UNIVERSITIES COUNCIL ON WATER RESOURCES
JOURNAL OF CONTEMPORARY WATER RESEARCH & EDUCATION
ISSUE 140, PAGES 24-29, SEPTEMBER 2008

Communication of Climate Change Uncertainty to Stakeholders Using the Scenario Approach

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A decade ago, Shackley and Wynne (1996) noted:

> It is frequently assumed that scientific uncertainty is a problem for environmental policy. Many decision makers and advisory scientists believe that policy ideally should rest on reliable, robust, and hence certain scientific knowledge. (p. 275)

Today, with the development of complex systems science as well as the focus on long-term sustainability, we are now aware that additional science cannot always provide all of the answers. As a result, natural resource managers and policy makers must find ways to move forward despite the presence of uncertain future conditions and the associated risks. Unfortunately, the presence of any uncertainty has been, and often still is, an excuse for delaying action. This is partly due to the belief that scientific certainty is a prerequisite for building consensus (Shackley and Wynne 1996) and negotiations are delayed until more information is available. The climate change issue provides a prime example of this effect. In various political circles and organizations, much of the focus has been on how to reduce the level of uncertainty in climate change predictions. Reduction of some of the uncertainty is reasonable, but uncertainties that are inherent to the system cannot be eliminated. Once inherent uncertainties dominate, then the focus should shift away from reducing uncertainties and move on to clarifying and communicating what *is* known about the system and determining effective and robust responses. The following section defines inherent uncertainty and identifies common sources. Next, some of the challenges in communicating uncertainty to stakeholders are described and a scenario-based approach is presented as a means of overcoming these challenges. A case study in which collaborative modeling conveyed information about the potential impacts of climate change on water supply and demand is provided for illustration. The paper concludes with recommendations for both messengers and recipients of information containing uncertainties.

Recognizing Inherent Uncertainty

Diefenderfer et al. (2005) distinguish two sources of uncertainty: *knowledge uncertainty* and *inherent uncertainty*. Knowledge uncertainty, also referred to as epistemic uncertainty, is due to incomplete knowledge about the system. In modeling, knowledge uncertainties can be gaps in the model's structure or in the data required to support it. If a system contained only knowledge uncertainty, then, in theory, complete knowledge about the system could be achieved through further scientific investigation. In contrast, inherent uncertainty is a result of natural variability in processes such as non-linear and chaotic behavior patterns; so when present, no amount of research will generate absolute predictions. The belief that scientific knowledge that supports policy must be certain is a result of falsely assuming that all of the uncertainty present is a type of knowledge uncertainty.

Sources of Inherent Uncertainty

Both human and ecological systems contain many elements that are characterized by inherent uncertainties. For example, water resource systems rely on the hydrologic cycle which is certainly unpredictable, particularly in western U.S. watersheds that are characterized by highly variable precipitation. The influence of climate change, that is altering patterns of rainfall distribution around the planet, further decreases our ability to predict stream flow. However, the link-ages to human influences on both the supply and the demand upon the resource increase the complexity and thus the challenge in making the predictions required to manage these systems. Population, income, and technology affect water demand in agricultural, municipal and industrial sectors (Smith et al. 1996, Ghabayen and McKee 2006). In sustainable river management, uncertainty is no longer regarded as a margin of error but is seen as an intrinsic part of the operating environment for the river system and its managers (Clark 2002).

Challenges in Communicating Uncertainty to Stakeholders

Three challenges to communicating uncertainty to stakeholders have been identified in the literature: intolerance of uncertainty, lack of attention to the amount of uncertainty in modeled results, and omission of elements that contain uncertainty.

Uncertainty Intolerance

As noted in the quote at the beginning of this article, there has been an attitude that uncertainty is unacceptable and indicates faulty or incomplete science. In a more recent paper, Clark (2002) noted that scientists and engineers who work professionally in river management are able to accept uncertainty. However, politicians and the public tend to be "risk averse and regard uncertainty as not only unacceptable, but also as someone else's 'fault.'" (Clark 2002: 353). The risk averse attitude is not surprising, particularly in our highly litigious culture. However, intolerance to uncertainty, when it is inherent to the system, can create challenges in the development and implementation of public policy.

Over-Confidence in Model Results

A significant problem surrounding communicating uncertainty is not in the translation of a complex and large amount of information, but in conveying the importance of the uncertainty in the results. Both scientific experts and laypersons have been found to have too much confidence in highly unreliable data.

> [T]he uncertainty surrounding the experts' best guess may be as important as the substance of the guess. One wants to know 'just how high could it be?' and 'do these experts know enough for me to take their best guess seriously?' A good deal of evidence ... suggests that were such qualifications provided, they would not be used properly. In particular, people seem to be as confident making inferences from highly unreliable data as from reliable data, rather than less confident, as statistical theory dictates (Fischoff and Furby 1983: 186).

Omitting Complex, Uncertain Aspects of the System in Analysis

Moser and Dilling (2004) describe the uncertain character of climate change as one contributing reason why the professional water community, to date, has been reluctant to consider climate change in their planning activities. This is unfortunately not an uncommon response when modeling a system – to omit the elements for which we have limited understanding. For example, when the first report by the Intergovernmental Panel on Climate Change was generated in 1990, little quantifiable information was available on the natural feedbacks related to a warmer climate. Therefore, the authors omitted the information from the computer models (Leggett 2001). Unfortunately, when analyses lack elements that help define the behavior of the system, policies developed from these analyses may not be ideal for the conditions that will be realized.

Scenario Approaches to Manage and Communicate Uncertainty

Scenarios are defined as "plausible combinations of circumstances that can be used to describe a future set of conditions" (Smith et al. 1996). The scenario approach provides an alternative to the convention of aggregating results into an average value and then representing the uncertainty with error bars or statistics, as shown in Figure 1. Whether the audience is technically-trained or not, expressing results in terms of scenarios provides a clearer picture of the range of future states possible. Figure 1(a) shows five equally plausible

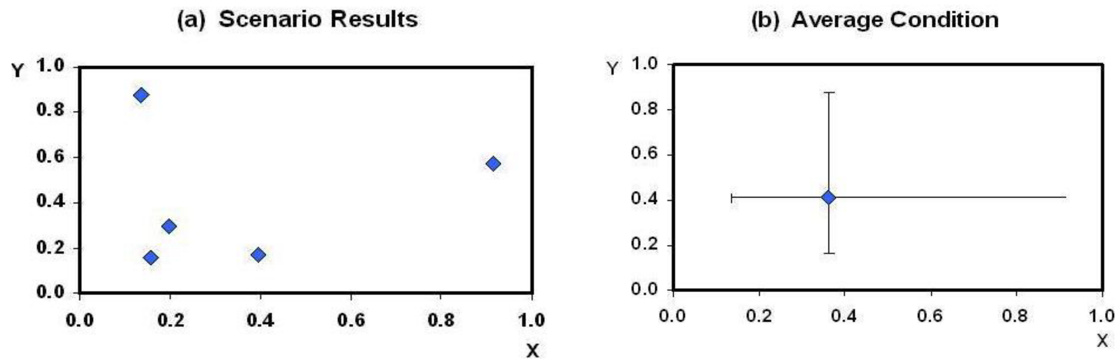

Figure 1. Graph (a) shows results as an array of discrete states, while graph (b) shows only the average of the five scenarios, along with error bars that provide the range of possible conditions.

scenarios, while Figure 1(b) reports the average of the five scenarios and uses error bars to represent the extent of the individual scenarios. So, both figures represent essentially the same feasible region or decision space. However, Figure 1(a) more clearly conveys that any of the five states are equally plausible, while Figure 1(b) implies that the average condition is most likely and that the probability of occurrence decreases toward the limits of the feasible region. When people are presented with results in the form of an average, there is a temptation to focus primarily on the single point, and the importance of the range of uncertainty is lost.

Note that in Figure 1(a), the model uncertainty resulting from knowledge uncertainty is not represented. For this illustration, I assume that the inherent uncertainties are significantly larger than the model uncertainties, such that the feasible region defined by the range of scenarios largely encompasses the region that would have been defined from the model uncertainty.

The simplest form of a scenario analysis generates an array of equally-plausible scenarios. In circumstances when different probabilities of occurrence are relevant, Bayesian Belief Networks may be used to estimate the likelihood of each scenario. Bayesian Belief Networks characterize the cause-effect relationships in a system using conditional probabilities (Ghabayen and McKee 2006).

The use of scenarios, whether equally plausible or containing assigned probabilities, helps to alleviate the three challenges described in the previous section. First, using a framework of discrete scenarios helps to spell out the sources of uncertainty and highlights their inherent nature, which may reduce people's intolerance of uncertainty. Next, explicitly displaying a range of conditions helps to prevent anchoring and overconfidence in a single point (as in the average state). The message that the future could be any of the number of states is continually reinforced. Finally, the discrete scenarios also present the results in a format that is manageable and can be readily used for further assessment. Presenting the scenarios through a decision support tool can further this goal by providing a framework for stakeholders to manage and evaluate the scenarios effectively.

Case Study: The Okanagan River Basin, British Columbia

An application of the scenarios-based approach was recently completed in a case study in south-central British Columbia, Canada, in the Okanagan River Basin (Figure 2). The purpose of the initiative was to communicate and foster dialogue about plausible future scenarios describing the balance of supply and demand, and to test and discuss appropriate management and policy responses (Langsdale et al. *In Press*, *In Review*). Prior to this initiative, research findings indicated that climate change impacts could reduce water supply, while simultaneously increasing demand (Cohen et al. 2006). This research, as well as contributions from a selected group of stakeholders, supported the development of the model. Stakeholders, who included water managers, researchers, planners,

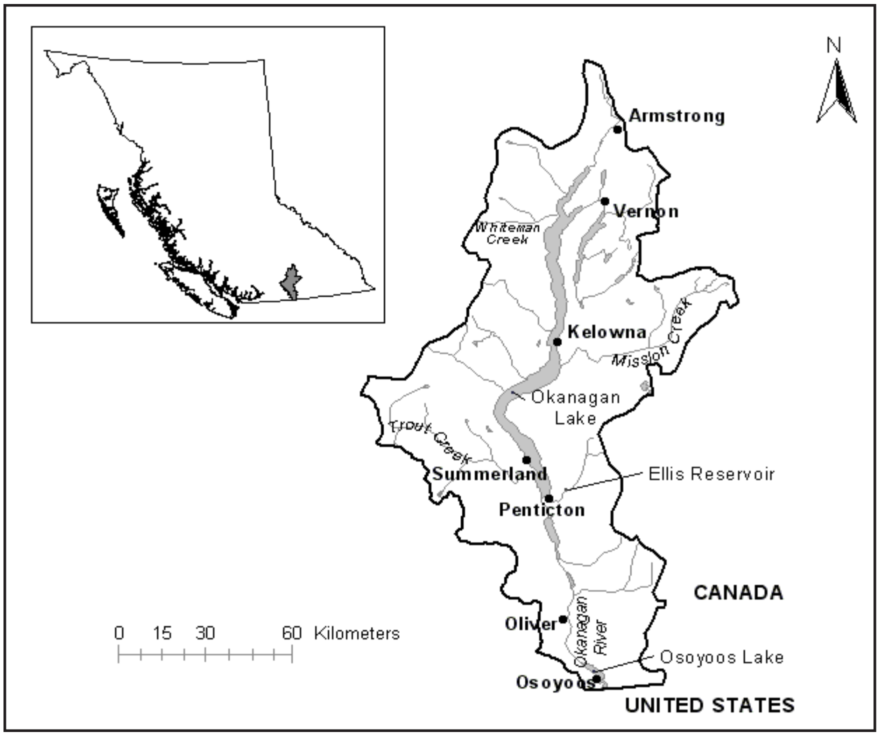

Figure 2. Okanagan Basin Map with inset for location in British Columbia (from Cohen et al. 2006).

elected officials, biologists, and environmental NGO representatives, advised the purpose of the model, and contributed information about on-the-ground system operation and management policies (Langsdale et al. 2006, *In Review*).

Scenarios were developed collaboratively with the stakeholders using a simulation model. Model users may select, in turn, a historic scenario, or six future climate scenarios based on three different downscaled climate models over two 30-year time periods (2020's and 2050's). Additionally, the user may select from three population growth rates (slow, moderate, rapid) for each future time period as well as a large number of policy and management adaptation options. The three climate models contain different assumptions and present different views of future conditions, and are considered equally plausible. The range of output in the climatic and population scenarios provides the means to communicate the range of future conditions to the model users. During the interactive sessions, participants acquired a sense of the range of uncertainty in the future scenarios, as well as the effectiveness that adaptation measures could have for a range of future conditions (Langsdale et al. *In Press*).

Through interactions with the model and related discussion, the project team informed the participating stakeholders of the model-based uncertainties, assumptions, and limitations. Because the purpose of the initiative was not for detailed design but to stimulate discussion, model uncertainty was not the primary focus. Instead, discussion remained centered on understanding the range of conditions that could occur in the future, as well as on identifying effective adaptation strategies to reduce the negative impacts of these plausible future conditions. Participants found the process valuable and gained a sense of the complex dynamics of the system. Several people found that the range of future conditions appeared worse than they previously believed, while a few people found that the projections were less severe than their understanding before the exercise (Langsdale et al. *In Review*).

Discussion

Uncertainty is no longer simply something to be avoided and removed through more research. The complex systems that we manage contain inherent uncertainties due to the presence of non-linear and random behavior characteristics. Therefore, the uncertainty must be included in the analysis and conveyed in a clear manner so that policy makers and resource managers can move forward despite the risks involved. A scenario-based approach, (such as system dynamics) allows stakeholders to explore the range of possible futures and test policy options within this range. Dialogue in political circles about climate change frequently frames the problem as: "How can we reduce uncertainty in our estimates of future (climatic) conditions and how climate change will impact us?" and the presence of uncertainty has been an excuse for delaying action. In the Okanagan case study, the discussion instead focused on: "Given that there is considerable uncertainty about our future, how can we best manage the water resource to reduce risk and increase system reliability?" By allowing policy makers and resource managers to explore different scenarios, the message is communicated clearly that our best understanding reveals that a range of conditions are likely to occur. Therefore, policies should be formed, not by optimizing to a single most probable outcome, but by choosing a strategy that is robust under a range of possible futures.

Recommendations

Both messengers and receivers of information have roles to play to ensure that the presence of uncertainty is clearly communicated and regarded. Messengers of information to both technically and non-technically inclined stakeholders should avoid the temptation to aggregate results more than necessary. The use of scenarios provides a mechanism for presenting the results in an easily understood format, while maintaining important information about the range of uncertainty and the probability of occurrence of various points in the feasible region.

Recipients and users of the information also can assist in the communication by learning to distinguish inherent uncertainty from knowledge uncertainty and understanding that each warrants different responses.

All parties in the communication of information need to recognize the unfortunate tendencies (a) to omit information that contains significant uncertainties from the assessment, and (b) to overly rely on model results that are highly uncertain. Scenario-based approaches, particularly when managed using decision support tools, can help to avoid these traps. Decision support tools help to characterize complex systems and to manage the inherent uncertainties, and the multiple scenarios provide a constant reminder that the results are highly uncertain because any of the scenarios are possible.

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