Bringing Actors Together Around Large-Scale Water Systems: Participatory Modeling and Other Innovations

Michel J.G. van Eeten, Daniel P. Loucks and Emery Roe

Water Management in Human-Dominated Ecosystems

How do policymakers reconcile the public's demand for a better environment that requires substantial ecosystem improvements with the public's concurrent demand for reliable services from that environment, including water and power? Less formally, how do large-scale water systems save

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Michel J.G. van Eeten is Associate Professor in the School of Technology, Policy and Management, Delft University of Technology, the Netherlands. Recent publications include *Ecology, Engineering and Management: Reconciling Ecosystem Rehabilitation and Service Reliability* (with Emery Roe; Oxford: Oxford University Press). Current research interest include the reliability of critical infrastructures (such as electricity, water, telecommunications and the internet) and the development of methods to recast the intractable policy issues. Since 1999, he has been a Visiting Scholar at the University of California, Berkeley and Mills College, Oakland. He may be contacted at <M.J.G.vanEeten@tbm.tudelft.nl>.

Daniel P. Loucks is Professor of Environmental Engineering in the School of Civil and Environmental Engineering, Cornell University, where he teaches and directs research in the application of economic theory and systems analysis methods to the solution of environmental and regional water resources problems. He has authored numerous articles and book chapters, served on various committees of the National Research Council of the National Academy of Sciences, and was a U.S. member of an advisory committee for the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria. He can be contacted at <dpl3@cornell.edu>.

Emery Roe is Barbara M. White Professor of Public Policy at Mills College, Oakland, California. Emery Roe has published widely on science, technology and environmental controversies, including the debates over large technical systems, sustainable development, and ecosystem management. His books include *Narrative Policy Analysis* (Duke University Press, 1994), *Taking Complexity Seriously: Policy Analysis, Triangulation and Sustainable Development* (Kluwer, 1998), *Except-Africa: Remaking Development, Rethinking Power* (Transaction, 1999), and *Ecology, Engineering and Management: Reconciling Ecosystem Rehabilitation and Service Reliability* (with Michel van Eeten; Oxford: Oxford University Press). He may be contacted at <eroe@mills.edu>.

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the fish and the ecosystems and still have hydro-electricity to use and water to drink? This paradox of rehabilitating ecosystems and ensuring at the same time their service reliability is real for the foreseeable future.

Developments are under way to address the paradox in new ways. They revolve around engineers and line operators who seek to ensure reliable, predictable water and power supplies and ecologists who are committed to reintroducing something like the complexity and unpredictability that the ecosystem and landscape once had. Ecologists stress the significance of experiments, most notably in ecosystem rehabilitation on the basis adaptive management (Arrow, 1995; for the more controversial aspects of this position, see the special issue in *Ecological Economics,* volume 15). Engineers and operators in the control rooms of large technical systems, on the other hand, are focused on service reliability, which often precludes large-scale experimentation and classic trial-and-error learning.

Five areas of innovation are emerging for striking tradeoffs and setting priorities around ecological rehabilitation and engineering reliability. We discuss each area, drawing from recent interviews in three major ecosystems in the United States: the Everglades, Columbia River Basin, and San Francisco Bay-Delta (Van Eeten en Roe, 2002). One key area of innovation are the gaming exercises and participatory modeling efforts we encountered in the cases. They are explored in more detail in this paper and address an important debate regarding participatory processes: how to balance learning and adaptation with compliance and accountability (e.g., Guijt, 2000).

First, however, we briefly introduce these case studies and show how the challenge for water management manifests itself.

San Francisco Bay-Delta

The San Francisco Bay-Delta is a web of waterways created at the junction of the San Francisco Bay and the Sacramento and San Joaquin rivers and the watershed that feeds them. The area has been dramatically altered by humans in the last two centuries, not in the least by the large-scale waterworks of the California and federal government. Waterways and islands are protected by more than 1,100 miles of levees as well as other flood control structures. Some Delta islands have subsided to such a degree that they are now 20 feet below sea level. It has been estimated that two-thirds of the state's rain falls in northern California, while two-thirds of the people reside southern California, an asymmetry used to justify the massive, reliability-driven water conveyance infrastructure of the California State Water Project and the federal government's Central Valley Project. The Bay-Delta is the hub of these two water distribution systems, that together divert on average around 25 percent of the total inflow of water into the Delta—though this percentage fluctuates erratically over time.

For decades, the Bay-Delta has been the focus of competing economic, ecological, urban, and agricultural interests. A variety of governmental and non-governmental organizations seek to conserve the largest estuary on the Pacific side of North and South America, home to a reported 130 fish species and millions of local and migratory birds. Anglers and commercial fishers are concerned about the sustained use of one of the most productive natural salmon fisheries on the American West Coast. California's agricultural industry, which at the end of the last century accounted for nearly $25 billion per year, demands the supply of irrigation water to millions of acres of the world's most productive farmland. As found in the other case studies, there are variety of stakeholder groups representing each of these interests.

The state's key organization managing the water supply system is the Department of Water Resources (DWR). It provides water for municipal, industrial, agricultural, and recreational uses; manages the control room of the State Water Project (located next to the Bureau of Reclamation's control room of the Central Valley Project); regulates dams and reservoirs; and provides flood protection and emergency management. It is mandated to protect and restore the Bay-Delta and wider watershed by controlling salinity and providing water supplies for water users, by planning long-term solutions for environmental and water use problems facing the Delta, and by administering levee maintenance and special flood control projects. DWR works with local water agencies such as the Metropolitan Water District of Southern California serving the greater Los Angeles area.

The provision of these services has harmed the environment. Increasingly, DWR has been required to meet environmental mandates, most notably those associated with the Endangered Species Act (ESA). The 1990s witnessed the emergence of a massive interagency program called CALFED (CALifornia state and FEDeral agencies). It continues to be a joint effort to simultaneously address environmental and water management problems with the Bay-Delta. The need for a consortium of agencies reflects that, while DWR is a major player, ecosystem restoration and water reliability are under the purview of other state and federal agencies also, such as the California Department of Fish and Game (DFG).

CALFED identified several key threats to the Bay-Delta services and resources: declining fish and wildlife habitat; native plant and animal species threatened with extinction; degradation of the Delta as a reliable source of high quality water; and a Delta levee system faced with a high risk of failure. Consequently, CALFED arrived at four "Primary Objectives" to be pursued at the same time in order to create a "win-win" resource policy. The objectives have been variously summarized as "ecosystem quality," "water supply reliability," "water quality," and "levee system integrity." It has been estimated that the CALFED Program, once implemented, will cost about $10 billion. More than $300 million on ecosystem restoration in recent years has been spent by the Program in recent years.

Columbia River Basin

Attention between maintaining salmon populations and highly reliable power, flood control and irrigation services is nowhere clearer than in the

Columbia River Basin of the Northwest Pacific. Covering four states, as well as part of British Columbia, the region has the world's largest hydropower system (the Bonneville Power Administration) having arguably the world's largest fish and wildlife program. Some $427 million per year are spent on fish and wildlife measures, which is why a senior BPA planner remarked,"We are the largest fish and wildlife agency in the world."

The Columbia River Basin statutory decision making authority is divided among a complex set of actors including federal agencies, a number of Native American tribes, governments from four states, and other stakeholders such as utility companies, industrial and residential power users, and many recreational and environmental interest groups (McConnaha and Paquet 1996; McLain and Lee 1996).

The Basin's many dams are seen as a, if not the, major threat to the ESA-listed salmon. Over 30 dams owned by the Army Corps of Engineers (ACE) and the Bureau of Reclamation (BR) generate most of the hydropower in the region. The hydropower is sold by BPA, which manages the control room for the grid and associated water system operations. BPA is the region's main power supplier and also sells surplus power to California and the Southwestern U.S. The crisis around salmon decline in the region has had far-reaching effects on these organizations. Currently, BPA funds about 250 fish and wildlife projects a year, from repairing the spawning streams to studying fish diseases and controlling predators, totaling up to about one-fifth of the agency's operating budget. Projects for BPA funding are identified by the Northwest Power Planning Council's fish and wildlife program.

The Northwest Power Planning Council (NPPC) is a four-state council formed by Idaho, Montana, Oregon and Washington to oversee electric power system planning and fish and wildlife recovery in the Columbia River Basin. It should also be noted that there are other major ecosystem restoration efforts in the region, most notably the Interior Columbia Basin Ecosystem Management Project (Quigley et al. 1999; Van Eeten and Roe 2002).

The institutional context for service provision by the BPA is set by the Pacific Northwest Electric Power Planning and Conservation Act of 1980. The Act seeks to"protect, mitigate and enhance fish and wildlife affected by the development, operation, and management of [power generation] facilities while assuring the Pacific Northwest an adequate, efficient, economical, and reliable water supply." But how is BPA to do this, given imprecisely defined terms like"restore,""enhance,"and"reliable"? As the senior biologist planner at the Northwest Power Planning Council told us, the last clause of the Power Act"AERPS" (adequate, efficient, economical, and reliable power supply) "never has been quantified, so it is not very clear what it actually means."

Florida Everglades

The human hand has also massively transformed the Everglades. Ogden (1999, 174) provides a good review of the recent changes in the there. Researchers and other authors (including Light et al. 1995; United States Army

Corps of Engineers and South Florida Water Management District 1999) found that: the area of the original greater Everglades has been reduced by almost 50 percent due to the conversion of large portions to agriculture and later to urban land uses; the depths and distribution patterns of the water system in virtually all the remaining areas of the Everglades have been altered; approximately 70 percent less water flows through the Everglades of today than originally; of the seven major landscape features in the presettlement Everglades, three have been eliminated entirely; exotic species have been introduced; and the number of ESA-listed species was up to nearly 70 in 2000.

The greater Everglades ecosystem, called the south Florida ecosystem, stretches south from Orlando and includes the Kissimmee Valley, Lake Okeechobee, the remaining Everglades, and on to the waters of Florida Bay and the coral reefs. Between Lake Okeechobee and the Everglades National Park are the Everglades Agricultural Area and three Water Conservation Areas. Overlaying the ecosystem—and connecting it to the coastal area of metropolises including Miami—is an elaborate water management infrastructure, most notably the Central and Southern Florida Project built by ACE.

Created through legislation in 1948, the Central and South Florida Project is managed by SFWMD and ACE. It encompasses 18,000 square miles, 1,000 miles of canals, 720 miles of levees, and almost 200 water control structures. The project's mandates are to ensure reliable water supply, flood protection, water management and related services to south Florida. Population in South Florida has risen from 500,000 in the 1950s to more than 6 million today. As a result, not only are the quality and quantity of the water that enters the ecosystem seriously degraded, but it is also widely accepted that there is not enough water for the people either. Water restrictions have been increasingly invoked in response to shortages. Shortages, however, have been as much a matter of timing as of quantity. The water management infrastructure currently shunts 1.7 billion gallons of freshwater into the ocean every day, as a result leaving the Everglades with too little water in the dry season and too much in the rainy season.

Legislation in 1992 and 1996 provided the ACE with the authority to review the Central and Southern Florida Project. The Corps was asked to develop a Comprehensive Plan to restore and preserve the south Florida ecosystem, while enhancing water supplies and maintaining flood protection. Together with SFMWD, ACE undertook the Central and Southern Florida Project Comprehensive Review Study, now known as Comprehensive Everglades Restoration Plan, to restore and protect the south Florida ecosystem. The US Congress recently approved the Plan for approximately $7.8 billion.

Innovations in Water Management

The major initiatives undertaken in the three case studies have found it difficult to bring actors together around a shared strategy for water management that would simultaneously improve water reliability and ecosystem rehabilitation. Notwithstanding these problems, our case studies have also revealed five important areas of innovation around the management of large-scale water systems. One of these areas revolves around participatory modeling and is discussed in more detail in the next section. First, however, we turn to four areas of innovation that set the context for the modeling efforts: interagency management of control rooms, ecologists in control rooms, new accounting and budgeting options, and bandwidth management.

Interagency Management of Control Rooms

Planning and management of large-scale power and water operations are increasingly an interagency process. Each control room we visited is *de facto* managed by a "team" consisting not only of the service provider operating the control room, such as California's Department of Water Resources and the Army Corps of Engineers, but also state and federal fish and wildlife agencies and other environmental units.

The most intense agency interaction takes place around short-term decisions. Short-term planning staff in the Bonneville Power Administration (BPA) work with other agencies through their technical management team, which meets weekly or biweekly. The Bay-Delta CALFED Program has a similar institution in its "OPS [Operations] management team," as has the South Florida Water Management District (SFWMD) around the design of its regulation schedules. Unresolved issues around reconciling rehabilitation and reliability are typically pushed to a higher interagency coordination team, which acts as a dispute resolution mechanism. So many issues are pushed up that two CALFED respondents said their management team was buried in operational issues most of the time.

Yet, even when interagency management teams reach agreement, line operators in control rooms may still need help. A BPA biologist working as a "interpreter" between the management team and the control room said, "Real-time people would get a planning document they literally couldn't read, so I help make the connections about where the fish are and what they need."

Ecologists in Control Rooms

This biologist-interpreter is an innovation that merits attention, because he is actually in the control room and not just part of the management overseeing it. His translation is two-fold. He puts planning instructions into operational terms and he helps relate ecological information to real-time decisions on water and power generation. We found a similar example in Florida, where the senior manager in the SFWMD operations office had just hired an environmental scientist to work in the control room. In the words of the manager, the scientist will manage constructed wetlands and serve as "translator" between the line operators and the districts' planning staff where ecologists are now located. Ultimately, the senior manager hoped to capitalize on "windows where we can enhance both reliability of water supply and ecosystem functions..."

Underlying this innovation is the remarkable congruence between the ways ecologists perceive the aquatic ecosystem and line operators perceive the high reliability system for power and water. Ecologists and line operators frequently describe their respective systems as more than the sum of their parts, as displaying non-deterministic behavior, with complexity that can never be fully captured and, therefore, making management extremely challenging, with managers always reluctant to intervene—at least in major ways—in systems they do not know, because this potentially creates more problems than it solves (Von Meier, 1999).

New Budgeting and Accounting Options

Extensive participatory modeling efforts (more below) in the three cases have generated new budgeting and accounting options. In CALFED, this led to the development of an Environmental Water Account (EWA). An EWA, CALFED officials have argued, would provide flexibility that achieves ecosystem benefits more efficiently than a regulatory approach and at the same time improves water reliability. There are variants of the EWA, but the general idea is to give regulatory agencies (US Fish and Wildlife Service, US National Marine Fisheries Service, and California Department of Fish and Game) control over an account filled with water or assets that are fungible with water (CALFED, 2000, p. 54-59). The account would be used to respond to real-time ecological events. Instead of trying to capture all contingencies through standards, which wastes resources ("overshooting") and hampers the flexibility of line operators, salient regulation would now be limited to providing a baseline level of ecosystem protection. With that baseline met, the EWA would be used to respond to natural variability more efficiently. For example, when real-time monitoring indicates that fish are unlikely to be affected, the "export/inflow ratio" (mandating a maximum ratio of water exported from the Delta to the south compared to water entering the Delta from the north) could be "flexed" to provide water for the EWA and to improve water-supply reliability. That water could then provide additional security in more sensitive times.

In effect, the EWA brings ecosystem functions and processes into the control room as parameters that can be managed in the real-time optimization process, instead of being static constraints on optimization and undermining reliability. Fisheries agencies enter into direct co-management over the water supply system, bringing them into a new relationship with line operators. Critical in this regard is that the water account would force fisheries agencies to make tradeoffs among competing ecological objectives, for example, resident fish in the dam versus anadromous fish downstream, a burden that line operators feel is now on their shoulders alone.

Bandwidth Management

Line operators in control rooms focus primarily on keeping the system stable within specified bandwidths regarding water supply, water quality, flood control, power generation, and other activities dependent on ecosystems. The notion of bandwidths is used by operations planners to identify parameters and limits within which they must maintain the system. Some parameters are given literally in the form of bandwidths, such as regulations schedules that describes minimum and maximum water levels for Lake Okeechobee at any point in time. Other parameters function as bandwidths too, such as mandated fish protection or water quality standards. As the number and complexity of bandwidths have increased, so has the size of the computer systems that run continuously in control rooms to schedule and coordinate line operator tasks.

We found two core processes emerging in bandwidth management: managing within bandwidths and setting bandwidths. Interagency management of control rooms, bringing ecologists into the control room, participatory modeling and environmental water accounts are all examples of rethinking the bandwidths for line operators when providing reliable water and power and improving the ecosystem simultaneously. Managing within bandwidths is about learning where the flexibility is within the current constraints to improve ecological functions, while providing or enhancing reliable services. There are, however, obvious limits to how much flexibility one can find within the current bandwidths. Operators continually face situations in which they cannot keep the system within all the bandwidths that are handed to them. The discrepancies among conflicting bandwidths can be too large to be resolved without changing the bandwidths themselves.

The source of discrepancies among bandwidths is easy to locate. The overall set of bandwidths is the aggregate of an array of more or less decoupled processes in fragmented and specialized agencies. Processes of reassessing conflicting bandwidths and setting new, more coupled ones are crucially significant because these, more than anything else, force agencies to look at ecological functions and reliable services simultaneously, identify and explore their tradeoffs, and set priorities in the form of recoupled bandwidths. Ironically, we found that agency fragmentation and specialization sometimes generated more pressure for recoupling bandwidths than did integrated programs and plans. That said, it remains difficult, sometimes impossible, to nail down the exact shape the tradeoffs should take—which brings us to a fifth and final area of innovation: participatory modeling.

Participatory Modeling and Gaming Exercises

In each of the cases, modeling has played a major role in helping to identify the shape of the difficult tradeoffs between ecosystem rehabilitation and water reliability faced by water management. Modeling exercises brought together operators, regulators, engineers and ecologists from the agencies involved. Each brought their own assumptions or their own models. Through participatory processes, most notably gaming exercises, the views of these stakeholders were related to each other, allowing the modeling to support decisionmaking and inform management in new ways.

Before we turn to those processes, we take a closer look at the basic procedure that allowed multiple actors to relate their assumptions and objectives to overall decisionmaking alternatives.

Procedure

The approach being implemented in these cases is the same as we see in many recent initiatives to bring stakeholders together around water management strategies. The procedure for comparing and evaluating alternative water management policies or practices is based on the results of hydrologic/hydraulic simulations of those policies or practices. The procedure converts the output of these simulation models (flows, depths, velocities, qualities, etc.) that are deemed credible and acceptable by the public to values of multiple objectives or system performance criteria. Each objective or criterion can be expressed in different metrics or units of measure. They can include navigation, hydropower, recreation, shore erosion, flood damage or extent, environmental impacts, and ecological habitats. It is an approach that identifies and displays these impacts. It is not a procedure for finding the 'optimal' water management policy, but rather one that can contribute useful information to the political debate that must take place in the search of that optimum.

Each step of the approach involves working with the various stakeholders and publics in the basin. These individuals provide important inputs to the evaluation process. In addition stakeholders who will be involved in influencing or making water management decisions need to understand just how this multi-objective evaluation process works if they are to accept and benefit from its results. Stakeholder involvement in this process can help lead to a common understanding (or 'shared vision') of how their system works and the tradeoffs that exist among conflicting objectives. If all stakeholders fully understand this evaluation approach or procedure and how it is applied in their basin, they will be better able to use the results and participate effectively in the political process of selecting the best water management policy or practice. This multi-objective identification and evaluation approach merely identifies what these impact tradeoffs are, not what they should be. This approach includes six steps:

I. *Identification of the various system performance indicators and their units of measure at each site or region of interest in the watershed or basin.* Examples:

- Water Supply: Quantity, quality, reliability, and cost of supplies, etc.
- Navigation: Maximum draft, Flow velocity, Income, etc.
- Hydropower: Income, Reliability of firm power target, etc.
- Recreation: Suitability for boating (0-1), Income, Visitor days, etc.
- Environment: Concentrations of Algae, dissolved oxygen, nitrogen, etc.
- Ecology: Habitat suitability for selected indicator species or landscapes (0-1), etc.
- Shoreline Erosion: Erosion Potential (0-1), Land Depth or Area Loss, etc.
- Flooding: Area, Expected economic damage, etc.

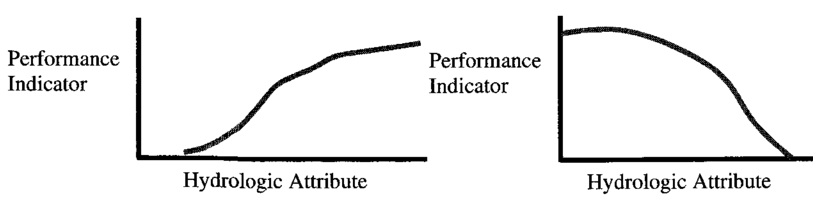
II. *Identification of the hydrologic attributes (sometimes called stressors) that impact each of these performance indicators or objectives at each site and in each time period as applicable.* Examples include maximum, mean, median, minimum or variance of water depth, flow, velocity, river width, concentration, temperature, etc. This can be any function of any simulated hydrologic variable or combination of variables over any selected time period and region, as appropriate for the performance indicator.

III. *Identification of functional relationship between each selected performance indicator or objective and its selected hydrologic attribute(s).* This usually involves the specialists or experts in each performance indicator, which could be the stakeholders in some cases. This is an important step and can take considerable time to reach a consensus on various functions, especially the ecological ones. Here is where we found important gaming exercises and modeling sessions, to which we return below. Examples:

- Hydropower energy KWH(t) = fn(storage head * turbine-flow in period t)
- Fish habitat(t) = functions of water flow, depth, velocity, quality in period t.
- Erosion potential(t) = fn(maximum velocity, depth in period t)

Figure 1

Performance indicators expressed as functions of hydrological attributes

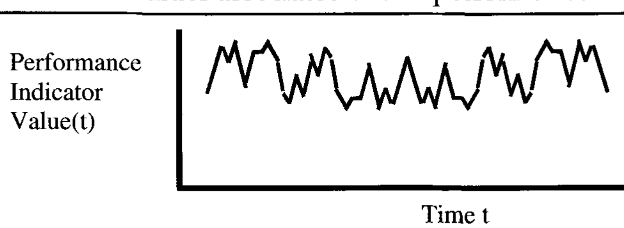


It is possible that multiple functions may apply to a single performance indicator and/or that one performance indicator (e.g. a certain species of fish) may become the attribute of another performance indicator (e.g. fish-eating birds or a bigger species of fish).

IV. Generation of time series of objective or performance indicator values associated with alternative water management policies or practices. Hydrologic or hydraulic simulations will generate time series of hydrologic variables such as flows, velocities, depths, water qualities, etc. These can then be combined as required to obtain the time series of attribute variable values. These time series of attribute values that can then be converted to time series of performance indicator values.

Figure 2

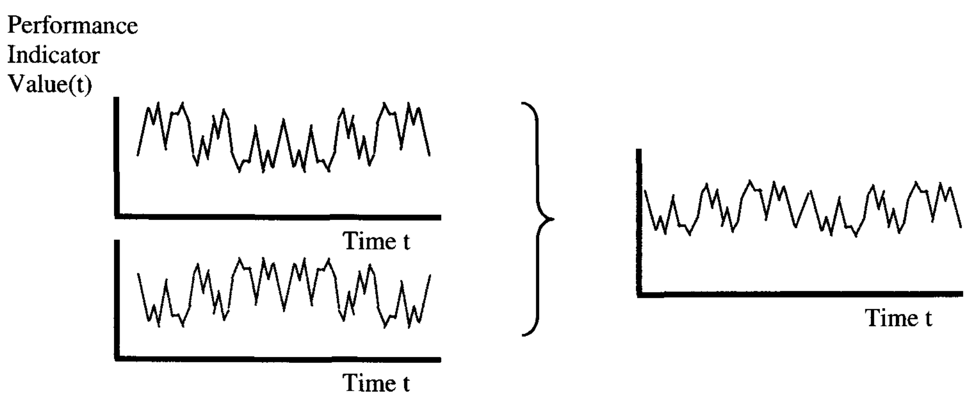
A time series of values associated with a performance indicator.



V. *Generation of composite values over time and space as appropriate for each performance indicator.* There are various ways to obtain a composite value, whether over time as in the above figure, or over space. The best way can be different depending on the particular performance indicator, and the calibration of indicator values to what professionals or stakeholders consider valid or most representative of what is observed in the basin. Geometric means, weighted arithmetic means, and maximum or minimum values are just some of the ways of obtaining a composite performance indicator value.

Figure 3

Creating a composite performance indicator value from multiple performance indicator time series.



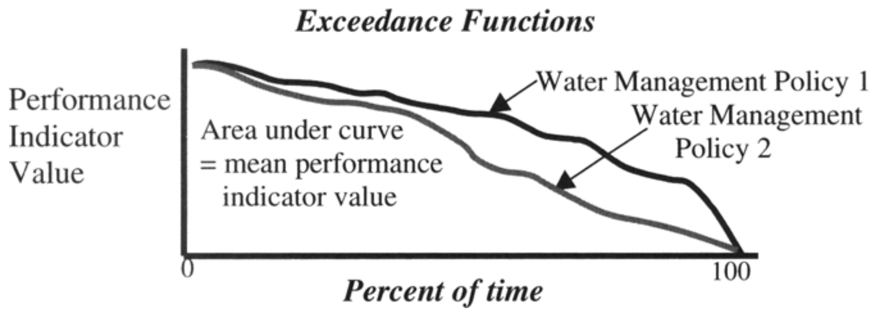
VI. *Summation, display, and comparison of composite performance indicator values.* It is not easy to compare multiple composite time-series data for each performance indicator for each water management alternative. One way of making this comparison easier is to collapsing a composite time series into an exceedance function showing the percent of time certain indicator values are exceeded. The area under each exceedance curves is the mean. Different exceedance functions will result from different water management policies. One can establish thresholds to identify zones of performance indicator values and assign a color to each zone. Color-coded map displays of ranges of performance indicator values and scorecards can be used to summarize and display data. These color-coded map displays can be dynamic, showing changes over time. Measures of reliability, resilience and vulnerability can be calculated and displayed as well. The mean values of each indicator for any set of sites can also be displayed in scorecards as shown below. The best value for each indicator can be colored green; the worst value for each indicator can be colored red. The water management alternative having the most number of green boxes will stand out and will probably be considered more seriously than the alternative having the most number of red boxes.

Making the procedure work with multiple actors

The procedure ideally leads to an integrated model that includes all relevant performance indicators. In practice, many of the causal links between

Figure 4

Different exceedance functions will result from different management functions. Color-coded map displays of ranges of performance indicator values and resources can be used to summarize and display data.



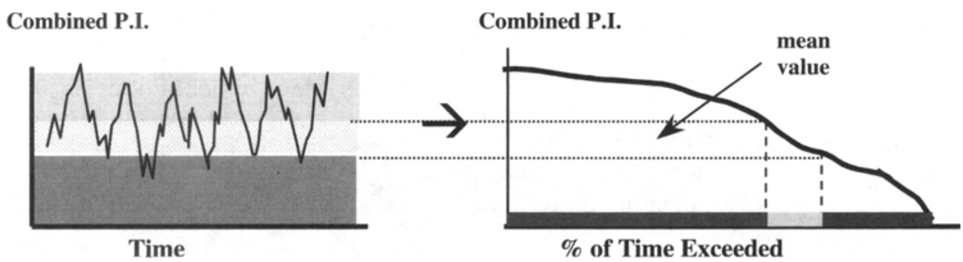
hydrological attributes and performance indicators are uncertain and politicized. This holds especially for the ecological indicators. Different actors (agencies and stakeholders) bring their own models to the table, each based on different causal assumptions and each describing different parts of the overall system (including both the water system as well as the ecosystem). It has been very hard to reach a working consensus on the links between these partial models. Without these links, different water management strategies cannot be evaluated.

Still, the cases showed that the models were nevertheless successful in helping to evaluate water management strategies. This success is in no small part due to the participatory processes and gaming exercises in which the models were embedded. One particularly successful example was a days-long "power-modeling" exercise by teams assigned to generate and evaluate different alternatives for the Comprehensive Everglades Plan. As described by the senior Everglades planner, there was a selection of relevant performance measures, which were then fed into an expedited alternative formulation and evaluation cycle:

> An alternative was formulated and then modeled by the modelers (about 10–12 people, mostly South Florida Water Management District modelers). The [alternative evaluation team] (30–40 interagency people) would then compare the model outcomes with the performance measures and assess the alternative. This evaluation was taken by the formulation teams to tweak and reformulate the alternative, model it, and then see whether or how it had improved. A key part of this process was the "power modeling" weekend, which remodeled the reformulated alternatives and did the model runs during the nights... The power modeling (initially called "tweak week") built up trust, but wasn't a giant love-in....The [team] evaluated not just ecosystem restoration scenarios, but they also had people evaluating flood and water supply performance of these scenarios. Sometimes you would have water supply [people] saying they were happy, but ecological people saying they weren't. The process was one of constant reformulation, and they were always multipurpose, so in the end different concerns were integrated.

Figure 5

Establishing color-coded zones of indicator values for subsequent statistical analyses.



Features of the power-modeling weekend were also found in the CALFED gaming exercises. The games typically took place over the course of several days and involved agency officials and stakeholders, including those responsible for water supplies and listed endangered species. They tested various scenarios under which water could be allocated month by month over the course of actual years from the historical timeline. The goal in most cases was to identify, capture, and allocate water, if necessary by finding flexibility in the water-supply system to meet both the fixed water needs in the baseline (e.g., legal commitments to meet the needs of endangered species) as well as the other water supply needs above and beyond the baseline. This led to the development of new policy options, such as the environmental water account. These new options were then the topic of subsequent gaming exercises.

All these considerations lead to a rather remarkable conclusion: The gaming (or equivalent participatory setting) itself is the linked, comprehensive model for which decision makers have been calling. The tweak weeks, gaming exercises, and the like are the model in which decision makers must be interested if the goal is to evaluate water management options that involve many different actors. While current attention is focused on the seemingly intractable task of technically integrating and connecting the patchwork of models describing water systems and ecosystems, the game does just that. The line operators and regulatory staff themselves function as the links that have so far escaped modeling. To put it more formally, the people provide the non-algorithmic knowledge needed to connect the models (Hukkinen 2000, personal communication). The game is basically a simulation of system behavior, when the system is taken to include the natural and the organizational. Because the participants in the games are the links, scenarios can unfold, reverberate through the system, and produce surprises from which learning can then take place. Ecology and engineering share the notion that the chief manifestation of complexity is surprise (Demchak 1991). Learning from such surprises (i.e., learning about complexity and whole-system characteristics), is preceded by the ability to generate surprises under conditions that are not fatal or prohibitively costly to ecologists or water managers. This is exactly what the gaming exercises and the related events have accomplished and brought to the ecosystem management initiatives.

The results of gaming and similar participatory modeling efforts were recounted to us by different interviewees in different terms. But they converge on increasing trust among participating agencies, focusing and expediting decision making by identifying the key issues; identifying the crucial gaps in modeling and research beyond the ubiquitous call for "more research;" creating a new and shared language between participants (which is then picked up by management) that expresses a better understanding of the system and its possibilities. It also inspires new policy styles, drawing the fisheries agencies out of their conventional regulatory answers and drawing water managers out of hard-infrastructure solutions, thereby proving a unique opportunity to explore the recoupling of services and functions, including generating new policy options, such as the environmental water account.

As mentioned above, the environmental water account coming out of the participatory modeling exercises is part of a wider set of innovations revolving around new accounting and budgeting mechanisms. This finding addresses the theoretical debate on how to balance learning and adaptation with compliance and accountability (e.g., Guijt, 2000). While accountability and compliance has always been a key concern in the cases, the learning and adaptation processes facilitated through the gaming exercises made it possible to develop more effective accountability mechanisms—e.g., in the form of the water account. While many have argued that there are contending priorities, our findings suggest that learning and adaptation can reinforce accountability and compliance and vice versa. As such, these cases hold out the promise that we can move beyond the idea that these are conflicting priorities.

Conclusion

The five areas of innovation found in the three case studies have brought actors together in new ways around water management strategies. We paid special attention to the role of participatory modeling, because it has been able to generate new policy options. For such complex and often deadlocked water management issues, new options are at a premium. The cases demonstrate that participatory modeling efforts are a key part of successfully addressing these major water management issues faced in the U.S. as well as elsewhere.

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