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Evaluating Knowledge Production in Collaborative Water Governance

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ABSTRACT: Despite the crucial role of knowledge production in environmental decision-making, previous research provides limited practical insight into the knowledge-related outcomes that can be achieved through collaboration, or the associated determinants of success. In this multiple case study, knowledge production is analysed in a collaborative water allocation planning process in South Australia. A theoretical framework was developed and used to systematically evaluate and compare knowledge-related processes and outcome criteria across four planning catchments. Data sources included 62 semi-structured interviews, documents and personal observations. Most of the theorised outcomes were achieved across the cases; however, only one case had generated widespread acceptance among participants of the knowledge that was used to develop the water allocation plan. Comparing processes across the cases revealed key factors that influenced their outcomes. Ultimately, community participants across the cases had limited involvement in technical investigations, suggesting the need to re-examine expectations about the potential for joint fact-finding within collaborative processes that are limited in scope and duration and nested within broader state-driven processes.

KEYWORDS: Collaborative governance, knowledge production, water allocation planning, South Australia

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INTRODUCTION

Water management regimes are evolving in response to a growing emphasis on ecological values, meeting basic human needs, and re-evaluating the ties between economic growth and water use. Protecting in-stream uses of water has become a high priority in many countries, leading to efforts to clarify and redefine the rights of consumptive users relative to those who value the maintenance of stream flows for ecological, cultural, and recreational purposes. In the context of stream flow restoration, Hillman and Brierley (2002: 169) describe the decision-making process as "an iterative progression from data acquisition through information-gathering and the establishment of a knowledge base to decision-making". This perspective emphasises the importance of effectively linking knowledge to action in water governance, and the need to establish legitimacy and credibility among relevant stakeholders in the information that is used to make decisions (Cash et al., 2003). In practice, knowledge can be a source of major disputes as water managers, water users and other stakeholders attempt to determine an allocation of limited supplies, collectively considered to be fair and efficient.

This is illustrated in examples from Australia where the use of disputed data and science by government agencies to justify the reallocation of water from local consumptive uses to the environment has damaged trust among water managers and users and resulted in substantial criticism of policies (Kuehne and Bjornlund, 2006; Pigram, 2006).

These types of challenges have prompted recommendations for more collaborative approaches to water governance, where understandings of water conditions and decisions about the allocation of available water are determined collectively among scientists, resource managers, and water users (e.g. Lach et al., 2005; Morris et al., 2006). Collaboration exists in many forms but has been broadly defined as the sharing of power and responsibility among state and non-state actors in decision-making for environmental management (Carlsson and Berkes, 2005). There are characteristics commonly associated with collaborative processes that collectively distinguish them from participatory processes more generally. For example, collaborations are typically viewed as place-based initiatives, focused on issues within a catchment or sub-catchment (e.g. Sabatier et al., 2005). They involve multiple parties, including state and non-state actors, who have an interest or stake in the outcomes (e.g. Conley and Moote, 2003; Margerum, 2008). Many researchers view collaboration as a forum that meets over a long term or an indefinite period; however, some acknowledge that a collaborative process can also be finite in duration, over a shorter term (e.g. Leach et al., 2002; Innes and Booher, 2010). Arguably the most critical aspect of collaborative processes is that they provide a forum where participants are engaged directly in decision-making through a face-to-face, authentic dialogue (e.g. Innes and Booher, 2010). Watershed partnerships (e.g. Sabatier et al., 2005), advisory committees (e.g. Leach et al., 2002) and multi-stakeholder platforms (e.g. Warner, 2006) are examples of the types of processes and fora that exhibit these qualities.

In theory, collaboration provides opportunities to focus data collection, planning, and decision-making at more ecologically and hydrologically appropriate scales, and to engage resource users and their knowledge more effectively (Dovers, 2001). By integrating conventional scientific knowledge with alternative forms of knowledge (e.g. practical, experiential), it has been suggested that collaboration can produce a more contextualised and adaptive base of knowledge for addressing environmental problems (Neis et al., 1999; Berkes et al., 2000; Folke et al., 2005; Lane and McDonald, 2005). Importantly, collaboration has the potential to link knowledge to action (Cash et al., 2003), and can help to alleviate tension and conflicts over the knowledge used to make decisions (e.g. Margerum and Whithall, 2004; Fernandez-Gimenez et al., 2006).

Despite the crucial role that knowledge plays in environmental decision-making, criteria related specifically to knowledge production are often not included in frameworks for evaluating collaboration (e.g. Conley and Moote, 2003; Sabatier et al., 2005; Koontz and Thomas, 2006; Ryan and Bidwell, 2007; Rogers and Weber, 2010). Where the role of knowledge production in collaboration has been explicitly considered (e.g. Imperial, 1999; Innes and Booher, 2010; Brugnach and Ingram, 2012), related *process* and *outcome* criteria are not always specified adequately. Consequently, evaluations of actual collaborative processes to date have provided limited practical insight into what they can and cannot achieve, or how the process of knowledge production should be structured and run.

In this article, we draw from literature concerned with collaboration, knowledge, and environmental decision-making to develop a theoretical framework for evaluating knowledge production in collaborative governance processes. The framework is used to evaluate collaborative processes involved in the development of water allocation plans in four South Australian catchments. Our systematic evaluation of real-world cases of collaboration contributes to the collaborative environmental governance literature by providing insight into whether or not and how theorised process and outcome criteria for successful knowledge production are achievable in practice.

A FRAMEWORK FOR EVALUATING KNOWLEDGE PRODUCTION

Recent research and practice in the field of environmental governance have highlighted the potential benefits associated with collaboration, including outcomes related to knowledge production, and the conditions under which they may be achieved. Based on a review of this literature, we propose five characteristics related to collaborative processes and their outcomes that are indicators of successful knowledge production (Table 1).

Table 1. Characteristics of successful knowledge production in collaboration.

Characteristic	Indicator criteria	Sources
Process		
Effective communication among participants	Facilitators with 'interactional expertise' are involved in the process	Allen and Kilvington, 2005; Carolan, 2006; Brugnach and Ingram, 2012
	Use of technical jargon is avoided or adequately managed in the process	Jacobs et al., 2005
	Scientists communicate the methods, assumptions and uncertainty of their investigations to participants	Funtowicz and Ravetz, 1993; Innes, 1998; Hillman and Brierley, 2002; Ballard et al., 2008
	Field trips and workshops are used to promote common understanding of issues among participants	Feldman et al., 2006; Brugnach and Ingram, 2012
Participation by relevant and affected interests	All relevant interests (including indigenous) within the catchment are represented in the process	Innes and Booher, 1999; Berkes et al., 2000; Kapoor, 2001; Trachtenberg and Focht, 2005
	Scientists are involved 'at the table' in discussions of knowledge and related policies	Petts, 1997; Innes, 1998; Michaels, 2001; Fernandez-Gimenez et al., 2006
Joint fact-finding	Process is incorporating information from a variety of sources, including local knowledge	Neis et al., 1999; Berkes, 2004; Trachtenberg and Focht, 2005; Brugnach and Ingram, 2012
	Efforts are made to promote understanding of, and dialogue about, knowledge among participants	Lane and McDonald, 2005; Blackstock and Richards, 2007; Wallington et al., 2008; Hommes et al., 2009; Innes and Booher, 2010
Outcomes		
Understanding and acceptance of knowledge among participants	Participants understand the knowledge upon which decisions are based	Dietz et al., 2003; Dilling, 2007; Johnson, 2008; Innes and Booher, 2010
	Participants are aware of the limitations and uncertainty in the knowledge	Innes, 1998; Hillman and Brierley, 2002; Jacobs et al., 2005; Ballard et al., 2008
	Participants accept and agree to the knowledge base upon which policy decisions are based	Innes et al., 2004; Petts and Brooks, 2006; Dilling, 2007; Wallington et al., 2008; Johnson, 2008; Hommes et al., 2009

Enhanced civic trust and engagement	Participants have increased their knowledge about resource and ecological conditions in the catchment	Petts, 1997; Margerum, 1999; Dietz et al., 2003; Berkes, 2004; Ballard et al., 2008
	Participants have increased their knowledge about others' perspectives of resource use and its allocation in the catchment	Berkes, 2004; Castillo et al., 2005; Folke et al., 2005; Fernandez-Gimenez et al., 2006
	Trust has been generated among technical experts and community participants	Conley and Moote, 2003; Innes and Booher, 2010; Brugnach and Ingram, 2012

Process criteria

Effective communication among participants

The literature highlights numerous procedural factors that can promote effective communication among scientist and non-scientist participants in a collaborative process. Effective leadership and facilitation have been identified as critical for successful collaboration (Margerum, 1999; Leach and Pelkey, 2001; Blackstock and Richards, 2007; Brugnach and Ingram, 2012). In particular, some researchers have highlighted the importance of having individuals with 'interactional expertise' involved to enable the exchange and integration of different forms of knowledge (Carolan, 2006). A coordinator is needed who can enhance communication among scientists and non-scientists by providing access to technical information (e.g. helping to communicate information in an understandable way) and by promoting the integration of local knowledge in the process (Allen and Kilvington, 2005; Jacobs et al., 2005). A related communication challenge is reduction or elimination of technical and local jargon (Jacobs et al., 2005).

A special challenge for collaborative processes is dealing with uncertainty. There is a growing consensus that uncertainty needs to be openly discussed in decision-making processes (e.g. Funtowicz and Ravetz, 1993; Dietz et al., 2003). In a collaborative process, information only becomes 'shared knowledge' among all participants if its meaning, biases, and accuracy have been discussed satisfactorily (Innes, 1998). Effective collaboration requires knowledge providers to be open about the level of uncertainty and the reliability and validity of sources (Hillman and Brierley, 2002).

Recent studies have demonstrated the benefits of interaction among scientists and local participants in activities such as field trips and training workshops (Castillo et al., 2005; Ballard et al., 2008; Brugnach and Ingram, 2012). Feldman et al. (2006) describe such 'boundary experiences' as a way of facilitating the translation of information and ideas, and building a sense of community among participants by helping them to transcend their individual perspectives.

Participation by relevant and affected interests

There is a broad consensus among many collaboration researchers that representation of all relevant and affected interests is essential (e.g. Innes and Booher, 1999; Kapoor, 2001; Conley and Moote, 2003). From this perspective, processes must allow for fair consideration of the views of a full range of participants, including their perceptions of environmental conditions (Trachtenberg and Focht, 2005). In this context, scholars and practitioners are increasingly recognising the importance of engaging Indigenous communities through collaboration (e.g. Berkes et al., 2000; TRaCK, 2010) – although the extent to which collaboration as conventionally conceived is an appropriate vehicle for doing so is contested (von der Porten and de Loë, in press).

Innes (1998) contends that in a collaborative process, technical experts should not simply issue facts and offer professional opinions at arm's length. Instead, scientists should be 'at the table', participating directly in discussions on information and policy issues. Previous research has suggested that involving scientists directly in a collaborative process can benefit both the scientists and other participants, and is often essential to success (Petts, 1997; Fernandez-Gimenez et al., 2006). For example, Michaels (2001) found that a Massachusetts watershed technical advisory group ceased to function as an effective vehicle for information exchange once technical personnel withdrew from the process.

Joint fact-finding

Collaboration is often thought to provide a stronger information base for decision making through integrating local sources of knowledge with external sources of expertise (Berkes, 2004). 'Joint fact-finding' is a term used to characterise processes where the knowledge used to make decisions is identified collaboratively (Innes and Booher, 2010). Joint fact-finding is premised on the view that phenomena can only be understood in context and cannot be isolated or studied in a strictly abstract way (Innes and Booher, 2010). Trachtenberg and Focht (2005) contend that in contexts where high uncertainty exists, all relevant sources of knowledge should be considered, with justification provided for ultimately relying on one source over the others. Unfortunately, systematic collection of knowledge from actors such as landowners is not always straightforward. Major challenges include the fact that landholder knowledge on local resource use and the environment is seldom available on a collective basis (Allen and Kilvington, 2005), and that most planning processes lack formal mechanisms to collect and incorporate such information (Hillman and Brierley, 2002).

To effectively integrate and use multiple sources of knowledge, collaborative processes must provide fora where different perspectives can be openly debated and discussed (Blackstock and Richards, 2007). Dialogue about knowledge in a collaborative process can weed out dubious findings, make explicit underlying assumptions and biases held by the knowledge providers, and dismiss unsupported claims (Innes and Booher, 2010). Knowledge gains legitimacy "where it is established within an open context of engaged criticism between experts and non-experts" (Wallington et al., 2008: p.18). Therefore, it is essential that collaborative processes foster well-structured dialogues among scientists and community participants about knowledge of the environment and human-environment systems (Dietz et al., 2003). Critical debate and argumentation are viewed as being crucial to social learning (e.g. Armitage et al., 2008; Hommes et al., 2009), building trust and social capital among participants, and promoting understanding and acceptance of information (Innes and Booher, 2010). Importantly, social learning is purported to de-emphasise which types of knowledge are valid in decision-making and instead views knowledge production as a dynamic process that is contingent on knowledge – regardless of the source – being "formed, validated and adapted to changing circumstances" (Berkes, 2009: 153).

Outcome characteristics

Understanding and acceptance of knowledge among participants

Collaboration can increase understanding and acceptance among participants of the knowledge that is used to make decisions (Innes and Booher, 2010). Reliable and credible information on resource conditions has been identified as the foundation for successful management (Ostrom et al., 1999). Genuine consent relies on participants being fully informed (Trachtenberg and Focht, 2005), while significant tension can manifest in a process if there are inconsistent expectations regarding the level of certainty of technical information (Hillman and Brierley, 2002). For information to be meaningful and used effectively, it must be understandable, and end users, including the public, must be confident in its quality (Dietz et al., 2003; Dilling, 2007; Johnson, 2008). Petts and Brooks (2006) stress that scientific information is not automatically accepted by the public. Rather, the credibility of information is critically evaluated and judged by those affected by, or otherwise interested in, the issues of concern. Ultimately, participants' acceptance of, and agreement with, the base of knowledge that is used to make decisions will determine whether or not a collaborative process will result in community acceptance and ownership of problems and solutions (Syme et al., 1999; Wallington et al., 2008).

Enhanced civic trust and engagement

Mutual learning and trust building among participants have been identified by several researchers as critical indicators of success in collaborative initiatives (e.g. Petts, 1997; Innes and Booher, 1999; Margerum, 1999; Conley and Moote, 2003; Berkes, 2004; Blackstock and Richards, 2007). Through collaboration, participants learn new ideas, become aware of each other's perspectives and recognise that others' views are legitimate. Ultimately, a successful collaborative process can build considerable trust among the participants in the community (Innes and Booher, 2010). These outcomes resemble products of social learning, which can be defined as "a process of iterative reflection that occurs when we share our experiences, ideas and environments with others" (Armitage et al., 2008: 88).

COLLABORATIVE ENVIRONMENTAL GOVERNANCE IN CONTEXT: SOUTH AUSTRALIAN EXPERIENCES

Over the past two decades, Australian governments have reformed their water management institutions in response to ecological, economic and social pressures caused by severe and recurring water shortages (Pigram, 2006; Stoeckel and Abrahams, 2007). The reform process reached an important milestone in 2004 when the Council of Australian Governments (COAG) signed the *National Water Initiative* (NWI), a comprehensive water policy statement for the country. Among other things, the NWI committed state governments to addressing over-allocated or stressed water systems within their jurisdictions (COAG, 2004). Under the agreement, statutory water plans were identified as the primary mechanism for determining how much water within catchments is available for consumptive uses, and for ensuring that sustainable levels of extractions are achieved and maintained. Responsibility for water planning has been assigned to catchment-based management authorities. An overarching priority of the NWI is to engage water users and other stakeholders in achieving the objectives of the agreement (COAG, 2004).

Since the establishment of the NWI, water reforms in Australia have continued at a fast pace in response to concerns about the inadequacy of previous actions to achieve their environmental objectives and severe drought conditions that continued to plague southern Australia. A 2009 assessment of NWI implementation was critical of the progress made by states in returning over-allocated catchments to environmentally sustainable levels (NWC, 2009). At the same time, widespread drought has resulted in critical environmental degradation in the Murray-Darling Basin and across southern Australia. High-profile cases of ecological decline, such as in the Lower Lakes and the Coorong in South Australia, were linked to a combination of drought and unsustainable levels of extraction.

In the midst of these challenges, the Australian Government further expanded its role in water policy and management, especially within the Murray-Darling Basin. In April 2008, the Australian Government introduced the *Water for the Future* plan with accompanying funding of $12.9 billion. A key initiative under the plan was the *Restoring the Balance in the Murray-Darling Basin Program*, which aimed to purchase $3.1 billion worth of water entitlements over 10 years within the basin to be used to protect or restore environmental assets. By the end of 2009, the government had purchased 766 million m^3 (Mm^3) of water entitlements worth over $1.2 billion (Commonwealth of Australia, 2010). The government's decision to use a large-scale entitlement buy-back scheme in the Murray-Darling Basin has been linked to failures of state-led water planning efforts to adequately secure water for the environment (e.g. Loch et al., 2011). The *Commonwealth Water Act 2007* and 2008 *Intergovernmental Agreement on Murray-Darling Basin Reform* introduced further institutional changes, including the establishment of the Murray-Darling Basin Authority. The new authority was given responsibility for developing a basin-wide plan, including environmentally sustainable diversion limits for the basin's surface water and groundwater resources.

We completed the fieldwork for this study between January and July 2008. Our main focus was on the statutory planning aspects of the NWI and in particular, the water allocation planning process in South Australia. Water planning under the NWI is being implemented in South Australia through a water allocation planning framework established under the *Natural Resources Management Act 2004*. The Act divides the state into eight regions – each with its own Natural Resources Management Board (NRM Board) consisting of a combination of community members and state agency representatives with knowledge and experience in natural resources management. The NRM Boards are responsible for developing regional management plans, contributing to state-level planning, and for developing and delivering local programmes and promoting community engagement and education. Under the Act, the NRM Boards are required to prepare water allocation plans for each of the catchments and/or groundwater areas within their jurisdiction that are deemed to be at risk and have been 'prescribed' through regulation. The legislation outlines the required scope and contents of plans, as well as the technical matters to be investigated in their preparation. Water allocation plans are required to be reviewed and updated as needed every five years. The plans are used by the state Department for Water (department) to direct the issuance of water entitlements, annual allocations and end-use licences, to manage the trading of water among entitlement holders, and to permit water-affecting activities (e.g. dam and bore construction) within the area. While the major focus of the plans is the future allocation and management of available water within catchments, they are also the means by which stressed water systems are returned to sustainable levels of extraction. Therefore, there is potential for plans to directly impact some existing water users.

NRM Boards must consult with the public on the proposed structure of the plan (a 'concept statement') and on a draft version of the plan. In addition to these legislated consultation requirements, many NRM Boards have formed community advisory committees to collaborate with catchment stakeholders more directly in preparing the plan. The committees are formed of water users, industry and interest-group representatives, and catchment residents chosen by the Boards from individuals who have expressed an interest in participating. The number of participants on the committees varies depending on the size of the prescribed area, as well as the number of water users and variety of water uses within the catchment. The committees are facilitated by a plan coordinator from the presiding NRM Board and are typically chaired by one of the catchment representatives. Committees typically meet face-to-face every one to three months; however, the frequency of meetings can vary depending on the stage of the planning process.

In sum, a collaborative process is being used by NRM Boards in South Australia to develop water allocation plans within their jurisdiction. The specific form of collaboration occurring within the South Australian system is consistent with the perspective on collaboration offered by Ansell and Gash (2007), which emphasises joint decision-making among state and non-state actors, as well as Leach et al.'s (2002) characterisation of 'advisory committees' in that they operate over a finite period to address a specific project, programme or regulation. Most important in characterising collaboration in our South Australian case is the fact that the collaborative processes are nested within a more traditional, top-down governance structure. The advisory committees function within a legislative framework that defines the issue and prescribes the terms of reference for technical investigations. Moreover, the knowledge needed to develop the water allocation plans is largely generated by state agency scientists. While the NRM Boards collaborate with the advisory committees to develop draft water allocation plans, the plans are submitted to the department for review and approval. Ultimately, decisions determining how water is allocated within catchments rest with state officials. Relative to the evaluative framework presented above, this clearly has implications for the collaborative processes and their outcomes.

METHODS

A qualitative case study approach enabled us to consider the unique characteristics of real-world collaborative processes while examining, in depth, the interests, attitudes, and knowledge of the individuals who were involved directly in the processes (Margerum, 1999; Gerring, 2007). We used multiple cases to permit comparison of collaborative efforts across cases and to reveal how variations in the processes and contexts may influence their outcomes (Conley and Moote, 2003; Yin, 2003).

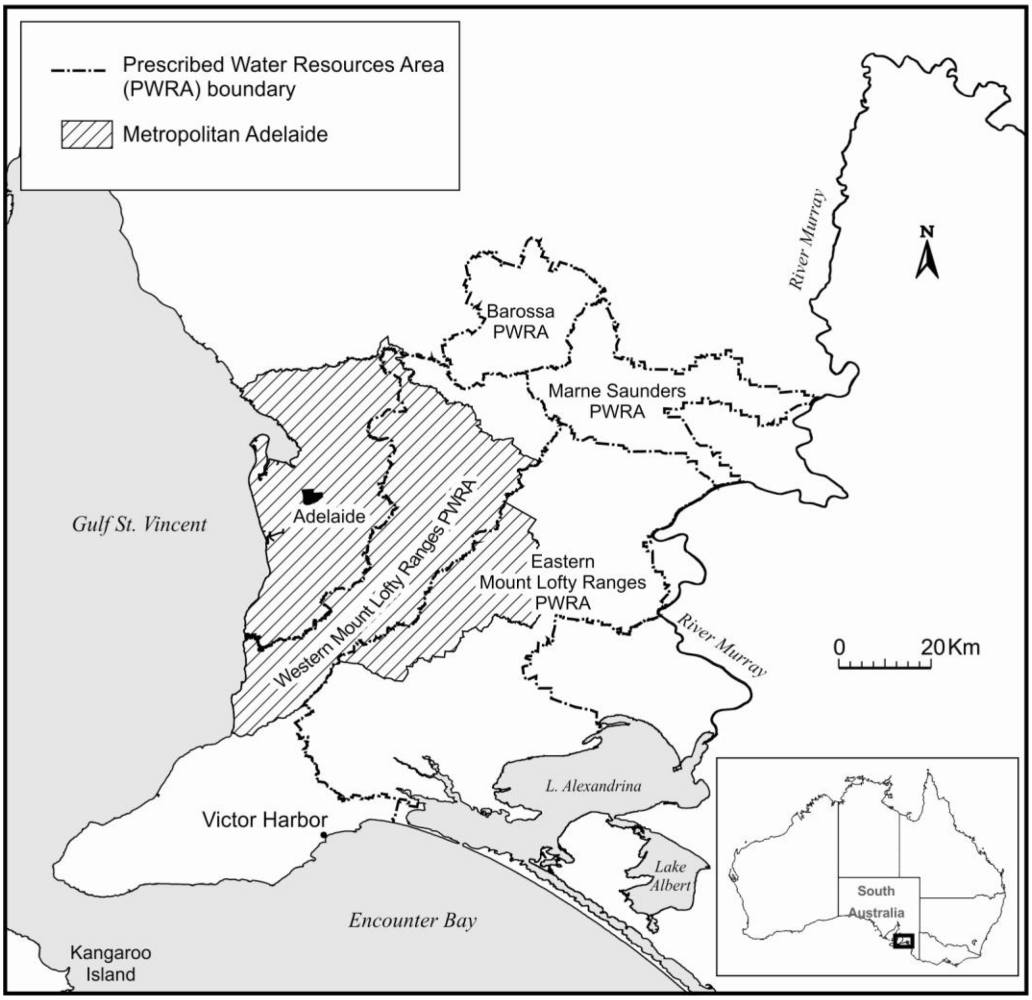
Case study areas

As shown in Figure 1, four prescribed water resources areas were selected as case studies in South Australia: Western Mount Lofty Ranges (WMLR); Eastern Mount Lofty Ranges (EMLR); Marne Saunders (Marne) and Barossa Valley (Barossa). These catchments were selected on the basis that (1) a water allocation plan was being developed, (2) the responsible NRM Board had formed a community advisory committee to support collaborative plan preparation, (3) the process had produced tangible outputs (e.g. draft policies or a draft plan), and (4) planning participants, including advisory committee members and government agency staff, were accessible and willing to participate in the research. These criteria limited the number of case study areas available for the study, which admittedly introduces potential bias in our case selection. As evidenced below, however, the four cases analysed in this study reflect a range of environmental conditions (resource types, precipitation patterns, topography, catchment size) and water use characteristics (urban versus rural settlement, various agricultural and industrial uses) that exist within South Australia.

The Adelaide and Mount Lofty Ranges NRM Board was responsible for water allocation plans in the Barossa and WMLR areas. The Barossa area is centred approximately 60 kilometres north-east of Adelaide and covers a total area of 711 km^2. In addition to surface water and groundwater sources, water is imported to the region via the Barossa Infrastructure Limited scheme. Some irrigators in the region also hold River Murray water entitlements, which are delivered through SA Water infrastructure (Adelaide and Mount Lofty Ranges NRM Board, 2009). There are 560 water allocation licences issued across the area which equate to approximately 11 Mm^3/year of licensed water use. Approximately two-thirds of both the licence and volume totals are for groundwater use (Adelaide and Mount Lofty Ranges NRM Board, 2009). Over 90% of water use in the Barossa area is for irrigation purposes. Grape vines are by far the dominant irrigated crop, with some water used for pasture and lucerne. A water allocation plan for the Barossa area was adopted in December 2000. In 2004, the plan was reviewed and it was determined that a new plan was required. At the time of this research, the NRM Board was in the process of preparing the new plan, in collaboration with the nine-member North Para Water Allocation Plan Advisory Committee.

The WMLR area covers approximately 2750 km^2 to the immediate east and south of Adelaide. The area includes eight surface water catchments and three major water courses. Eight reservoirs are distributed through five of the catchments, supplying 60% of metropolitan Adelaide's water requirements in an average year (Adelaide and Mount Lofty Ranges NRM Board, 2010). Development of water resources within the WMLR area, including reservoirs supplying water to the city of Adelaide, has been most extensive in the Central Hills region. Consequently, water users within this region were expected to be significantly more constrained under a new water allocation plan than users within other parts of the catchment. Within the WMLR area, there are approximately 11,500 wells, 13,000 dams and 250 watercourse extraction points, a major portion of which is used to irrigate 15,500 ha of agricultural crops (Adelaide and Mount Lofty Ranges NRM Board, 2010). Pasture is the main irrigated crop, comprising 39% of the total irrigated area; however, grape vines (34%) and fruit and nut trees (18%) also cover a significant portion (Adelaide and Mount Lofty Ranges NRM Board, 2010). Commercial forestry is prominent in the WMLR area, with over 15,000 ha of forest production throughout the catchment. There are also water-dependent ecosystems in the WMLR area, including swamps in the southern portion of the catchment which have been listed as critically endangered ecological communities under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*.

Figure 1. Location of the case study areas.



At the time of this research, the WMLR plan was being developed by the NRM Board, in collaboration with three advisory committees representing subregions within the broader WMLR area: the Central Hills Water Allocation Plan Advisory Committee (nine members); the McLaren Vale Water Allocation Plan Advisory Committee (seven members); and the Fleurieu Water Allocation Plan Advisory Committee (nine members). The committees met independently during the planning process, although joint committee meetings were also held periodically to review and discuss technical information and policy issues across the entire catchment. While the department typically provides technical support to the preparation of water allocation plans throughout the state, for the WMLR plan, the NRM Board had also contracted with the department to assist in the development of the plan itself.

The Marne and EMLR areas are within the jurisdiction of the South Australian Murray-Darling Basin NRM Board. The Marne area covers 743 km^2, lies approximately 70 km north-east of Adelaide, and encompasses the catchments of the Marne River and Saunders Creek. The water resources within the Marne area were prescribed in 2003. At the time of this research, the Board was in the process of preparing the first water allocation plan for the catchment, in collaboration with the eight-member

Marne Saunders Water Resources Planning Committee. The estimated water demand in the Marne area is 7.5 Mm^3/year; almost 70% from groundwater sources (South Australian Murray-Darling Basin NRM Board, 2009). Some water is used for stock and domestic, industrial, and intensive livestock purposes; however, over 95% is for irrigation (South Australian Murray-Darling Basin NRM Board, 2009). The main irrigated enterprises in the Marne area include lucerne, grape vines, and olives. There are also several water-dependent ecosystems.

The EMLR area is 50 km east of Adelaide and covers 2,845 km^2. It contains 16 surface water sub-catchments, incorporates the eastern slopes of the Mount Lofty Ranges and the Murray Plains and lies within the Murray Darling Basin. Land use in the EMLR area is dominated by grazing and cropping which account for 77% of the total area (South Australian Murray-Darling Basin NRM Board, 2011). Other land uses include pasture and irrigated horticulture (7%), and more intensive uses, such as urban settlement, mining, industry, and manufacturing (5%). The annual water demand in the EMLR area is estimated to be 13 Mm^3 from surface sources and 32 Mm^3 from groundwater (South Australian Murray-Darling Basin NRM Board, 2011). The area contains wetlands of national significance and the confluence of two creeks that originate in the catchment is part of an internationally listed Ramsar site: the Coorong and Lake Alexandrina and Albert Wetland.

Water resources in the EMLR area were prescribed in 2005. The area includes the Angas Bremer catchment, which was first prescribed in 1980. At the time of this research, a water allocation plan was being prepared for the entire EMLR area and would replace the existing Angas Bremer plan. The Board was working in collaboration with two separate advisory committees, representing the northern and southern regions of the area; however, the two committees began meeting jointly shortly after the start of the process. The combined committee included 19 members.

Data collection and analysis

Semi-structured interviews, documents and personal observations of advisory committee meetings were used to examine knowledge production in the case study processes. Between March and July 2008, 62 interviews across the four cases were completed by the lead author with members of the advisory committees, and with department and NRM Board personnel who were involved in the process as policy and scientific advisors or as plan coordinators. A summary of the participants interviewed for the study is shown in Table 2. Questions were asked to gain insights into the process, in general, and into specific issues pertaining to the evaluative framework (see Table 1). For example, participants were asked if they felt they understood and accepted the knowledge that had been used to inform the water allocation plans and whether they felt the process had enhanced their knowledge of both water resources and other stakeholders' interests within their catchment. Interviews ranged between 60 and 90 minutes and were digitally recorded and transcribed verbatim.

A total of 137 documents were analysed for the study. Minutes of advisory committee meetings provided records of committee discussions about technical information. Draft water allocation plans, policy discussion papers and technical investigation reports were also key sources of information on how knowledge was produced in the process. They also provided information on the hydrological, ecological, water use, and socio-economic characteristics in the study catchments.

Table 2. Characteristics of interview participants by sector and case.

Sector	Barossa	Marne	WMLR	EMLR
State government	1	2	5	3
NRM Board	3	1	4	2
Land manager	2	6	7	10
Industry/business	3	0	3	2
Other	0	0	7	1
Total	9	9	26	18

Between February and July 2008, the lead author attended a total of 11 advisory committee meetings covering all of the cases. At these meetings, he was able to directly observe the dynamics of the committee process, including the presentation and discussion of technical information and associated water allocation plan issues. Observations were recorded as written notes and included in the analysis.

Interview transcripts, documents and observation notes were analysed using QSR NVivo 8, a qualitative data analysis software package which helped to systematise analytical procedures and facilitate storage and management of data. All data were reviewed line-by-line and coded into analytic categories corresponding to the indicator criteria in the evaluative framework (see Table 1). Evaluative conclusions were then made for each of the indicator criteria by assessing the coded evidence. For many criteria, multiple sources of data were used to cross-check evidence and verify findings. Observations at advisory committee meetings and references in meeting minutes allowed us to, for example, validate claims by interview respondents that they understood and accepted the knowledge produced in the process.

RESULTS

Effective communication among participants

Facilitator with interactional expertise

We found facilitators with interactional expertise to be present in all of the cases; however, the form and relative effectiveness of the facilitators differed across cases. Each of the nine interview participants in the Marne case and 18 participants in the EMLR case identified the plan coordinator from the NRM Board as the main facilitator. Typical comments from the committee members about these individuals included "good broker between the committee and the scientists" and "really practical – has the technical knowledge but also the broader perspective", indicating that they had brought interactional expertise to the process. This was confirmed by our observations and in the minutes of meetings of the Marne and EMLR advisory committees.

Participants in the Barossa and WMLR cases identified a range of individuals who helped to facilitate communication among scientists and community members in the process, including committee chairpersons, NRM and departmental representatives, and committee members with relevant subject area expertise. Despite the lack of a single dedicated facilitator, seven of nine interview participants in the Barossa case and 20 of 26 participants in the WMLR case felt that their discussion on technical information had been effectively facilitated. Only one participant in the Barossa case and six in the WMLR case identified major problems with the facilitation of technical discussions in the process. In the WMLR case, a few participants expressed frustration that departmental policy staff present at committee meetings were often unable to address important technical issues during discussions. A farmer and Barossa committee member pointed to staff turnover at the NRM Board and department as a problem – an issue also apparent in the committee meeting minutes. To effectively facilitate the process, he felt that at least five years of experience was needed to understand the local area and its residents.

Avoiding or managing technical jargon

The interviews indicated that the use of technical jargon was generally avoided or adequately managed in all of the cases. Seven of nine interview participants in each of the Barossa and Marne cases, 11 of 18 participants in the EMLR case and 16 of 26 participants in the WMLR case described the use of "good, understandable language" by scientists and an effort to use terms consistently. Community participants also reported having a good understanding of technical and landholder jargon through previous experiences and indicated that committee members would simply ask if a technical term needed to be clarified. To avoid an excessive use of jargon in the EMLR process, the plan coordinator described "sitting down with scientists to go through their presentations, making sure they weren't too technical". Public discussion papers, draft plans and technical reports typically included glossaries with explanations of key terms, abbreviations, and units of measurement.

There was some evidence that technical jargon was an issue in the WMLR process. Ten of the 26 participants, including agency and community representatives, expressed concern about the highly technical language used by departmental scientists when communicating with the WMLR advisory committees. Participants also reported the inconsistent use of certain terms (e.g. well versus bore, headwaters versus 1st order stream) among departmental presenters. Communication issues were also evident in the documents and personal observations from the WMLR case. There were references in the minutes of WMLR meetings to problems related to technical terminology and the need for the use of clearer and more consistent definitions in public documents related to the plan. Frustration was also observed among community representatives over technical terms at a number of WMLR committee meetings.

Communication of uncertainty and limits of knowledge

There was clear evidence in the meeting minutes for each case that there were regular discussions among committee members and scientists about the methods and data sources used in the technical investigations, and their associated limitations. Further, most of the planning and technical documents that were reviewed contained descriptions of investigation methods and knowledge gaps and limits. The department and NRM Board representatives in each case felt that methods, data sources and levels of uncertainty associated with the technical information had been adequately explained to the committees. For example, the plan coordinator in the Marne case explained that "for each major piece of technical work, the author came along and went through what they did, how they did it and why". Similarly, a departmental hydrogeologist working on the WMLR plan recalled that "we've outlined the inaccuracies and there hasn't been any attempt to put it over on them, saying things we don't know".

Use of field trips and workshops

Interviews and meeting minutes indicated that events such as field trips and workshops were used to a limited extent in the Marne, EMLR and WMLR cases. Early in the process, the Marne advisory committee participated in a field trip to investigate low flow dam bypasses in a nearby catchment. The meeting minutes of the EMLR committee referenced a field trip to learn about significant wetland habitats within the area. The Central Hills and Fleurieu committees in the WMLR area also used field trips to investigate issues relating to their policy discussions. The Central Hills committee toured a sub-catchment to develop a more practical understanding of how different aquatic habitat types had been characterised within the plan. There was no evidence that such an event had been organised during the current planning process in the Barossa case.

Participants across the cases generally recognised the benefits of field trips as a means of sharing information and building a practical understanding of water allocation issues. On the Central Hills sub-catchment tour, we witnessed technical experts from the NRM Board and department sharing ideas and discussing issues informally with committee members throughout the tour. Participants across all of the cases expressed frustration at the lack of such events. A member of the McLaren Vale committee in the WMLR area described the importance of "seeing the practical side" of the water allocation issues and was critical that his committee had been "making all these decisions by sitting around tables eating minties". Notably, there were a few participants across the cases who questioned the value of field trips, particularly given the time constraints on both department and community representatives. They felt that committee members should already have a practical understanding of issues in their catchment. One EMLR committee member remarked that diagrams and photos presented at meetings had been sufficient for their needs.

Participation by relevant and affected interests

Representation of all relevant interests

About half of the participants in each case were generally satisfied with the composition of the advisory committees and felt that the major water use sectors and geographic regions within each area were adequately represented. However, participants also expressed some concern about the absence of certain interests from the process. The four plan coordinators acknowledged that aboriginal communities within their areas had not been sufficiently engaged. A NRM Board representative on the Marne committee described this as a "big failing of the process", particularly given the recent commitments by Australian governments under the NWI to provide water for cultural and spiritual purposes. While participants in the EMLR case generally felt that industry and existing water users were adequately represented in the process, four of the 18 participants said that environmental and social interests were missing. Notably, two of the nine participants in the Marne case expressed that the membership of their committee was skewed towards non-licensed water users and environmental interests, and voiced concern that the committee's endorsement of the draft plan and its technical basis provided a false sense of security and was probably not representative of the broader community.

Scientists 'at the table'

The meeting minutes from each case indicated that technical experts from the department and NRM Boards interacted on a regular basis with all of the advisory committees. In contrast, the interviews revealed that participants' satisfaction with the level of involvement of scientists varied considerably among the cases. Seven of nine participants in the Marne case and 14 of 18 in the EMLR case were satisfied with how technical experts had been engaged. According to a farmer on the Marne committee, "the right people were there to present the various components". In contrast, over half of the 17 community participants in the WMLR case were critical of the lack of opportunity to discuss technical issues with the scientists. In the Barossa case, while a departmental groundwater scientist was involved as a member of the advisory committee, six of the nine participants criticised the lack of involvement of surface water experts in the process.

Committee members in the WMLR and EMLR cases raised two noteworthy issues related to the quality of scientists' participation in the process. First, participants felt that confusion had resulted from multiple scientists presenting and interacting with the committee at different times on similar topics. A farmer on one of the WMLR committees commented that "at times, we don't know who we're listening to or where they're coming from. If the same people are feeding you information regularly, you can question and get to know those people". In the WMLR case, almost half of the 17 community participants criticised the poor communication skills of some of the scientists, which limited their ability to discuss technical issues when they had opportunities to meet the experts face-to-face.

Joint fact-finding

Incorporating local knowledge

The technical investigations in all of the cases were conducted almost exclusively by departmental scientists. Technical reports and planning documents from each case also revealed that the investigations primarily relied on government data sources, such as departmental gauging stations to estimate surface water flow and run-off, Bureau of Meteorology stations for rainfall data, and departmental borehole data to determine well locations and yields.

The document and interview data provided examples in each case where investigators had used multiple sources of data, including community and landholder data, to determine, for example, allocation limits for fractured rock aquifers, fish species distribution, stock and domestic water requirements, and dam capacities of surface water. In a few of these instances, landholder knowledge was collected in a systematic way to supplement or help validate other information sources. For instance, a mail survey of catchment residents organised by the Marne advisory committee was used along with mapping, aerial photography and published data to estimate livestock and domestic water demand in the catchment. In the WMLR case, workshops were held with irrigators to validate the department's water demand estimates for individual sub-catchments. In the EMLR case, stream-flow data collected by a local catchment group were used to fill gaps in departmental data sources for hydrological modelling.

Participants across all of the cases reported that the technical investigations were conducted independently of the committee. In fact, the technical reports and meeting minutes reviewed from each case revealed that investigations were often initiated, and in some cases completed, prior to the committees being formed. For example, the Barossa committee largely relied on information produced during the previous water allocation planning process. A study of environmental water requirements in the Marne area was completed before the advisory committee was formed. The common practice was to present the technical information to the committees at or near the completion of the investigations to inform their discussions on water allocation issues. As a NRM Board participant in the WMLR case described, "the committees were more involved in how information was used in a policy sense".

Notably, only three of 26 participants in the WMLR case and two of 18 participants in the EMLR case raised any concern about the reliance on the department for technical knowledge in the process. Some expressed apprehension related to a perceived conflict of interest in the government conducting the technical investigations and approving the plan. An industry representative on one of the WMLR committees felt that the technical aspects of the plan were "not getting the level of independence that the process deserves" and would have preferred consultants conducting the technical investigations rather than public servants. One participant in each of the WMLR and EMLR cases expressed concern about being forced to accept the results of the department's investigations because it was the sole source of information. According to a farmer on the EMLR committee, "it's the only opinion we get and no one's got the financial resources to argue that it's not right".

Promoting understanding of, and dialogue about, knowledge

There was evidence in the interviews, documents, and observations for each case that a substantial effort was made to educate participants about the technical information being produced and used in the process. Key technical components, such as identifying environmental water requirements, were presented to committees many times during the process. It was also evident that additional presentations and discussions were organised, as required, to help committees to understand technical issues. A departmental representative in the WMLR case explained that they had "offered as many meetings as required" and had "certainly made the hydrologists, hydrogeologists, and ecologists available to the committees". A WMLR committee member confirmed, "we've been encouraged to ask for additional presentations, so there haven't been any restrictions". There were also examples in each case of NRM Board and departmental representatives responding to specific technical questions or requests for additional information from committee members at subsequent meetings. In the EMLR case, due to concern by the committee of modelled surface water management boundaries, finer scale maps of the proposed boundaries were produced so that members could consider what they would "mean on the ground".

The extent to which participants had the opportunity to question, challenge and debate technical information during the process varied considerably among the cases. All interview participants in the Marne case were satisfied with the extent to which technical information was examined and discussed by the committee. Discussions on knowledge at Marne committee meetings were described as negotiable, with ample opportunity to question and debate technical information. Participants in the Marne case pointed to missed deadlines and lengthy meetings during the process as evidence of their close examination of technical knowledge. One committee member reflected that they had "gone over due dates because we were getting into the details and sorting it out so that everyone was happy before leaving the table". Lengthy and repeated discussions on technical information among participants were also evident in the committee's meeting minutes. Participants in the Marne case also emphasised the willingness of departmental scientists to review their technical information and re-run hydrological models in response to requests and challenges from the committee.

In contrast, four of the nine participants in the Barossa case and seven of the 18 participants in the EMLR case expressed concern about the lack of opportunities the committee had to digest and discuss technical information. Participants in both cases attributed this to the time constraints of committee meetings. A farmer on the Barossa committee commented, "we only had two hours at meetings, had an agenda to stick to and really didn't get that into [the technical] part of it". Under these circumstances, participants in both the Barossa and EMLR cases acknowledged the need for the committee to eventually end discussions, make decisions and "get on with things". According to an industry representative on the Barossa committee, "the chairs allowed debate [about the technical information] but also had to remain mindful of the boundaries and deliverables of the process".

In the WMLR case, strong criticism about time pressures and inadequate discussion of technical information was widespread among advisory committee members. Departmental and NRM Board participants acknowledged the constraints that the tight timelines had placed on the process in terms of explaining and discussing the technical information with the committees. A comment by one of the NRM Board representatives was illustrative of the situation: "everything is happening so quickly and people are being bombarded with all of this information – it would have been nice to have more time". An observation by the chair of one of the WMLR committees reinforced further insights gleaned from plan documents, meeting minutes and personal observations into how technical information was presented to, and discussed by, committees:

> The science is often rolled into proposed policies and rules. So you get straight into gut reactions to policies instead of having discussion around technical issues and understanding. As far as trying to manage a structured process of introducing the information and then providing an opportunity to discuss it and debate it and then resolving a position – we'll there's a two-stage process there that you have to run. In our case, it's been lumped together.

Understanding and acceptance of knowledge

Participants' understanding of knowledge

Participants in each case were generally satisfied with their level of understanding of the knowledge being used to develop their water allocation plan. We also witnessed a strong familiarity by committee members with the technical information at advisory committee meetings in the Marne and WMLR cases. Several participants across the cases qualified their level of understanding in some way. Some felt that they had only understood the technical details on certain topics or geographic areas. One committee member in the EMLR case admitted to being selective in his efforts to understand the technical information and "shutting off on some things", depending on the topic or who was speaking. Only one committee member in each of the Barossa, WMLR, and EMLR cases admitted to having a limited understanding of the technical information. A farmer on the EMLR committee explained that he strictly understood "the basics" of the technical information and felt contented to "leave that to the hydrologists".

Participants' awareness of knowledge limits and uncertainty

Participants in each case were universally aware of limitations and uncertainty associated with the knowledge that was being used to develop water allocation plans. This was clearly evident from interviews and was confirmed in the minutes and personal observations of committee meetings. In fact, many participants associated their high level of understanding of the technical information with being aware of its limits and gaps – "understanding enough to know about the holes in the science", according to one WMLR committee member. Some participants described deficiencies in knowledge for particular areas of their catchment (e.g. the Fleurieu Peninsula in the WMLR catchment) or specific aspects of the water resources (e.g. fractured rock aquifer systems) or their use (e.g. estimates of water demand by stock and domestic users). A major limit of the technical information, highlighted mainly by participants in the larger EMLR and WMLR areas, was the inability of regional scale modelling to capture the local variability that exists at finer scales. This was most evident in the Central Hills region of the WMLR area. Even within the smaller areas, however, some community representatives cautioned that technical information produced by the department was inconsistent with the knowledge of local landholders. For example, a farmer in the Barossa case described having 73 year's worth of rainfall data for his property that would "show a different picture to what they look at".

Participants' acceptance of knowledge

The extent to which participants were willing to accept and agree to the knowledge that was produced in the process varied considerably among the cases. This was revealed primarily in the interviews but also observed at meetings of the advisory committees. In the Marne case, all committee participants were accepting of the knowledge basis of the plan, despite its recognised limits. Notably, their acceptance was highly contingent on adopting an adaptive approach to water allocation planning. Recognising the urgency to improve management of the water resources in the catchment, participants in the Marne case expressed the need to proceed with water allocations based on the best available knowledge – "drawing a line in the sand", according to a farmer on the advisory committee – but also emphasised the need to continue monitoring and studying the resource and the importance of evaluating and potentially adjusting policies in the future.

Fewer than half of participants shared this perspective in the other cases. The more common opinion in the Barossa, EMLR and WMLR cases, particularly among community representatives, was that much of the technical information was too broad brush to support a meaningful and defendable plan. A few of the agency representatives in these cases expressed similar reservations. A NRM Board participant in the WMLR process commented, "we seem to be developing some policy without complete science – that's a risk to us and the department".

Enhanced civic trust and engagement

Knowledge of resource conditions

All nine participants in the Barossa and Marne cases said that their involvement in the planning process had significantly increased their understanding of water resource conditions in the catchment. A few participants in each area described having some previous understanding from living or working in the area, but that the process helped to build on that knowledge. For example, one farmer on the Barossa committee felt that the process had confirmed what he had previously observed and "put it into technical terms". Similarly, the plan coordinator in the Marne case said that she had gained a more specific, in-depth understanding of water and ecological conditions in the catchment through her involvement in the process.

While most participants in the WMLR and EMLR cases also described gaining knowledge on resource conditions through the process, three participants in each of these larger areas indicated that their knowledge of resource conditions had not changed substantially. A farmer on the WMLR committee admitted to being sceptical of the technical information available for the area and therefore felt that he had not gained a good understanding of the water resources in the catchment. An industry representative on the EMLR committee attributed his failure to adequately learn about the water resources to the large size of the catchment and his unfamiliarity with its geography.

Knowledge of others' perspectives

There were mixed results among the cases regarding whether participants had increased their awareness and understanding of others' perspectives towards water in the catchment. Our findings based on interview data were substantiated by observations of the advisory committee meetings attended.

Seven of nine participants in the Marne case and 11 of 18 participants in the EMLR case felt strongly that they had gained this type of knowledge through the process of participation. Community representatives in each case described gaining a better understanding of water use issues faced by other sectors or in other parts of the catchment than their own. A few participants in the Marne and EMLR cases admitted that the process had influenced their deeper core values towards water allocation. For example, a catchment resident and non-irrigator on the Marne committee claimed to have gained strong empathy for water users in the area through their interaction on the committee and altered his former view of irrigation as a "wasteful and illegitimate practice".

In contrast, four of nine participants in the Barossa case felt that they had not been enlightened through the process to other participants' water use issues and practices. They claimed to have been familiar with water use issues among various sectors in the catchment prior to their involvement. In the WMLR case, 14 of 26 participants admitted to having gained only a limited understanding of the issues faced by water users in other parts of the large area. Community representatives in the WMLR case also expressed concern that the departmental representatives lacked an appreciation of some of the unique practical issues associated with water use in specific locations within the catchment. Notably, across all of the cases, the department and NRM Board participants acknowledged that the process had improved their knowledge of the practical issues faced by water users, as well as the social implications associated with the water allocation policies being considered.

Trust among participants

There was conflicting evidence regarding the level of trust that had been gained among scientists and community participants in the cases. While we witnessed positive working relationships in all of the advisory committees based on the meetings attended, the interviews revealed variable outcomes among the cases. All nine participants in the Marne case reflected positively on the level of trust achieved through the process. They described a casual relationship, familiarity and high level of trust among the group and commented that community representatives and scientists alike were open to asking each other questions during and outside of committee meetings.

Over half of the participants in each of the other three cases expressed concern about trust among participants. Importantly, most of the concerns related to an underlying and pre-existing personal distrust of government in general, rather than to specific issues with participants directly involved with the advisory committees. For example, a viticulturalist on the EMLR committee emphasised that he had gained respect for the NRM Board and departmental scientists involved in the process but held strong disdain for the government officials, or "faceless men downtown".

In the WMLR case, the structure and organisation of the process appeared to have created barriers to building trust among the participants. For one, the inconsistent involvement of departmental scientists with the advisory committees left many community participants feeling less familiar with the technical experts than in the other cases. Several WMLR committee members also cited a lack of connection between the three individual advisory committees as a barrier to developing more trust among the community participants through the process.

DISCUSSION

In this study, we proposed a framework for evaluating knowledge production in collaborative governance processes and applied the framework to four water allocation planning processes in South Australia. By systematically evaluating four real-world cases of collaboration, we offer insight into whether theorised outcomes related to knowledge production are achievable in practice and the requisite process elements for success.

For information to be meaningful and used effectively in environmental decision-making, end users, including the public, must understand it and have confidence in its quality (Cash et al., 2003; Dietz et al., 2003; Dilling, 2007; Johnson, 2008). Previous research on collaborative approaches has suggested that collaboration can increase the understanding and acceptance among participants of the knowledge used to make decisions (Innes et al., 2004). To varying degrees, we found evidence of this in our four cases. Most participants in each case understood the knowledge produced in the process and were keenly aware of its limitations. Only participants in the Marne case demonstrated an acceptance of *and agreement with* the knowledge that formed the basis for their recommended plan. The majority of participants in the other three cases felt that the technical knowledge of their catchment was too broad-brush to support a defendable plan.

We also evaluated whether the planning process had enhanced civic trust and engagement within the catchment communities. With noted exceptions, the majority of participants in all our cases had increased their understanding of water resources and ecosystems in their catchments, and better understood the perspectives of others towards water use and water allocation issues. There was also evidence that trust was built among the community participants, NRM Board personnel and departmental scientists who were directly involved with each of the advisory committees. These findings are consistent with previous studies which have shown that collaboration can lead participants to become more aware of each other's perspectives and recognise that others' views and knowledge are legitimate (e.g. Castillo et al., 2005; Fernandez-Gimenez et al., 2006; Giordano et al., 2010).

Comparing our evaluation of process criteria across the four cases, we can gain an insight into the factors that may have influenced the knowledge-related outcomes that were achieved. Most importantly, there was limited evidence of joint fact-finding in any of the cases. The technical investigations were primarily conducted by departmental scientists and community participants had little direct involvement in their design and execution. Further, there were few examples in each case of local knowledge being accessed and used in the investigations. For the most part, technical information was provided to participants at or near the completion of investigations which the committees considered in developing their plans. Notably, we found that there was little expectation among participants across all of the cases that community representatives would have a direct role in producing technical knowledge for the plan. These findings contrast sharply with current ideas in the literature about how local participants in a collaborative process should be engaged in knowledge production. Collaboration is widely promoted in the literature as a means of promoting the 'co-production' of knowledge – a process that considers "a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem" (Armitage et al., 2011: 996).

We suggest that the lack of involvement of community participation in the technical investigations may reflect characteristics of collaboration in South Australian water allocation planning that distinguish it from other forms of collaboration that allow more direct involvement of local actors in knowledge production. The advisory committees were situated within a broader legislated process that defined the issue, the range of policy options, and the terms of reference for technical investigations. The development of the plans was a relatively short-term exercise and, in all but the Marne case, time was found to be a severe constraint on the committee process. In contrast, collaborative processes that are less formal and broader in scope and duration are typically engaged throughout an entire policy cycle, from problem definition and policy adoption to implementation and evaluation (Leach et al., 2002). Local participants in such processes often have more opportunity to be directly involved in the planning, design and execution of technical studies.

To varying degrees, we found evidence that the remaining process characteristics in our framework were present among the cases. This may help to explain why, despite a lack of joint fact-finding, successful outcomes were achieved. For example, participants across the cases understood and were aware of the limits of the knowledge that was produced and used to develop the water allocation plans. In each process, we found a concerted effort by the NRM Boards and the department to educate community representatives in the technical information pertaining to water resources and ecological conditions in the catchment. During presentations and discussions on technical information, scientists were open and clear about the methods of their investigations and the uncertainty and limits associated with the results. Further, technical terminology, or 'jargon', was generally avoided or explained when necessary. With the exception of the Barossa case, field trips were successfully used (albeit to a limited extent) to build understanding among participants of contentious or complex technical and policy issues. This finding supports claims that 'boundary experiences' can facilitate the translation of information and ideas and build a sense of community among participants by helping them to see beyond their individual perspectives (Feldman et al., 2006).

The Marne and EMLR processes each had a dedicated, active and strong coordinator (Bellamy and Johnson, 2000) who was able to act as an effective broker between scientists and non-scientists. Though the Barossa and WMLR advisory committees also had various participants who offered "interactional expertise" (Carolan, 2006), they appeared to lack a clear leader and facilitator. These differences may help explain why participants in the Marne and EMLR cases appeared to have achieved a comparatively higher level of awareness and understanding of each other's perspectives than in the other cases and underscore the importance of strong leadership within collaborative processes. These findings are consistent with previous assertions in the literature that an effective facilitator can enhance communication among scientists and non-scientists by helping to communicate technical information in an understandable way and promoting the integration of local knowledge into the process (e.g. Allen and Kilvington, 2005; Jacobs et al., 2005).

The degree to which relevant and affected interests within the cases were represented was also mixed. There was evidence in each case that scientists were directly involved in advisory committee discussions about knowledge. Consistent with previous research, we found that having technical experts 'at the table' helped to build understanding and trust both among scientists and non-scientists (e.g. Petts, 1997; Fernandez-Gimenez et al., 2006). Our findings highlight the importance of involving individual scientists recurrently through the process and for participating scientists to be able to communicate effectively with non-scientists.

Water users who stood to be directly regulated under the new water allocation plans were well represented on the Barossa, EMLR and WMLR committees. Participation by water users on the Marne committee was more limited. This raises some doubt as to whether the Marne process allowed for a fair consideration of the views and knowledge of a full range of interests in developing the plan.

There was no evidence that aboriginal communities were engaged in any of the processes. Each of the plan coordinators expressed strong concern about this omission, particularly in light of recent commitments nationally in Australia to provide water for cultural and spiritual purposes and to include aboriginal representation in water planning. This echoes widespread criticism in the literature that expectations of indigenous participation in water management institutions are not being met and confirms the need for further research to better understand the barriers and incentives to indigenous participation in the water sector (Jackson and Morrison, 2007).

Overall, the deficiencies we observed related to stakeholder representation draw attention to previous research on collaboration that has demonstrated negative consequences of inadequate representation (e.g. Lane and McDonald, 2005). For example, in the context of collaborative restoration efforts in the Great Lakes Basin, Beierle and Konisky (2001) attribute implementation failures in part to the omission of important stakeholder groups from the planning process.

Working with a predetermined set of technical information – as was the case in the South Australian advisory committees – runs the risk that participants in a collaborative process will end up considering a relatively narrow and potentially biased range of policy options (Reed, 2008). To mitigate this risk, Wynne (1992) suggests that scientific knowledge should be debated and negotiated in public, as part of an environmental policy discourse. In our study, the Marne process was the only case where there was clear evidence that the committee had ample opportunity to question and debate the technical information produced by the department. There was also evidence that during the Marne process, the results of technical investigations were reviewed and in several instances revisited in response to questions and challenges from committee members. In this sense, the process of producing knowledge in the Marne case was 'dialectical', in that participants (both scientist and non-scientist) had the opportunity to "challenge each other's assumptions and force self-reflection" (Innes and Booher, 2010). This distinguishing feature of the Marne process may help to explain its consistent success across all of the outcome criteria that we assessed; in particular, participants' acceptance of, and agreement to, the base of knowledge used to inform their plan. These findings affirm previous claims that critical debate and argumentation of knowledge are critical conditions for successful collaboration (e.g. Lane and McDonald, 2005; Innes and Booher, 2010) and demonstrate that it can be incorporated into a collaborative process that is constrained within a prescriptive regulatory framework.

CONCLUSIONS

Our concern with knowledge production in collaborative governance reflects a broader apprehension among researchers in the environmental governance field that a significant gap exists between the promises of collaboration in theory and what it can achieve in practice (e.g. Bellamy et al., 1999; McCloskey, 2000; Jeffrey and Gearey, 2006; Plummer and Armitage, 2007). Collaboration is purported to offer numerous benefits related to knowledge production; however, previous evaluations of collaborative governance in practice have provided only limited insight into whether, and under what conditions, such outcomes can actually be achieved. In this study, we begin bridging this gap by systematically evaluating knowledge production in four cases of collaborative water allocation planning in South Australia.

Our findings affirm that a number of theorised process and outcome criteria associated with successful knowledge production and use are achievable in practice. Despite the limited involvement of local actors in producing knowledge within the collaborative processes that were examined, the processes had generated understanding (and in one case, acceptance) of the knowledge used to base policy decisions and had built civic trust and engagement within the catchment communities. This paradox draws attention to limits of current procedural theory in the collaborative environmental governance literature for designing and implementing successful collaboration (e.g. Innes and Booher, 2010) and offers important insights for evaluating knowledge production in collaborative processes.

Communicative rationality theory has been criticised for failing to account for the influence of external factors, such as existing institutional frameworks, on collaborative processes (Murray, 2005). This study showed that joint fact-finding, a cornerstone of Innes and Booher's (2010) concept of collaborative rationality, was not achieved within collaborative processes that functioned within a prescriptive, overarching institutional framework. However, the cases examined in this research achieved successful outcomes related to knowledge production despite the fact that the collaborative processes fell short of joint fact-finding and authentic dialogue. Margerum (2008) has challenged fellow researchers in the collaborative environmental governance field to focus and sharpen their analyses of collaboration by ensuring that they take into account the distinct qualities of different forms of collaboration. Our study confirms the importance of this more nuanced approach to evaluating collaboration and the premises on which it is based.

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