to which an innovation is changed or modified by a user, in the process of its adoption and implementation. The concept of SDI first emerged in the mid 1980s around the need for cooperation and sharing of spatially-related information across countries and organisations. In Australia, national land-related information initiatives commenced with a government conference in 1984 which eventually led to the formation of a committee responsible for national SDI development. Likewise, in USA discussion about the national SDI initiatives started around 1989, primarily in the academic community (National Research Council, 1999) and progressed rapidly after the executive order from the President's Office was issued in 1994 (Gore, 1998)

This national SDI development has been coined the first generation of national SDI initiatives and the motivations were in reducing duplication, using resources more effectively, and creating a base from which to expand industry productivity and the spatial market. It was a "product based" approach and the coordinators of SDI developments were dominated by National Mapping Agencies. The second generation of national SDI initiatives started around 2000 when some of the leading nations on SDI development changed their development strategies and updated their SDI conceptual models (Rajabifard et al., 2003b). This approach is "process based" and includes people as a component of SDI and the interoperability of data and resources. The concept of more independent organisational committees or partnership groups representative of different stakeholders is now tending to dominate SDI development.

3.4 Principal Agent Theory and Partnerships and Collaboration

According to neo-institution economics (NEI), 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 there are three aspects that are considered. The first aspect is the definition of who has authority/responsibility (principal) and who is carrying out work on the behalf of an authority (agent). The second aspect 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 percep-

tions 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.

As catchment management issues is characteristics by multilevel stakeholder participation in SDI implementation, the theories of hierarchies and P-A may assist in exploring in greater depth the context of building SDI at catchment scale. Table 1 summarises the various SDI theory, main contributors of that theory in spatial science domain, their characteristics, strengths, limitations, and value for catchment governance.

Table 1: Summary of SDI theoretical foundation and their contribution to catchment SDI development.

SDI Theory/ Citation	Contributors in Spatial Science Domain	Characteristics	Strength	Limitations	Value for Catchment Governance
Hierarchical Spatial Theory (Car, 1997)	(Car et al., 2000; Chan and Williamson, 2001; Rajabifard, 2002; Rajabifard et al., 2002; Timpf and Frank, 1997; Rajabifard et al.,2003)	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)	(Campbell and Masser,1995; Chan and Williamson, 2001; Gattiker, 1990; Pinto and Onsrud, 1993; Rajabifard, 2002; Spence, 1994; Rajabifard et al., 2003)	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	Diffusion and adoption of innovation through the catchment community is important
Evolution Theory (Rogers, 1995)	(Rajabifard et al., 2003)	An innovation is changed over time or modified by a user	User centric and dynamic	May be less important over multiple organisations	Process based SDI model or new model is appropriate
P-A Theory (North, 1990)	(Harvey, 2001; McDougall, 2006; Nedovic-Budic and Pinto, 1999; Wehn de Montalvo, 2003)	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 across catchments

Hierarchical spatial theory 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 be easily accommodated by these theories. These relationships are particularly important for catchment governance. The diffusion theory describes the

spread of a new idea from its source to the ultimate users. The concept of SDI has emerged from developed economies and 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 a degree of uncertainty involved in it. Diffusion theory is also applicable for catchment management as new ideas are spread through the community and stakeholders via diffusion. The evolution theory (Rogers, 1995) describes the dynamic nature of SDI as an innovation that is changed over time or modified according to users' requirement. The first generation of SDIs (product based) evolved into second generation (process based) and included people as a component of SDI and the interoperability of data and resources. Now, the third generation of SDIs are evolving where users play a vital role for information management (Budhathoki et al., 2008; Goodchild, 2008). The advent of spatial technology and web services provides the way for more inclusive and open models of spatial services where grass-root citizens and community groups with no prior experience in spatial technologies can participate. Google Earth, OpenStreetMap (www.openstreetmap.org) and Wikimapia (www.wikimapia.org) are a few examples where the custodianship of spatial data is no longer in the hands of mapping agencies but the vast majority of society who are utilising these products. The application of SDI for catchment governance and management may well utilise a new conceptual model of SDI within this environment. The Principal-Agent 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 the interests, importance and influence. This could be determined by an interest power matrix (De Vries, 2003). This then enables strategies to be developed for community led stakeholders participation to support catchment governance and management.

4. CONCEPTUAL FRAMEWORK DERIVED FROM SDI THEORETICAL FOUNDATION

From our understanding of the various theories which relate to SDI development a conceptual framework can be explored for catchment SDI. It is assumed that there are basically 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 large scale issues such as climate change, land use change and ecological system change. As Figure 2 illustrates, there are four management hierarchies in catchment governance including farms, sub-catchments, catchments and basin. 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 data in the form of a farm level SDI.

The sub-catchment authorities and other community groups share water, land and nature data with local government and sometimes other levels of government build sub-catchment SDI. Catchment authorities work towards the ecological sustainability of catchments. They share catchment data to state government and other levels of government. They work for the broad vision of natural resource management building catchment level SDI. The Basin SDI is the highest level of SDI hierarchy within the catchment management framework. The Basin SDI could be a part of Global Spatial Data Infrastructure (GSDI) or Regional SDI. In countries like Australia, Basin SDI covers the whole country or part of the country. For example, the Murray-Darling Catchment which stretches across four states and one territory is an example of Basin SDI. In some countries, it may cross the international boundaries.

**Figure 2: Conceptual framework: Applying hierarchical spatial theory.**
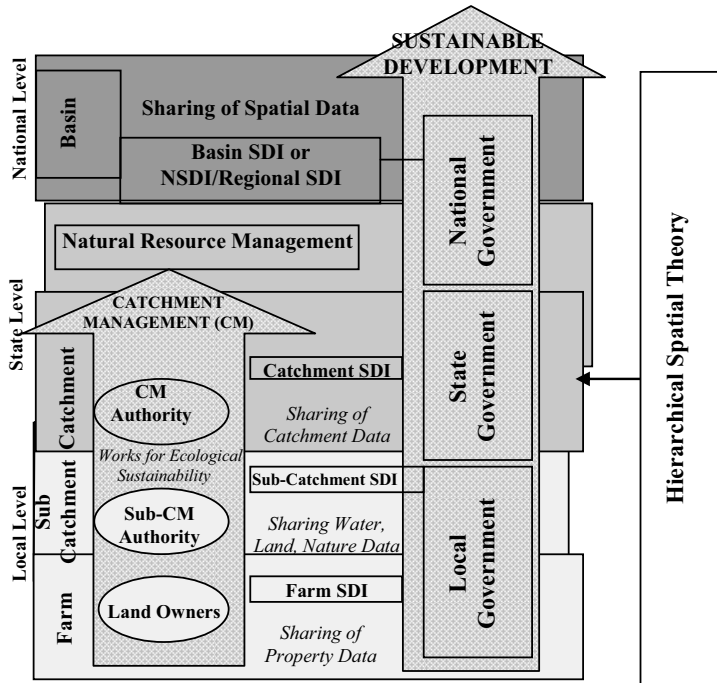
The emergence of catchment management authorities to facilitate improved local and regional outcomes for natural resource management now also introduces a multi-jurisdictional level of activity involving many stakeholders. Australia, like the USA, is a federation of states and understands the complexities of sharing and managing spatial data across three tiers of government. SDI development in Australia has been significantly constrained by these traditional jurisdictional structures which continue to slow our progress. Therefore, to support initiatives such as catchment management, it is important that new frameworks be examined which may facilitate improved SDI development at the catchment level.

The proposed framework modelled on the hierarchical spatial theory has a number of strengths and limitations. Firstly, if we examine the strengths of the proposed framework, we already know and understand the many formal and informal hierarchical structures and processes exist within a catchment environment. These structures and processes enable the modelling of responsibilities and hence potential data flows. For example, hierarchies of catchment SDI already fit nicely with existing management groups such as land care, farming groups and catchment management authorities. Secondly, stakeholders interact in a hierarchical fashion in many instances in line with existing institutional arrangements. Finally, the catchment authority's goals are often aligned to government priorities/goals and therefore a hierarchical framework is perhaps appropriate.

However, the framework also has a number of potential weaknesses. Perhaps the most obvious of these is the complex and large number of levels and cross-jurisdictional linkages which have the potential to dilute information flows and create

institutional complexities. This is particularly evident where the hierarchy in catchment SDI and administrative/political SDI do not align.

5. CASE STUDY

The purpose of this case study is to examine the proposed conceptual framework in the context of an operational catchment environment. The case study to be examined is the Murray-Darling Basin (MDB) which is an area of national significance for social, cultural, economic and environmental reasons in Australia. Administratively, the MDB falls under the four state government jurisdictions, namely Queensland, Victoria, New South Wales, South Australia and one territory, the Australian Capital Territory as shown in Figure 3. It includes the catchment of Australia's three longest rivers, the Darling (2,740 km), Murray (2,530 km) and Murrumbidgee (1,690 km) and their many tributaries (Australian Bureau of Statistics 2008). Both the MDB community and governments are partners in protecting the health and productivity of the MDB.

Figure 3: Case study area (Murray-Darling Basin Authority (MDBA)).

In the Murray Darling Basin, there are 22 Catchment Management Authorities (CMA) which work at local level forming catchment authorities and sub-catchment authorities for integrated catchment management. In addition, there are various volunteer groups (like landcare, bushcare, coastcare) and indigenous communities which also work at the grass-root level to achieve the integrated catchment management goals (Australian Bureau of Statistics, 2008). The three tier government structure (commonwealth, state and local) also exists to manage and utilise the resources of the basin in a way that is economically sustainable. Among the 22 CMAs, 4 are in Queensland, 9 are in New South Wales, 5 are in Victoria, 3 are in South Australia and 1 is in Australian Capital Territory. There are many overlaps and gaps between catchment boundaries and the administrative boundaries in Murray-Darling Basin. Figure 4 highlights the management hierarchies in catchment governance in the MDB.

Figure 4: Catchment management hierarchies in MDB.
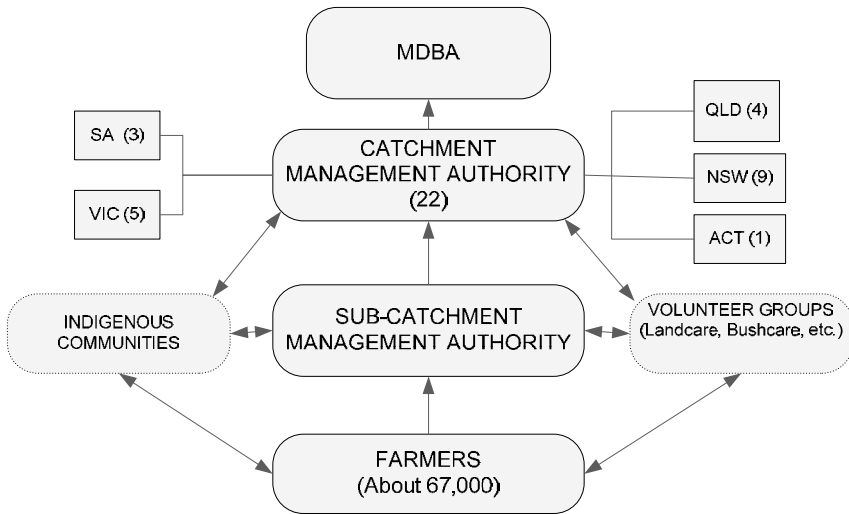
6. DISCUSSION

The spatial data obtained from MDBC and Australian Bureau of Statistics has been used to analyse the spatial interaction across the existing local governments and the catchments. Using spatial analysis tools, it can be shown that many catchments over-lap a number of local and state government boundaries. Table 2 shows the number of local government boundaries which within individual catchment boundaries. It is inter-esting to note that a large number of local authorities (more than 60%) straddle catch-ment boundaries, although the catchments are often larger than the local government authorities.

Table 2 illustrates the institutional complexities for building SDI for catchment man-agement. The proposed conceptual framework in section 4 has been examined using the case study of Murray-Darling Basin. As described in the conceptual framework, the main players are government organisations and community groups for catchment gov-ernance in MDB. The hierarchies of catchment management fit nicely with existing management groups such as land care, farming groups, indigenous communities and catchment management authorities as shown in Figure 4. There are good practices where stakeholders interact in a hierarchical fashion for better environmental outcomes

with existing institutional arrangements. Therefore, the proposed framework modelled on the hierarchical spatial theory is considered appropriate for building SDI at catchment level. However, the hierarchies in catchment and administrative/political SDI do not align so effective cross-jurisdictional linkages will be required to improve the efficiency of information flows and institutional arrangements. The large number of local government authorities and the disparity of spatial extents and boundaries require new and innovative approaches to manage spatial data across these environments.

Table 2: Local authorities status with catchment boundaries.

STATE (Name)	CMA (Number)	LOCAL GOVERNMENT AUTHORITIES (LGAs)			
		Number of LGAs that fall within catchment boundary	Number of LGAs that straddle catchment boundary (number)	Total	Proportion of LGAs that straddle catchment boundary in each state
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	0%
Total	22	54	116	170	

7. CONCLUSIONS

Spatial data and the development of SDI offer great potential for catchment managers and decision makers. Current SDI initiatives are generally dominated by national mapping agencies and state government organisations and modelled on the existing administrative/political hierarchies. However, catchment management issues do not follow the rules of these hierarchies and are community centric in nature. Therefore, there is a need to re-examine SDI development approaches to accommodate the needs of catchment governance and management.

Hierarchy theory holds some promise for building the community-government interaction required for SDIs at various catchment levels such as farm, sub-catchment, catchment and basin level. This framework is complex, having potentially many levels and linkages. The case study of the Murray-Darling Basin illustrates the complexity of the catchment management environment with a large number of local government authorities and a disparity of spatial extents and boundaries. There is no doubt that SDI holds some promise in solving these complex data management problems and can contribute the final goal of delivering improved catchment management outcomes.

ACKNOWLEDGEMENTS

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