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Exploring the potential of knowledge brokering to enhance natural resource management: findings from the Catchment Knowledge Exchange project in Victoria

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Exploring the potential of knowledge brokering to enhance natural resource management: findings from the Catchment Knowledge Exchange project in Victoria

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Despite significant efforts in natural resource management (NRM), the environmental condition of Victoria's catchments is mostly 'poor to moderate', and continuing to decline in many places. NRM is a complex undertaking involving social, economic, and environmental objectives, across policy, research, and practice dimensions. It is therefore not easy to ensure that the knowledge required to underpin effective NRM is readily available to practitioners. Knowledge brokering is an emerging approach with the potential to improve knowledge sharing and exchange. While it has attracted attention in other areas of public interest (such as health and information technology), its potential in NRM has received relatively limited attention. This article reports on a Victorian knowledge brokering case study which was a major element in the Catchment Knowledge Exchange project. A key finding is that knowledge brokering is a role that is being undertaken informally, without proper acknowledgement or definition. This raises challenges for knowledge management in the context of NRM. We conclude that the 'people' component of knowledge brokering is the driving element, although organisational processes and information technologies are critical in enhancing the effectiveness of knowledge brokers. Demonstrating the benefits of knowledge brokering in terms of the ultimate measure of its contribution towards improving the condition of catchments remains a challenge.

Keywords: knowledge management; catchment management; social network analysis

Introduction

The distillation of knowledge from information and the focusing of knowledge generation into areas of need have been identified as key challenges for effective integrated catchment management in Australia. In a review, Campbell (2006) concluded that the Australian natural resource management (NRM) knowledge system is not adequately supporting effective evidence-based decision making. One of the critical issues raised in Victoria's Catchment Condition Report (VCMC 2007) related to knowledge management. Victoria is relatively information-rich; there has

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been long-term investment in the development of knowledge assets in the form of reports, unpublished material (grey literature), spatial and non-spatial datasets, libraries, information systems, land-use models, and applications. A wealth of tacit knowledge held by individuals and communities adds to this. Nevertheless, continued gaps in understanding brought about by lack of information, imperfect communication, and sporadic processing of existing information have been identified as fundamental constraints to more effective NRM. The Victorian Catchment Management Council's report (VCMC 2007) recommended that a more considered, purposeful *system* of knowledge management be developed.

Many knowledge brokering activities are at the developmental or trial stage, so there is limited documented evidence about the value of knowledge brokering or the performance of particular approaches. For example, Van Kammen et al. (2006), p. 611) note that: 'knowledge brokering as an approach to closing the "know–do" gap is still in its incipient stage and it is important to start documenting the experiences'. It is also important to understand the context in which knowledge brokering can operate. In this paper we take a case study approach undertaken on the thematic area of soil health in Victoria. This is significant, as it allows us to reflect on the insights gained from trialling a thematic-based knowledge brokering approach and formally 'document the experiences' as suggested by Van Kammen et al. (2006). Therefore, we are able to ascertain the potential benefits of knowledge brokering as a means to enhance NRM.

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NRM knowledge system

This article focuses on the NRM knowledge system and explores the concept of knowledge brokering, specifically as a way to facilitate a community of practice (CoP) that improves knowledge exchange and uptake. CoP, a term first introduced by Lave and Wenger (1991, p. 98), was originally described as 'a set of relations among persons, activity and world, over time and in relation with other tangential and overlapping CoPs.' The NRM knowledge system comprises many overlapping CoPs as there are many domains of expertise, for example, soil, hydrology, and biodiversity. This article presents a knowledge broker trial focused on one CoP, soil health in Victoria. The findings from this trial are presented, and future challenges for NRM knowledge brokering are identified.

Knowledge can be seen as a driver of innovation and prosperity through improving the adoption of evidence-based practices (e.g. Poulos & Zwi 2006), driving value-adding in businesses, and contributing to the competitive advantage of nations (Porter 1990; OECD 1996). There is a compelling case to ensure that decision makers have access to the best available knowledge. The availability of a sound body of knowledge can ultimately assist in better decisions, both top-down (policy makers) and bottom-up (communities and landholders).

NRM can be defined as the management of those resources and ecosystem services that are obtained from land, water or the atmosphere and contribute to our environmental, economic and social well-being. Natural resources are increasingly managed holistically, which reflects a real-world trend in decision making that considers multiple impact and outcomes (Pettit et al. 2008). However, NRM is complex, and it is a perennial challenge to ensure that knowledge pertinent to decision making is readily accessible, to both policy makers and communities.

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The importance of knowledge in NRM has been indicated by the assessments of Campbell (2006) and Mitchell et al. (2007). Campbell (2006) considered knowledge as one of the three pillars of sustainable NRM, along with commitment and capacity. Mitchell et al. (2007) concluded that a lack of data, information and knowledge to support decision making at local and regional scales is a major barrier to NRM in southern Australia.

The role and state of knowledge sharing for regional NRM in Australia have been the subject of several reports. Regional bodies across Australia have expressed concern about the fragmentation, volume, and accessibility of information, together with concerns about the relevance of information at different scales, the need for two-way exchange and the lack of sharing across regions. Campbell (2006) and others (Mitchell et al. 2007) have elaborated on these complexities, in terms of the physical task of catchment management and of the many institutional arrangements in place.

Traditional perspectives on science communication in NRM tend to conceive of knowledge transfer as flowing in a linear, uni-directional way from scientists to landholders (Rogers 1962), although such approaches are subject to criticism (Bielak et al. 2008). In contemporary approaches, it is apparent that knowledge exchange is multi-directional and needs to occur across the data–information–knowledge–wisdom continuum, as illustrated in the NRM knowledge hierarchy of Bellinger et al. (2004) and MacEwan (2008) (Figure 1). Within this theoretical construct, the knowledge hierarchy relates the flow and connectedness of data, information, knowledge and, ultimately, wisdom (see Figure 1). The challenge arises in understanding the 'who, how or what' factors that drive an effective NRM knowledge system. A knowledge system needs also to recognise the knowledge-seeking behaviour of the individuals and CoP that it seeks to support. Professionals use a variety of strategies to seek out information, but typically tend to seek knowledge face-to-face and from an easily accessible and trusted person (Cullen et al. 2001). In this context, a recent development is knowledge brokering (Campbell 2006).

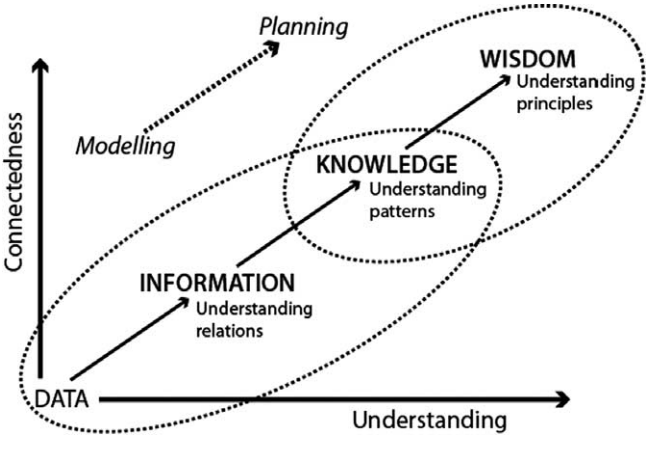

Figure 1. NRM knowledge hierarchy (MacEwan 2008, p. 21: adapted from Bellinger et al. 2004).

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NRM knowledge brokering

Knowledge systems can be thought of as 'soft systems' which 'only become evident as a result of active construction and joint learning' (Röling 1992, p. 42) and which provide a means for making sense of the complex relations between the multitude of generators and users of both explicit and tacit knowledge (Harding et al. 2009). Knowledge brokers are a means for improving the exchange of knowledge in particular knowledge systems (Campbell 2006).

Knowledge brokers are the intermediaries; the people who can help facilitate and connect the providers and users in a knowledge system. According to Campbell and Schofield (2006), knowledge brokering refers to processes used by intermediaries in mediating between sources of knowledge (usually science and research) and users of knowledge. The knowledge broker operates across the domains of data, information, knowledge, and, in some instances, wisdom (as illustrated in Figure 1).

Knowledge brokers have had a role in the health and information technology sectors for a number of years (CHSRF 2003; Poulos & Zwi 2006). The Canadian Health Services Research Foundation (CHSRF), at the forefront in promoting discussion on knowledge brokering, sees knowledge brokering as one of the human forces that makes knowledge transfer more effective. Knowledge brokering is about bringing people together to have conversations, to build relationships, uncover needs and share ideas and evidence that will let them do their jobs better (CHSRF 2003).

Internationally, knowledge brokering is gaining some attention in NRM (for example, Creech 2004). In Australia, a number of NRM organisations such as Greening Australia, Co-operative Research Centres (CRCs), and Catchment Management Authorities (CMAs) have appointed knowledge brokers, thus acknowledging the capabilities of knowledge brokering to enhance NRM. There have also been national workshops on 'knowledge into policy and practices' held specifically for knowledge brokers to share experiences and explore the processes of getting science knowledge into policy (Salt 2009). Brokering has been conducted in a variety of ways, including workshops, expert panels, face-to-face briefings, websites, synthesis reports, and networks. However, knowledge brokering is often informal, and, as in the more established fields of health, there remains a paucity of research and practice in brokering and little documentation of evaluation of its effectiveness.

Case study: knowledge brokering across the Victorian Catchment Management Framework

In exploring the potential benefits of knowledge brokering as a means to enhance NRM we have taken a case study approach with Victorian CMAs, where we have developed a knowledge broker trial based on one specific CoP with a focus on soil health.

Victoria's Catchment Management Framework is an extensive network of organisations and participants, who contribute collectively to maintaining and improving the health of Victoria's catchments (Ewing 1999). At the core of the Framework are 10 regional CMAs, and the state-wide Victorian Catchment Management Council (VCMC). The VCMC, the CMAs and a wide range of

government departments, statutory bodies, local councils, and research organisations contribute to Victoria's catchment management efforts and to our collective catchment knowledge. There are also many generators, users and exchangers of informal, tacit and local knowledge across Victoria's 32,000 farm businesses, and 1,500 community-based NRM groups (DPI 2008).

The Catchment Knowledge Exchange (CKE) project (which operated from June 2005 to July 2008) and the Soil Health Knowledge Broker Service trial (which operated from October 2006 to October 2007) endeavoured to meet the needs of all 10 CMAs and others with an interest in and responsibility for soil health in Victoria, and was refined in light of ongoing experience throughout the trial.

As part of this case study approach we have undertaken a soil health knowledge brokering trial which comprised:

- capturing key knowledge and formulating a collective thematic statement through a Soil Health Forum;
- availability of a knowledge broker via a dedicated telephone;
- an interactive website;
- mapping the CoP using a social network analysis approach.

In evaluating the case study, a qualitative analysis has been undertaken based on feedback from Soil Health Forum participants, and insights gained from the knowledge broker and semi-structured interviews with nine key CMA personnel in Victoria.

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Case study and evaluation methodologies

Soil Health Forum

As an initial step in establishing the trial, a Soil Health Forum was held in Bendigo, Victoria on 15 June 2006. The purpose of the forum was to:

- find out what was happening in soil health endeavours in Victoria and nationally;
- discuss soil health priorities, share knowledge and knowledge needs;
- launch the Soil Health Knowledge Broker Service.

There were over 100 participants at the forum, which was held as a one-day event structured on two themes. The first theme focused on investment in knowledge, engagement and delivery, while the second theme focused on soil health knowledge and Victorian landscapes.

A group discussion session focused on determining the required knowledge needs around soil health. A participant response survey was used to evaluate the Soil Health Forum and obtain feedback on the concept of a Soil Health Knowledge Broker Service. Participants were asked to respond (on a scale of 1 to 10) to a series of questions and could also provide qualitative feedback in the form of comments. Responses were provided by approximately 40 per cent of the workshop participants.

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Soil Health Knowledge Broker Service trial

The major element of the CKE project was to design and conduct a Soil Health Knowledge Broker Service trial (hereafter 'the trial'). This role was taken by EWR Consulting. The trial aimed to provide measurable improvements in the generation, dissemination, and utilisation of knowledge in the soil health field, in conjunction with timely and relevant information to support those making NRM decisions relating to soil health. Soil health is an ecosystem service fundamental to sustainable and productive farming systems. Soil is also critical to the environmental health of the natural environment and is potentially a store for carbon.

The Soil Health Knowledge Broker Service included a dedicated telephone number and an interactive website. An important characteristic of the trial was its 'real world' focus, operating within a particular theme relevant to the Victorian Catchment Management Framework and very real time and resource constraints. While focused on human interactions, the trial also made use of innovative information technologies, thematic reviews, and documented operational procedures.

In addition to providing a Soil Health Knowledge Broker Service, the knowledge broker was required to monitor and record project activities continuously, and report on these activities regularly to a project control board. Through this process, refinements to the conduct of the trial were identified and adopted, subject to the agreement of the project control board. As part of this process, the knowledge broker periodically reflected on the operation of the trial, which provided many useful insights into the practicalities of knowledge brokering. The evaluation component of the CKE project also enabled consideration of the broader potential of knowledge brokering to improve catchment management.

As CMAs were identified as key stakeholders in determining the success or otherwise of knowledge brokering, the views of the Chief Executive Officers (CEOs) of the CMAs were sought to ascertain their experiences of, and views about, the potential of knowledge brokering. This approach reflects a purposeful approach to sampling, whereby interviewees are selected on the basis of their relevance to the research questions posed (Bryman 2004). Semi-structured interviews were held with six of the 10 CEOs, each lasting approximately one hour. This feedback was supplemented by one-hour interviews with three additional CMA staff responsible for undertaking or supervising knowledge brokering related roles. Semi-structured interviews were selected because they enable subjects to contribute in their own words, while being undertaken in a setting with a clear sense of the research issues being investigated (Dunn 2000). All nine interview subjects were provided with a plain English summary of the project and interview schedule prior to interview to ensure that they understood the project and that interviews had a clear focus (Dunn 2000). Immediately following each interview, a summary of the points made by each interviewee was prepared and subsequently analysed qualitatively to identify recurrent themes.

Interactive website

The operation of the trial was supported by a dedicated website. This enabled requests to be made to the knowledge broker and provided a means by which the knowledge broker's response could be shared more widely. The intention was to

establish a 'real world' presence for the trial, as well as to test the potential for making use of online collaborative tools, in this case a wiki. Online NRM knowledge management sites such as Victoria Resources Online (DPI 2009) and Australian Agriculture and Natural Resources Online (AANRO 2009) were considered as possible online spaces to house the trial. However, at the time, neither of these online sites could accommodate the two-way interactive web functionality that the trial was designed to deploy. The soil health dedicated website and wiki were established to support participant postings and moderate discussions. Through the use of such online collaborative technologies, the wider soil health community could contact other soil health enthusiasts and actively contribute to NRM knowledge exchange.

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Social network mapping

In order to benchmark the current form of the soil health knowledge network relevant for Victoria, a Social Network Analysis (Wasserman & Faust 1994) was conducted at two points during the project (March 2006 and January 2008).

The social network 'map' and associated analysis was developed using Medical Decision Logic's VisuaLyzer software (version 1.1). This software has been specifically developed to support the public and clinical health areas, but is able to graphically display any small or mid-sized social network. Social network maps of the soil health practitioner and soil health group networks were constructed. Names of individuals were codified using numbers, to meet confidentiality requirements.

Catchment Knowledge Exchange project findings

Identifying knowledge needs: feedback from the Soil Health Forum

The evaluation steps within the forum provided an opportunity to obtain some initial feedback from the broader soil health community in Victoria. Over 100 questions or knowledge needs were captured in the group discussion sessions, with the largest clusters around landscape interaction and the way soil impacts on biodiversity, water, and ecosystem services, and around soil biology. These insights led to a collective thematic statement on soil health which captured 'point in time' knowledge about soil health.

The participants' responses in evaluation of the Soil Health Forum included: 'I am interested in obtaining as much information as possible', 'any contacts with others about soils is excellent' and 'would like to see what is involved and be kept up-to-date with what is happening'. A key finding from the forum was that there is an increasing awareness that top-down approaches to extension are not effective. Thus, knowledge brokering potentially offers a novel approach which can work across the knowledge hierarchy (Figure 1) and in and between organisations to facilitate NRM knowledge transfer. Another key finding was that the provision of relevant, accessible information and knowledge sharing is necessary to support the sustainable management of soil health. The evaluation also identified the soils information asset in Victoria as fractured, that there are few opportunities for sharing knowledge, and that the historical investment in basic soils information needs to be safeguarded and modernised. These concerns highlight the importance of key technical considerations related to data management supporting soil

information and process considerations in addressing the fractured nature of this information asset.

Insights of Soil Health Knowledge Broker Service trial

1. People are the core component of knowledge brokering

An important insight gained from the trial was that the human element of knowledge brokering must be central. Success in knowledge exchange and management will not flow from investment in databases and web-based interfaces alone, even though these are critical in the undertaking of knowledge brokering activities. Support networks, such as CoPs, were necessary for this approach to knowledge brokering. For people to engage with a CoP, they needed to see constant, as opposed to infrequent, activity by the knowledge broker, even if that activity was at low levels.

More challenging insights from the trial principally related to issues associated with the organisational context (processes) of knowledge brokering. For example, within organisations, there is often an ambiguous perception of what constitutes a knowledge brokering role. As knowledge brokers often work across organisations or regions, this creates challenges because of potential concerns about organisational loyalties and mixed or blurred lines of accountability. This was experienced during the trial. Clearly defining roles, responsibilities, and accountabilities could assist in reducing the impact of organisational tensions. However, this might not be easy to implement, as knowledge brokering can operate across a complex web of organisations as illustrated from the social-network analysis (Figure 2).

Sound operational processes are important components of a robust approach to knowledge brokering, since they are useful for demonstrating accountabilities. More specifically, clear operational processes and procedures are useful in setting a standard of service and care, providing guidance about how activities can be undertaken, and facilitating the storage, sharing, and reuse of information. This acknowledgement of a custodian of specific soil-health data and information assets is a critical step in being able to practically support the implementation of a soil health thematic-based knowledge brokering service.

The interviews with the CEOs and other personnel of the CMAs showed that knowledge brokering would be most useful where it adds value to existing efforts, and where it is focused on delivering practical and tangible benefits for catchment management. Two respondents provided specific examples of how knowledge brokering activities were useful in promoting the exchange of knowledge between researchers and practitioners. Meanwhile, most concerns related to the potential vagueness of knowledge brokering and whether it would be seen as duplicating existing efforts, which could reduce funding for other priorities. In essence, the results from these interviews indicated the importance of process clarity and the challenge in determining the value that could be added by funding knowledge brokers. The full set of themes identified in these interviews is summarised in Table 1.

2. Web and information technology tools offer valuable support to knowledge brokers

The trial highlighted the usefulness of web technology as an extension of the people and process components of knowledge brokering. The dedicated website

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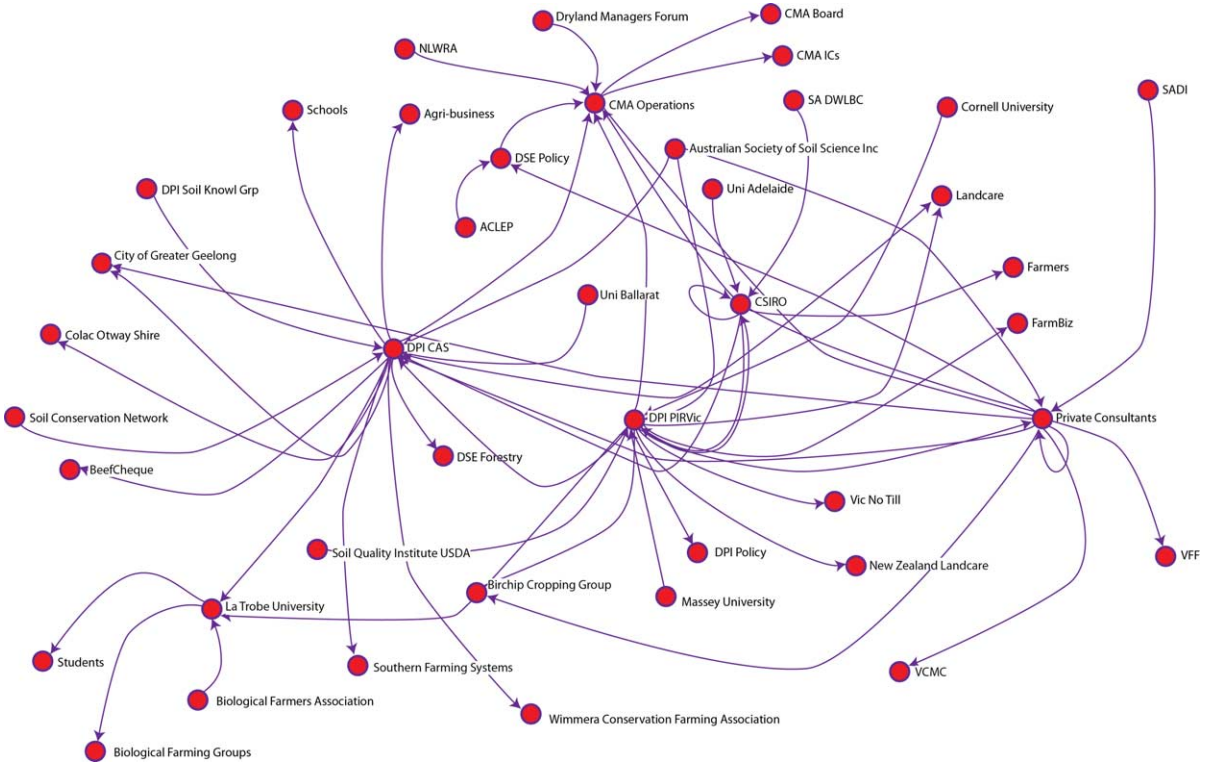

Figure 2. Soil-health organisational social-network map (March 2006). ACLEP, Australian Collaborative Land Evaluation Program; CAS, Catchment and Agricultural Services; CMA IC, Catchment Management Authority Implementation Committee; CSIRO, Commonwealth Scientific and Industrial Research Organisation; DPI, Department of Primary Industries; DSE, Department of Sustainability and Environment; NLWRA, National Land and Water Resources Audit; PIRVic, Primary Industries Research Victoria; SADI, Smallholder Agribusiness Development Initiative); SA DWLBC, South Australian Department of Water, Land and Biodiversity Conservation; USDA, US Department of Agriculture; VCMC, Victorian Catchment Management Council; VFF, Victorian Farmers Federation.

Table 1. Key themes in feedback provided by CEOs of CMAs

Feedback regarding knowledge brokering (KB)	Comment
KB is a sound concept, although the terminology is confusing	The term 'knowledge brokering' can be confusing and made brokering sound more formal than it is.
KB is being undertaken even if not called KB	One respondent stated: 'We're already doing it'. The CHSRF also noted that very few people had KB in their title; even if that was the role they undertook (CHSRF 2003).
KB should build on, and extend, existing efforts	This comment was made on the basis of the existing activities undertaken, and a desire that KB should be seen as an adjunct to existing efforts, not as a replacement for them.
KB needs to be focused on problems and solutions	There was a strong feeling that KB needed to have clear deliverables and accountabilities, and that being focused on problems and solutions would help in this respect. For example, suggestions included that efforts be focused on questions such as 'How can we improve the effectiveness of biodiversity efforts, so that we can learn systematically from past successes and failures?' Or, they could be targeted to addressing specific issues such as 'Sharing of information about the potential of carbon sequestration'.
KB needs to be tailored to particular situations	Some respondents thought that what might work in one situation may not be appropriate in another situation.
KB needs to be targeted	Feedback reinforced that the target audience for KB activities be identified clearly, i.e. staff in catchment management regions, head office staff, or individual landholders.
People need to be educated about what KB is and is not	Knowledge brokering was sometimes equated with facilitation or extension. The difference between knowledge brokering and knowledge management also needs to be made clear.
KB should be flexible and change focus over time	Respondents were keen to ensure that KB did not become an end in itself, just because of the brokers' interests.
KB can be useful for capturing corporate knowledge	Issues associated with loss of corporate memory, because of staff turnover, short-term contracts and loss of experienced staff, were considered to be real and important. KB was considered as a way to reduce the impacts of these issues.

established in the trial attracted a significant number of interactions, and the number of 'hits' grew as the content increased and people became more aware of the service (406 hits in October 2006, 1867 in January 2007, and 4006 hits in July 2007). Information technology has an important function in knowledge management. However, to approach knowledge brokering based on technology alone would be unlikely to be successful. As online sites move from the traditional information

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push style to the more participatory and collaborative concept of Web 2.0 where 'collective intelligence' is considered a key attribute (O'Reilly 2005), the role of technology to support knowledge broker activities is expected to increase.

3. Knowledge brokers need to operate in a complex organisational environment

A visual representation of organisations identified by respondents in the March 2006 social network analysis is shown in Figure 2. The 'spaghetti' linkages of this map illustrate the complexities of the knowledge system and underscore the importance of personal contact. This social network map provided a useful tool for the knowledge broker to identify key individuals and organisations within the Victorian soils community.

The initial soil health network map (Figure 2) comprised 43 actors. This was by no means a complete or definitive map of the Victorian soil health community; rather it captured some of the most commonly cited pathways. The network was represented with 59 links, which included both single and multiple reported relationships. Through various forms of analysis of actors within the organisational network, it was apparent that a distinct core of organisations was central to the operations of the network. Whether measured in terms of nodal centrality (degree of connectedness), key linking actors across sub-structures in the network (known as cut-points), or as identified actor positions in the network, five key organisational groupings repeatedly emerged: the Victorian Department of Primary Industries extension (eight links), the Victorian Department of Primary Industries research (16 links), private consultants (12 links), Australia's Commonwealth Scientific and Industrial Research Organisation (10 links), and CMAs (9 links). It was anticipated that the social network analysis would also be used to track changes in the network structure and hence was run at two points in the project. However, a number of the original participants were not re-identified in the second survey, as a result of fewer interviewees, and consequently there were fewer potential linkages. Therefore, only indicative conclusions can be drawn regarding the temporal changes in the network. The most connected elements of the soil health practitioner network are well defined by centrality and cut-point analysis, which remained relatively stable between the March 2006 and January 2008 analyses. The less-connected or peripheral elements of the practitioner network appear to be undergoing the most change. A knowledge broker needs to be aware of the organisational context in which they are to operate and the strengths of those connections between organisations and individuals.

Challenges for knowledge brokering in catchment management

One of the key challenges facing knowledge brokering (and more broadly knowledge management) is the accessibility of NRM data. This challenge involves the formalisation of data custodians and their role in supporting data supply and information generation. Work is currently under way in Victoria to formalise the role of soil health data custodianship and the formulation of a Victorian Soil Information System (VSIS) (Hunter et al. 2009). Such roles and information systems are important steps in being able to support the process component of knowledge brokering, and enable landscape and land-use modelling to underpin NRM planning and policy making (Figure 1).

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The best extension officers have always operated as knowledge brokers, mediating between science and practice, and having an influence on both. However, the extension landscape in agriculture and NRM is changing rapidly, and 'traditional' extension officers are increasingly rare. We would suggest that knowledge brokering is a better conceptualisation of the rationale for public investment in specialist intermediary roles to leverage the public investment in science.

Knowledge brokering must determine the most effective mix of effort and investment between people, process, and technology. Our social network analyses provided insight into the complex array of relationships among soil health organisations in Victoria. Each of these organisations has different roles, responsibilities, processes, and technologies. A knowledge broker service must be able to bridge the gap between and within organisations. With the recent advent of collaborative Web 2.0 and social media tools such as wikis, blogs, and social networking sites, there exist both opportunities and challenges in best utilising technology and tools to connect CoPs, and in formally or even informally supporting a model of knowledge brokering in catchment management, as an adjunct to the focus on people and their relationships.

A further insight from our study is that any future comprehensive evaluation of NRM knowledge brokering should be undertaken over at least a three-year time horizon. This article reports on one case study in Victoria for one CoP, soil health, conducted over a 12-month period. The study would be improved by consideration of more themes and being run over a longer period of time. Supporting technology tools such as the dedicated interactive website, established solely to support the trial for a specified limited duration, would be challenged in achieving high levels of adoption, as opposed to a dedicated website that is established and has known or perceived longevity.

Undertaking longitudinal social network analysis has difficulties (Wasserman & Faust 1994), particularly when only two snapshots in time are used to measure change. A more controlled experiment could be worthwhile to determine the influence of a knowledge broker on an evolving social network which extended over a number of years. Unfortunately, limited metrics were acquired in determining the usage patterns of the dedicated website. In further studies, web analytics should be used to measure and evaluate the value of supporting website resources (see, for example, Pettit et al. 2010).

The size of the sample for semi-structured interviews of personnel across CMAs was limited by available resources. Also, ideally participants involved in these interviews would have extended beyond CMAs to include state government (policy and extension), consultants, industry, researchers and data providers. A longer knowledge brokering trial period with supporting resources may have resulted in greater participation rates from a larger number of organisations and a richer set of findings.

Knowledge brokering is a relatively new area of endeavour and its role in enhancing NRM is yet to be realised. Despite the study limitations, this approach is relatively novel, and we hope other researchers will learn from our approach, both its strengths and its limitations.

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Conclusions

We have identified three components that are fundamental to the concept of NRM knowledge brokering: people, process, and technology. From this trial of a Soil Health Knowledge Broker Service in Victoria, we conclude that the 'people' component must be the driving element of a successful knowledge brokering approach. However, the organisational processes and technology tools are also necessary supporting elements. Organisational process and technology must assist with knowledge transfer and need to be flexible and adaptable enough to enable knowledge brokers to operate effectively. Challenges remain in providing 'process clarity' to a role which needs to be able to operate across a complex network of organisations, as illustrated in Figure 2, and transcend organisation boundaries to facilitate the exchange of data, information, knowledge, and ultimately wisdom (Figure 1). From a technology perspective, the recent proliferation of social media technologies and an openness of many organisations to consider utilising such technologies offer a ray of hope for knowledge brokers to overcome some of the organisational barriers traditionally in place preventing data, information, and knowledge exchange. We recommend that knowledge brokers further embrace such technologies in order to assist in NRM knowledge transfer.

Further evaluative studies are required to understand how knowledge brokers can work across the knowledge hierarchy and also across various NRM themes. Our knowledge brokering trial focused on the theme of soil health; other themes such as climate change, biodiversity, and water are also fundamental to integrated catchment management and could equally be explored. Evaluation should incorporate measures of effectiveness and efficiency to ascertain the value of knowledge brokering as a critical role in supporting NRM activities.

In a time when natural resources are under increasing pressure from factors such as population growth and climate change, knowledge brokering must be able to demonstrate tangible and intangible benefits in improving the condition of catchments and integrated catchment management across Victoria and other regions. This is by no means an easy task and, we believe, would benefit from further studies examining how knowledge brokering is, or can be, undertaken in and across all NRM themes to improve interactions between research, policy, and practice. From the perspective of soil health knowledge, science and practice have come a long way, but there is still much to do. There is a wealth of knowledge, but it must be used more coherently as a 'whole', and knowledge brokers can potentially play an important role in the NRM knowledge-management system.

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