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COLLABORATIVE MODELING FOR DECISION SUPPORT IN WATER RESOURCES: PRINCIPLES AND BEST PRACTICES[1]

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ABSTRACT: Collaborative Modeling for Decision Support integrates collaborative modeling with participatory processes to inform natural resources decisions. Practitioners and advocates claim that the approach will lead to better water management, balancing interests more effectively and reducing the likelihood of costly legal delays. These claims are easy to make, but the benefits will only be realized if the process is conducted effectively. To provide guidance for how to conduct an effective collaborative modeling process, a task committee cosponsored by the Environmental Water Resources Institute (EWRI) of the American Society of Civil Engineers and by the U.S. Army Corps of Engineers' Institute for Water Resources developed a set of Principles and Best Practices for anyone who might convene or conduct collaborative modeling processes. The guidance is intended for both conflict resolution professionals and modelers, and our goal is to integrate these two fields in a way that will improve water resources planning and decision making. Here, the set of eight principles is presented along with a selection of associated best practices, illustrated by two different case examples. The complete document is available at: http://www.computeraideddisputeresolution.us/bestpractices/.

(KEY TERMS: collaborative modeling; decision support systems; public participation; planning; participatory modeling; Shared Vision Planning; Mediated Modeling; conflict resolution.)

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INTRODUCTION

As water-related professionals are well aware, water resources planning and management is characterized by multiple layers of complexity and uncertainty arising from the intersection of complex natural and human systems and the conflicting interests of competing stakeholders. Addressing these challenges requires both technical skills, such as the understanding of hydrology and ecology and how they interact, and process skills, such as appreciating the institutional

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setting and the ability to engage stakeholders and build their trust. Collaborative Modeling for Decision Support (Collaborative Modeling) combines both skill sets to manage water resources in a fair and effective process. Collaborative Modeling for Decision Support is defined as "integrating collaborative modeling with participatory processes to inform natural resource management decisions" (Lorie, 2010). It is an umbrella term that includes many related approaches developed by different practitioners and expert communities over recent decades, such as Shared Vision Planning, Mediated Modeling, Group Model Building, Computer-Aided Negotiation, and Participatory Modeling (see Table 1). The Principles and Best Practices document described here (Langsdale *et al.*, 2011) was written to increase visibility among water resources practitioners, but draws upon guidance developed in related fields such as conflict resolution and policy analysis, and the experience of the multiple authors. The principles and practices were written with water resource managers in mind, but they are just as applicable to environmental and other resource management contexts.

DEVELOPMENT OF THE PRINCIPLES AND BEST PRACTICES DOCUMENT

In the fall of 2008, members of the Environmental Water Resources Institute (EWRI) of the American Society of Civil Engineers and the Institute for Water Resources of the U.S. Army Corps of Engineers (USACE) established and jointly sponsored a Task Committee to develop a set of Principles and Best Practices for Collaborative Modeling for Decision Support. The coauthor team members (who are also the authors of this article) were carefully selected to ensure a diversity of experiences, skills, and perspectives. All have direct experience with one or more Collaborative Modeling processes, and some have extensive experience. Some of the authors identify themselves as modelers and others as facilitators. All have training and/or experience in environmental resource management. Authors are affiliated with federal and state agencies, academia, and consulting; together we appreciate the variety of ways that Collaborative Modeling teams can take form.

A literature review provided the foundation of the document; however, iterative development of the principles and practices relied heavily on personal experience with a number of cases related to water resources and natural resources management. (See Langsdale *et al.*, 2011 for citations and cases.) The team interacted through monthly conference calls and in person at the annual World Water and Environmental Resources (EWRI) Congresses in 2009 and 2010. We welcomed others to review a draft set of principles presented at our interactive task committee meeting at the Congress in May 2010. Twelve experts (not including the coauthors) participated, and provided critical feedback and suggestions for improvement through small group discussions and

TABLE 1. Terms for Methods that Combine Integrative Collaborative Modeling with Participatory Processes.

Term	Description	Definitional Work(s)
Collaborative Modeling for Decision Support (*formerly* Computer-Aided Dispute Resolution, CADRe)	Named by a community of practice following their 2009 workshop sponsored by the U.S. Army Corps of Engineers, Sandia National Labs, the U.S. Environmental Protection Agency, and the U.S. Institute for Environmental Conflict Resolution; not a new methodology, but a term that includes all related approaches	Bourget, 2011
Shared Vision Planning	Method refined by U.S. Army Corps of Engineers that combines (1) traditional water resources planning, (2) structured public participation, and (3) an integrated computer model	Werick and Whipple, 1995; Hagen, 2011
Mediated Modeling	Model building is used as the basis for a mediation process with, rather than for, multiple stakeholders	van den Belt, 2004
Group Model Building	Quantitative or qualitative system dynamics models are used to enhance team learning, foster consensus, and create commitment. Applied to organization and resource management problems	Vennix, 1996
Computer-Aided Negotiation (CAN)	Defined as "a marriage between two fields: (1) computer modeling/simulation, and (2) dispute resolution." Shares roots with SVP through early work on the Potomac River Basin	McCrodden, 2011
Participatory Modeling; Participatory Integrated Assessment Modeling	Stakeholder involvement in integrated assessment has become an increasing focus since the late 1990s, particularly motivated by the Environmental Directive of the EU	Hare *et al.*, 2003; Rotmans, 1998

individual feedback. Later that same day, we hosted a panel discussion for additional feedback among the wider water resources community. Several others provided external written reviews at other stages. All the feedback ensured that our recommendations were broadly applicable and did not contain agency- or field-specific language. Suggestions helped improve the organization and clarity of the draft recommendations and added new ideas from closely related fields.

Released in February 2011, the document includes eight Principles, with associated Best Practices and example "vignettes" from actual case studies. It is available publicly on the web to ensure wide accessibility. The authors hope to enhance and improve the document over time.

PRINCIPLES OF COLLABORATIVE MODELING FOR DECISION SUPPORT

The following set of principles focus on simultaneously integrating the construction of model building with a participatory process. The full descriptions and supporting material are available in the complete document (Langsdale *et al.*, 2011; available at www.computeraideddisputeresolution.us/bestpractices).

1. Collaborative modeling is appropriate for complex, conflict-laden, decision-making processes where stakeholders are willing to work together.
2. All stakeholder representatives participate early and often to ensure that all their relevant interests are included.
3. Both the model and the process remain accessible and transparent to all participants.
4. Collaborative modeling builds trust and respect among parties.
5. The model supports the decision process by easily accommodating new information and quickly simulating alternatives.
6. The model addresses questions that are important to decision makers and stakeholders.
7. Parties share interests and clarify the facts before negotiating alternatives.
8. Collaborative modeling requires both modeling and facilitation skills.

"Examples of Best Practices from the Case Studies" describes these principles in more detail, including the associated best practices, illustrated by two very different applications of Collaborative Modeling. These cases are introduced in the following section.

CASE STUDIES

The full report includes short vignettes from a variety of cases to illustrate the best practices. Here, we present only two contrasting cases for clarity. The first case is an assessment of water resources futures for the Okanagan Valley in British Columbia, Canada. The second is a very large Shared Vision Planning study to consider changing operational rules for the management of Lake Ontario and the St. Lawrence River.

Climate Change and Water Resources in the Okanagan Valley, British Columbia

In 2005, representatives from the University of British Columbia and Environment Canada's Adaptation and Impacts Research Group led a one-year collaborative modeling exercise in the Okanagan Basin in south-central British Columbia (Langsdale *et al.*, 2009). This watershed was of particular interest because its semiarid climate, significant role of agriculture, and recent intense population growth made it more vulnerable to the impacts of climate change and at risk for water shortages. During the five years preceding this effort, climate scenarios had been downscaled and used to generate associated hydrologic and crop water demand scenarios. Residential demand scenarios were also in early stages of development for both climate change and population growth scenarios. Sharing this information with stakeholders had increased their awareness and concern about the impact of climate change combined with other stressors. However, looking at each study's results independently, as presented, did not describe if water shortages would increase in the future. The collaborative model integrated all of this available technical information and captured it within a context of local water management rules, and thus provided information that was more informative for helping the community to determine water management policies.

The collaborative modeling process included a series of five stakeholder workshops, as well as one batch of small group meetings to review the model in more detail. Fifty-one stakeholders participated in at least one event of the series, with the most representation from provincial government, local government, environmental NGOs, and agricultural interests. The direct financial costs were very low (approximately CAD\$100,000 or US\$82,000 in 2005) as the lead modeler and facilitator (Langsdale) was a graduate research assistant, and several supporting team members volunteered their time on the project.

The purpose of this effort was not to support a specific, immediate decision, but to foster dialog among the water resources community about the specific impacts of climate change and the effectiveness of a range of adaptation options. As no direct impacts were expected, it is difficult to measure the success of this project; however, a positive indicator that the results have been influential is that the regional water board referred to this study in their Sustainable Water Strategy Action Plan (Okanagan Water Stewardship Council, 2008).

Operating Rules for the Lake Ontario-St. Lawrence River

This study, conducted under the auspices of the International Joint Commission, was the most ambitious Shared Vision Planning effort undertaken to date, costing US$20 million (U.S. dollars in 2008) and spanning five years with continuing consideration. The study had the very specific purpose of reevaluating the operational rules of the dam that crosses the St. Lawrence River and affects water levels in Lake Ontario and in the St. Lawrence River. The study area encompassed portions of the Provinces of Ontario and Quebec in Canada and the State of New York in the United States. The study examined alternatives for updating half-century-old operational rules to consider dissatisfaction raised by some interests with the working of the system and in light of environmental concerns and climate change issues.

The Study Board charged with conducting the study decided to use Shared Vision Planning as a way to link research, public input, and decision making across geographic regions, stakeholder groups, and differing expertise. The linked models developed for that process provided a common framework for the nine technical work groups, a public interest advisory group, and the Study Board to see how possible operational changes would affect water levels, flows, and their associated impacts throughout the system. The models informed a series of iterative decision workshops, where participants worked through decisions based on the information at hand while clarifying what further information and relationships would be helpful for improving future decision making. Results from the models were made available during the study over the internet on what became known as "The Board Room" to provide for maximum possible transparency and to allow those interested to explore information in detail.

The Study Board provided a final report with three alternatives to the International Joint Commission in 2006 (International Lake Ontario-St. Lawrence River Study Board, 2006). The Commission convened a working group in 2009 to explore a regulation plan acceptable to the United States, Canada, Ontario, New York, and Quebec, and issued a draft of the new approach for public comment in March 2012. The new approach would allow for more variability in water levels to help restore environmental conditions while moderating extremely high and low water levels to benefit other basin interests. An Adaptive Management strategy would improve the capability to adapt to future changes, including socioeconomic changes, bigger storms, or more severe droughts.

EXAMPLES OF BEST PRACTICES FROM THE CASE STUDIES

Principle 1: Collaborative Modeling Is Appropriate for Complex, Conflict-Laden, Decision-Making Processes Where Stakeholders Are Willing to Work Together

Most problems in water resources planning and management are not straightforward, but need to consider multiple objectives and uncertainties. If potential decisions may affect stakeholders, then they should be allowed to have input up front. The saying "better to ask forgiveness than permission" does not apply in the case of managing public resources — it certainly will not build goodwill or trust for the agency. Furthermore, although the public engagement activities increase up-front costs, engaging stakeholders and decision makers throughout the planning and decision process can reduce resistance to implementation, so overall project length and cost may actually be reduced (Shabman and Stephenson, 2007).

Best Practice: Garner Support of Decision Maker(s). In the Lake Ontario-St. Lawrence River study, decision makers were actively involved, particularly in the iterative decision-making workshops, which served as a check to ensure that the information presented was useful and to identify what was still required to support the decision process. A challenge associated with this long-term study was to respond to personnel changes, particularly in key decision-making positions. Additional meetings were required to further consider alternatives and discuss varying perspectives.

In the Okanagan study, because there was not a specific decision, there was no clearly defined "decision maker." However, as policy makers, the elected officials certainly had authority to act on the study results. One mayor was very interested in the process, but was unable to attend the full-day sessions. Instead, the study leader met him separately in his office to present the model, discuss insights, and gather his input. This was not ideal, but did maintain awareness of the effort and support from the mayor. Ensuring the process meets the needs of the decision maker is critical for building support for implementation of the results of the process, and that the investment by all parties in the collaborative modeling effort will be fruitful.

Principle 2: All Stakeholder Representatives Participate Early and Often to Ensure That All Their Relevant Interests Are Included

Actively involving stakeholders, defined as all those who can affect, may be affected by, or who have an interest in a decision, is the best way to ensure that all interests are considered in a decision. As resource management decisions are value laden, the balance of these diverse interests is required to identify the most beneficial decision (or most widely acceptable decision). Continually engaging representatives of these interests throughout the process can improve understanding of the system, build respect, and increase the chances of building "informed consent" if not consensus around the best alternative(s). To be most effective, stakeholder representatives should be engaged early and often, so they have input in the problem definition, in the performance metrics, in developing and evaluating alternatives, and in selecting a preferred alternative.

Best Practice: Identify Who to Invite to the Process. One way to build the invitation list is through a "stakeholder (or situation) assessment." This is conducted primarily through informational interviews with stakeholders about their attitudes, knowledge, and any local conflicts related to the issues at hand. At the conclusion of each interview, the stakeholder is asked who else is interested in the issues; this process is continued until the interviewee obtains referrals with whom he or she has already interviewed. At a minimum, the general rule is to have a representative from each interest/perspective. This can take considerable up-front effort, but ensures that all critical interests are represented at the table. A broad range of stakeholders assures a good base of knowledge and is a critical factor for a successful process.

In the Lake Ontario-St. Lawrence River study, many of the interested parties were critical to the effort, whereas others were less obvious. The stakeholders included the governing bodies, but also shoreline residents and environmental interests. With such a large study, it is obvious that you cannot include every individual stakeholder directly in the collaborative modeling engagement, nor would every stakeholder want to participate. One option for structuring participation is the "Circles of Influence Model," developed by sociologist Robert Waldman and shown in Figure 1, where those most directly involved with the model (Circle A) communicate with trusted participants at the next level (Circle B), who in turn provide a trusted link to interested parties with still less direct involvement (Circle C). As applied in the Lake Ontario-St. Lawrence River study, representatives trusted by each stakeholder group (Circle B) directly informed the model builders (Circle A), allowing the larger stakeholder population to connect to the work through someone they already trust. Similarly, government agency members of work groups provided linkages to their agencies. The publicly available Board Room provided a way to keep the broader group of interested persons (Circle C) better informed.

In the Okanagan study, the Circle of Influence approach was not used because the relatively small size of the study allowed all stakeholder representatives to engage directly with the modeling team and because there was no need to engage a wider group (although some representatives' colleagues did attend group meetings, and representatives were encouraged to share the model and any workshop findings). To identify participants, the invitation list was built primarily using existing contact lists as researchers on the team had already been working in this area for several years. Before starting workshops, targeted invitations were sent to contacts requesting that they, or someone else in their organization, attend, and a public announcement was made. Word of mouth during the process drew additional participants along the way. As a result, there was significant turnover in attendance at each event, which added facilitation challenges. Perhaps newcomers were inevitable (and a sign that the workshops were meaningful for the community), but a lesson learned is that relying on existing lists did not identify all those who should have been invited; a stakeholder

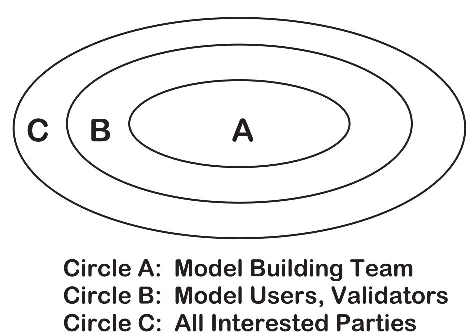

FIGURE 1. Circles of Influence Model.

assessment may have better solidified the participant list and opened communication between the stakeholders and the modeling/facilitation team.

Principle 3: Both the Model and the Process Remain Accessible and Transparent to All Participants

Best Practice: Select Software That Is Easy to Learn and Can Be Made Available to All. The choice of software and the associated features of the user interface are important for creating transparent models that the stakeholders can delve into and understand, as opposed to "black box" opaque processes. How models are used is what is really critical. The best way to ensure that the model remains transparent is to continue to ask the participants or end users how to make it clear to them, as something that is obvious to one person is not always obvious to someone with different expertise or experience.

The Okanagan Model was built in STELLA™ software (isee systems, Lebanon, NH) and included a user-interface level. Through several meetings, the stakeholders reviewed and tested each iteration of the model. In addition to direct feedback and suggestions, the team observed how the participants used the model, what was clear to them, and where they got "stuck."

The Lake Ontario-St. Lawrence River study linked a number of models, including a STELLA™ model to simulate water levels and provide economic evaluations, and separately coded Flood Erosion and Protection System Model, Shoreline Response Model, and Integrated Ecological Response Model. However, the main user interface, named "The Board Room," was constructed in Microsoft Excel and made use of its many graphical and user-friendly input and output features to dynamically link the other models.

Principle 4: Collaborative Modeling Builds Trust and Respect Among Parties

In a negotiation setting, building relationships and trust is a prerequisite of finding a mutually agreeable solution. This relationship building helps participants identify with a wider community; it changes their focus from "How can *I* maximize my *personal* gains?" to "How can *we* maximize gains for the *community*?" The focus on trust and respect is consistent with findings by moral psychologist Jonathan Haidt (2012): when provided only with logical arguments, people tend to remain firmly attached to their original positions; however, if emotional connections are made first between people with different values and interests, this opens people's minds to considering new points of view. So, beyond bringing people together into one room to work together, how do we encourage this *positive* relationship building?

Best Practice: Approach the Project with Humility. Collaborative modeling changes the paradigm from "experts know best" to "everyone knows a piece of the whole puzzle, and decisions are value-laden, so everyone needs to participate to find the best solutions." This must be reflected through the modeler's and facilitator's attitudes, as well as how they design the process and the specific meeting agendas. In the Okanagan case, Langsdale began the first workshop by saying, "This work is for my doctorate, however, if it isn't useful for you, the stakeholders, then tell me, and we can all go home and prevent wasted effort." Despite the dramatic emphasis, it conveyed that we needed their input, and that the effort was not intended to be just an academic exercise.

Best Practice: Design and Execute a Process Where Stakeholders Are Valued for Their Contributions. One of the primary ways of showing stakeholders that they are valuable to the process is to ask them for their input, for example, asking them to contribute to the development of the model. This contribution can take a number of forms depending on the stakeholders' abilities, including gathering data, testing model assumptions, evaluating the user interface, generating alternatives, and validating output. Those without technical expertise can still contribute by ensuring that the model contains the measures important to them, and modeled simulations are consistent with their real-life experiences.

In the Okanagan case, the sessions were used to generate content and to review models. For example, in the second workshop, the participants divided into groups and developed causal loop diagrams (on large paper) of how the water resources system worked. They identified what reduces available water resources, and what increases the available water resources in the Okanagan. They also identified the purpose of the model, what they were hoping to learn from it, and then what scales would be suitable for these purposes. This input served as the foundation for constructing the first version of the computer model. In the subsequent sessions, the participants continued to contribute directly to model development by critically reviewing the models, supplying missing data, and validating model output.

Principle 5: The Model Supports the Decision Process by Easily Accommodating New Information and Quickly Simulating Alternatives

"Quickly" is a relative term, but the intent in a Collaborative Modeling or Shared Vision Planning process is to support a *planning* level study, so the focus is more on breadth and integration of many issues, rather than on depth, detail, and precision. To support dialog on evaluating and generating alternatives, a simpler model allows for the flexibility to keep pace with the conversation, making the difference between supporting or limiting the conversation.

Keeping the model relatively simple and high level is the key to success at this phase. Later, the more detailed and precise analysis for the design phase can be conducted more efficiently as options have been prioritized and the *critical* data gaps have been identified.

Best Practice: Ensure the Model and Modeler Can Accommodate Rapid Modifications and New Alternatives, and Can Simulate Relatively Quickly. Part of the beauty of a collaborative modeling process is that the diversity of ideas, expertise, and connections can prompt participants to "think outside the box" and explore a wide variety of creative solutions. Being able to quickly determine the likely effect of a possible solution supports the back-and-forth brainstorming energy that can characterize this approach, focusing the group on promising areas and highlighting unexpected consequences.

In the Lake Ontario-St. Lawrence River study, a historical dataset of 101 years (4,848 quarter-months) allowed relatively quick simulations of water level and flow impacts associated with alternative regulation plans. Hundreds of plans were tested with this historical dataset, which could be run in as little as two minutes by using just the STELLA™ portion of the model only, or 90 min if accessing the full suite of linked models. A full stochastic 50,000-year hydrology set was developed as part of the study, and four 101-year "centuries" were extracted to represent extreme periods. These extracted "centuries" allowed for additional quick simulation to check for robustness. Full stochastic analyses, which took more than a day to run, were only performed for plans that held particular promise.

Principle 6: The Model Addresses Questions That Are Important to Decision Makers and Stakeholders

When technical experts invest energy toward model building on their own, they frequently build tools that are interesting to them, and then find users who can make use of the tool. In collaborative modeling, the order is reversed, ensuring that the model's purpose drives the design.

Best Practice: Frequently Ask the Team and All the Participants Throughout the Process, "Who Will Use the Model?" and "How Will It Be Used?" The facilitator and modeler leading the effort must not just ask these of each other, but of all the participants.

In the Okanagan study's second workshop, participants were asked what spatial scale would be most useful for answering their questions. Responses ranged widely, from modeling all 60 tributary watersheds, to treating the entire basin as a single element. Despite the range of proposals, the group easily agreed to three zones, divided by the topography, as it served their purposes of generally testing the balance of water supply and demand for each of the three primary water sources in the basin (tributary streams serving primarily agricultural needs, Okanagan Lake serving primarily residential urban areas, and Okanagan River serving all needs downstream of the lake). The one stakeholder who insisted that modeling each tributary watershed was necessary was a modeler himself and perhaps was focusing on his own experience with models, rather than thinking about the minimum needed to address the issues at hand. It is not uncommon for experts to want more precise and detailed information because this is what they know and take pride in. When doing general planning studies frequently ask, "Who will use the model?" and "How will it be used?" throughout the effort to avoid unnecessary investment in model development.

Best Practice: Build a Simple Model Early in the Process, and Then Improve It over Time with Input from Stakeholders and Experts. Collaborative modeling involves a wide array of people, often including those who know little about computer models as well as those with highly informed but narrow views of modeling. Building a simple "mock" model at the outset provides a visible example of the sort of model everyone has to work on together. The simplicity of the mocked-up model helps direct the collaborative focus to the overarching design questions ("Who will use the model?" and "How will it be used?") rather than the minutia of programming details, and it provides a space where all can offer what they know and learn what they do not. The mock model is not a first draft; there are no promises that its outputs are accurate, but these mock models do sometimes preview the structure of calculations that will be used in real models with real data. Because the mock model is built quickly, there is greater willingness to radically transform it to a more useful form.

In the Lake Ontario-St. Lawrence River study, a "mock" model was built very early in the process to serve as a relational diagram of available and needed information, and to show how the various efforts would fit together and support decision making. There was no expectation that the model would produce comparative information for assessing alternative regulation plans, but rather that the model would contain all the needed puzzle pieces and that with further development they would yield the desired information. The initial model provided a framework for ensuring that stakeholders' key concerns would be addressed, and that these key concerns could be explicitly related to performance indicators affected by water level and flows.

Principle 7: Parties Share Interests and Clarify the Facts Before Negotiating Alternatives

Best Practice: Engage Stakeholders in Iterative Model Development and Technical Analysis to Foster Shared Learning. Particularly, in complex situations, participants rarely have a complete understanding of the various interactions in the system. More typically, each participant contributes knowledge in a particular area of experience or expertise. Building a model collaboratively not only helps capture that knowledge but provides a greater understanding of the system.

In the Lake Ontario-St. Lawrence River study, "fence post" plans were developed that served solely to define what a single interest might want if there were no conflicting interests to consider. Although no one expected such a "fence post" plan to serve as a final alternative, they helped define the boundaries of what could — and could not — conceivably be achieved. One such "fence post" plan showed that it was not possible to achieve significantly reduced lakeshore damages even if other considerations such as environmental or hydropower impacts were ignored. Similarly, "perfect forecast" plans (using historical data) helped illustrate both the limitations of current forecasting (what can be known in advance now) and the benefits of potential improved forecasting in the future.

The Okanagan study process was designed to help the participating stakeholders focus on learning about, and agreeing on, the best description of the water resources system before evaluating and comparing alternatives. The study process included six steps, allowing for: (1) Visioning and brainstorming objectives; (2) System mapping, defining the purpose and scope of the modeling effort; (3) Qualitative modeling, including review of the first version of the computer model, focusing on model structure and the interface; (4) Quantitative modeling working sessions; (5) Calibration and validation of output, review of interface and alternatives; and (6) Exploring futures, testing and discussing alternatives.

Principle 8: Collaborative Modeling Requires Both Modeling and Facilitation Skills

Best Practice: Choose Modelers with Collaborative Skills and Diverse Modeling Abilities, and Choose Facilitators with the Ability to Understand and Appreciate What Modeling Can Provide. The choice of both modeler and facilitator is an important decision. Modelers must be able to listen, distil expectations from technical and nontechnical participants, and adjust models to reflect what is relevant and what will be of interest to decision makers. The modeler may be required to develop a new model, rather than executing a ready-made model to best respond to the input of project participants. Facilitators must be sufficiently informed to translate between different disciplines, ensure that discussion remains relevant, and synthesize what people are saying. In rare cases, the modeler and facilitator can be the same person.

The Lake Ontario-St. Lawrence River study included both modelers and facilitators as project participants. The study participants with a modeling background were comfortable engaging with the broader group. In general, these modelers were able to explain technical information clearly in lay terms, sometimes using analogies, as well as to listen to a general discussion, synthesize what was heard and what that meant for the model (again in lay terms), and then make the adjustment in the model. This study benefited from having in-house expertise in both modeling and facilitating.

In the Okanagan study, Langsdale served full time on the project as both the lead facilitator and lead modeler. She brought previous modeling experience to the project, supplemented by colleagues who mentored and assisted in developing the model as well as in designing the stakeholder engagement process. Langsdale's basic level of facilitation skills was sufficient for managing the participating stakeholder group, who, as volunteers, were very interested in the effort, and demonstrated little conflict with each other. This arrangement of a single lead modeler/facilitator was appropriate to the size and scope of the effort, and certainly eliminated coordination between two leads; however, it was often challenging to focus attention simultaneously on the model content, on the process, and on the stakeholders; possibly, opportunities for improvement were missed. These advantages and disadvantages should be carefully weighed when selecting facilitation and modeling leads.

SUMMARY

Collaborative Modeling for Decision Support can be an effective approach and rewarding experience for all those involved; however, these benefits will only be realized when it is conducted well. Collaborative Modeling recognizes that resource management problems are not just technical issues, but value laden with the complexities of how society interacts with the natural environment. Accordingly, it changes the paradigm from that of technical experts independently recommending "optimal" solutions to one where technical experts support planning processes alongside all who are affected by, can affect, or have an interest in the decision at hand. Because working in a new paradigm may be uncomfortable, or at least unfamiliar, those who design, execute, and sponsor Collaborate Modeling processes need to be cognizant of the factors that increase the chances for success. The complete document, Collaborative Modeling for Decision Support in Water Resources: Principles and Best Practices (Langsdale *et al.*, 2011) as well as this article identify these keys to success, according to the wealth of experience by the coauthor team.

First, the conditions need to be right; everyone needs to be willing to participate, especially those in decision-making authority so that the recommendations will be implemented. Second, a deliberate effort must be taken to identify trusted representatives, and to ensure that everyone who needs to be at the table is willing and able to take part. Third, clear and open communication about the design and expectations of the engagement and decision-making process, and a transparent, user-friendly model help to enable equal participation and the collaborative environment. Fourth, support positive relationship building, fostering trust and respect among all involved by showing humility and valuing each participant's contributions. Fifth, ensure that the model assists with (rather than delays) the planning effort by remaining nimble and flexible to accommodate new information and new alternatives. Similarly and sixth, ensure that the model is built in a way that it remains relevant to the purpose of the study over time; that it is designed for those who will use it and that it answers the questions that are important to the decision makers and stakeholders. Seventh, following principles from interest-based negotiation and value-based decision making, focus first on building a shared understanding of the facts and the complexities of the issues, before identifying, evaluating, and negotiating alternative actions. Last but not least, ensure that the team convening and leading the effort contains appropriate modeling and facilitation skills. In rare cases, one person may bring both skill sets to the project. More typically, the team will require at least two people, one modeler and one facilitator. In these cases, ensure that the modeler appreciates and values the role and contribution of the facilitator, and vice versa.

When conducted well, the approach can increase knowledge about the system and lead to decisions that effectively balance multiple interests and are supported through implementation. The shared learning (Principle 7) and social capital (Principle 4) that are encouraged through the process can support management of the resource over the long term and provide a foundation to build upon when confronting future decisions. Thus, collaborative modeling enables more sustainable water resources management.

We hope that this set of Principles and Best Practices will be a valuable resource for those who would like to convene, support, or participate in a Collaborative Modeling for Decision Support process. These Principles and Best Practices, developed through experience, will help a collaborative approach realize its full potential benefits and maximize the probability of success.

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