RECLAMATION

Managing Water in the West

An Exploration of Bureau of Reclamation Approaches for Managing Conflict over Diverging Science

***Institutional Solutions for Water Resource Conflicts* Workshop, Salt Lake City, Utah, September 24–27, 2007**

Reclamation Research and Development Proposal X7515

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

July 2008

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

An Exploration of Bureau of Reclamation Approaches for Managing Conflict over Diverging Science

Institutional Solutions for Water Resource Conflicts **Workshop, Salt Lake City, Utah, September 24–27, 2007**

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July 2008

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Background

As a major institutional agent supplying Western water resources, the Bureau of Reclamation (Reclamation) provides important leadership, technical, and financial resources in water management, serving as the West's "water broker" (Bowersox 2000; Pisani 2003). In recent years, growing numbers of constituencies using water and the over-allocation of water resources have contributed to conflict over the resource in the American West (National Research Council 2004). Although the conflicts arise from many sources, one common theme is that Reclamation managers often must make decisions about water use and allocation when scientific studies provide uncertain or competing recommendations. We conducted a preliminary study of Reclamation water managers and water scientists to try to understand the approaches or techniques they use or consider useful for dealing with scientific conflicts over water allocation and how these compare to techniques found in the relevant literature.

We report the results of (1) an electronic survey of Reclamation senior managers and (2) a panel discussion amongst Reclamation senior managers as to the current institutional capabilities for managing diverging scientific findings in water dispute resolution processes. We conclude with a discussion of the strengths and weaknesses of the different tools and techniques managers reported in the survey and in the panel discussion.

Methods

Both an electronic survey and a panel discussion were part of Reclamation's *Institutional Solutions for Water Resource Conflicts* workshop held at the University of Utah, September 24–27, 2007. Reclamation workshop attendees included Regional and Assistant Regional Directors; Division Chiefs; Program, Facilities, Services, Division, and Area Managers; Project Specialists; Natural Resource Specialists; a Geographic Information Systems Specialist; a River Operations Supervisor; a Water Rights Analyst; a Supervisory Civil Engineer; a Regional Water Quality Coordinator; Hydrologists; Physical Scientists; and a Research Director. Non-Reclamation attendees included university professors, graduate students, and a research social scientist from the U.S. Geological Survey (USGS).

Electronic Survey

Workshop attendees were asked to answer the following three questions in the electronic survey:

A. Do you ever face a conflict over water allocation that stems in a substantial way from disagreements among scientists as to how much water is required for various uses? (Yes or No)
B. If your answer was "yes," how do you proceed in these cases? (Open-ended question)
C. Are there tools or techniques that are particularly useful in helping you to resolve disagreements stemming from conflicting or diverging science? (Open-ended question)

As indicated, question A required a yes or no answer. Memo fields were provided for the answers to questions B and C so that respondents could relate their thoughts at some length. Responses to questions B and C were allocated to four broad categorical bins:

- Scientific information seeking and review processes,
- Ongoing learning and decision processes,
- Participatory and collaborative approaches, and
- Other.

These categories of approaches were developed from a literature review of how scholars have identified, described, and compared approaches to scientific conflicts. The "scientific information seeking and review processes" were those that attempted to resolve scientific conflicts from within the scientific community (outside or within Reclamation). These approaches attempted to find the best available science with additional scientific studies to verify or obtain more information or use scientific peer review to determine the quality of the available science. These approaches handled scientific conflicts as technical challenges. A final decision can then be made once the best available science is obtained. The "ongoing learning and decision processes" have been distinguished in the literature from the scientific activities included in the previous category, because management decisions are continuously revised after the outcomes resulting from those decisions are monitored and evaluated. (Walters 1986; Holling 1995; Walters 1997). The best scientific information available at any point in time is not considered sufficient for the long term. These types of processes are commonly called adaptive management and are generally holistic in that they attempt to manage ecological systems rather than the individual components separately. The "participatory and collaborative approaches" differed from the two previous categories in that they incorporated some degree of input from nonscientists in order to resolve scientific conflicts (Gray 1989; Weber 2000; Snow 2001; Koontz et al. 2004). These approaches sought to manage both the technical challenges and the conflicting values and interests that may play a part the conflict.

Panel Discussion

The panel explored the role of science in conflict-collaboration processes. Curt Brown, Director of Research and Development, facilitated the session. Panel members included Jeff Nettleton, Manager of the Rapid City Field Office, Great Plains Region; Chris Gorbach, Supervisory Civil Engineer, Upper Colorado Region; Carol Erwin, Phoenix Area Manager, Lower Colorado Region; Jason Phillips, Program Manager, Mid-Pacific Region; and Pat McGrane, Supervisory Engineer, Pacific Northwest Region.

In the panel discussions, the panelists and the moderator addressed the following questions. The audience was also free to participate in the discussion.

A. What experiences have you had where managing or applying science has helped resolve a conflict?
B. Under what conditions has applying science not been sufficient to resolve a conflict?
C. Have you had experience with joint science investigations (joint fact finding, collaborative model building, etc.)? Has this been useful?
D. What has been your experience with science panels (blue ribbon, National Academy of Sciences)?
E. How have you dealt with the issue of the uncertainty and risk in science and modeling, as an issue in a conflict? Has "adaptive management" or other methods (e.g., "no surprises" agreements) worked to address uncertainty?
F. Have you had success with methods that seek to explain or educate parties about the technical complexities of a dispute?

Panel responses were summarized for each question. For each of the specific approaches that were discussed, we listed the strengths and drawbacks identified by the panel.

Results

Electronic Survey

A total of 33 persons responded to the survey questions. There were 60 Reclamation senior managers and scientists attending, so approximately 55 percent of registrants responded to the survey. Of the 33 respondents, 18 (55 percent) indicated that they had never faced a conflict over water allocation that stemmed, in a substantial way, from disagreements among scientists as to how much water is required for various uses; 15 (45 percent) indicated that they had experienced such problems and responded to question B (Table 1); and 12 respondents answered question C (Table 1). Only 7 of the 15 respondents to question B responded to question C. The other five respondents to question C did not indicate that they had ever faced a scientific conflict of water allocation, but provided what they considered to be useful tools or techniques for resolving scientific conflict. These five suggested tools and techniques in the "scientific information seeking and review processes" and the "participatory and collaborative approaches" categories only. Two respondents' answers to question C fell into different categories than their answers to question B. Interestingly, a larger proportion of responses to question C indicated that some type of participatory and collaborative approach was the most useful during scientific conflicts than for question B (Table 1).

Table 1. The number and proportion of responses for each category of approaches from the electronic survey questions B and C.

Electronic Survey Question B: How did respondents proceed in cases of scientific conflict.		
Category of techniques	Number of responses ($n = 15$)	Proportion of Responses (%)
Scientific information seeking and review processes	6	40.0
Ongoing learning and decision processes	2	13.3
Participatory and collaborative approaches	5	33.3
Other	2	13.3

Electronic Survey Question C: What did respondents consider the most useful tools and techniques to resolve scientific conflict.		
Category of techniques	Number of responses ($n = 12$)	Proportion of Responses (%)
Scientific information seeking and review processes	4	33.3
Ongoing learning and decision processes	2	16.7
Participatory and collaborative approaches	6	50.0
Other	0	0.0

There was a wide variety of tools and techniques reported for survey questions B and C, and responses fell into all categories except for "other" for question C (Table 1). For question B, examples of "scientific information seeking and review processes" included refining estimates, engaging outside reviewers, designing experiments to answer critical questions, siding with Federal experts over State and local experts when there was a disagreement, and convening blue-ribbon committees. Responses placed into the "ongoing learning and decision processes" category included conducting adaptive management experiments, using a flexible management style, and convening a technical subcommittee that met on a regular basis to discuss scientific differences. Examples of "participatory and collaborative approaches" were conducting peer-reviewed science and then balancing the findings against economic and political considerations, holding open meetings with multiple agencies that allow public participation, working diligently with partners to determine the basis of ongoing conflict in an attempt to address it, and continued negotiation among stakeholders. There were two responses placed in the "other" category: one simply described the nature of the conflict and the other tried to steer the conversation away from science and ask the stakeholders to focus "on the big picture."

For question C, examples of "scientific information seeking and review processes" responses were watershed modeling for water quantity and water quality, using Geographic Information Systems, using population viability analysis, and using a National Academy of Sciences panel review. Responses in the "ongoing learning and decision processes" category were regular meetings of the scientific team using a flexible leadership style and management of risk and uncertainty. Examples of "participatory and collaborative approaches" were collaborative processes involving stakeholders, open and transparent meetings with all stakeholders, and using mechanisms such as multi-attribute tradeoff analyses to help reveal differences that stem from stakeholder resource values and interests.

Panel Discussion

Summaries of the panel discussion for each question (question provided again):

A. What experiences have you had where managing or applying science has helped resolve a conflict?

   See summary for question B.

B. Under what conditions has applying science not been sufficient to resolve a conflict?

   Summary: In answer to questions A and B, the panel noted that one point to keep in mind is that political problems may not be solvable with science. While science can inform a discussion, it can rarely referee a dispute. Sometimes one or more of the parties does not even want to know or acknowledge the science that exists, because it may not support their particular set of objectives. In view of this, one panelist pointed out that science could not resolve issues unless the involved parties want the issues resolved. He noted that it is important that common goals are established at the beginning of the collaboration process and that all parties stay committed to the process and reaching the goals.

C. Have you had experience with joint science investigations (joint fact finding, collaborative model building, etc.)? Has this been useful?

   Summary: *Joint scientific investigations* (also known as *joint fact-finding*) were offered up as a possible way to mitigate differences over science. Such ventures were seen as potentially helpful for the involved parties to become familiar with the relevant data. These ventures helped prevent arguments over data (i.e., they helped prevent arguments about what was actually present in the basin).

D. What has been your experience with science panels (blue ribbon, National Academy of Sciences)?

Summary: Experiences with *peer-review, joint development processes*, and *independent science* were mixed. Universities had the potential of being unbiased. The U.S. Geological Survey was considered to offer reliable expertise. Those undertaking multi-scientist processes were cautioned, however, to make certain that independent experts were committed to thoroughly familiarizing themselves with local data and conditions. In other words, for instance, the dynamics of stream hydrology can vary from one place to another. The dynamics that apply in an expert's own region may not apply in the local region in question. Owing to this fact and others, it was noted that reports generated from independent sources were not always useful. Panelists also expressed the view that *blue ribbon panels* can be subject to political pressures.

E. How have you dealt with the issue of the uncertainty and risk in science and modeling, as an issue in a conflict? Has "adaptive management" or other methods (i.e., "no surprises" agreements) worked to address uncertainty?

Summary: During conflict and collaboration processes, issues sometimes arise around *scientific uncertainty*. It was noted that the degree of uncertainty is directly related to the complexity of the system. Sensitivity analysis was proposed as a way to bracket potential outcomes when the parties cannot agree on assumptions. In addition, scientists and engineers can often quantify risks associated with uncertainty. Contingency plans can be prepared in case the most likely projected outcome does not occur.

Adaptive management strategies can be of use in such cases. With adaptive management, alternate plans will already have been explored. When uncertainty revolves around biological issues, it is sometimes more fruitful to try various alternatives and then monitor the results than to engage in extensive studies. However, in the view of one panelist, adaptive management requires clear milestones in order to be fully successful. Another panelist cautioned that more scientists and more studies do not always resolve uncertainty. More science can also create more uncertainty. Still another panelist mentioned that those presenting scientific findings must have excellent communication skills and must be able to establish a rapport with the parties. Poor communication skills and inadequate "people skills" can result in an adverse outcome.

F. Have you had success with methods that seek to explain or educate parties about the technical complexities of a dispute?

Summary: The panel discussed the question of when it might be appropriate to engage in *educational efforts* around scientific issues. Panel members generally saw educational efforts as most effective when they were *designed to open up lines of communication*. In this regard, educational efforts have been successfully used when they were designed in such a way as to let each party instruct all the others about their particular water usage. These processes can help clear up misperceptions and faulty information.

In some cases, a multi-party educational effort has led stakeholders who thought they were competing over water resources to actually become partners. This was the case with Rapid City and the Rapid Valley Water Conservancy District, where the irrigation district's needs for water were declining at the same time that the city's needs were growing. Rapid City's agreement to provide the district with water treatment plant effluent and to subcontract for supplemental water out of Pactola Reservoir on an as-needed basis met the district's future needs and allowed the city to contract with Reclamation for all of the available storage in Pactola.

Multi-attribute trade-off analysis has been used as a science educational tool. It has been successfully employed, for instance, to help stakeholders identify the performance and impacts of alternatives. Furthermore, it has helped parties to see how those alternatives could support their own objectives. Finally, it can be useful for reminding stakeholders with long-held desires for a particular structure just what their underlying objectives were and show them how other alternatives might satisfy those objectives as well.

Tribal experts have been found to be effective for helping to instruct Tribal members. The panel pointed out that Tribes use experts they trust, but that these same experts can also serve as instructors.

The panelists had several recommendations for increasing the institutional capacity within Reclamation for managing issues around science in collaborative processes. First, Reclamation should become proficient in emerging technologies such as ground water modeling, the use of flood control rule curves, and methods for assessing climate change. Other emerging technologies mentioned included desalination, water conservation, conjunctive use, and source water protection.

The strengths and weaknesses that panelists identified for specific approaches were compiled (Table 2). Table 2 should not be considered exhaustive, but rather provides a rough overview of the panelists' experience with each approach to scientific conflict.

Table 2. The strengths and weaknesses of different scientific approaches, identified by panelists during the panel discussion at the Reclamation Institutional Solutions for Water Resource Conflicts Workshop, held in September 2007.

Panel Discussion: Experience with different approaches to resolving scientific conflict		
Categories of techniques and specific approaches	Suggested pros to approach	Suggested cons to approach
Scientific information seeking and review processes		
Joint scientific investigations	• Can familiarize parties with relevent data preventing disputes	
Independent science	• Universities and the USGS can provide reliable expertise	• Information from independent experts is not always useful for the specific place in question
Blue ribbon panels		• Can be subject to political pressures
Sensitivity analyses	• Can bracket potential outcomes when parties cannot agree on underlying assumptions	
Ongoing learning and decision processes		
Adaptive management	• Is useful when there is scientific uncertainty • Learning from trial and error experimentation can be more effective than conducting extensive studies before taking action	• More scientific study may not resolve uncertainty • More science may create more uncertainty • Requires that managers have excellent people skills for positive outcomes
Participatory and collaborative approaches		
Multi-party educational efforts	• Can clear up stakeholder misperceptions and faulty information • Can lead to partnerships among stakeholders	
Multi-attribute trade-off analysis	• Can help stakeholders understand the performance and impacts of alternatives • Can help stakeholders identify different alternatives that help them reach their objectives	

Discussion

Overall, the results indicate that Reclamation managers at the Workshop approached conflicts with a wide array of techniques and that no method was predominant. There were no specific approaches that the panel identified as superior to the others in resolving conflicts involving science. This may have been due to differing natures of scientific conflicts. The panel discussion also indicated that different strategies were needed depending on the underlying cause of the scientific conflict. Thus, some discussion on strengths and weaknesses of the different types of approaches identified in the literature is warranted.

Scientific Information Seeking and Review Processes

Several respondents indicated that they had conducted more scientific study to resolve scientific conflicts. Public agencies are the main targets in litigation surrounding natural resource decisions (Adler et al 2001). Therefore, managers must pursue the best scientific and technical information throughout the decision-making process in order that decisions are not overturned and consensus lost

(Adler et al. 2001). Because of this, Henry and Conrad (2008, p. 136) argued that, "science conducted for regulatory purposes in many cases is actually likely to be more reliable than science conducted outside the regulatory arena." The courts have usually deferred to the judgments of government scientists during reviews unless there was substantial evidence that they were arbitrary or capricious (O'Leary 2006). Thus, this approach may be the most fruitful for conflicts between scientists that result from contradictory measurements of the same thing or from the use of different models or assumptions, because it may correct mistakes in poorly conducted studies or reveal obsolete methodologies (Boden and Ozonoff 2008).

However, this approach may not provide resolution for other types of scientific conflict that result from varying yet equally reasonable models or assumptions or from different types of questions asked by different scientific or professional disciplines. Scientific progress does not necessarily end scientific conflict, because science is "an ongoing activity and a changeable body of knowledge," and progress may instead increase the degree of uncertainty and thus conflict (Shapiro and Guston 2006, p. 536). The panel lent support to this by emphasizing that obtaining more science does not always help to solve conflicts. Instead, the pursuit of scientific consensus may result in delays in decision-making processes (Bradshaw and Borchers 2000). Incentives for inaction may exist, because agency decisions and actions can have immediate costs to managers while there are few or deferred costs of inaction (Walters 1997). Consequently, there may never be enough scientific certainty to satisfy those who use "wait and see" strategies (Bradshaw and Borchers 2000).

Scientific review processes are less time consuming than pursuing additional scientific studies and can help determine whether existing scientific information is valid (Shapiro and Guston 2006). Peer review is commonly employed during regulatory and political decisions and was repeatedly mentioned from survey respondents as a way to resolve scientific conflict. Outside peer review of scientific information attempts to identify the "best" science (Shapiro and Guston 2006). Since January 2005, Federal agencies have been required to utilize outside peer review for any "highly influential scientific assessments" used in support of a regulatory action (OMB 2005; Shapiro and Guston 2006). The scientific community at large relies on peer review to ensure quality research standards, both in defining and judging what is good or bad research when allocating funding, in book or journal publication, or when informing agency decision-making (Chubin and Hackett 1990; Langfeldt 2006; Shapiro and Guston 2006).

Outside peer review has multiple terms, such as blue-ribbon panels, special juries, technical advisory groups, and expert commissions that all generally mean obtaining scientific review that is independent from decision-makers. The outside peer review examines the available information and may even conduct additional research before providing recommendations to decision-makers.

However, there is evidence of biases and problems associated with peer review processes (Ernst 1994; Stehbens 1999; Langfeldt 2006). Peer review processes have also been criticized as inconsistent and vulnerable to bias despite guidelines and practices for avoiding conflicts of interest (Roy 1985; Ernst 1994; Holden 2000; van Kolfschooten 2002; Langfeldt 2006). Investigations have found that peer review often does not detect poor quality analyses, inadvertent mistakes, or even fraud. Moreover, these deficiencies were often not corrected after they were brought to light (Stehbens 1999; Smith 2006; Boden and Ozonoff 2008). In addition, multiple peer reviews of the same research have been shown to vary considerably in their findings (Cole et al. 1981; Stehbens 1999).

Outside expert review may also be problematic when the members of the selected review panel or committee are biased toward specific points of view (Stehbens 1999; Shapiro and Guston 2006). Members of the workshop panel discussion provided mixed reviews of outside peer review. Reviewer conflict of interest may be difficult to avoid because scientific peers are often chosen from the same discipline as the reviewed research and, as a result, may unfairly judge a competitor's work (Stehbens 1999). Peer review processes may sometimes favor traditional research methods and existing paradigms and discourage innovative, nonconventional research (Stehbens 1999; Frey 2003; Langfeldt 2006). As a result, peer review may be cumulatively advantageous or disadvantageous for individual scientists or scientific viewpoints (Ernst 1994; Langfeldt 2006). The workshop panel noted that blue ribbon panels can sometimes be subject to political pressures.

In conclusion, improperly implemented technical approaches to scientifically based conflicts have potential limitations and can actually serve to aggravate bias under certain conditions. In some circumstances, little may be gained from obtaining more science, and more science may actually increase uncertainty and foster conflict. While peer-review has become a valuable quality control on the scientific enterprise in support of decision-making, potential dangers must be studiously avoided. Thus, peer review has been shown to have potential limitations and these must be taken into consideration before using it as the primary tool for resolving disputes over science.

Ongoing Learning and Decision Processes

In many instances, scientific uncertainty is unavoidable owing to time or financial constraints or to the complexity of the physical system (Bradshaw and Borchers 2000; Patt 2007). In general, "the greater the uncertainty, the more 'adaptive and heuristic' the resulting agreement should be" (Adler et al. 2001, p. 16). Being adaptive requires ongoing evaluation to decide whether to change courses of action based on performance measures (van der Brugge and van Raak 2007). Ongoing learning and decision processes allow action, but require reassessment and revision of actions at specific future points (Adler et al. 2001).

Performance-based adaptive decision-making or the structured process of "learning by doing" is commonly called adaptive management (Walters 1997). Adaptive management acknowledges that there will never be complete understandings of complex social-ecological system dynamics (van der Brugge and van Raak 2007). Given the inherent and increasing levels of scientific conflict over water resources in the arid Western U.S., adaptive management approaches have shown promise for water managers due to their holistic and long-term scope (Walters 1986; Holling 1995; van der Brugge and van Raak 2007). Furthermore, adaptive management can potentially "create win-win outcomes for scientists, bureaucratic administrators, politicians, and resource/environment interest groups" (Walters 1997). The panelists indicated that adaptive management approaches have been useful, particularly with high levels of scientific uncertainty, but that they were difficult to implement correctly. In practice, there has been a very low implementation rate of successful adaptive management by agencies (Walters 1997). Two survey responses to both questions B and C indicated that they had utilized ongoing learning and decision processes; however, only one respondent (to question B) specifically mentioned that he or she had attempted an adaptive management approach.

Ongoing learning and decision processes, like adaptive management, have the potential to improve management of increasing complex resource dilemmas in systems where scientific uncertainty is increasingly the norm, rather than the exception. However, the political feasibility of such approaches may be problematic. Given this, adaptive management approaches may be best for smaller scale conflicts that encounter fewer political obstacles and require fewer financial resources (Walter 1997; Kiker et al. 2001; Scholz and Stiftel 2005).

Participatory and Collaborative Approaches

Several survey respondents mentioned that they had used or considered participatory or collaborative approaches to be useful for resolving scientific conflicts. In fact, many agency decision-making processes are required by law to incorporate some degree of participation by the public, interest groups, other agencies, and State and local governments (CEQ 1978). Natural resource agencies can play varying roles in participatory and collaborative approaches, from the dominant actor with the final say to equal-footing participants (Koontz et al. 2004).

The degree of public participation can range from addressing public comments on draft plans to decision-making processes that require consensus from all participants. Increasingly, collaborative management approaches have been promoted and initiated due to increasing public distrust in the ability of government agencies to appropriately address environmental issues and legislative efforts to increase public participation in policy making (Cortner and Moote 1999; Koontz and Thomas 2006; Koehler and Koontz 2008). Collaborative approaches maximize participation by outside members, because stakeholders have shared authority to make recommendations to agencies and sometimes even make management decisions, rather than simply providing agencies feedback (Weber 2000; Koontz et al. 2004; Pralle 2006). Proponents argue that because collaborative approaches require widespread agreement to arrive at decisions, more stakeholder and citizen cooperation can result along with better outcomes (Weber 2003; Layzer 2006; Koehler and Koontz 2008). Additionally, allowing interest groups to have more influence upon decisions can prevent bureaucratic stalemate by reducing the amount of litigation (Koontz and Thomas 2006; Pralle 2006). Proponents of collaborative approaches also argue that decisions are more democratic, owing to increased equity and accountability (Fung and Wright 2001; Weber 2003; Koontz and Thomas 2006; Wagenet and Pfeffer 2007). However, the realization of such beneficial characteristics likely depends on the active and lasting participation of an informed citizenry, neutralization of power disparities among stakeholders, and the commitment of participants to create effective solutions to resource problems, informed by science (Scheffer et al. 2000; Koontz et al. 2004; Bidwell and Ryan 2006; Koontz and Thomas 2006).

Critics argue that collaborative approaches frequently fail to achieve or sustain these characteristics. Many collaborative efforts have been unable to attract and maintain a representative group of participants, particularly among the general population and local governments (Koontz et al. 2004; Koehler and Koontz 2008). Many stakeholders' primary incentive to participate in collaborative efforts is to avoid traditional agency regulation (Koontz et al. 2004). Of those that participate, collaborative approaches may overly favor some interests over others, thus undermining the more equitable premise of such approaches. For example, some collaborative efforts have benefitted local stakeholders and disenfranchised broader public interests that were late to join or discouraged from participating (McCloskey 1996; Koontz and Thomas 2006; Pralle 2006). Collaboration can also reinforce existing power disparities among stakeholders (Bidwell and Ryan 2006; Koontz and Thomas 2006).

Finally, very little is known about how effective collaborative efforts are at making decisions that have positive social and environmental outcomes. As a result, Koontz and Thomas (2006, p. 111) make the argument that "collaboration is not a panacea; it is a choice that policy makers and public managers should make based on evidence about expected outcomes." Only recently have studies shown that some successful collaborative approaches have led to advantageous social outcomes, such as increased trust and social capital among participants and increased scientific knowledge among participants (Lubell 2002; Leach and Sabatier 2005; Koontz et al. 2004; Koontz and Thomas 2006). However, collaborative attempts have also led to increased fractionalization and distrust in other case studies (Koontz et al. 2004). Furthermore, Weible (2007) showed that collaborative approaches did not increase some stakeholders' trust in scientists or willingness to use scientific information. In the end, the participants and nonparticipants that disagree with collaborative decisions often resort to litigation to achieve their objectives, and conflicts are resumed (Koontz et al. 2004; Pralle 2006).

Environmental outcomes have not been well studied to this point, because (1) data that measures environmental outcomes are difficult to measure, (2) there may be long time horizons between the implementation of collaborative outputs and environmental change, and (3) it is difficult to design research protocols that untangle the effects of multiple interacting variables that influence environmental change (Koontz and Thomas 2006). Until these outcomes are known, collaborative approaches must be undertaken with considerable caution. In fact, one of the major criticisms of collaborative approaches is that economic and social concerns are often given priority over scientific knowledge, which may lead to unfavorable environmental outcomes (Layzer 2006). Some collaborative decisions have disregarded scientific recommendations when economic interests were adversely affected (Layzer 2006).

Clearly, collaborative management approaches face considerable challenges in reducing natural resource conflicts, owing to the perceived zero-sum nature of water resources in the West and the competitive behaviors and strategies of stakeholders. If collaborative approaches do not always prove to be effective at resolving natural resource conflicts, then it behooves us to identify when they are and are not appropriate.

Mixed Approaches

The best and perhaps the most difficult to implement approaches to conflicts involving "noncontradictory argumentation" and/or high levels of scientific uncertainty may fall between these three categories of techniques. Several very similar approaches and frameworks have been developed that advocate the need for combining adaptive management approaches with participatory and collaborative approaches in order to solve complex and recurring natural resource conflicts. For example, adaptive co-management and adaptive governance, which come, respectively, from the fields of sustainability and resilience research and water policy research, have shown some promise for avoiding conflict over science. (See, for instance, Lebel et al. (2006) or Scholz and Stiftel (2005).)

Adaptive co-management is "a process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of trial-and-error" (Folke et al. 2002, p. 8). Adaptive co-management incorporates social and policy learning across scales, shared management across organizational levels, cooperation across organizations, and collaboration among stakeholders (Olsson et al. 2004; Walker et al. 2006; Plummer and Armitage 2007). Likewise, adaptive governance brings stakeholders into the conflict management process at an early stage as part of the adaptive management process (Scholz and Stiftel 2005). Adaptive governance argues that "wicked" natural resource conflicts require that governance systems coordinate the efforts of independent and fragmented systems of users, interests, institutions, and information (Scholz and Stiftel 2005). Adaptive governance includes consideration of pertinent social and economic contexts in the adaptive management process (Folke et al. 2005, Dietz et al. 2003). Both approaches call for the creation of new adaptive governance institutions that utilize adaptive management approaches to account for uncertainty in ecological systems, but also take into account uncertainty in social systems, in order to create long-term sustainable solutions (Olsson et al. 2004; Scholz and Stiftel 2005; Walker et al. 2006).

Benefits to adaptive co-management and adaptive governance may include legitimacy of decision-making at a broader scale, greater equity and accountability, and greater local capacity for decision-making (Plummer and Armitage 2007). However, the appropriate role for representatives and degree of transparency needed in decision-making processes is unclear (Conde and Lonsdale 2005; Scholz and Stiftel 2005). Participation that has little impact on final decisions may alienate users and interests; however, at the other end, consensus solutions frequently do not last and may constrain future flexibility if there are limited common points of agreement (Coglianese 1999; Koontz et al. 2004; Scholz and Stiftel 2005). Transparency of processes is important for building trust and accountability, but it may also limit compromise and creativity, which are important for adaptability (Scholz and Stiftel 2005). Furthermore, these approaches are limited by the same issues of political infeasibility as adaptive management approaches. Also, like all collaborative approaches, these approaches require increased capacity for local-level monitoring and enforcement and corrections to imbalances in power among stakeholders to avoid reinforcing existing inequalities and catering to narrow interests (Nelson et al. 2007; Plummer and Armitage 2007).

Conclusion

Our review of the literature and of the input provided in the survey and the workshop panel suggests that there are no "silver bullets" for resolving scientific conflicts. However, some approaches may be better suited for the different types of scientific conflict that Reclamation managers undoubtedly face. Additional study is needed to determine under what circumstances different approaches are useful in reducing or resolving conflicts involving science. New solutions or combinations of approaches may be needed to address the weaknesses that scholars have identified with current approaches to scientific conflicts.

Future Directions

Based on their wide range of approaches to scientific conflict, survey respondents were likely dealing with multiple types of scientific conflict. Reclamation senior managers likely had different interpretations of what a scientific conflict entails. The wide range of responses also indicated that there was no common methodology for dealing with scientific conflict and that some evaluation of the different approaches is needed to provide guidance on how to more effectively deal with scientific conflict.

Future project objectives will be to determine:

- what types of scientific conflict Reclamation managers are facing,
- whether they utilize the same or different types of approaches for different types of conflict,
- whether different professional disciplines utilize different approaches, and
- whether managers have had any direction in formulating their approach to scientific conflict.

We will also evaluate the effectiveness of different approaches to scientific conflict by determining (1) whether or not managers felt that the approaches that they had employed were generally useful, (2) whether or not their approaches resolved the scientific conflict and, if they did, then (3) whether their approaches provided short-term or long-term solutions (i.e., were scientific conflicts recurring over time?), and (4) whether there were any negative consequences to using their approaches. We will also determine whether there are any promising approaches to conflict involving science that Reclamation managers have not attempted.

The final objective will be to create tools that Reclamation managers can use to identify and categorize the types of scientific conflict they have and the most effective approaches for dealing with it. Informing managers about the potential weaknesses of each approach may help them mitigate their potential shortcomings.

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