Taming the waters: strategies to domesticate the wicked problems of water resource management

Denise Lach*

Center for Water and Environmental Sustainability,
210 Strand Ag Hall, Oregon State University, OR 97331, USA
E-mail: denise.lach@orst.edu
*Corresponding author

Steve Rayner

James Martin Institute for Science and Civilization
Said Business School, University of Oxford, OX1 IHP, UK
E-mail: steve.rayner@sbs.ox.ac.uk

Helen Ingram

Social Ecology of Peace and International Cooperation,
Political Science, University of California, Irvine, CA 92697, USA
E-mail: hingram@uci.edu

Abstract: Increasing demands on water resource organisations are explored in three large US river basins: the Columbia River, Southern California, and the Potomac River Basin/Chesapeake Bay in the Washington DC metropolitan area. Interviews with staff of water management organisations revealed a strong preference for strategies that consolidate resources and over-build systems in order to provide reliable, low-cost, and safe water services. As challenges to these strategies emerge and as problems shift from tame to wicked, organisations develop strategies that spread the risks through cooperation. When domesticating strategies fail, some organisations have moved to local and adaptive negotiation of solutions with affected parties. The three management approaches reflect a general trend away from infrastructure-intensive strategies to social interaction-intensive strategies. Instead of managing the uncertainty of physical structures and organised routines, water resource agencies are beginning to 'manage' ambiguous relationships with partners who have conflicting demands and needs.

Keywords: complex problems; managing change; water management; wicked problems.

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Biographical notes: Denise Lach is also an Associate Professor of Sociology and Associate Director of the Institute for Natural Resources, both at Oregon State University, where she is responsible for helping integrate social science ideas and methods in interdisciplinary projects.

Steve Rayner is James Martin Professor of Science and Civilisation and Director of the James Martin Institute at the University of Oxford's Saïd Business School. He also directs the UK Economic and Social Research Council's national research programme on Science in Society and is a member of Britain's Royal Commission on Environmental Pollution.

Helen Ingram is Warmington Endowed Chair of Social Ecology at the University of California at Irvine. She has written numerous books and articles about water resources politics and policy, particularly as related to the Colorado River and transboundary water management. In addition, Professor Ingram is known for her research on policy design and implementation.

1 Introduction

Some observers of growing water problems across the USA have been predicting and often advocating fundamental changes in water resources management (Anderson and Leal, 2001; Howe et al., 1986; National Research Council, 2002). The adverse environmental and social consequences of past practices are evidenced in the loss of habitat for endangered species and fierce competition among advocates for how diminishing water resources should be used. In many places, multiple water users are at loggerheads about issues of water allocation and water quality.

Such extreme stress on water institutions would seem to be the appropriate context for innovation, and water analysts have suggested a number of techno-scientific and behavioural modifications to be adopted in water management. For instance, probabilistic forecasts of seasonal and inter-annual variation hold promise for helping water resources managers improve both present operations and investment decisions designed to provide greater flexibility in future operations. Similarly, advances in water metering and pricing could enable water utilities to finely tune and reduce water demands. The use of such advances could postpone expensive and environmentally damaging infrastructure construction or even make it unnecessary. Privatisation of water utilities and the substitution of markets for public agency control might introduce economic discipline into water use and result in substantial water conservation.

We found in our research, however, that responses by existing water institutions to mounting stresses have been very timid experiments with incremental and marginal techno-scientific and behavioural innovation while continuing to pursue longstanding agency norms and goals. Challenges have been met with changes in organisational linkages and relationships so that risks inherent in unstable political and physical environments are spread across a range of organisations and stakeholders. These new arrangements, we argue, leave much of the structure and behaviour of water agencies unchanged and many problems unresolved.

In the sections that follow we explain the methodology we used to explore water agencies' responses to growing problems in three geographically separate regions. A description of the traditional response of water agencies to what were perceived as ordinary or tame problems will follow. The notion of extraordinarily complex or 'wicked' problems will be introduced along with a description of three distinctive modes of management, focusing on the risk-spreading strategies with which agencies have responded. The paper concludes with an assessment of the consequences of the strategies agencies have adopted to respond to changing pressures and constituents.

2 Methods

The data for this paper were collected through semi-structured interviews (Spradley, 1979) in three locations: the Columbia River system of the Pacific Northwest, the Metropolitan Water District of Southern California, and the Potomac River Basin/Chesapeake Bay in the Washington DC metropolitan area. Over 100 interviews were conducted with staff of water management institutions, including regional staff of federal agencies, regional management organisations, water supply companies, wastewater disposal companies, and emergency management organisations. Interviews were also conducted with environmental groups and tribal representatives.[1] The goal was to sample a transect of individuals through water management institutions from local to regional scales.

Sampling for these interviews was non-random, variously described as theoretical (Glaser and Strauss, 1967; Agar, 1980) or purposeful (Morse et al., 2001). With the assistance of key informants at several institutions, we used snowball sampling to identify others in the social networks along which information travels within and among organisations in these basins. The approximately 90-minute interviews were conducted face-to-face usually by two researchers to reduce interviewer bias. Quotes from respondents used in this paper have been modified as necessary to protect identities.

A team leader in each basin formulated provisional results for that region and the entire research team met to analyse the results, compare findings across regions, and develop the framework for understanding how water resource organisations manage the inherent uncertainty of the water. Initial results of our analysis were presented to a focus panel of water resource managers at the Annual Meeting of the Water Resources Planning and Management Division of the American Society of Civil Engineers in 1999. Panel members indicated that our results would find widespread acceptance among the water resource management community in the USA.

3 Management mode 1: controlling tame water problems

3.1 Framing the problem

In this first mode, water is viewed as a benign resource that can be managed through the application of expertise, authority, and money. Problems are seen as discrete issues of not having water in the right places at the right times, in the right amount, and/or of sufficient quality. Water management is typically divided into functional areas of expertise: experts who manage flooding; others who ensure that safe drinking water is delivered; still others who work to provide irrigation water; and others who manage water hydroelectric energy supplies. These functional experts see water as a controllable resource, given appropriate amounts of authority, expertise, equipment, and money (Schwarz and Thompson, 1990).

Once controlled through the application of expertise to meet a defined mission, organisations can treat water as a ‘tame’ problem. Tame problems are those that Kuhn suggested could be handled through ‘normal science’ (Kuhn, 1962). While they may be difficult and complicated, methods exist to solve tame problems. When asked, for example, if aridity might be a limit to growth in Southern California, an experienced water official told us “there is plenty of water in the ocean”. According to him, by the time population grows beyond available supplies, technological advances will

reduce the cost of desalinating water enough that it would be an attractive – and unlimited – resource. What it would do to other ecological or human systems did not fit into his functional expertise or responsibility, so to him the solution was pretty straightforward. As the diversity of definitions, needs, and stakeholders involved in the issue increases, the nature of the problem is likely to shift to 'wicked', creating problems that are difficult to solve with technological approaches (Rittel and Webber, 1973, 1984). This will be discussed in more detail in Section 3.2

3.2 Risk-spreading strategy

We found that the first mode for managing uncertainty of water resources involves reduction of natural system complexity to reflect only those purposes deemed essential to the organisation at a particular time and location. When water is managed by an organisation as a resource to serve specific domestic, agricultural, industrial, or other needs, the needs become defined as the mission(s) of the agency. The jurisdictions of these organisations are then established to reflect the narrowly defined purposes. Municipal water organisations, for example, focus on delivering safe, reliable, and low-cost water to those within their service area, regardless of impacts or risks to others outside their functional and geographical jurisdictions. Organisations are obligated to fulfil their own missions and take notice of other parties only when they are likely to impinge on their own success.

Respondents we interviewed expressed a clear hierarchy of values to which they believed their organisations were held accountable. Reliability of service ranked far above other organisational values according to virtually every water official we talked with. Each echoed the municipal water utility director's claim that, "We cannot optimise. We must be conservative in our decisions". Water managers also placed high value on avoiding public controversy. They expressed concern that publicity about their organisation would reduce public confidence in their ability to deliver the water services whether it was drinking water, flood control, waste management, or hydropower.

The first line of defense to meet the goals of reliability and minimal controversy was to consolidate control over the resources required to meet specific organisational missions. While at first this meant control over the resource itself as demonstrated in the case of Southern California discussed below, it also meant over-building systems to ensure that the right quantity and quality of water was available to all users at all times. The products of first mode response to uncertainty include large-scale engineering structures, and compacts, court decisions, and laws to manage water. One consequence is physical structures that permanently alter the natural environment and may have irremediable long-term effects. Legal instruments are often blind to the claims of disadvantaged populations and future equity adjustments are difficult to expectations of those already advantaged (Ingram, 1990).

Consolidation of resources and redundant infrastructure has, until recently, buffered many organisations in the three study areas from the effects of growing scarcity and threats to quality. These overbuilt systems, policy, and administrative arrangements, however, also reduced flexibility for fine to new demands. For example, Miles et al. report that the Columbia River system

> with more than 250 reservoirs and 100 hydroelectric projects, [is] one of the most highly developed in the world … Under current conditions and institutions there are very limited possibilities for changes in infrastructure, such as adding additional reservoir capacity to better meet conflicting demands. (Miles et al., 200, p.6)

The notion that nature is controllable through the application of expertise and resources leads to multiple, separate hierarchical organisations, each with clear lines of authority and responsibility (Worster, 1992; Maass, 1957). As the size of water systems increases in terms of infrastructure, numbers of participating agencies, and geographic spread, potential for conflict over allocation of the resource also increases.

3.3 Role of knowledge and science

The kinds of experts who fashion and implement first mode responses are hydrologists and engineers who treat water as the product of natural and built water systems. The challenge is a matter of physical control through the construction of infrastructure that will clean water to desired quality, and to store, release, and channel water to places and times where and when it is needed. The engineering perspective, which dominates organisations in the first mode, views water as a product that can be manufactured to customers' needs through the application of appropriate technology. One prominent water consultant noted:

> When I went to work for the California Division of Water Resources in 1953 the staff consisted of several hundred engineers, one or two economists, no water quality professionals, no biologists (ecology was not recognised yet), no political scientists, and no land use planners.

Solutions developed by experts with such limited backgrounds tend to be the construction of structural facilities such as dams, canals, levees, and pipes; all designed to reliably deliver water services to the clients of the agency.

Inevitably, competition from other agencies looking to exploit the same source of supply introduces the need for additional legal expertise that can sort out matters of property rights. Water lawyers, the new experts, treat water like land that can be owned so that application of laws, legal precedent, and reasoning can manage the rights and responsibilities of water users (Blatter and Ingram, 2001).

3.4 Case example

A classic example of the resource control response engaging engineering and legal expertise is found in the water history of the city of Los Angeles and Southern California. As early as the 1870s, the City of Los Angeles laid claim to the total supply of the Los Angeles River. The city declared legal war upon upstream users, and won a series of court victories. What it could not achieve through the courts, it won by an aggressive campaign of annexation. Expanding the city's boundaries was at once seen as a way of justifying – indeed requiring – more water to build a larger metropolis. As the growth advocates in Southern California put it, "if you don't get the water, you won't need it". This expansion required massive physical infrastructure and created a tangled web of institutions charged with overlapping jurisdictions and claims.

The metropolitan water district (MWD), the most powerful water agency in Southern California, is an administrative regime composed of many member agencies. State Water

Project and the Colorado River Authority water flows through the MWD for distribution to other agencies. The creation of the MWD and the built infrastructure of Southern California reflect the assumptions that with enough resources (in this case, power and money), relevant information, and a focus on reliably delivering safe water at a reasonable cost, water problems can be addressed and solved.

When asked to identify examples of innovations, most California agency officials reported changes they thought were important, and many proudly told us that they considered their organisations as being 'on the cutting edge'. We found, however, that they were reluctant to consider major changes to their current systems. Mistakes can be costly to agencies due not only to high public value placed on reliable water services, but also because mistakes draw adverse public attention to entities that prefer to keep a low profile. We learned that what many of our interviewees identified as important technical, organisational, or behavioural changes could more accurately be described as incremental modifications to traditional actions. They did not require discontinuities in either values or practices. Included among the incremental changes catalogued by our interviewees was the purchase of additional sand bag filling devices in preparation for El Nino, installation of propellers in tank structures to discourage the build up of bacteria on reservoir walls, and acquisition of a silt removal machine to improve recharge in infiltration basins. While incremental innovation may involve the growth and expansion of organisations and rearrangement of power relationships within and among organisations, most of these organisations engaged primarily in incremental technical innovation, tweaking existing structures to address problems as they emerged.

3.5 Limiting factors

Although water agencies have the capacity to adapt to changing conditions, incremental innovation ultimately does not allow for the magnitude of change that may be necessary as conditions change. Something else is required as demands for service increase and social values change to require multiple (and sometimes conflicting) use of the resources. The pursuit of further sources of supply, for example, results in collision with and struggle for control over increasingly scarce supplies. Moreover, virtually all development of new water services for human use has negative consequences to the natural environment (Ingram, 1990). And, institutional accommodations among agencies, imposed by the courts or negotiated among parties, become too rigid to respond to the magnitude and/or types of changes required as demands for water services increase and/or change.

New agencies, with missions in fundamental conflict with those of the water industry, and agencies that formerly had little clout (e.g., fisheries, parks), are voicing demands that cannot be easily accommodated in the first management mode. Moreover, shifts in public tastes and values result in the passage of laws which make it harder for water agencies to continue with business as usual because there are new actors with authority who do not share similar service priorities in their own narrow missions. The increase in water quality and wildlife protection regulations by water quality and environmental agencies, for example, means that routines and standard operating procedures of other agencies need to be continually examined, altered, and sometimes changed. The need to make real shifts in values and decision-making processes was acknowledged in a number of our interviews.

Expectations engendered by first management mode are ultimately unrealistic and self-defeating. Water consumers have been encouraged to believe that no behavioural changes will be required as water resources become scarce. Consequently, they react negatively when water services become a public issue. As constituents notice changes in the reliability, safety, or cost of their once taken-for-granted water, agencies are in the position of violating their organisational values and norms for invisibility.

In the three basins we examined, first mode strategies of consolidation and/or incremental improvement are inadequate as demands for water services increase and change. As these responses became less effective, water service providers increasingly sought new strategies; in particular, they looked for ways to share responsibility for managing the system and spreading risk so that their organisation would not be held solely responsible for failure.

4 Management mode 2: coordinating and domesticating

4.1 Framing the problem

Many water problems have undergone a fundamental shift to become what are called 'wicked problems'. These are problems that have multiple and conflicting criteria for defining solutions, solutions that create problems for others, and no rules for determining when problems can be said to be solved (Rittel and Webber, 1973). Sometimes, just identifying a wicked problem turns into a major task and working on such problems requires

> cycling through the phases of problem definition, information gathering, solution, and outcome. It can be said that we don't really 'solve' wicked problems; rather we 'design' more or less effective solutions based on how we define the problem. (Pacanowsky, 1995)

Wicked problems always occur in a social context; the wickedness of the problem reflects the diversity of those involved in the issue.

Water has come to have very different values for different people, and capturing those values through quantification of water rights or cost analysis often fail (Brown and Ingram, 1987). Competing definitions include water as a public good that is essential to a sense of place and community, as it clearly is to the Cocopa who name themselves the river people and whose lives and livelihoods are bound to the Colorado River Delta (Garcia-Acevedo, 2001). This conflation of water and culture can also be found in multicultural, irrigation-based communities in the Imperial and Central valleys of California. Water is also a symbol of environmental protection and sustainable lifestyles. Such concerns have created heightened fears about water quality, not just for human consumption but also for nature (Blatter and Ingram, 2001).

The agriculture/fisheries crises being experienced throughout the western USA illustrate how the solutions constructed by a party create problems for others. The wickedness grows out of the antagonists' different worldviews and values that are non-commensurate. Further, fisheries recovery may take decades and it is difficult to identify a firm improvement trajectory and extremely difficult to say that 'a species has recovered'. Since lifestyle, ethics, and security issues are entangled with the biological concerns it is hard to evaluate when enough is enough and problems are solved.

A recent issue of the *Journal of the American Water Resources Association* contained nineteen papers that grappled with the wickedness of water management problems (Lant, 1999). And, in the latest report on the status of watershed health, the National Research Council recognised that water service providers are facing problems that will not "likely be solved through the construction of additional control works, more regulations, or more money" (National Research Council Committee on Watershed Management, 1999, p.vii).

Demands on water systems continue to increase as population concentrates in urban areas, regulations for clean water and habitat protection proliferate, and infrastructure ages. These emerging problems go far beyond original agency missions into arenas previously considered external to organisational responsibilities. With the creation of the US Environmental Protection Agency (EPA) and the enactment of several environmental protection acts, water service providers are facing increasingly visible challenges to their authority to deliver the quantity and quality of water required by new and existing constituents. Instead of invisible water agencies providing services with little controversy, challenges to system practices and decisions about allocation and supply in overbuilt systems become increasingly controversial and commonplace. First mode strategies are no longer sufficient to address the problems and constituents that threaten the core values of water agencies.

4.2 Risk-spreading strategy

The natural complexity of water systems has always been exacerbated by the inter-jurisdictional nature of rivers, aquifers, and other sources of water, particularly in the three case study river basins. In all three basins we found that water organisations recognised that the boundaries drawn around their missions and responsibilities became inadequate for emerging problems. The most common initial response to these changing conditions was to invite new players into an alliance that brought additional expertise and authority to the problems. In the earliest stages this looked like coordination among organisations that are responsible for managing different aspects of the system. Water resource organisations looked for partners, for example, that were responsible for managing species and/or habitat protection to supplement water control and allocation systems. Or, they began working with agencies at different scales of governance (e.g., federal and state agencies complementing local governments).

These early multi-agency coordination efforts reflect the 'durable myth of optimisation', the ubiquitous belief among managers that their agency is uniquely constrained and that redundancies and inefficiencies can be eliminated and system capacity increased through coordination with partners that have greater flexibility. In addition, it assumes that new partners bring new information and knowledge at low or no cost. New partners, however, also bring new, wicked problems that are not easily addressed by water systems that are over-built and oversubscribed to meet demands of flood control, hydropower, and a reliable, low cost water supply.

Recognising this, the problem is set aside and taken out of the limelight by agreement among constituents, often asking challengers to switch from criticising the system to helping solve the problems. The new strategy looks like earlier efforts to coordinate agencies but has a purpose distinct from optimisation. Some type of group (e.g., council, commission, advisory group) is created in order to legitimately remove the issue from the visible decision space. The distinguishing feature of these groups is the inclusion of new

partners and recognition that coordination alone will not solve emerging problems. The partners must explicitly cooperate in the search for solutions that are acceptable to all constituents.

We call this response 'domestication' to suggest that agencies and other water service providers are still trying to find some way to control or tame problems much as they were earlier able to control water systems with engineering and administrative solutions. In the case of wicked problems needing domestication, however, there are no easy or inexpensive solutions. The appointed group is tasked to study the issue further, find or create new knowledge for the system, and develop alternative solutions that (hopefully) continue to support the values of water service providers. When asked about progress towards resolving domesticated problems, it is possible to say, 'We're studying the problem', or the 'commission is considering all alternatives'.

Agreement for tabling the problem is secured from constituents by invitation to participate in decision making. Given legitimacy and access through their participation, the new players – including environmental groups, neighbourhood associations, and environmental protection and regulation agencies – sit down with the water control and allocation interests who have historically made decisions about the system. In effect, these parties now share responsibility for finding acceptable solutions to increasingly wicked problems.

4.3 Role of knowledge and science

Cooperating partners pool information about the system, bringing new information to all. Modelling and monitoring strategies are made possible and even desirable by domestication efforts seeking new information about how the system works. These and efforts to respond to new laws and regulations bring new types of employees – biologists, social scientists – to organisations once dominated by engineers and lawyers. These employees and new constituents may promote indicators of success that complement or challenge the primary value of providing reliable and low cost water services.

4.4 Case example

The Chesapeake Bay Program (CBP), created in 1983 to tackle environmental issues in the Bay, has grown into a large bureaucracy, domesticating the multiple issues facing governing and regulatory agencies through research and other programmes. The organisational structure of the CBP includes representatives (both legislators and agency staff) from Maryland, Pennsylvania (which has no bay front land), Virginia, and Washington DC; the Chesapeake Bay Commission (a tri-state legislative commission); the US EPA; various participant advisory groups (e.g., universities, NGOs); and a citizen advisory group. As one of our respondents described it:

> The Program has a complex organisational structure. There is a high level of buy-in – governors of Maryland, Pennsylvania, and Virginia, the mayor of Washington DC, the Chairman of the Chesapeake Bay Commission, and the EPA Administrator are the Board of Directors for the CBP. This means that the states run the show and therefore they like it.

In addition to the politicians on the Board of Directors, the CBP provides opportunities for other types of participation and input. Advisory committees are the primary method the CBP uses to organise disparate participation, with separate committees for citizen, local government, and scientific and technical input. A respondent described the Local Government Advisory Committee, for example, as: "very active, with oversight for a community grants program. There has been a major effort to get local governments involved, but it has been difficult because local government varies by state".

4.5 Limiting factors

The decision frame of water service providers, which has been dominated by the value of reliably providing high quality water at low cost, is challenged by partners representing new values and phenomena that have often been externalised by traditional values. Any new tools or information for decision making, for example, must be acceptable to a diverse group of constituents with differing worldviews.

The CBP sponsors an extensive modelling programme based on historical data. The complex model with multiple subroutines is used for decision-making by a large number of individuals and organisations, each with its own assessment of the validity of the model. One subcommittee chair told us that he was concerned that increasing reliance on the model had not been accompanied by any discussion about the 'believability of the model outputs'. He fears that constituents, who do not understand or agree with the assumptions built into the model, could challenge results at any time. He believes that there needs to be "lots of discussion on ensuring buy-in from jurisdictions in the process and the conclusions".

With rare exception, partners in earlier and existing coordination efforts worked within the dominant understanding of water and development that promoted the growth of water infrastructure to support growing populations. Conflicts in coordination efforts are best described as conflicts of mission – one state agency may oppose a dam proposed by a federal agency because it affects the species it manages; one municipality may be looking for ways to manage storm run-off that has negative impacts for another down stream. With the introduction of new players through domestication processes, however, the definition of mission itself may become the source of conflict. Conflicts are now more likely to be about worldviews, what counts as evidence, and why decisions are made the way they are. These conflicts were recognised by the National Research Council with recommendations for managing water resources:

> … apparent contradictions among agencies are inevitable in a government structure that by design, represents various stakeholder groups. However, in general, the various levels of government are in pursuit of common goals. Certainly those who are empowered to act may have some jealousies about their authorities, but these conflicts are far less significant than the conflicts that arise over how the land and water of a watershed may be used (National Research Council Committee on Watershed Management, 1999, p.165).

The inclusion of multiple worldviews is the price that water service providers pay for spreading the risk of managing these complex systems. However, our respondents report that differences in worldviews are destabilising hierarchical responses in multiple ways and raise the visibility of water systems in new ways about new issues. For example, some activists are promoting the fundamental 'right' to water and vehemently oppose rationing by price. They argue that under these schemes rich people will still be able to

water their lawns while poor people may not be able to afford drinking water. Other activists promote privatisation schemes, pressing for closer tolerances on systems they perceive as bloated and ripe for efficiency efforts. These 'new ways to notice' water providers challenge core values and question their ability to provide services.

Water agencies that have become involved in large-scale cooperation and long-term domestication activities to manage the complexities of water systems eventually find this mode of managing uncertainty unsatisfactory. The primary limitation of the domestication strategy is that physical system limitations remain unaddressed during an often-extended period while solutions are explored and created. Water service providers may experience increased violations of organisational norms and goals through such physical limitations while at the same time their value system is questioned by public and repeated discourse about water management. Some critics are unlikely to ever participate in finding solutions, but will have increased access to discussions about problems and solutions. Cracks in the credibility of research, or the inability of policy (based on the research) to deliver reliable, safe, and low-cost water in the face of increasing uncertainty again challenges water resource agencies to look for ways to ensure they can deliver the services they promise.

5 Management mode 3: adaptive management and civic science

5.1 Framing the problem

New partners in domestication strategies often insist upon what appear to be incommensurable demands on existing programs or organisational values. And, the new committees and/or research may reveal few possibilities that can satisfy diverse demands without challenging the assumptions and operations of the existing systems. Just as biologists challenged the conservatism of the first-order responses to uncertainty, new participants bring different needs, expectations, and worldviews when water resource managers move to domestication strategies. These new participants challenge the authority of traditional expertise to solve local problems without participants' explicit involvement. Citizens expect decision-making processes to be transparent, and for that, they need information that is accessible, understandable, and related to the problem at hand (Fischer, 2000). In recognition of these challenges, some organisations have started to develop ways to respond to the uncertainty of large water systems that move beyond the current taming and domestication strategies.

5.2 Risk-spreading strategy

Agencies and organisations in the Columbia River Basin of the Pacific Northwest have experimented with ways to move beyond domestication strategies through 'adaptive management' and 'civic science'. In addition to trying to capture reality with the complex models developed during domestication efforts, Lee suggests that planning must also attend reflexively to local experience and knowledge (Lee, 1993). If problem-specific information can be continuously generated and integrated into the decision process, adaptive management proponents suggest that problem-specific responses are possible in a relatively short time. Adaptive management decisions are likely to re-focus on local and context-specific problems rather than the system-wide approaches to uncertainty

promoted during domestication as described above. This time, however, different partners will be asked to participate in the development and monitoring of management strategies that balance conflicting demands in ways that are unique to the situation. For example, adaptive decisions may include variable pricing of water for different uses; access to a range of water quality appropriate to different kinds of uses; and locally appropriate technology that complements existing large scale, long-term infrastructures.

One possible method for involving non-professionals in adaptive strategies in meaningful ways is through 'civic' or 'vernacular' science (Fischer, 2000; Lee, 1993; O'Riordan and Rayner, 1993) whereby existing and conventional responses are subject to open negotiations with a wide variety of participants including stakeholders (i.e., those affected by the agencies' decisions). Social values and behaviours are used to complement the engineering, legal, organisational, and biological strategies common to the first two responses to uncertainty. Social values are likely to challenge water service providers' traditional discussions about alternatives, costs, and limitations, however, making this strategy difficult to implement in existing institutions.

5.3 Role of science and information

While an adaptive strategy may bring local responsiveness to water management, it is information and decision intensive. It requires information about a whole range of difficult problems: in addition to water flow, allocation, and distribution criteria, information is needed about local and specific preferences, needs, and interactions with natural and built systems. It also necessitates structures for collecting and integrating information such as public meetings, outreach activities, and other social processes for consultation and decision-making. Not only must participants become better informed about water, they must attend to value differences and conflicts within the community. The process requires an openness and willingness of individuals to shift their attitudes and expectations to accommodate the new demands on the physical system and the diverse attitudes of other users. Expertise in decision-making, conflict resolution, and scientific translation and interpretation are necessary for meaningful participation by the new stakeholders.

5.4 Case example

While the Northwest Power Planning Council (NPPC) decision-making process is built around the idea of adaptive management, staff told us that they use different strategies to process 'professional' and 'political' information. Professional input is sought from scientific and technical experts and contractors through workshops and working groups with relevant scientists, extensive review of current scientific literature, and attendance at professional meetings. The NPPC sponsors or co-sponsors many professional activities including individual research projects, agency initiatives, and networking workshops.

Professional information is elicited throughout the NPPC decision process as issues are formed, rules are drafted and finalised, and programmes are evaluated. This external source of information complements internal sources of information from technical and legal staff, supporting the mission of the agency, which has been dominated by the need to produce reliable and low cost electricity.

External information is also elicited from what staff members call 'political' sources. These include stakeholders such as members of the affected public, representatives of relevant federal and state agencies, environmental and other interest groups, and lobbyists. Although political information is elicited at the same time as professional information, it has less credibility with decision makers according to our respondents. For example, NPPC staff told us that input elicited during public hearings carries less weight in decision-making than information provided by professionals. Even though the NPPC is mandated by law to consider multiple perspectives when making its plans, observers have suggested that very few non-traditional solutions have been produced. While the NPPC talks about how multiple perspectives bring value to management and has created a decision-making structure to elicit those perspectives, they continue to rely on input that reflects the traditional responses to uncertainty – infrastructure modifications, coordination, and domestication.

As years of domestication have dragged on without solution, however, previously unacceptable strategies brought to the table by non-professional participants have begun to surface as possible solutions. One example is to breach or remove dams on the main stem of the river. This idea was such anathema to most Pacific Northwest water managers that it was ridiculed as unreasonable only a few years ago. With continuing questions raised by environmental and other groups about assumptions underlying dam removal schemes and management of the river basin, the idea took on new life and was seriously considered by the United States Army Corps of Engineers in its salmon recovery plan. The plan released in 2000, however, rejected breaching federal dams and relies on traditional technological fixes including barging young salmon around dams, improving hatchery practices, freezing harvest levels, releasing more water from reservoirs, and studying the results before making any recommendations that might include dam breaching; in other words, back to domesticating the problem.

Sending salmon recovery into a new round of domestication involves a monitoring program that includes setting goals for fish return and promises to reexamine other options at regular intervals. At great expense – approximately $400 million per year – managing the Columbia River Basin for conflicting interests is still being domesticated with research, commissions, and legislation. Attempts at the NPPC exemplify how difficult it has been to find ways that legitimate discussion of ideas brought to the table by non-professional participants. Challengers to the control and incremental innovation strategy (i.e., biologists, ecologists, and modellers) have been pretty well integrated into discussions of water management over the past 20 years. Challengers to the coordination and domestication strategies, however, are just starting to be heard.

Managing water resources in the Columbia River Basin has been complicated by the listing of several salmonid species as endangered or threatened. After decades of incremental innovations and domestication, which has cost the region approximately $3.5 billion since 1978 (Brinckman, 2001), the state of Oregon proposed an innovative approach to the recovery effort. The Oregon Plan asks individuals and organisations to restore and maintain salmon runs within the single watershed they call home. While ultimately denied by the US Fish and Wildlife Service as an insufficient recovery plan, the state went ahead and created watershed councils, believing that local citizens could provide the commitment necessary for recovery strategies to work only if they were invested in the proposed solutions.

5.5 Limiting factors

Currently, more than 100 watershed councils around the state of Oregon bring together residents and representatives of relevant agencies and organisations to develop solutions to locally framed problems.[2] Scant resources are provided to the councils in the form of salary for part-time coordinators, grants for biological and economic assessments, and technical assistance for specific projects. Participation on the council is voluntary and requires commitment in the form of meeting time and actual restoration work in the watershed. Implemented in 1998, the effort is relatively new so evidence of increased salmon runs does not exist yet.

Researchers have found that these civic water service organisations develop strategies for managing uncertainty that are similar to other water providers. Most early projects are incremental changes or improvements such as replacing culverts or planting along riparian areas. The councils have not yet tackled the larger problems of non-point source pollution or land use practices that are among the emerging issues for other water organisations. Many watershed councils have begun processes of domestication by creating technical committees to take contentious issues off the table and find out more about them (the civic equivalent of 'more research needed'). The question remains whether personal relationships, commitment to a home watershed, and common experiences will create relationships that allow these water resource organisations to move beyond domestication and other strategies for managing uncertainty.

6 Conclusions and future directions

We found that water agencies do indeed innovate in response to increasingly challenging water problems, but the response is organisational rather than adoption of advanced techno-scientific or behaviour modification tools. In fact, innovation has occurred less in management than in the treatment of risk and responsibility. In mode 2 – coordination and domestication – risk is spread to a growing number of agency and nongovernmental organisational partners, and responsibility is diffused to a whole host of actors each of whom has very little control over growing problems. In mode 3 – adaptive management and civic science – risk is spread yet further by engaging affected parties in the solution of water problems, with accountability devolved to local actors who must gather knowledge and devise strategies on their own. At the same time, the mission oriented and geographically bound water organisations continue to persist, and whenever possible, continue to pursue their discrete, narrow concerns in concert with domestication and adaptive strategies.

We observed that as decision constraints grew, new organisational forms, structures, and responses were created. These emerging responses do not displace existing routines; rather, they introduce additional strategies for dealing with wicked problems. Water organisations have access to at least three modes of qualitatively different responses to managing the resource, and can refer to these responses when they must demonstrate that they are doing something about mounting problems.

We are not suggesting a model of successive displacement of one organisational strategy for another. Instead we propose a model of accretion where new response strategies are grafted on to existing structures, norms, and behaviours. Inevitably, emergent responses create tension as they overlay, without displacing, traditional

organisational missions and strategies. Organisations are likely to be using different strategies simultaneously for different, or even the same, problems. The first mode, which we found is highly preferred by organisations, assumes that problems are tame and uncertainty can be managed by individual agencies through routinising both regular and irregular system events. Often this requires developing redundant infrastructure and operating procedures, all designed to reduce the impact of unusual events. Change to the infrastructure and routines are typically incremental: improvements to, rather than replacement of, the existing system. Expertise to manage system uncertainty is found in the knowledge bases of engineers, lawyers, and economists who can help water resource agencies meet their missions of safe, reliable, and low cost water.

The picture that emerges is one of organisations initially seeking to discreetly routinise the natural irregularities of water availability for a variety of purposes. However, competing expectations from society result in organisations with different missions tripping over each other until their invisibility is threatened by political attention. In response, they form coordinating and cooperating bodies that domesticate the problems of competing uses, without really resolving them.

The third mode emerges as water agencies and organisations open themselves to new partners and expectations in attempts to create adaptive and flexible responses to growing uncertainty. Resolving such uncertainty comes through negotiation of self-identified needs for local and situational problems. Now organisations take on the task of integrating new kinds of information and new partners – often conflicting – who bring fundamental challenges to the way decisions are made. New definitions of 'risk' emerge, including "how fair is safe, reliable, and low-cost enough?" Creating adaptive organisations may bring rapid and major changes to the way water resources are managed, allocated, and distributed although, as we found in the Pacific Northwest, this is likely to be a difficult task for traditional organisations. Expertise is needed from citizens, mediators, and conveners who bring knowledge and experience with local problems, but also bring demands for local solutions and challenges to existing values. Integrating this knowledge with other expertise bases is one of the major tasks facing organisations considering adaptive management or civic science strategies.

The summaries above are static and isolated pictures of first, second, and third mode responses of organisations and agencies to uncertainty. By 'freezing' the dynamic organisations, we are able to create a conceptual framework for thinking about managing uncertainty. The three different strategies for managing uncertainty reflect a general trend away from infrastructure-intensive strategies to social interaction-intensive strategies. Instead of managing the uncertainty of physical structures and organised routines, water resource agencies are beginning to 'manage' ambiguous relationships with partners who have conflicting demands and needs.

Serious questions remain and may become more important over time. While the adoption of alternative management strategies may buy time and promote cooperation and learning, it may still be that symptoms of problems in the physical water system may not be adequately characterised. Habitat for endangered species may not improve and water for all kinds of uses may become more scarce and decline in quality. Should the nature of wicked water problems require innovations more fundamental than organisational modifications, then the strategies being pursued under the three modes discuss here may well not lead in the right direction.

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Notes

[1]Regional coalitions or compacts included the Bonneville Power Administration, the Northwest Power Planning Council, the Pacific Northwest Utilities Conference Committee, the Columbia Basin Fish and Wildlife Authority, the Pacific Fisheries Management Council, the Pacific State Marine Fisheries Commission, the Columbia River Compact, the Northwest Waterways Association, and the Columbia River Inter-Tribal Fish Commission. State agencies included the Oregon Department of Fish and Wildlife, Washington Department of Fisheries, Montana Department of Fish, Wildlife, and Parks, Alaska Department of Fish and Game, Idaho Department of Fish and Game, Washington Department of Wildlife. The authorities included the Fairfax County Water Authority, Washington Suburban Sanitary Commission, and the Washington Aqueduct Division of the US Army Corps of Engineers.

[2]For more information about Oregon watershed councils, see the website of the Oregon Watershed Enhancement Board (OWEB) at www.oweb.state.or.us/.