The Need for Effective Information Exchange Between Knowledge Generators and Knowledge Users in Water Management

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Introduction

To say that the world is facing a water crisis is to understate the seriousness, extent and implications of the problems now confronting developed and developing societies. There are many problems related to water availability and quality and these are summarised, not in order of priority, in Table 1.

The aim of this paper is to investigate the need for effective information exchange between knowledge generators and knowledge users in water management. The global water crisis and humans' rights to water will be reviewed and the importance of regional initiatives involving community participation will be examined. The nature of the communication process relating to water management issues at a regional scale is then explored using models to illustrate the process and to identify the barriers to developing regional strategies. Finally some suggestions are made about developing 'network thinking' at the regional scale.

The Water Crisis and the Human Right to Water

There are obvious linkages between environmental degradation, and in particular water-related problems, and economic development (Itakura et al., 1999). Somewhat paradoxically, however, there is also a link between water-related issues and wealth. Comparing countries there is a clear positive correlation between oxygen levels in rivers and income, and between and within countries there is a negative correlation between income and access to safe drinking water (World Bank, 1992).

Table 1: A summary of the problems related to water availability and quality.

- Increasing demand for water and overexploitation of surface waters. Resulting water scarcity is a problem in the Middle East, Northern Africa, Sub-Sahara Africa, Northern China, West and South India, and Mexico. This is placing increasing constraints on domestic supply and economic activity.
- Potential changes in rainfall patterns due to global climate change. This could exacerbate regional shortages.
- Soil erosion results in the world's rivers carrying 15 billion tonnes of sediment annually. This causes stream sedimentation, reduces channel capacity and contributes to flooding, and has negative impacts on in-stream biological communities.
- Increased runoff due to catchment clearing and compaction of soils.
- Increased damage from flooding. This results from increased rainfall and changes in runoff patterns due to catchment clearing.
- Increased production of "water hungry" foods. This results from changes in living standards and population shift from rural to urban environments.
- Loss of aquatic biodiversity. This results from habitat loss, river regulation, and reduced capacity of water to support life due to contamination.

- Water pollution is causing a decrease in water availability. Poor sanitation and inadequate water treatment processes. Major cities in South-East Asia discharge raw sewage to the aquatic environment. The most widespread form of water pollution is contamination with disease-bearing human waste. As recently as 5 years ago several Victorian coastal towns discharged poorly treated sewage to the marine environment.
- Poor access to safe drinking water supplies. 45% of the world's population in rural areas (excluding China) lacks access to safe drinking water. 80% of all human disease is due to unsafe water. In Asian countries diarrhoeal diseases kill 1.5 million children each year. As recently as a decade ago only 6% of the population of Victorian country towns consistently received water that met the WHO standards.
- Escalating costs for access to water. People living in slums on the fringes of major cities in the developing world may pay up to 10% of their annual income for water.
- Escalating costs of the application of water treatment technologies to supply drinking water.
- Water pollution is causing a decrease in water quality. There are numerous cases of contamination with toxic chemicals and heavy metals from industry.
- Overexploitation of groundwaters especially "fossil water" resources. This is causing subsidence, saltwater intrusion into aquifers and pollution.
- Reduced recharge of groundwaters due to surface sealing associated with urbanisation.
- Water logging and salinisation of soils. This is the result of elevated water tables due to irrigation and catchment clearing. This causes increased salinity in streams and rivers.
- Increasing eutrophication. This is causing an increase in the incidence of algal blooms. This affects oxygen levels in aquatic systems and impacts upon human health.
- Water diversion. This is causing changes to river flow patterns, reduction in surface area of major lake systems, ecological, social and economic impacts. The salinity in Lake Corangamite, Victoria, has increased due to diversion of inflowing river water; this has altered the biological communities of the lake and triggered a virtually permanent blue-green algal bloom.
- Conflict. This occurs between water user sectors within a region, between states within nations and between nations. International conflicts involving water have occurred 21 times in the last decade; 15 of these involved violence. Resources in dispute include the Jordan, Ganges, Mekong, Euphrates and Nile Rivers.
- Environmental, social and economic effects of river regulation and dam building.
- Decline in high value and artesanal fisheries.
- Threats to wetlands. 80% of wetlands in the Asian region are under moderate to severe threat.
- Increased vulnerability to water borne diseases due to irrigation schemes. The prevalence of malaria and Schistosomiasis has increased.
- Inefficiencies in irrigation contribute to scarcity and conflict. 80% of water transported in some schemes may be lost due to evaporation and seepage. 20 tonnes of water may be needed to produce 1 tonne of rice; 75% of the water may be used to manage weeds.

- Irrigation causes waterlogging and salinisation. Irrigation uses 60 to 90% of annual water withdrawals worldwide.
- Poor government planning and inappropriate pricing resulting in subsidies for inefficient water use.

Source: Ellis, 1990; World Bank, 1990 and 1992; Andreev, Andreeva, Filippov and Aladin, 1992; Andreev, Plotnikov and Aladin, 1992; Petr, 1992; Williams, 1992; AMICC, 1997; Smith, 1998; Eades, 1999; GACGC, 1999; Kim, Lee and Jung, 1999; Kira, 1999; Manopimoke, 1999; Meadows and Meadows, 1999; Gleick, 2000.

An holistic analysis of global environmental impacts by the German Advisory Council on Global Change describes the most important problems affecting the environment in terms of 16 syndromes (German Advisory Council on Global Change, 1999). These syndromes fall into three categories, utilisation, development and sink. These are listed in Table 2 together with the symptoms or water related problems characteristic of each (modified from German Advisory Council on Global Change, 1999).

The global dimension of the water crisis is inescapable. Water related problems of varying severity can be found across a range of geographical scales. Water related issues are not problems "there" but problems here, they are not problems "in the future" but problems now, they are not problems for "them" but for us. Aral Sea Syndrome, albeit on a smaller scale, is developing in western Victoria in the vicinity of Lake Corangamite. Water related conflicts occur on all scales viz. between nations (for example, see Table 1), between states within nations (for example, the Murray-Darling River and the "cap" on water extractions), between regions within states (for example, environmental flows in the Glenelg and Wimmera Rivers), and within regions (for example, different users of water in the Merri River).

> Against this backdrop there is a need to consider the human right to water. The Universal Declaration of Human Rights (1948), the International Covenant on Economic, Social and Cultural Rights (1966), the Declaration of the World Food Summit (1996) and the United Nations Conference on Human Settlements (1996) all affirm, either explicitly or implicitly, the human right to adequate water. These social rights are not legally binding but involve an obligation on the part of governments to attempt to ensure that this right is honoured. Attempts to address the water crisis that involve market-based solutions must take this fundamental right into account. It would seem that part of this right to water is the associated right of people to participate in the decision making process as it affects water-related issues.

The Importance Regional Initiatives and Community Participation

Community participation in water related decision making is most likely to occur at the local and regional levels and at this level the water crisis may differ in extent depending on the social, economic and environmental characteristics of the region.

A regional-specific assessment of the global water crisis can be made using the "criticality index" K (German Advisory Council on Global Change, 1999), which combines measures of the natural water resources of a region, the demand on those resources by humans, and the problem solving or response capacity of society. That is:

$$K = \frac{\text{water withdrawals}}{\text{water availability x problem solving capacity}}$$

Table 2: The most important problems affecting the environment: syndromes and water related symptoms.

Syndromes	**Symptoms**
Utilisation	
1. Sahel	- over-cultivation of marginal land
2. Over-exploitation	- overexploitation of natural ecosystems
3. Rural Exodus	- environmental degradation through abandonment of traditional agricultural practices
4. Dust Bowl	- non-sustainable agro-industrial use of soils and water bodies
5. Katanga	- environmental degradation through depletion of non-renewable resources
6. Mass Tourism	- development and destruction of the environment for recreation
7. Scorched Earth	- environmental destruction through war and military action
Development	
8. Aral Sea	- environmental degradation through poorly managed or unsuccessful large-scale projects
9. Green Revolution	- environmental and development problems caused by transfer of locally inappropriate farming methods
10. Asian Tigers	- disregard for environmental standards during rapid economic growth
11. Favela	- environmental degradation through uncontrollable urban growth
12. Urban Sprawl	- destruction of the landscape through planned expansion of urban infrastructure
13. Major accident	- singular anthropogenic environmental disasters with long-term impacts - pollution of water resources resulting in scarcities - health hazards - failure of water resource development projects
Sink	
14. Smokestack	- environmental degradation through large scale diffusion of long-lived substances - contamination of surface and groundwaters - health hazards - eutrophication - acid rain.
15. Waste Dumping	- environmental degradation through controlled and uncontrolled disposal of waste - contamination of groundwaters - scarcity of drinking water - health risks.
16. Contaminated Land	- local contamination of the environment at industrial sites - pollution of groundwaters.

Where water is scarce, demand high and capacity to respond low, the global water crisis is manifested in an acute form. Measures that can be applied for each component are discussed in German Advisory Council on Global Change, 1999. Problem solving capacity could be measured in terms of economic strength, water-related expertise, infrastructure for supply and treatment of water, efficiency and stability of political institutions. Obviously, a key aspect of problem solving capacity is the education, motivation and political empowerment of the population. Another key aspect of problem solving capacity is 'network thinking' - the degree to which the regional community has developed effective linkages between the various sectors involved in water use and management. A major constraint to water management in many regions is that management is fragmented between sectors and water rights and ownership not are clearly defined. Even where fragmentation is not pronounced communication between sectors is a critical issue.

It is now recognised that regions and catchments are the most suitable scale for managing natural resources, particularly coastal and inland water issues (Alexandra, Higgins and White, 1998; Rhoades, 2000), and regional strategies are most effective when generated and overseen by the community with appropriate support from other sectors (National Natural Resource Management Task Force, 1999). The regional scale offers the best opportunities for planning and action, industry and community development, resolving conflicts and determining priorities, and integrating social, economic and environmental considerations. Most of the strategic planning for catchment management makes use of the adaptive management approach. The basis of this approach is the acceptance that people do not have full control over or understanding of their environment and therefore regular revision of management plans is necessary to account for unanticipated changes or development of knowledge (Alexandra, et al., 1998). In the adaptive management cycle the effects or outcomes of management are monitored so that the degree of success of management strategies can be assessed. This generates a management cycle wherein successive refinements of management activities occur in response to the testing of management strategy options (Alexandra, et al., 1998).

The philosophy of regional or catchment-based adaptive management strategies to tackle natural resource problems is based on the "bottom up" process of community involvement in identification of problems, understanding of problems and proposing solutions for which there is consensus (Robinson, 2000). This stems from the very real demand by the community for increased participation in the decision making process (Rhoades, 2000) which, in turn, reflects concerns by the community about the nature of representative government (Curtis and Lockwood, 1998, cited in Robinson, 2000). Public participation in decision making is essential if resource management is to be effective. Public support for environmental management relies on the community being well informed (Sani, 1999).

Regional strategies are most effective when generated and overseen by the community. This approach requires devolution of decision making and appropriate support. One aspect of this support is the requirement for ready access to relevant data and information. A key requirement for adaptive management is environmental, social and economic information. For effective natural (and in this case specifically water) resource management there is an increasing need to combine the experience, knowledge and preferences (or values) of the community with the expertise and knowledge base of managers, business and researchers (Robinson, 2000).

This raises two key issues - communication and decision making. Models and methodologies, such as multi-objective decision support systems (Robinson, 2000), have been developed to facilitate decision making at the regional scale. However, these decision making management tools assume effective communication between stakeholders (or the business, community, research and management sectors). Models and methodologies dealing with the communication process and communication strategies at the regional scale do not appear to be well developed. This is a barrier to decision making. While individual organisations involved in natural resource management may have knowledge exchange strategies and programs the key issue is the degree to which integration of communication between sectors occurs on a regional or catchment scale.

Alexandra, et al., (1998, pg 7) refer to a working partnership between regional stakeholders as the central element of an adaptive management system and an "informing system" as the means by which information is delivered to environmental managers. However, the informing system described by Alexandra, et al., (1998) stops short of proposing a regional strategy to effect knowledge exchange. The informing system that seems to have been adopted in Australia is biased towards data collection and transferral of the data to managers. An important issue regarding this system is whether knowledge based upon that data is transferred to the community and other sectors such as business. The involvement of the community in environmental monitoring, one of the key aspects of integrated catchment management and at the core of the current national approach to state of the environment reporting (Alexandra, et al., 1998), does not of itself improve knowledge or understanding. Environmental monitoring, whether it be conducted by managers, researchers or the community, generates data or information; this information must be assessed, interpreted and related to other data (environmental, social and economic) to increase understanding, that is, to become knowledge. This view is supported by Smith (1998) who concluded that the nature of the

water quality information available for Australia was such that the assessment of water quality issues had been constrained by the large amount of unprocessed data in some areas. Adding to this unprocessed data will not improve catchment management.

This should not be interpreted as a criticism of community involvement in environmental monitoring, either as a part of adaptive catchment management or in terms of the information generated by such programs, which is vast and can be of high quality (see the examples of Saltwatch, Watertable Watch and Waterwatch as described in Alexandra, et al., 1998). Rather it is a call for some critical self-analysis of the systems we have set up to determine whether they can be made more effective. The community can generate conductivity data by the database full but without some analysis of the data, over space and time, some interpretation of the trends, and communication of the outcomes of the analysis back to the community this will not improve knowledge or understanding. Critically, it will not aid the community in evaluating the options for management to address the problem. What is needed at the regional level is a review of how effectively the regional network or informing system is operating.

In essence the key question is, do regions have a knowledge exchange strategy and an effective informing system?

The Socio-cultural Context of Water Management

Each society, and particular sub-groups of society, has its own water culture, which will influence the resolution of water related management issues. Water related behaviour is learned early in the process of socialisation and becomes a habit that is generally not consciously perceived or reflected upon (German Advisory Council on Global Change, 1999). Any approach to dealing with water related issues must acknowledge and address this. The issue then becomes whether or not there are universal elements or aspects of water management or whether all aspects must be societally contextualised.

Part of the solution to water related management issues is a change in human behaviour. This is in addition to instruments which may be market-based or state-supported (German Advisory Council on Global Change, 1999), although it is likely that the future involves a change in the traditional role of government in this area (World Bank, 1992). Community-level responses to the water crisis involve education, public discussion of the issues, and communication between sectors. This will foster learning, which will result in changes in attitudes and behaviour. Behaviour relevant to the global water crisis occurs at various levels of society from the individual to the community to national and international organisations. However, it must be remembered that people always act in local contexts that are spatially and temporally specific and the socio-cultural context is important when considering community or regional initiatives (German Advisory Council on Global Change, 1999).

The critical role of individuals and their networks within regions in resource management is in network thinking. This can be illustrated using the Hinge Model as shown in Figure 1. The model is a five level conceptual model that describes the process by which environmental outcomes are determined, that is, how interactions, and exerting pressure at different scales result in management policies that have positive or negative environmental outcomes. The left-hand side of the model depicts a belief system based upon the market value of resources, a dependence upon financial capital, pro-development at local and national scales, pro-growth and economic development, market forces and “winners and losers”. The right hand side of the model depicts a belief system based upon essential ecosystem services, dependence upon natural capital, balanced development at local and national scales, sustainable growth and development and sustainability and equity. These are of course the extremes of a continuum of belief systems. The two belief systems work in opposition, that is they push each other backwards and forwards or up and down, depending upon factors operating at five levels: personal, community or regional, state, national, international.

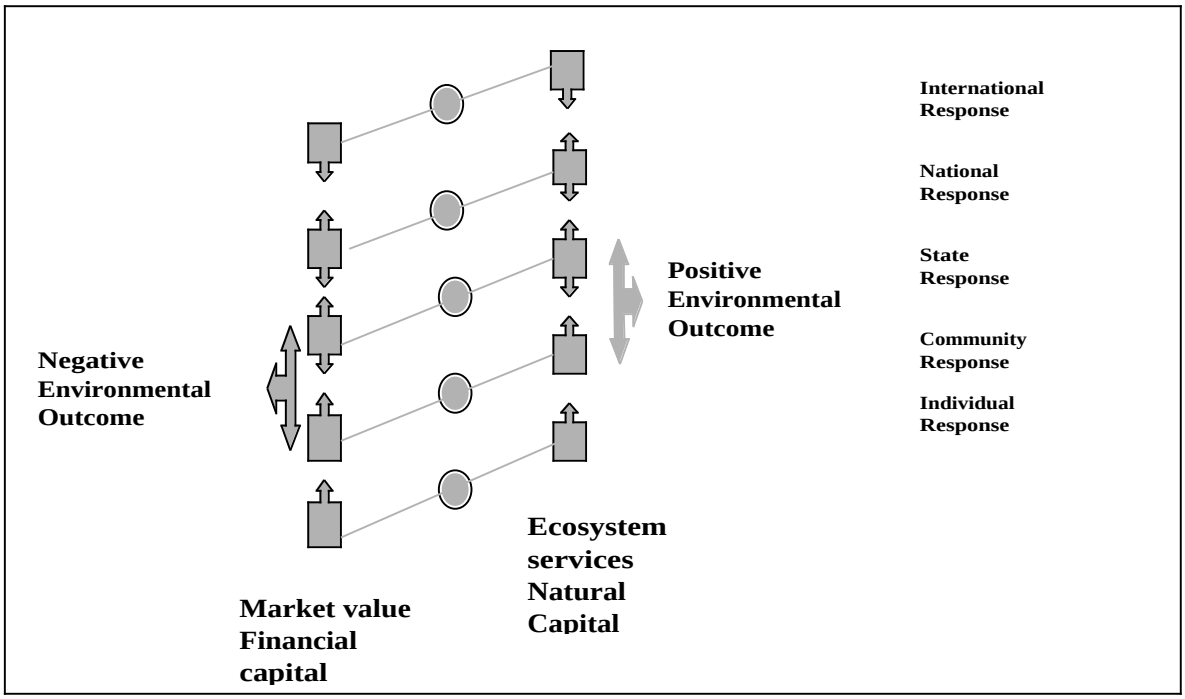

Figure 1: The Fulcrum Model - demonstrates the critical role of individuals and their networks within regions

Level 1 represents the individual's response. The process starts with key individuals working within their community and region. Despite the fact that education is undertaken at the community level, community responses do not occur spontaneously at a mass level. A community responds because key individuals, who can capture the imagination of the community, motivate others and mobilise the efforts of their networks compelling action. The response of the individual is based upon a personal cost-benefit analysis of the outcome or effect for a given issue. If the individual deems that the cost of development (what may be lost) exceeds the benefit (what may be gained) then they will be compelled to act within their community to effect support to oppose the development. If the individual deems that the benefit exceeds the apparent cost then they will be compelled to act within their community to effect support for the development. The response of individuals generates a community level response.

The community level response, Level 2 of the model, depends upon the persuasiveness and standing of key individuals in the community and how those key individuals mobilise resources. This has been termed "political entrepreneurship" (World Bank, 1992). This is possibly the most important determinant in the community level response. The political entrepreneur is not only able to motivate others but is able to engender trust and, critically, to demonstrate the benefits of community response. Response at the community level will depend upon the immediacy of the issue to the community, as influenced by the political entrepreneur, and the degree of education within the community on the issue. The community level response may be directly or indirectly effected. Directly by implicit and cultural needs, which will be based upon immediate needs or the apparent benefits of development in the absence of informed opinion on true costs. On the other hand it may be effected indirectly through education and training, which informs the community of true costs. The community level response may be one of valuing natural capital, in which case positive environmental outcomes will occur, or it may be one based upon emphasising financial capital, in which case negative environmental outcomes may occur.

To this point the process is bottom-up. The state level response, Level 3, can be part of a top-down process depending upon ideology of the party in power. If the response at the state level is one of balanced development then the effect of the community response will be a positive environmental outcome. If the response of the state is pro-development then there may be a negative environmental outcome.

The state level response will be influenced top-down by the national level response, Level 4. The national response will reflect the self-interest of the party in power. This may or may not be the same as the party in power at the state level. If the national level response is one of sustainable development then there may be a positive environmental outcome. This may be effected in partnership with the state level or it may be effected by overriding the state level response. If the national level response is one of pro-growth then there may be a negative environmental outcome.

The national level response may be influenced by the international view (Level 5), that is the international community may bring pressure to bear on a national government to force more positive environmental outcomes or to promote a "market forces" response, which may effect negative environmental outcomes. The international community response reflects power players within regions and globally. If the international community exerts pressure for sustainability and equity considerations then a positive environmental outcome is likely. If on the other hand the international community exerts pressure for economic development via market forces then negative environmental and social outcomes may occur.

The model highlights several key features of the network thinking process. Firstly, the crucial role of individuals operating within their community. Secondly, that it is both top-down and bottom-up, that is international, national and state responses may change individual attitudes via education, training and research; state, national and international responses are influenced by individuals exerting their views either by public action or through the ballot box. Thirdly, that it is not unidirectional, that it does not flow cleanly or simply from one level to the next and how action at one level affects the next level depends upon the receptiveness of the next level to the action occurring. This receptiveness varies depending upon political ideology and so at times the net effect is movement towards a positive environmental outcome while at other times the net effect is movement towards a negative environmental outcome. The balance between the two major forces (belief systems) shifts over time but not necessarily in a constant direction. The process shudders back and forth as nations move towards economic development and increased consumerism and as governments (national and state) change. The strength and direction of movement will be influenced by such factors as knowledge and understanding, climate and market.

The response to water management issues and hence the strength and direction of movement occurring will depend on the effectiveness of the communication process. In order to analyse this effectiveness a number of questions need addressing. What is the nature of the communication process at the regional level? What is communicated? Where does the knowledge come from? And from here, what are the barriers to developing regional strategies?

The Nature of the Communication Process

When considering how the process of network thinking works at a regional level there is a need to consider the nature of the communication process, that is how communication occurs. According to Cullen (1997), there are two recognised models of science communication. The first is the source-channel-sink model, which involves a transmitter, a channel of communication and a receiver. The receiver is conventionally viewed as passive that is it is largely a one way process. In the current context this one way process may be made worse by the notion of "the expert" communicating with the "poorly informed" which connotes information as power and a position of privilege. Inadequacies in the model have been documented (Campbell, 1996, cited in Cullen, 1997)

The second model is one of two-way communication through dialogue or conversation. This interactive model is based upon the idea that communication occurs so that the recipient acquires knowledge (i.e. learns) but in listening to the response of the recipient the communicator also learns and gains new insight into the problem. This makes the communicator and receiver partners in the communication process; if more than two partners are involved then this process involves the concept of an information network rather than a series of one-way channels. The current approach to resource management, which involves stakeholders in the consultation process, is obviously based upon this model.

Two way communication via a true network is essential if "deep learning" (after Cullen, 1997) is to occur. Deep learning occurs when the network partners experience the concept under discussion, put it into their

own language and apply it to their own problems. Deep learning depends upon dialogue between the "expert" and the community. This dialogue must allow the community to attempt to apply the knowledge gained and thereby to test their understanding and correct errors. The Landcare movement in Australia is an example of such a process whereby the landowners become the agents of management at the property or sub-catchment level.

It is important now to consider two questions. Firstly, how effective is our current model of communication between the sectors involved in water management issues at the regional scale? Secondly, what model can we use to think about communication relating to water-related issues at the regional level? Figures 2a to 2c present a model which simplifies the region into four sectors: the community, managers, business and researchers and illustrated the communication interactions between sectors within the regional envelope.

The sub-model shown in Figure 2a depicts the sequence of events when a management issue arises. The various sectors become aware of the issue (step 1). Key awareness considerations are how the various sectors become aware of the issue, who becomes aware of the issue first (and the implications of this) and who acts first to address the issue. Managers may become aware of the issue via long term monitoring programs; if such programs are not in place managers may be unaware of the issue. The community may become aware of the issue via first hand exposure (eg. loss of aesthetic amenities or effects on landowners) or via communication with managers. Business may become aware of the issue via first hand exposure (eg. effects on operations) or via communication with the community and/or managers.

Exposure to the issue results in communication between community, business and manager sectors (step 2). It is obvious that delays in communication resulting in differing levels of awareness between these sectors is an obstacle to addressing management issues. Critical communication considerations at this stage are coordinated communication between the sectors and providing for differing information needs between sectors. If communication between sectors is not coordinated and does not involve the two-way process described above then "push - pull" situations can arise. That is, the community may be informed ahead of managers and may feel that it has to "pull" reluctant or cautious managers into the issue. If managers are informed ahead of the community they may feel that they have to "push" a reluctant community into management action. If business is not informed along with other sectors it may feel pulled by the community and pushed by managers at the same time.

Communication between sectors leads to involvement of researchers in the issue (step 3). A key consideration here is how researchers become involved in the issue, that is who is responsible for their involvement? If the community involves researchers the research outcomes are often left to the researchers to develop; such outcomes may not be useful for management. If the managers involve the researchers then research may be limited to monitoring and not tackle fundamental processes because of time constraints. If business involves the researchers this is generally on the basis of consultancy and the outcomes may be useful for the businesses involved but not of more general applicability. It is also likely that research outcomes will be confidential and this may prevent information flow to the community and to managers. Sometimes researchers initiate the research themselves. In this situation the research may be narrowly focussed and strictly discipline-based because research funding may be limited.

The question of which sector initiates the research is important because it affects the important issue of ownership of the information collected. Sueishi (1999) argues that the involvement of researchers in an environmental issue has the potential for creating a monopoly in terms of the control of knowledge and/or systems for the collection of information. Sueishi (1999) goes further and poses the question of whether researchers need to be involved in all issues and whether there are some issues that do not need specialist information.

Figure 2: Regional Communication Model

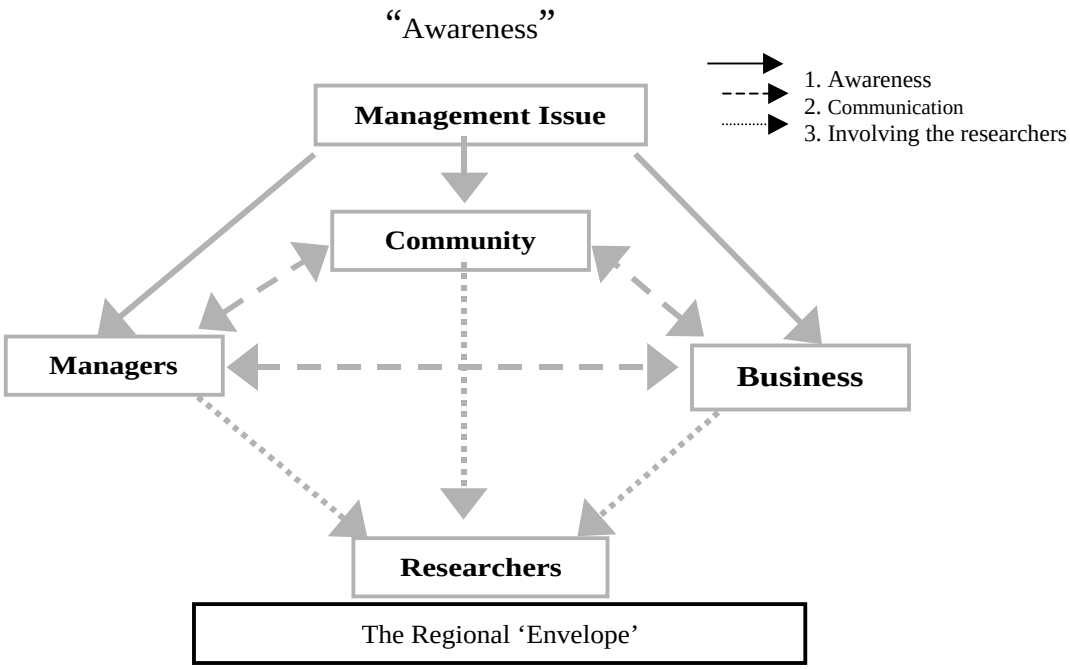

Figure 2a: Becoming aware of the management

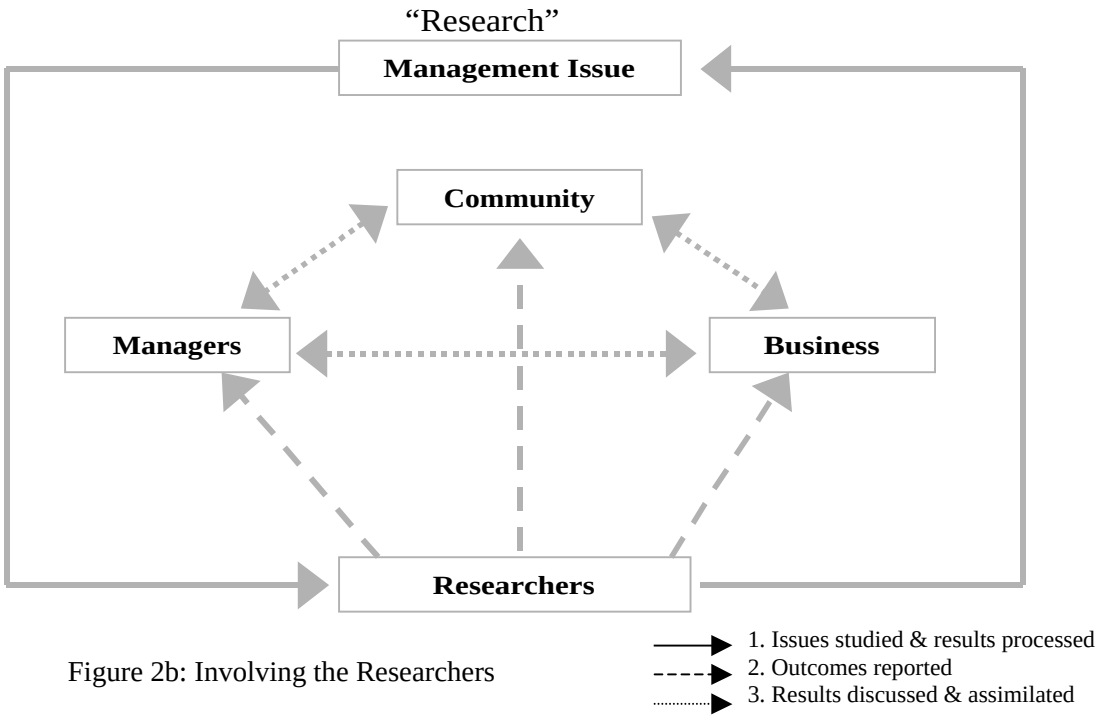

Figure 2b: Involving the Researchers

Figure 2 ctd.: Regional Communication Model

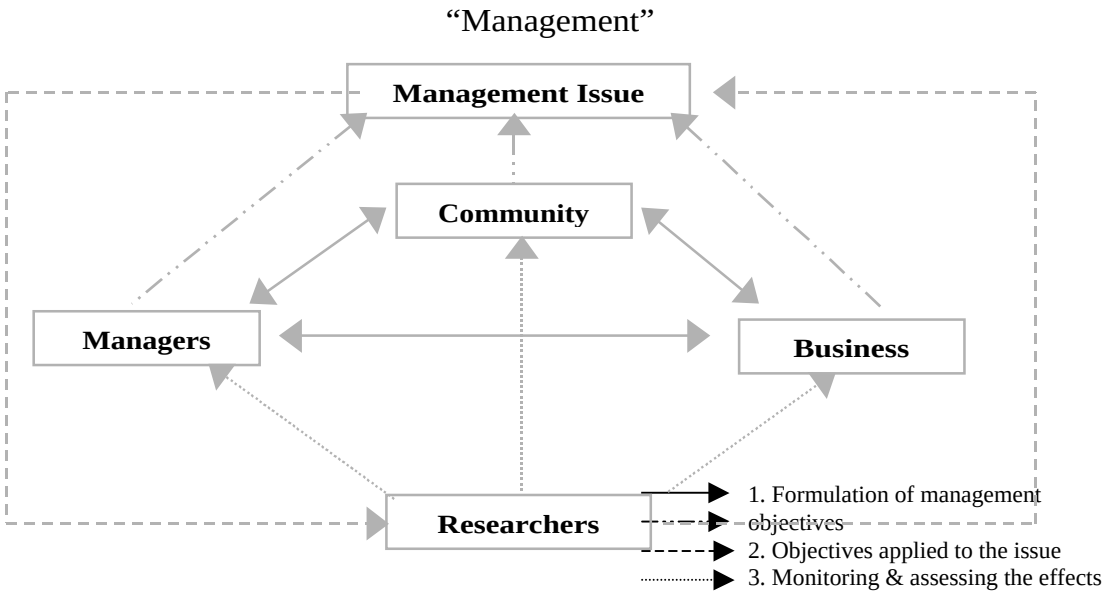

Fig. 2c: Applying the research outcomes to management

The sub-model presented in Figure 2b shows what happens when researchers are involved in the regional network. Researchers study various aspects of the management issue (step 1). As discussed above the exact nature of the aspects studied and the scope of the research is determined by which sector involves the researchers. Partnerships between sectors for conducting research into management issues should be explored at this step however, partnerships should not become knowledge cartels and result in exclusivity with respect to other sectors. The researchers (step 2) then process the outcomes of the research. A key consideration here is the integration of research outcomes particularly, as will be discussed later, if the research is broken down into discipline-specific questions.

The outcomes of research are then communicated back to the other sectors (step 3). The key issue at this step is which sectors the researchers communicate with. This will be largely determined by which sector(s) initially involved the researchers. Key to this process will be the methods by which researchers communicate with the other sectors and what information is communicated with those sectors. If researchers only present their findings to their peers (ie. within their research network) or in a highly technical form, even if this occurs at public seminars, then certain sectors may be locked out of the communication process. There is increasing pressure on researchers to publish their work in refereed journals rather than in the so-called "grey literature". If researchers initiate the research themselves or at the behest of managers or business then they may have no mandate to organise public meetings to disseminate the findings of that research. These issues are further discussed below.

Step 4 in the model involves communication between the other sectors to assimilate the research outcomes. This step is crucial and is where "deep learning" occurs. Key issues at this step are how the research outcomes are understood by the various sectors. It is essential at this stage that the other sectors be confident enough to interrogate the researchers and to push the researchers to put the research outcomes into forms that can be applied in management deliberations. The research sector must not remain aloof or isolated at this step.

The submodel presented in Figure 2c shows what happens when research outcomes are applied in management deliberations. Manager, community and business sectors assimilate the outcomes of research and formulate management objectives and strategies (step 1) which are then applied by the various sectors to the management issue (step 2). The various sectors may apply different components of the overall management strategy; in this way each sector is actively involved in management action. At step 3 the researchers monitor the effects of the various management actions. Key considerations for monitoring are is it being conducted and who is monitoring the effects of the management actions. Business and manager sectors generally conduct monitoring via professional researchers acting in research partnerships or as consultants. The community may be directly involved in monitoring but it is essential that the information collected actually be useful in assessing the efficacy of management action. The issue of who should be responsible for monitoring and who owns the information collected should be clearly addressed prior to the implementation of management action. The establishment of partnerships between all sectors for the purpose of monitoring should also be considered at an early stage.

The researchers, at step 4, assess outcomes of monitoring. The key issue at this stage is that the management objectives have been clearly enunciated so as to allow accurate assessment of the efficacy of management actions. The monitoring-feedback loop is essential if management is to be adaptive.

Partnerships between researchers and other sectors for monitoring are increasing. A major initiative of the National Heritage Trust for example, has been to foster partnerships between all levels of government, industry and the wider community (Conacher and Conacher, 2000). Part of the benefit of establishing partnerships for research and monitoring is that gateways that block information flow between sectors can be identified and information flow promoted as part of the process. However, as referred to above partnerships become counter-productive when they effectively become a network within a network and exclusive rather than inclusive.

What is being communicated?

Communication between sectors within the region could be through the exchange is of information, knowledge or wisdom. Generally, information is exchanged to share a point of view, to inform to bring about a change in attitude or behaviour. Information does not of itself change attitude or behaviour. Knowledge is more than information in that it includes discernment. Discernment is possible when sufficient familiarity with a particular subject has been gained to allow critical assessment of further information. Wisdom is what is needed in management - this is knowledge plus just judgement as to action. We need to communicate more than just information. Cullen (1997) argues that communication, in the context of environmental management, is not just about passing on knowledge but about imparting a clear message that will change attitude or behaviour in the receiver. This means ensuring information becomes knowledge by overview, critical assessment, weighing up conflicting pieces of information, assembling information into coherent groupings. It also means ensuring that, along with knowledge, some judgement as to appropriate action is also imparted to the receiver. When considering water management issues at the regional scale we need to ask several questions. Does this occur? What do the various receivers of information receive? What are we passing around the regional network?

Scientific knowledge about any environmental issue has four elements (after Cullen, 1997): what we know; what we think we know; what we would like to know; and what we do not know and are unaware of. 'What we know' is accepted knowledge that is widely agreed upon by researchers as a basis for predicting outcomes. 'What we think we know' is disputed knowledge where different ideas may compete or a false idea is accepted without scrutiny (this may result from the rush to manage which requires answers to problems which may not have been adequately researched eg. estuarine mouth opening, environmental

flows). 'What we would like to know', which is determined by what we think we need to know, which is determined by what we think we already know. This is determined largely by people familiar enough with 'what we do know' that they can "estimate" what further knowledge is needed. 'What we do not know and are unaware of' refers to areas where we do not have useful knowledge and are not aware of this.

A critical aspect of the communication process within a region concerns the nature of the information or knowledge that is communicated between the various sectors. In the ensuing discussion it will be assumed that it is knowledge that is transferred between sectors; in reality it is often information that is transferred and not knowledge. If different sectors are receiving different parts of the knowledge or different versions of the knowledge then the potential exists for misinterpretation or different interpretations. This can lead to conflict in management deliberations and different views on appropriate management actions. Exchange of different parts or version of knowledge can result from the filtering of information between sectors. Some sectors will possess detailed technical knowledge while others may only receive filtered or simplified knowledge. This means that the various sectors may have different levels of understanding on certain management issues. This is influenced by which sector integrates the research outcomes (and whether integration is conducted at all) and who "owns" the knowledge.

This aspect of regional communication is modelled in Figure 3. This model builds on the first, second and third stages of information dissemination as outlined by Sueishi (1999). This model depicts how knowledge is disseminated from researchers to the other sectors within the region in different forms and the role of the media in knowledge transfer. Knowledge is passed from the research sector to the manager sector in a detailed technical form; however, researchers generally simplify research outcomes for transfer to the media and for the community. Researchers generally communicate with the community within their disciplines. This means that the community may receive several lines of filtered knowledge from the research sector. Managers communicate detailed technical knowledge to business but generally simplify knowledge for transfer to the media or directly to the community. In all cases knowledge transfer from managers involves a government policy "filter" which may influence the extent or interpretation of knowledge transferred. The business sector also filters knowledge to the media. The media further simplifies knowledge before transferring it to the community and may "popularise" such knowledge by introducing a particular interpretation that suits editorial policy.

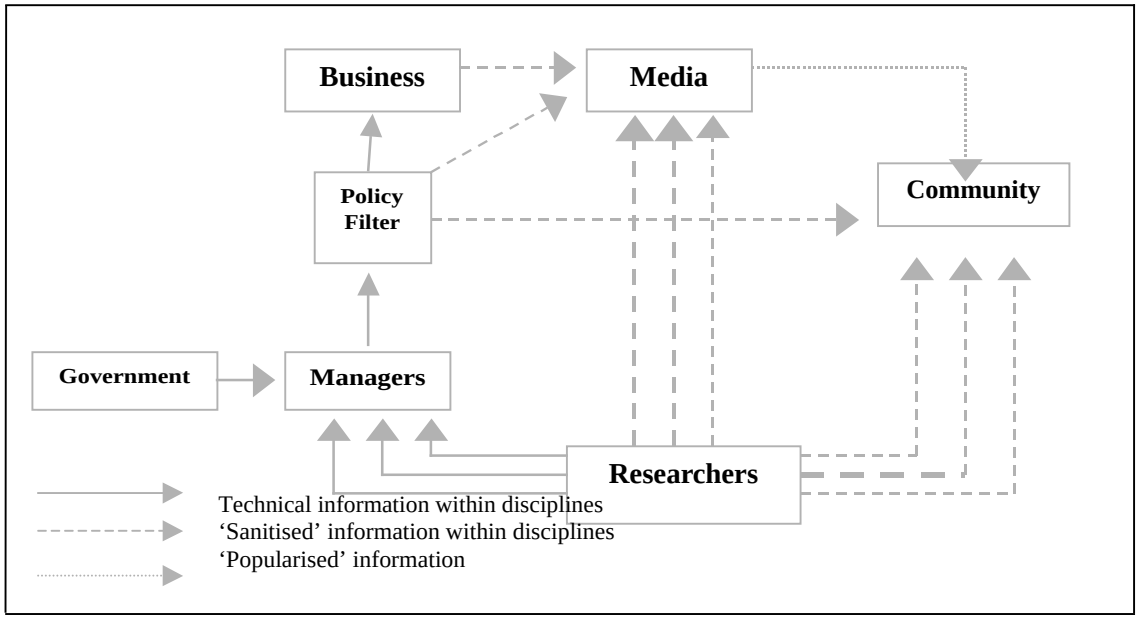

Figure 3: Knowledge Filtering within the Regional Envelope

This model suggests that the community receives selectively filtered knowledge from all other sectors. Certain sectors are in possession of detailed technical knowledge but interpretation may vary between sectors due to different filters being applied to that knowledge. A key issue in this model is which method of communication has most effect on the community sector and therefore exerts most influence on attitudes and behaviour. The crucial role of education is highlighted here. The importance of integration of knowledge across disciplines and across sectors and whose responsibility it is to effect such integration is critical. In the past such integration at a regional scale has not taken place. This has been addressed in Victoria to a certain extent by the formation of the Catchment Management Authorities.

This aspect of communication obviously affects the balance between the different elements of knowledge discussed above. Filtered information may contribute to disputed knowledge ("what we think we know") between sectors, may result in differences in research and management objectives ("what we would like to know") between sectors, and will result in different knowledge gaps ("what we do not know and are unaware of") between sectors.

Where does the information come from?

Scientists, managers and bureaucrats, landholders and the wider public communicate well amongst themselves. That is communication within sectors is good but communication between sectors is often poor. This is particularly true of scientists/researchers (Cullen, 1997). The model presented in Figure 3 depicts information flow within a region but information also flows into a region from outside. Key questions about this information flow are what information penetrates the regional envelope and how does this information pass through the envelope.

The relationship between the regional envelope and the wider context is modelled in Figure 4. In effect this model proposes that three communication networks exist. The first network (1 in the model) is the regional network, communication between sectors. Within this network communication is rapid and direct. The second network (2 in the model) is the sectoral network of which each regional sector is a part. This network sits outside of the regional network. This means that researchers communicate with other researchers outside of the region, managers communicate with other managers outside of the region and so on. Generally communication within the sectoral network takes place via professional publications and technical conferences. Communication within this network is less direct and tends to be slower, relying on publication cycles and annual conference timetables. The third network is the global information/knowledge network, which may be national or international. In this network, members of one sector may find out about knowledge in another sector by reference to the professional literature of that network and participation in professional meetings organised within that network. Communication between sectors within the global network is slow, indirect and "hit and miss", that is, the process of literature searching means that it is easy for key sources of relevant information to be overlooked.

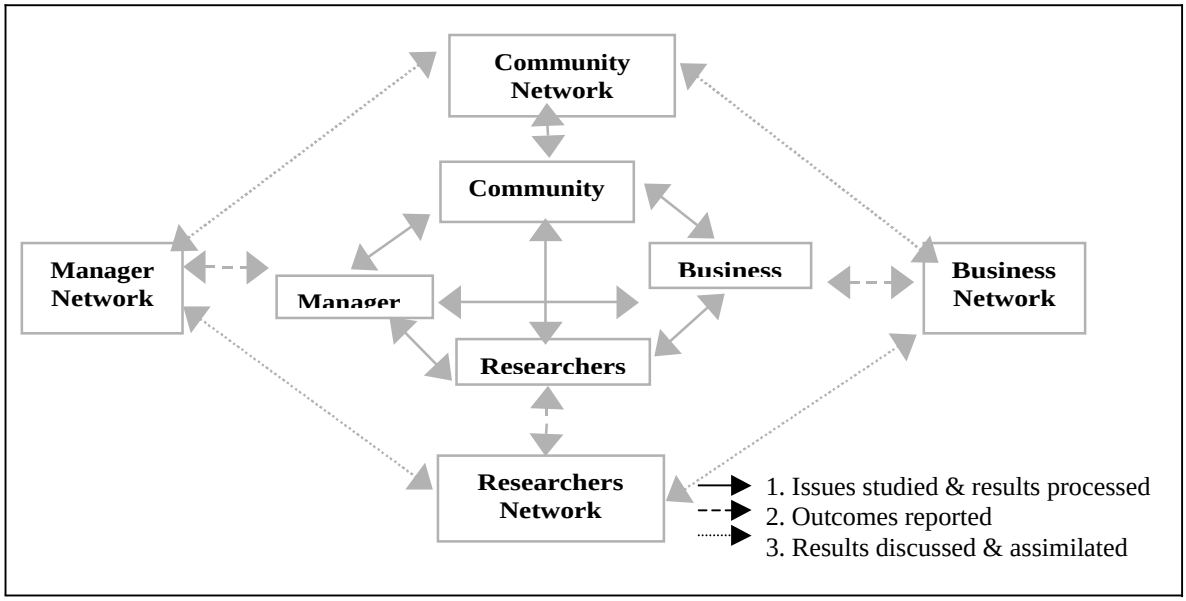

Figure 4: The Three Network Communication Model

The key issue raised by this model is whether the various sectors within a region are communicating with each other as part of the regional network or via the global network which involves slower and incomplete transmission of knowledge. It should be the objective of regions to short-circuit the knowledge communication process to ensure that it occurs within the regional network and not outside of it. The various sectors should be talking directly rather than communicating via the interrogation of each other's literature. If the sectors within a region communicate via sectoral and global networks rather than regional ones then there will be delays and gaps in knowledge transfer. This will exacerbate the problems discussed above.

For communication to be effective then "network thinking" should occur at the regional level. For each sector within the region the key question is what is our network? That is, does network thinking occur across sectors within a region or is it restricted to within the sectoral network?

Barriers to Regional Solutions

Severe gaps exist in information of all types (viz. technical, economic and social) – and particularly in information relating to sustainability (German Advisory Council on Global Change, 1999). Sustainable management of water resources is a cross-sectoral challenge, which requires new approaches to decision making. Network thinking is required but poorly developed in most contexts.

The integration barrier (Mitchell and DeSilva, 1992) shown in Figure 5 refers to the lack of interdisciplinary communication and research collaboration that has characterised the development of inland water resources, particularly in developing countries. This has resulted from networks being confined to within disciplines within sectors. Although research may be initiated to solve a broad problem, the manner in which research is undertaken often leads to it being fragmented into distinct disciplines. The outcomes of research tend to be narrow and often the necessary integration does not occur, either at the front end of the process (research design) or the back end of the process (application). The very nature of disciplinary-specific research provides barriers to the integration of research outcomes, and this is an impediment to the development of management strategies. Managers may be given incomplete information or may not have the necessary capability to undertake the integration of the various research outcomes. The community may be given partial insights into a mosaic of effects but the pieces may be insufficient to

give the community the overall picture. This prevents the community from participating in the management process.

The integration barrier limits the network boundary or envelope to that within sectors or within disciplines within sectors and therefore stifles true regional network thinking or skews it to a subset of the regional network. The need for a more interdisciplinary approach to research on natural resources management has been highlighted by the National Natural Resource Management Task Force, 1999. This would facilitate collaborative work and increase knowledge exchange across sectors. Institutional arrangements for research and development organisations should foster interdisciplinary approaches to water problems. This problem is being tackled to a certain extent through organisations such as the Cooperative Research Centres (CRCs), but one could easily ask who is integrating the research outcomes across CRCs? That is, where is the CRC for research integration? This problem is characteristic of all attempts to effect sustainable development of natural resources.

There appears to be a widespread and fundamental problem in adopting a truly holistic view of water resource development. Regional water management will not rely solely on multidisciplinary research but also on holistic programs which integrate research and education/communication (Meadows and Meadows, 1999).

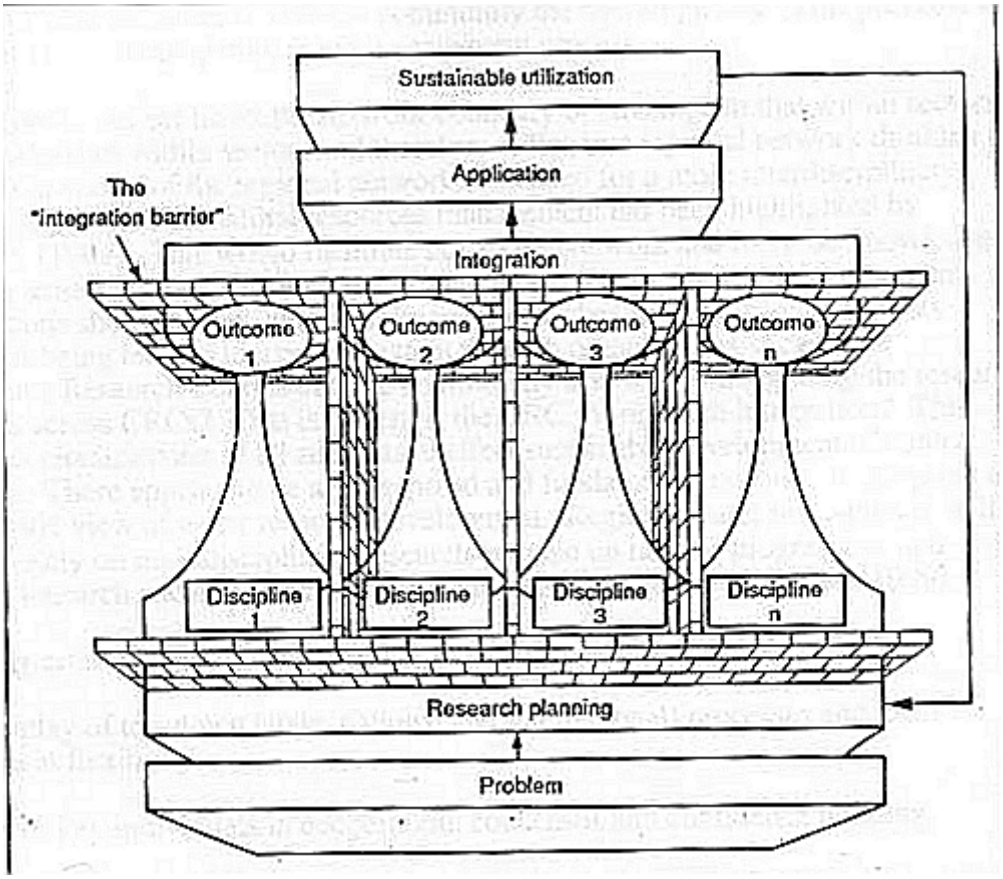

Figure 5: Conceptualization of impediments to the integration of information in multidisciplinary studies. The "integration barrier", shown as a series of brick walls, operates at both the research planning and completion stages.

Source: Mitchell and DeSilva, 1992.

As well as the failure to develop network thinking and the lack of integration of knowledge across disciplines a number of other barriers to establishing regional water strategies exists. These include

- the institutional reforms that may be involved in resolving cross-sectoral issues;
- the interplay of top-down (state, national and international) processes and local government flexibility;
- the role of key individuals in cooperation, consensus and confidence building;
- a lack of experience with new forms of participation and communication;
- a lack of feedback from the consultative or communication process;
- the time and energy required of volunteers in the community; and
- the conflicts between the strategic interests of organisations and immediate interests of individuals and the community.

Lack of effective community participation is shown to be a significant barrier to developing regional strategies. Education programs that incorporate ecological principles and are based upon local examples can enhance community participation in water management issues. These programs bring the community into contact with environmental problems in their immediate surroundings. In particular, such programs need to stress causes and processes of disruption to aquatic ecosystems. Examples include the International Lake Environment Committee Environmental Education Project (Kira, 1999) and the Saltwatch and Waterwatch programs referred to above. The involvement of the community in environmental monitoring is an integral part of current approaches to adaptive catchment management. Kawashima (1999) argues that the state of the environment should not be judged primarily by researchers or managers but by the community. If this is to be the case then on the one hand the community must understand environmental problems to a much deeper level than is likely to be the case at the present time. On the other hand there must be opportunities for local knowledge to be recognised and incorporated into the regional network thinking.

To meaningfully involve the community in adaptive catchment management requires that the community possess not only the required knowledge but also skills, attitudes and motivation to work with other sectors to manage water (Kawashima, 1999). Community understanding of water problems requires that the following knowledge is available and accessible:

- clear identification of the causes and effects of water related problems;
- an unambiguous assessment of the current severity of the problem;
- future perspectives via clear presentation of predictions and trends; and
- useable social, economic and technical information.

This reinforces the need for more effective communication of research outcomes within the regional context.

The Development of Network Thinking at the Regional Scale

To a large degree resolving regional level water related issues maybe a communication issue. It is clear that the development of network thinking at the regional scale is needed but it is also clear that communication between the various sectors within the regional network is fraught with difficulties.

There are numerous strategies for communication and these can be separated into those that communicate within sectoral networks (ie. within management, community, business, researcher networks) and those which cross sectoral networks and therefore have the likelihood of contributing to regional network thinking (see Table 3). The types of strategies being used within the region will determine the success or other wise of the communication process. If the communication strategies employed are exclusive (for example, largely technical reports and professional publications) then the result will be network contraction.

Table 3: Examples of communication strategies available within and between sectoral networks

Within Sectoral Networks	Across Sectoral Networks
- presentation at conferences - professional publications - technical workshops - technical reports - technical models - demonstration projects - websites	- websites - use of mass media - community meetings - education programs - short courses/workshops - direct contact on committees - public presentations/displays - technical reports and design guidelines - decision support systems and simple models - demonstration projects - extension (in agricultural sense).

Source: Adapted from Cullen, 1997

One factor that should not be underestimated that may prevent or discourage researchers, managers, and business from communicating with each other and the community is the very real possibility of the "hostile audience". This may occur because the management implications of the information being discussed are unpalatable or because the perception of the problem is different amongst the partners in the network ie. regardless of which sector is involved it may often be telling other sectors things they simply do not wish to hear. Even attempting to communicate that perceptions differ between sectors may be difficult. This discourages face-to-face communication and encourages communication through the safer networks within sectors. Cross-sectoral communication then relies upon serendipitous spill over across sectoral boundaries.

It is clear that effective communication will enhance network thinking within the region and promote the development of improved water management strategies. There are several ways to develop network thinking at the regional level. It can be achieved by developing a regional communication strategy and informing system that provides more knowledge not more information. It will require a community participation program that provides education based on local example, involvement of the community in environmental monitoring and improving community understanding of

- useable social, economic and technical knowledge;
- the causes and effects of water related problems;
- unambiguous assessment of the severity of problems; and
- the future perspective via predictions and trends.

The challenge for regions and participants at this symposium is to consider barriers to the exchange of information and knowledge, and those that prevent or hinder uptake of research and innovation, that is to critically self evaluate their current communication process. Each sector has to ask of itself: to what degree is participation in communication limited to within sectoral network strategies? Can we short-circuit global communication to strengthen regional network thinking? In this way it is hoped that strategies to promote communication between researchers and users to improve water management on a regional scale can be developed. The need for this type of approach is highlighted by Rhoades (2000). He concluded that, as of 1997, there were few published evaluations of whether participatory catchment management actually works, that no international conference had yet been held to critically compare experiences, and that the few studies evaluating such approaches to resource management had been in-house publications with limited dissemination of the findings.

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