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An adaptive systems toolkit for managing the Hawkesbury water recycling scheme

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Abstract

To achieve effective, sustainable and acceptable water recycling, the need for integrated and multidisciplinary management is now well recognised. The complexity of interacting technical, socio-cultural and environmental factors requires approaches which are responsible, robust and adaptable. This paper describes the toolkit which is being developed for managing the Hawkesbury Water Recycling Scheme. A management plan based upon the logic of environmental management systems provides the basic structure of the toolkit, with supporting systems including those relating to organisational support, decision support, monitoring and research, communication, and an external interface. Lessons learned to date suggest that this form of management approach can assist in operationalising principles of sustainability and adaptive management in relation to water recycling.

Keywords: Adaptive; Management; Systems; Toolkit; Water recycling

1. Introduction

Effective and sustainable water recycling must be underpinned by approaches to management which are integrated and responsive to both internal components of schemes as well as external policies and the community setting in which they operate. The need for multidisciplinary approaches that underpin acceptability, confidence and sustainability are now well recognised. The challenge is how to develop management approaches which are both adaptive and relevant to local conditions, while generating more generic lessons to inform recycling initiatives in different socio-environmental situations.

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The need for multidisciplinary approaches which synthesise technical, financial and social aspects in effective water reuse is becoming well recognised [1,2]. Successfully achieving a level of acceptability and confidence involves overcoming the technical challenges including microbial loads, heavy metal accumulation and the mixing of industrial waste streams, as well as social differences in psychology and cultural values as they relate to water [3]. These cultural differences commonly underpin other pragmatic differences in the way different countries understand health risks, in the context of local economic circumstances [4]. In Australia, socioeconomic and institutional issues include "managing public perceptions of recycled water; health and environmental concerns; lack of consensus among government agencies; high up-front costs of infrastructure; and prices of other sources of water supply that are not currently truly costed" [5].

As a result of developments in biological and physicochemical sciences, resource engineering, and applications in agriculture and risk assessment, understanding of fundamental processes relating to water recycling is improving. Key thematic areas include economics, soil, water and contaminant balances, and environmental and health risks, but broader questions of sustainability reflect complex interactions and require more holistic approaches to management [6]. International examples, such as in the case of the Monterey Scheme in the US, include innovative institutional arrangements, cost-sharing amongst all beneficiaries, devolution of responsibility, and tiers of financial support [7]. Another critical need in reflecting the beneficial uses of a range of waste streams is a range of different forms of practical demonstrations in urban, industrial and community contexts [8].

This paper describes the approach being developed for the Hawkesbury Water Recycling Scheme (HWRS). Following a brief description of the Scheme, a discussion is presented of the "toolkit" built around an environmental management system, and including broad-ranging support tools which have, and continue, to be developed. It is posed that this more effective type of framework may enable the complex interacting features of recycling schemes to be dealt with ways which improve the pursuit of sustainable practice.

2. The Hawkesbury Water Recycling Scheme

The HWRS seeks to showcase an integrated approach to effluent and stormwater recycling, utilising con-structed wetland technologies, and providing a focus for informed community awareness of the benefits and risks involved [9–11]. The Scheme involves the utilisation of treated effluent from the Richmond sewage treatment plant, along with the harvesting and polishing of stormwater collected from Richmond township and the Hawkesbury campus of the University of Western Sydney (UWS). The recycled water resource is then used for pasture and fodder production, horticultural production, irrigation of playing fields and gardens, or released as environmental flows. Practical and cost-effective strategies are being sought to engage the challenges and opportunities faced in managing the Scheme reduce pollution loads to a local creek and the Hawkesbury Nepean River system, while providing a safe and effective resource for a range of water users.

The HWRS encompasses all of the recycled water infrastructure and activities on the Hawkesbury Campus of UWS. Reuse of treated sewage effluent from the Richmond sewage treatment plant (STP) has been undertaken on the site since the 1960s. Since January 2002 the Scheme has been supplemented with additional supplies of urban stormwater. The separate treatment, yet integrated management of treated effluent and stormwater is an important feature of the Scheme.

Since November 2000, an Environmental Management Plan (EMP) has been progressively developed to assist UWS to meet various management obligations and commitments. The EMP provides direction for coordination and management of activities and general operations of the Scheme consistent with these obligations and agreements. The principle requirement of the Scheme's infrastructure is that it enables the effective and efficient transfer and storage of the treated effluent and stormwater resource to facilitate integrated and sustainable water use and management across the Hawkesbury Campus. This requirement is fundamental to UWS meeting its legal and moral obligations with regard to recycled water. As the water resource (and the Scheme itself) is used for research, teaching and demonstration purposes, it is important that the elements of the Scheme operate within designed capacities. On-going and regular maintenance is required to minimise disruption to water supplies/transfers and operational costs. A preventative maintenance program is essential as is the on-going prompt, reliable and effective response to breakdowns. This is because the treated effluent and stormwater is used at UWS by a wide range of outdoor laboratory facilities, including horticulture and grazing and farm units, the UWS dairy, irrigation of playing fields and a number of small independent sites, namely Greening Australia, Hawkesbury Skillshare, and Taronga Zoo's koala feed plantation. Recycled water from the Scheme is also provided to Richmond TAFE. A significant portfolio of postgraduate research, either directly associated with or supported by the water recycling infrastructure, has also been established over recent years. Possible opportunities for employment and business within the university and local and regional area may stem from the project.

The HWRS provides a valuable open laboratory for investigation into aspects of water recycling on the edge between urban, rural, educational land uses and significant nature reserves. It is also just one component of an integrated environmental precinct which complements local government stormwater initiatives, provides a valuable resource for Western Sydney, as well as an international hub for broad-ranging comparative research. The Scheme also enables a broad range of aspects to be developed and adaptively reviewed. These currently include environmental management systems, decision support tools, natural resource assessment, self-design of stormwater wetlands, and aquaculture.

The Richmond STP has a present capacity of 14,000 equivalent persons (EP) and an average daily flow of 2.5 ML, or average annual production of 927 ML [12]. In early 2005, the up-graded Richmond STP was commissioned and brought on-line. Also a possibility exists that within the next few years effluent from the North Richmond STP could be transferred to the Richmond STP, increasing available daily flows to the Scheme. A series of effluent wet-lands has been constructed to capture and store wet weather flows from the STP for periods of up to 5 days; 24 ML of wet weather flows can be stored in the wetlands and retreated as required prior to reuse. Treated effluent from the Richmond STP is collected in a receiving pond and then pumped up into the first University storage, Turkey Nest Dam (capacity 93 ML). Prior to the construction of the in-line stormwater detention pond (capacity 60 ML), wet weather discharges from the STP overflowed from the receiving pond down the stormwater channel to Rickabys Creek, and thence to the Hawkesbury-Nepean River. Treated effluent is piped from Turkey Nest to Horticulture Dam (capacity 84 ML) to the crop area north of Blacktown Road, and to Hillside Dam (capacity 76 ML). Between Turkey Nest and Horticulture Dam, supply lines lead to the Deer Farm, Amenities Paddocks and Experi-mental Area. Supply lines from the Horticulture Dam include one line to the playing fields, and a second main (pressurised line) supplies the Horse Paddocks and the two horticulture areas.

The HWRS uses a total water cycle management approach to integrate the above use of treated effluent with treated stormwater. As part of the Scheme, a 60-ML stormwater retention pond was constructed on UWS land at the junction of the two main stormwater channels draining the upper catchment of Rickabys Creek. From here the stormwater is pumped into four 1-ha wetlands. Polished stormwater that has passed through the wetlands is stored in a 25-ML holding pond for either pumping for storage or for release as environmental flows.

3. The toolkit: EMS and supporting systems

The developing management has an overall structure provided by the logic of EMS. This structure provides an operational framework for applying the principles of adaptive management and risk communication. Along with core aspects accounted for within the EMS structure, this structure also provides a framework for broader supporting systems including those relating to:

- organisational support
- decision support
- integrated monitoring and research
- communication support and an
- external interface.

This section briefly describes the components of the EMP following the EMS logic, followed by the supporting systems which continue to be developed, as shown in Fig. 1.

3.1. The environmental management plan

Following the structure of ISO 14004 [13], the general sections of the EMP reflect the principles of:

- environmental policy and commitment
- planning
- implementation of environmental programmes
- measurement and evaluation and
- review and improvement.

3.1.1. Environmental policy and commitment

The UWS is a signatory to the Talloires Declaration which focuses on promoting an institutional culture within universities and through partnerships with the broader community to enhance interdisciplinary capacity for environmentally sustainable development. The HWRS as part of this the Richmond Water Reuse Project is recognised as being relevant to this role of universities, the goals and values of UWS, especially

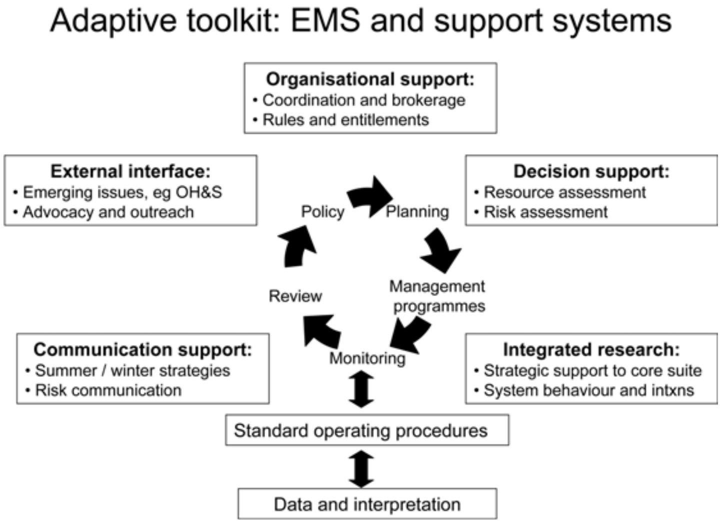

Fig. 1. Developing toolkit: EMS and support systems.

through the opportunities provided for research, teaching and learning about sustainable water management and community engagement. Similarly, major partner organisations including Sydney Water Corporation and Richmond TAFE continue to support and reflect a commitment to the environmental and social benefits of the Scheme.

3.1.2. Planning

Aspects of planning dealt with include the evaluation of potential environmental impact of the Scheme, along with related statutory requirements and national and state guidelines for the use of recycled water. Environmental objectives, plans and programmes are designed to address these planning requirements in a way which effectively implements environmental policy.

While UWS is no longer required to hold an EPA licence, the EMP provides the technical support for the agreement between UWS and Sydney Water Corporation. While influencing guidelines continue to change, the agreed basis for the agreement is the national guidelines for the use of reclaimed water [14]. Other statutory requirements include those under the Occupational Health and Safety (OH&S) Act 2000 in relation to OH&S hazards and responsibility for risk management. Environmental objectives and internal performance criteria relate to environmentally sustainable practice, particularly in relation to avoidance of environmental discharges and due diligence regarding risk management.

3.1.3. Environmental management programmes

The management programmes are based upon the preceding policy and planning aspects, and with programmes including clarification of core responsibilities and operational rules, management of storage, infrastructure and system maintenance and hazard identification and risk assessment. The clarification of responsibilities is supported by a collective decision-making structure (HWRS Management Advisory Committee), described further below. Management of storage is informed by modelling of the effluent reuse component of the Scheme by James [15] along with more recent decision-support research by Stewart [16,17] that integrates the stormwater and a range of other components and considerations of the Scheme. There is a complex arrangement of infrastructure which has developed over time, and which has been the focus of a recent review to determine critical improvement needs. Hazard identification and risk assessment within the EMP has led to a substantive effort of supporting research and management activity, which will be discussed further in the support systems.

3.1.4. Measurement and evaluation

A comprehensive core monitoring system is being undertaken to continue to assess effluent and stormwater quantity and quality; impact on soils, groundwater, and ecological communities; and potential health and community impact. Along with monitoring data regarding quality and quantity of product supplied from the Richmond STP, and overflow discharges monitored by Sydney Water Corporation, UWS has undertaken monitoring the quantity of recycled water used across different user precincts and a rolling suite of standard water quality parameters of the recycled water supplied from each storage through the system. Baseline conditions for the parameters are being collected; trendlines are being established along with the determination of site-specific action threshold levels to trigger contingency procedures. A strategy is also being currently implemented for analysis of soil application, building upon an applied research project [18], along with a complementary groundwater monitoring strategy [19].

3.1.5. Communication, reporting and review

A suite of mechanisms for communication and review are developing from the initial steps made in the EMP. Building upon quarterly reporting and data exchange with Sydney Water, the EMP and Scheme management were assessed in October 2003 by an auditing team from Sydney Water Corporation's recycled water products group. Progressive improvement in the EMP is stemming from the assessment. Fundamental changes include streamlining the core EMP document and consolidating management tasks and procedures into a tier of standard operating procedures. These procedures are then informed by the support systems described below. Communication with the different water users and communities of practice around the Scheme is also a critically important area of development and will be discussed further in the following consideration of support systems.

3.2. Support systems

Following the framework outlined in Fig. 1, the following sections briefly describe the range of support systems which enable and contextualise the implementation of the EMP. These include:

- organisational support
- decision support
- monitoring and research
- communications systems and review
- external interface.

3.2.1. Organisational support

The organisational systems provide the fundamental structures for setting policy and decision-making, and establishing institutional rules such as those for the allocation of available resources. This support system has two basic components: a collective body of all major users, the HWRS Management Advisory Committee (HWRSMAC) and a water coordination role undertaken by the ICEM Group. HWRSMAC meets twice a year and provides the collective legitimacy and advice to UWS senior management for the on-going activities of water coordination.

Coordination and integration of the Scheme is sought within an umbrella of collective ownership and management both through HWRSMAC and the EMP. As outlined previously, the EMP is structured to reflect the philosophy and logic of continuous improvement and environmental management systems (EMS). Through HWRSMAC and related coordination efforts, on-going communication with managers, water user groups, and other communities of practice provides a fundamental strategy to strengthen integrated management. These collective decision-making structures and coordination functions can determine and legitimise the rules of use and related responsibilities. In conjunction with the EMP, this forms the agreed rules by which the Scheme operates collectively as workable common property [20] rather than reflecting previous on-going conflict over water sharing and use was more of a "tragedy of open access".

3.2.2. Decision-support

The management programs within the EMP require a variety of support mechanisms that reflect analytical decision-support tools and related institutional rules, and proactive risk assessments. These act together to inform the structuring and sharing of resources, along with an understanding of risks in relation to the diversity of behaviours of the water users. To assist resource supply planning and allocation, a decision support model was developed. This model uses simple water cycle representations to describe the stormwater yield from a partly urbanised, rural catchment contributing stormwater to the Scheme. Long-term simulations provide an indicative yield and associated water quality information that is suitable for input to harvesting, treatment and water reuse models. This modelling can be particularly useful when used in conjunction with a system of allocation that reflects differential supply security at critical times for different enterprises and their related responsibilities. Details of some aspects of this decision support model are provided in another paper to this conference by Stewart [17].

Potential rules for allocation have emerged from decision support which link with other support systems (e.g., communicating summer strategies). Decision support work has also identified the need to differentiate a system of entitlements which reflect both aggregate and particularly high security needs for each water user's enterprise. Such needs may include cell differentiation in commercial horticulture stands, dust suppression for foaling, or fodder production for dairy herd structure. There is also a recognition of the need to relate the access to an entitlement with the appropriate and effective utilisation during periods of low irrigation demand.

Another related area of decision support has been that of risk assessment. There has been a rapid evolution of preliminary health risk assessment [21] to a broader risk communication focus using a range of methods with different communities of practice and local populations [22, 23]. Risk assessment, as a component of decision support, led to a risk communication research project. This study then provided a valuable platform for communication support and proactive engagement with newly emerging OH&S issues. This development reflects the open and interacting nature of the support systems.

3.2.3. Monitoring and research

A fundamental aspect of an EMS is the ability to monitor the effectiveness of the management programs. An integrated strategy for the Scheme provides core monitoring of water quality, quantity and storage. The strategy is underpinned by research which seeks to extend the monitoring tools in ways relevant to both local and more generic challenges, including those relating to health risk and sustainable application to soils some of which have inherent sodic characteristics. For all monitoring themes, challenges include the variability of the site and the behaviours among diverse communities of practice, the development of effective and inex-pensive measurement techniques, and the establ-ishment of performance criteria relevant to management needs and resource protection.

Spatial information systems are being developed as an essential tool. On a primary level this will allow spatial representation of the infrastructure location, programs and activities of the scheme to be documented as mapping units, and the roles and responsibilities of stakeholders to be recorded as spatial attributes. Most importantly the environmental health risk factors and potential risk areas can be visually represented to enable appropriate occupational health and safety measures (such as signage and buffer zones) to be established, thus demonstrating the due diligence of the managers. Progressively integrating other spatial data such as natural resource characteristics, areas of environmental significance, irrigation records, hydrologic information, agricultural activities on paddock unit, and climatic records will enable management to plan, manage, monitor, audit and review the scheme as part of the continuous improvement pathway. Successful implementation of a spatial information system depends on the sharing of geographically referenced data, collaboration and cross-organisational initiatives. In reviewing the use of GIS in health, Shams [24] identified that one of the barriers to developing an information system using GIS is an organisational culture positioned toward protecting information and intellectual property.

The risk communication study also provides support functions in monitoring. However, along with the objective assessments undertaken through preliminary risk assessment, it also incorporates interpretive and qualitative data on perceived risks and associations with management behaviours and communicative needs.

3.2.4. Communication systems and review

There are a range of different types of communication and review strategies to enable appropriate information to be translated and provided to different players in forms relevant to their organisational interests. This continues to be a most challenging and dynamic aspect of the support systems, and one which is essential for closing the loop on the EMS cycle of continuous improvement.

The water coordinators continue to seek to become more strategic and less reactive in their communication with water users, particularly regarding seasonal requirements and needs. Over the past 2 years, summer and winter water use strategies have been identified and communicated. Summer strategies identify assessments of resource availability, and then present a summary of consultation with each water user regarding high security needs and areas of low security where water use can be reduced. These strategies have been found to be very useful in simply communicating between users how each unit is doing what it can and overcoming misunderstandings due to incomplete communication between various water users. Likewise, winter strategies seek to identify opportunities for appropriate utilisation in periods of low demand and communicating storage levels.

Another critical challenge is interpreting and communicating information gathered through core monitoring to different audiences. Key conditions and trends in biophysical parameters of flow and water quality, predicted resource availability and storage, interactions between climatic, soil and surface/groundwater, and patterns of differential user demands and needs require innovative strategies for information sharing, for both day-to-day and long-term decision making.

The risk communication study has been of very valuable assistance here as a communication strategy in itself, and by identifying with different communities of practice, the type and form of information they would like. As an action research project, the study has certainly increased awareness of what different risks are perceived across the different communities of practice. The project has also strengthened a communicative platform for advocacy within and between different groups. A key current challenge is in responding to the types of information required, and translating key parameters in the core monitoring undertaken into a suite of styles and means relevant to a highly differentiated audience.

3.2.5. External interface

Perhaps the most important function of the support systems is their ability to provide a clear means for management to respond to emerging issues and institutional challenges. The authors have developed some confidence in the developing toolkit from observations of the way in which emergent issues have been able to be incorporated into already established platforms. For example, the risk communication work developed over the past few years has provided a platform for managing issues relating to OH&S assessments, planning and procedures — a key issue facing all levels of organisations. On the other side, substantive relationships and trust developed with individuals across the community of water users has been undermined by the continuing loss of experienced staff. It is obvious that these forms of management systems need to develop to a level of maturity whereby continued application and improvement is not reliant upon key individuals.

Support regarding advocacy is also important. The Scheme is being promoted and enhanced as a hub of local, regional and international collaboration focusing on integrated water cycle, environmental and landscape management. The Scheme continues to demonstrate its relevance and the integration of elements within larger regional and policy contexts.

4. Conclusions

While the interactions and inter-relationships of all aspects of relevance to sustainable water recycling are complex, dynamic and open, robust systems of management and support can engage with these issues in an integrated and practical fashion. The logic underpinning EMS can be strengthened by explicitly linking this core framework with an emergent and evolving set of support systems. This premise is based upon a view that adaptive management is an appropriate approach to learn the way through. However, while this type of management toolkit approach often hangs precariously in uncertainties, the experiences learned will complement the more focused scientific inquiry into subsystems. Through this, the EMP and support systems framework may provide a means to operationalise the path towards sustainable water recycling in all its diversity.

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