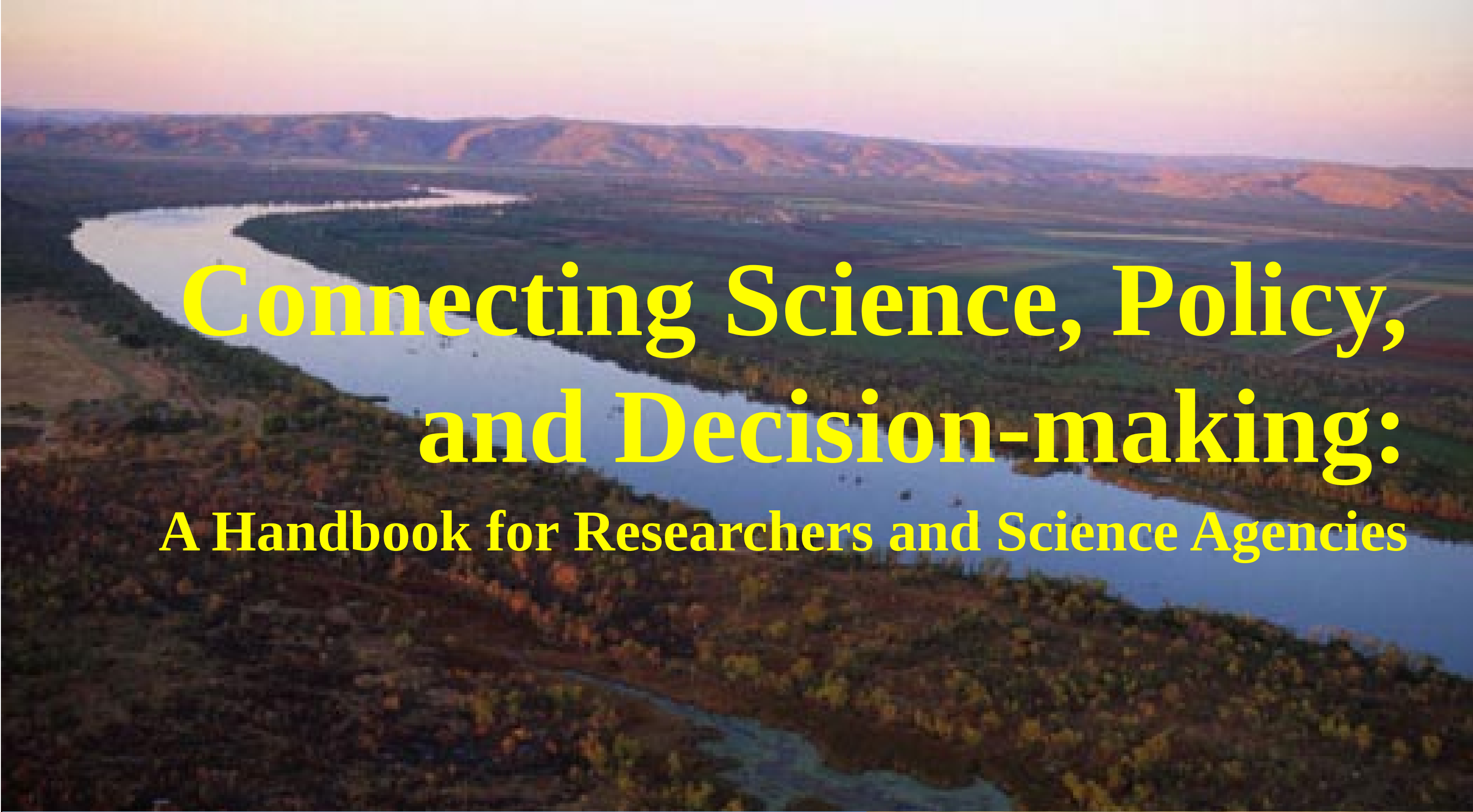
Connecting Science, Policy, and Decision-making:

A Handbook for Researchers and Science Agencies



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A Handbook for Researchers and Science Agencies

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Introduction: Strategies for Integrating Research and Practice

There is a well-documented need to improve the flow of information in both directions between scientists and decision-makers (see for example, National Research Council, 1995, 1998, 1999a,b). Improved access to scientific information and to the hands-on experience of decision-makers has multiple benefits from the perspective of developing new management options and adaptive capacity. At present, it is clear that many of the products and tools scientists have developed for water managers are not as fully utilized as they might be (Rayner et. al, 2002). This is at least partly because the scientists who have developed them do not fully appreciate the institutional, economic and cultural circumstances within which decisions are made. It is also partly because decision-makers frequently do not actively seek new sources of information or initiate contacts with experts who could be helpful to them in making more informed decisions.

It is common for researchers to develop products and tools that they believe will be useful, then make them available for use without verifying whether these are really the products needed. This "loading dock" mentality is generally the result of one-way communication, without sufficient evaluation of the needs of stakeholders. The result is that, at least in the context of federal agencies, millions of dollars are being spent on research that has the potential for utility but in fact may currently have little tangible societal benefit.

This handbook provides practical, hands-on suggestions for researchers and science agencies about ways to improve the focus of scientific research that is intended to be useful to decision-makers (as opposed to more basic research that is not intended for immediate application). These suggestions are based on interviews with researchers who study science and decision-making, federal agency science and policy personnel, and decision-makers and stakeholders. This report uses the applications (or lack thereof) of climate science to water management as an example, but is intended to be applicable to other types of science and other resource sectors.

A number of scientists have recognized the need to achieve more integration among disciplines in order to address emerging social and environmental problems. In fact, there is general acknowledgment that decision-making in the context of an increasingly complex and inter-related global system will require more interdisciplinary research and more involvement from decision-makers and stakeholders (NRC, 1999a,b). Amplifying the need for improved information and predictive capacity is the probability of increasing climatic variability associated with global change, and the related needs for adaptation (US Global Change Research Program, 2001; US Dept. of Commerce, 1999).

Attempts to bridge the gap between those who generate information and those who use it have not always been successful. There are certainly cases in which academics and scientists from multiple fields have successfully worked together on interdisciplinary problems. An early example is the Tropical Oceans–Global Atmosphere Program (TOGA) of the 1980's, in which oceanographers and atmospheric scientists worked together to identify the El Nino-Southern Oscillation (ENSO) signal. However, a true dialog between end users of scientific information and those who generate data and tools is rarely achieved. The Regional Integrated Science and Assessment (RISA) teams that are sponsored by NOAA and activities sponsored by the Environmental Protection Agency's Global Change Research Program are among the leaders of this investigation, and represent a new collaborative paradigm in which decision-makers are actively involved in developing research agendas. The U.S. Geological Survey (USGS) has also been actively investigating ways to enhance the use of USGS science through its recently initiated Science Impact program.

The RISA teams, which are located within five universities, primarily in the western US, are focused on stakeholder-driven research agendas and long-term relationships between scientists and decision-makers. Lessons learned within the RISAs have been incorporated in this document to the extent that they have been identified.

It is hoped that this handbook will be useful in a number of contexts, and for that reason some of the considerations are identified through questions rather than answers. **The handbook is intended to assist physical science researchers in developing successful relationships with stakeholders and decision-makers,** but is deliberately not prescriptive in terms of providing answers to many of the important questions. Because this handbook is being designed for use in a broad range of applications, and each application should be context-dependent, it would be inappropriate if not impossible to develop the answers to the questions identified here. However, answering these questions is likely to help researchers internalize a broader perspective and thereby increase the utility of their work.

This report focuses on the ingredients of successful interaction from multiple perspectives and identifies:

- **Conditions for providing useful services and products**
- **Keys to communication and collaboration**
- **Incentives for change**
- **Mechanisms for evaluation and feedback**
- **Measures of success in collaboration**

I. Conditions For Providing Useful Services and Products

There has been much documentation of the reasons why decision-makers and scientists rarely develop the types of relationships and information flows necessary for full integration of scientific knowledge into the decision-making process (Graffy, 2002; Kirby, 2000; Pagano et al, 2001; Pulwarty and Melis, 2000, Rayner, et al., 2002). The primary reasons are problems with relevance (are the scientists asking and answering the right questions?), accessibility of findings (are the data and the associated value-added analysis available to and understandable by the decision-makers?), acceptability (are the findings seen as accurate and trustworthy?) and context (are the findings useful given the constraints in the decision process?). The differences in perspective of scientists and decision-makers are more fully described in the table in Appendix 1.

Fostering relationships that cross cultural and professional barriers requires effort and incentives. Financial incentives do exist, and there are private sector "integrators" who specialize in translating scientific information for particular applications. However, most "cross-cultural" relationships are fostered within certain universities that value and encourage interdisciplinary work with stakeholders, and within parts of agencies that have recognized the need to establish connections with users of their data and research tools.

Step 1: Understanding the Context

A first step in developing useful products and services is understanding the **context** in which they will be used. **Scientists, whose world view is strongly influenced by the boundaries of their own research, may not recognize that the new information they produce may be a very small consideration in the manager's "decision space".** As used here, the term "decision space" means the range of realistic options available to a given manager to resolve a particular problem. New tools and information may have obvious applications from a theoretical perspective; however, most resource managers work within highly complex environments that are constrained by external factors.

Context Checklist

- How do laws and regulations limit the range of options available to the decision-maker? How difficult is it to change the institutional context?
- Within the institution, what are the policies, procedures, and precedents relative to this type of decision or activity? Are there defined decision rules, etc., that cannot be changed by the manager?
- How are the decision-makers affected by their training, their peers, and their supervisors in terms of expectations of behavior? Is there a disincentive to "break ranks" and use techniques that are without precedent in the institution?
- Does the decision-maker have sufficient resources (time and money) to properly integrate the scientific information into decision-making and operations procedures? If not, is this a real or a perceived problem?
- Is there a personal or institutional history of interaction between the scientist and the decision-maker?
- Is the range of options that is technically possible significantly different from what is practically possible?
- What are the key questions faced by this type of decision-maker on a daily, weekly, monthly basis?
- Is the range of options that is technically possible significantly different from what is practically possible?
- What are the historical roles of politics and the media in this decision space?

Step 2: Defining the Users/Clients and Understanding their Perspective

The potential to use particular data sets or decision-support tools depends in large part on what kind of individuals might be interested in using the information. Some time spent on defining the likely candidates for use of a potential product is appropriate, since it will affect the types of collaboration that may be necessary, the sophistication of the products, and the ways in which they will be distributed.

Short-term Versus Long-term Information, Skill, and Applications

The information needs of decision-makers are influenced by the time frame of their decisions. NOAA researchers commonly make a distinction between weather prediction information, which is produced on an hours to weeks time frame, and climate predictions, which may be on a seasonal to inter-annual time frame. The majority of decision-makers are likely to focus primarily on shorter time frames, though as longer-term predictions gain skill, this may change, particularly in areas with economic applications. Understanding the frame of reference of the decision-maker and the types of decisions he or she makes will help the researcher focus on products that are most useful. It should also be noted that short-term decisions also have long-term consequences, so identifying the information needed to make better decisions in all time frames is important.

Because of the focus on short-term information and quick results, it is difficult to get political support for research that focuses on long-term, incremental increases in knowledge that are the key to significant policy changes (Kirby, 2000)[2]. This is a symptom of today's societal preferences, which generally do not support current investments with long-term or uncertain future payback. This presents obvious policy and priority issues for researchers and decision-makers who are concerned about global change and adaptation.

Who is the audience?

- Is the potential user involved primarily in day-to-day operational decisions or longer-term policy decisions?
- Are the users researchers themselves, or are they primarily focused on the development and implementation of policy?
- Is there real potential for improving decision-making associated with new scientific information and understanding?
- Should the products be designed for particular types of users, or should the products be general in nature?
- Is there an expectation of direct use by decision-makers (or the public), or are intermediaries (integrators) likely?
- Are the users likely to be government employees or within the private sector?
- Is there a potential role for public interest groups or NGOs?
- Is the equipment (computer capacity), platform, etc. for this information generally available, or will specialized equipment or organizations be required to make it useful?

Step 3: Understanding the Credibility/Value of Information Needs in Particular Applications

It is important for scientists to think about how accurate and credible the information being produced is, compared to how accurate a decision-maker needs it to be in order to be useful. An evaluation of this may be highly subjective, but researchers need to think about the degree of certainty needed by decision-makers, what the potential benefits of using the information are, and what the risks associated with failure are.

> *Uncertainty is not the hallmark of bad science, it is the hallmark of honest science…This perennial question "Do we know enough to act?" – is inherently a policy question, not a scientific one"* (Hon. George Brown, 1997).

How much do decision-makers need to know in order to know enough to act?
(Note: A decision not to act also has consequences…)

- In the context of the type of information produced, how much risk and uncertainty is acceptable to practitioners? Is this a broad spectrum of acceptability, or do most decision-makers in this area agree about the levels of risk that are acceptable? Is there a safety net, for example, FEMA floodplain insurance if there are failures?
- Do the managers discuss uncertainty, probability and risk when describing their daily decisions?
- Is skepticism about value of climate products (or other science products that involve use of models) well founded? Given that people are already making inherently probabilistic decisions (particularly in agriculture) now, is concern about such products overblown? Should a threshold for utility of probabilistic information be developed for particular applications?
- What constitutes credible information? Is it intrinsic to the agency that produced it? Is it dependent on the individuals who worked on it or disseminated it? How are accuracy and credibility related? How can information about credibility be conveyed most easily?
- When evaluating probabilities of extreme events, statistics and probabilities may not help predict future events if the event is outside of previous experience, extremes are "too extreme". How can this be addressed?

[2] A reviewer of this document pointed out, however, that it has recently been asserted that focusing on the uncertainties of long-term global warming impacts has been used as a stalling technique in avoiding politically hazardous shorter-term steps.

Communication of Uncertainty

Although great progress has been made in projecting climate conditions up to a year in advance, the accuracy of predictions varies tremendously from year to year, season to season, and location to location (Hartmann et al., 2002). Some economic sectors (such as agriculture) are much more vulnerable to climate influences, especially extreme events, than others. An assessment of the accuracy of predictions for the southwestern U.S. and their utility has been produced by Hartmann et al., 2002, who show that providing skill scores (evaluations of the accuracy of past predictions) to potential users of climate information helps managers make better informed decisions, even in cases where the skill scores are low. This is because the skill score provides an evaluation of the accuracy of the forecast, and allows the decision-maker to assess the utility of the information for his or her own situation. If this type of evaluation can be shared with potential users, it greatly enhances the utility of the tools produced.

The value of information to a particular decision-maker also relates to how much difference the information could make in a particular outcome. In some cases, even a perfect prediction of future conditions may not make a significant difference, because there is very little that the decision-maker can do to respond to the information.

Understanding/Responding to Types of Uncertainty in Particular Applications

Understanding the types of uncertainty in the decision-making environment will help researchers work within the policy context better and design products that may have more immediate utility. In some cases uncertainty is created because the problem faced by the decision-maker has not been properly diagnosed; for example, estimates of the potential for extended drought may be based only on recent experience in a relatively wet climatic regime, while a review of the historic record could provide a broader view of the potential for future droughts. In other cases, uncertainty is caused by a changing regulatory environment, changes in economic conditions or inadequate information.

Types of Uncertainty in the Decision-making Environment

- Regulatory uncertainty is often an important component of the uncertainty in resource management decisions. In addition to changes in the regulations themselves, differing interpretation of regulations causes uncertainty. Interpretations may change based on directives (politics) at any level in the chain of command or the perspectives of individual regulators.
- Uncertainty may result from inadequate data, poor access to data that do exist, or data quality problems.
- Changes in climate forecasts throughout the season or year are common, and the regular updates of predictions may cause uncertainty.
- Incorrect conclusions from premature or inadequate data analysis may result in decisions that increase risk or have other negative consequences.
- Changing environmental, social and economic conditions mean that decisions are made against a shifting backdrop, increasing uncertainty.
- Public perception and politics affect all decision-makers, and in some cases may outweigh facts and professional judgment. The effect of media interpretations and political pressure is particularly acute when there is great risk and inadequate information. Fear of controversy severely limits the chances for innovation in many water management organizations (Rayner et al., 2002).

Step 4: Getting the Scale and Timing Right

Utility of information for decision-makers relates to whether the information is relevant to the particular region being managed and whether it is timely. A frequently cited problem in use of climate information by water managers is that the scale of the information that is available is too large to be useful. Global circulation models now do a relatively good job of predicting average conditions over broad areas, but do not take into account the particular topography and microclimate within regions, particularly as they relate to precipitation and streamflow. Although downscaling from large-scale climate models to local hydrologic models has now been successful in multiple locations, the models are not based primarily on an understanding of the physical processes within basins but rather on assumptions about runoff, soil moisture, groundwater inflows and outflows, etc. that are adjusted to match historic runoff measurements.

Because large surface reservoirs allow for regional averaging of precipitation conditions, management decisions related to reservoirs may be better suited to the use of climate predictions than other types of resource management decisions. Other examples, such as management of large groundwater basins, drought and wildfires may also lend themselves to use of large-scale predictions. Despite the adage "think globally, act locally," many people have conceptual difficulty translating between different scales of information. Developing products that match the boundaries of areas of interest to potential user groups will improve the utility of a given product.

Accuracy vs. Precision

In the example above, downscaling for local or regional applications results in an overall loss of accuracy, even though the information is more "precise". If decision-makers understood that there is a tradeoff between accuracy (how close to the truth you are) and precision (whether the information is specific to the area of interest), which would they choose?

Timing is Everything

Information must be timely to be useful. This requires that the researcher understand and be responsive to the time frames during the year for which specific types of decisions are made and entry points for information into the process. Pulwarty and Melis (2001) and Ray et al. (2001) have developed the concept of "decision calendars" in the context of the Western Water Assessment in Boulder. Failure to provide information at a time when it can be inserted into the annual series of decisions made in managing water levels in reservoirs, for example, may result in the information losing virtually all of its value to the decision-maker. Likewise, decision-makers need to understand the types of predictions that can be made and tradeoffs between longer-term predictions of information at the local or regional scale and potential decreases in accuracy.

II. Keys to Communication and Collaboration

An important starting point is the recognition that all individuals perceive themselves to be "stakeholders," meaning that they have a strong interest in outcomes that are related to their areas of professional and personal interest. When relationships are initiated, acknowledgment of the validity and importance of the perspectives of those individuals needs to be an underlying premise of the conversation. Emphasizing from the beginning an expectation that information will flow both from the researcher to the decision-maker and back to the researcher may allow for a more constructive approach.

Strategizing Prior to Contacts with Stakeholders and Decision-makers

- How can the strategy for approaching particular users or decision-makers be tailored to their interests?
- What is the role of the private sector, as opposed to government, in providing specialized science products for particular applications?
- How can local knowledge and the decision-maker's hands-on experience be used to improve outcomes?
- What are the messages that will result in long-term trust-building?
- Are there individuals within the system who can help provide orientation about decision-makers and institutional context? Can they provide introductions and other ways of getting to the right people? Can they suggest good ways to communicate effectively with these people?
- How vulnerable is the decision-maker within his/her own institutional context? How much personal or professional risk is involved in changing historical ways of doing business? Will the decision-maker's job be on the line if he/she uses a new approach that is not perceived as successful?
- To get a busy decision-maker's attention, the risk needs to feel tangible to him/her or he/she won't prioritize the issue. Short of waiting until a disaster is already imminent (or has already struck), how can this be accomplished?

Education and communication go hand in hand with scientific advancements to bridge the space between climate science and the potential benefits that societies can derive from it. (The International Research Institute for Climate Prediction, Columbia Earth Institute)

There are multiple facets to communication, some of which require common sense while others require concerted efforts to overcome barriers caused by different training and context. First impressions are very important, so thinking about how to structure initial encounters with potential stakeholders and decision-makers is always worthwhile.

Communication Strategies

- Emphasis on two-way communication between groups that develop products and tools and those who use them implies an evolving relationship. An iterative approach, involving testing of products and services and feedback over time, may be useful.
- Working through and within existing professional organizations is often a good way to introduce new ideas and concepts to a group of users or decision-makers. By gauging the reaction of the group, it is possible to identify those who are more open to new ideas or are more interested in the topic and may be early adopters.
- Working with early adopters within organizations or user groups may provide an inside contact who can facilitate information flows, set up meetings, provide a sounding board for alternative approaches, or demonstrate how science products can be used.
- Trust-building with groups of stakeholders requires long-term, sustained efforts. The resources to support this type of activity are frequently not available, but sustained contact may be more important in the long run than specific product characteristics.
- Summarizing key points to facilitate efficient communication can be very helpful. Short, highly graphic products that summarize conditions for decision-makers may pique their interest in more in-depth products.
- Matching the individual to the task helps pave the way for others to interact once initial barriers have been overcome. Different kinds of people excel at communication with different user groups or stakeholders (government officials, farmers or private sector companies, for example) and different group sizes.
- Planning meetings so that there is an appropriate ratio of stakeholders/decision-makers to scientists/researchers can improve the comfort level of participants.
- Soliciting and responding to input from user groups or stakeholders, even if it is relatively minor in nature, is likely to lead to buy-in for the final outcome and may lay the groundwork for future collaboration.
- Working with the press can have multiple advantages in disseminating information and encouraging interest of stakeholders. However, it is important to cultivate relationships with individual reporters who appear to have technical competence. Substantial benefits can be gained by distributing key points to the press in a briefing page prior to an event to be publicized.
- Intensive training workshops and short courses have been found to be effective catalysts for change, particularly involving role-playing with groups that have different backgrounds.

There is a natural tendency for groups to create special forms of communication, such as acronyms, that help define the "insiders." Overcoming this tendency, developing a common language and avoiding jargon and acronyms are very important for meaningful communication between scientists and decision-makers. A common problem for researchers is to lapse into their own jargon and use of acronyms. Most practitioners also have their own jargon.

> *The use of information in organizations is inextricably bound up with creating collective meaning and identity, as well as servicing implicit goals of organizational maintenance…*(Rayner et al., 2002).

The Changing Role of Information

The worldwide web plays an increasingly important role in the dissemination of information. Communication can be enhanced by carefully designing web sites that guide people to the appropriate data or analysis.

> *The increased emphasis on decentralized decisions and improved data accessibility greatly broadens the potential impact of science. The need for information on the consequences of decisions expands beyond traditional decision-makers. This is manifested by the active participation of citizens in advisory committees…and by the proliferation of stakeholder groups…*(US Dept. of the Interior, Science Impact – Enhancing the Use of USGS Science, April 4, 2002)

Ideas for Improved Websites

- Design websites in consultation with a group of potential users.
- Design cover pages for websites for ease of access by uninitiated users (see equity considerations, below) particularly focusing on the kinds of questions they may be interested in answering.
- Provide descriptions of links that focus on the utility of the information provided, rather than just describing the information itself.
- Provide information on how the data were developed, how they were intended to be used, and the current state of the science (particularly regarding certainty of results).
- Develop an information clearinghouse that provides multiple avenues for access, through mail-out brochures, fact sheets, development of generic powerpoint presentations that can be used by people accessing the website, contact people with phone numbers and email addresses, access to a speaker's bureau, video and CD data summaries and explanations.
- Provide opportunity for feedback so that users can comment on the website, including what is useful, how they used it, and what improvements they would like to see, rather than just counting "hits" on the website.
- Devote resources to regular updates of the website, including highlighting new information.

To increase the impact of scientific information, there should be a focus on usability, not just availability of information. This means moving to "value-added" products, where findings are provided in a format that allows for policy applications. (Note: working with potential users in development of a website would be good "neutral" territory for establishing relationships).

Equity Considerations

Knowledge creates wealth as well as power, and there are multiple examples throughout the world of scientific information being used as a tool without a full appreciation of the potential to create winners and losers (see. for example, Pfaff et al., 1999; Broad and Agrawalla, 2000; Broad et al., 2002). Access to information is an equity issue; for example, large water management agencies can usually afford sophisticated modeling efforts, consultants to provide specialized information, and a higher quality of data management and analysis, while smaller or less wealthy stakeholders generally do not have the same access or the consequent ability to respond (Hartmann, 2001). Understanding this point, those who develop products and services can make program decisions that either increase or decrease access to information for less sophisticated or wealthy users. This is of particular concern in developing countries, where access to information could have the greatest impact due to the high vulnerability of significant portions of the population to environmental hazards (T. Finan, personal communication). (Of course, providing access to information is not sufficient to ensure adaptation, there must also be resources and institutional support available to benefit from the information).

Equity and Economics: Impact of Information

- Who is paying for particular information and services, and who benefits? These questions may not always be answerable, but are well worth thinking about.
- Who (what groups, agencies or stakeholders) benefit from the changes in policies and programs that may result from improved access to data?
- How do public values like habitat and environmental quality, aesthetics, needs of future generations, etc., get incorporated into cost-benefit analyses and other forms of decision systems? If they are not formally incorporated, is there a way to recognize and respond to these values through other mechanisms?
- Are new tools such as hydrologic models, climate forecasts, and improved water quality monitoring really transparent, or are they enhancing technocratic control because only very sophisticated people can use the information? (A particular concern in developing countries, M. Lemos, personal communication.)
- What makes some agencies and institutions more likely to use new sources of information than others? How is the information used? Is it generally available or difficult to access within the organization or agency? Does availability of improved information always enhance democratic processes, or is the information controlled in ways that concentrate the benefits?
- Does better information lead to better decisions? Is there any way to monitor this?

Platforms for Collaborative Processes

Universities are good locations for development of new ideas and applications, but they may not be ideal for sustained stakeholder interactions and services. Many user groups and stakeholders either have no contact with universities or may not encourage researchers and academics to participate in or observe decision-making processes. University reward systems rarely recognize inter-disciplinary work, outreach efforts, and publications outside of academic journals, which limits the incentives for academics to participate in real-world problem solving and collaborative efforts.

In the international context there are numerous protocol and political considerations regarding the willingness to cooperate, and underlying agendas of existing national/regional players and organizations to be evaluated. It is important that institutions and individuals within them participate for long enough to accomplish the goals of a particular project, establish trust in the people and the products, etc. What are the options?

- Within the agricultural extension programs of universities are large networks of people who interact with local stakeholders and decision-makers within certain sectors (not limited to agriculture) on a regular basis. In other countries this agricultural extension work is often done with great effectiveness by local government (e.g., Department of Primary Industries, Queensland, Australia).

- In some states, watershed councils and other local planning groups have developed, and many are focused on resolving environmental conflicts and improved land and water management. Watershed councils have been particularly successful in the State of Oregon.

- Natural Resource Conservation Districts, within the US Department of Agriculture, are highly networked within agriculture, land management, and rural communities.

- Some non-governmental organizations (NGOs) and public interest groups focus on information dissemination and environmental management issues within particular communities. They are good contacts for identifying potential stakeholders, and may be in a position to collaborate on particular projects. Internationally, a number of NGOs have stepped forward and are actively engaged in working with stakeholders to advance use of climate information in decision-making (e.g., Asian Disaster Preparedness Center (ADPC), in Bangkok, Thailand).

- In the US, research is currently conducted primarily with federal government funding, in federal agencies or universities. Expanding the types of research conducted within management institutions and local and state governments is an option to be considered—the stakeholders can then have greater influence on ensuring that the research is relevant to their particular concerns.

III. Incentives for Change

Understanding what motivates the people who are potential users of information is important in meeting their needs and expectations. Because there is reluctance to change behavior, particularly within agencies and other hierarchical organizations (Rayner et al, 2002), an assessment of the potential to provide incentives of various kinds may be appropriate. In some cases, an explanation that the person or agency could improve performance if improved information were used may be persuasive. In other cases, decision tools, i.e., models that simulate climate/hydrology/management options to produce scenarios will help identify benefits of changes in management. Explicit examples of the economic benefits that may accrue are likely to provide incentives, and such situations may lend themselves to encouraging the involvement of private sector consultants.

The existing incentive systems within most public sector agencies, many private sector organizations, and even universities may work against innovation. A major consideration is developing policies for mentoring, promotion and tenure for academic researchers working in integrated/applied science. This applies to both social scientists and bio/physical scientists.

Identifying ways to provide special recognition, nomination to advisory groups, awards or thank-yous that are visible to the supervisors and peers of the stakeholder/decision-maker may help. Opportunities for stakeholders to jointly present findings along with the scientist/researcher through publications or conferences may be appropriate in some cases. Innovation within agencies is often discouraged, which means that truly innovative people find employment elsewhere, generally in academia or the private sector.

Incentives and Motivation

- What will cause agencies, scientists or individuals to work together or change their mode of operation, other than direct orders from a superior or an outright emergency? How can the needs of all participants be incorporated into a perceived “win-win” situation?
- New techniques generally don’t get applied until managers get involved. How can the self-interest of managers be best served? For academics and government scientists who have secure jobs, what is the incentive to move outside their current comfort zone?
- For stakeholders and decision-makers, what are good reasons to participate? What is the “hook” that will pique their interest?
- If it is clear that there are potential economic benefits involved, working with private sector innovators and translators in the research design and potential transition to operations may speed adoption of new techniques.

The Role of Leadership

Causing change to occur in operational or policy environments, especially where there is substantial precedent, requires people working in these environments who are willing to move away from the status quo. This implies some willingness to take personal and professional risks, and some ability to get others to follow. Particularly in federal agencies, many people who make policy decisions are appointed and may not have the opportunity to develop long-term relationships with those who generate scientific information. This represents a particular challenge in getting scientific information used in high-level policy decisions. In contrast, operational policy staff and research staff are likely to be in place for longer periods of time in agencies, providing better opportunities to develop the relationships necessary to integrate research and decision-making. Presence or absence of leadership or a "champion" within stakeholder groups or agencies may make the difference in successful integration of new information. Identifying people with leadership qualities and working through them will facilitate adoption of new applications and techniques. The importance of leadership in initiating change cannot be overestimated, though connections with on-the-ground operational types and data managers are also important to facilitate information exchange. New (recently hired) professional water managers have been found to be more likely to take risks and deviate from precedent and "craft skills" that are unique to a particular water organization (Rayner, et al., 2002).

Crisis as Opportunity

Many changes in policy and use of technology occur in response to actual or perceived crisis, when there tends to be greater investment in adaptation or at least political pressure to respond. Since it is virtually inevitable that there will be future droughts and floods and other environmental hazards that affect decision-makers, stakeholders, and the availability of money for mitigation and adaptation, preparing to use these situations to best advantage is a useful strategy. This could mean having constructive alternatives or proposed legislation ready for a future "opportunity." In addition to crises caused by natural hazards, crises can be caused by regulatory changes and abrupt changes in funding. For example, in the Pacific Northwest, California and New Mexico, Biological Opinions associated with implementation of the Endangered Species Act (ESA) have significantly impacted existing water allocations, in some cases by trumping existing priority water rights and causing major economic dislocation. In other cases, habitat conservation plans developed under the ESA have derailed potential crises and provided an avenue for constructive evaluation of options that would not previously have been considered.

It is widely known that there will be increasing pressure on water supplies, particularly in the western US, due to population changes, habitat and recreation needs, Native American water rights settlements, water quality concerns and drought. It is relatively well known what the vulnerable regions are (Gleick, 2000), and preparing for these almost inevitable future conflicts can be used as an opportunity to insert new decision tools into the mix. To the extent that researchers can proactively help develop local consensus approaches to handling future conflicts, the region may be in an advantageous position in applying for funding and implementing solutions prior to the onset of crisis conditions.

Role of Social Science

One intended audience for this handbook is physical science researchers. Historically, such researchers may have had an unnecessarily limited view of the role of social science in integrating their own brand of science with decision-making. Social scientists, working as team members or consultants in projects, can help with identifying stakeholders' needs and perspectives, suggesting ways to encourage and facilitate interaction and sustain relationships, characterizing uncertainties faced by decision-makers, helping develop products that are more usable and useful, and providing input on project evaluation and dissemination of products. Social scientists can help characterize sensitivity, evaluate risk under various kinds of perturbations, and identify adaptation strategies that may be workable. These roles expand the traditional view of social science and are legitimate parts of the research agenda for science applications. However, social scientists are also affected by disciplinary boundaries and are not always focused on policy-relevant solutions, so finding a willing collaborator with good communication and policy skills is important.

Many of the challenges in linking scientific information with decision-maker needs are in fact social science questions. This is the reason why the "Human Dimensions of Global Change" program was established within various federal agencies, including NOAA, and why continued funding of the social and economic investigations of the use of scientific information is important.

Integrators

The wide array of technical inputs in many decisions requires translators of scientific information to assist in interpretation and tailoring for specific uses. Currently there is widespread use of private sector and academic consultants in agricultural and energy applications of climate and weather information, and limited use of consultants in water resources management applications. In some cases, communication between scientists and decision-makers would be enhanced by expansion of the types of professionals (integrators) who specialize in translating information (NRC, 1995; Hartmann, 2001, Kirby, 2000; Jacobs and Pulwarty, in press).

There are currently few training programs that are explicitly oriented toward developing the capacity to integrate climate science for particular applications, though there are a large number of universities that sponsor interdisciplinary environmental research. A broader range of integrators could be developed through short courses and certification programs as well as through degree programs. Regular refresher courses, such as those available for doctors and lawyers, for example, could be useful. A skill that could be incorporated into such a program is assistance with developing and encouraging new relationships between stakeholders and scientists in particular sectors, to encourage collaborative learning and jointly developed research agendas.

Integrators are commonly self-selected; they may be managers and decision-makers with particular aptitude or training in science, or they may be scientists who are particularly good at communication and applications. Many current integrators have evolved as a result of doing interdisciplinary and applied research in collaborative projects, and some have been encouraged by funding provided by NOAA's Office of Global Programs.

Qualities of Good Science Integrators and Translators

- Outside the box mentality.
- Willingness to work across disciplines and think creatively.
- Credibility in the science community, capability of understanding and translating complex information correctly.
- Expertise in a particular sector (e.g. energy, agriculture).
- Understanding of the institutions and cultures of the particular country/region involved.
- Ability to facilitate, rather than replace, relationship building between the principals (scientists and user groups).

Where will an expanded group of integrators with special skills in integrating science and decision-making come from? Some suggestions for expanding the range of translators and integrators appear below.

Ideas for Developing Integrators

- Incentives for including integrators in research projects can be provided by the agencies that fund science projects—either in the project review criteria or through separate direct funding for the participation of integrators.
- Educational institutions can be encouraged or funded to set up programs to develop integrators in various environmental applications, perhaps at the Master's level.
- The American Academy for the Advancement of Science Fellows program is an excellent example of encouraging integration of science into agency activities at high levels, by providing post-doctoral fellowships to work for a year within agencies. The Sea Grant program also provides fellowships that may result in placement of recent science graduates in policy areas.
- Cross-training within and between agencies and public universities can be accomplished through Intergovernmental Personnel Agreements and less formal mechanisms.
- New programs can be developed to place government and academic scientists in policy and decision-making arenas, and to bring stakeholders and decision-makers into research arenas for specific time periods of a month to a year to elicit interest in and understanding of each other's agendas.

Ideas for Developing Integrators (cont.)

- Mediators and facilitators who already focus on environmental conflict resolution are likely candidates for further training in specific disciplines to enable them to expand their areas of expertise. A directory of these facilitators is available through the U.S. Institute for Environmental Conflict Resolution, a program of the Morris K. Udall Foundation in Tucson, Arizona (www.ecr.gov/roster.htm).
- Focused training seminars that provide hands-on practice with interpreting data and using existing tools can be very helpful in expanding the capability of integrators and potential users of data.
- Programs that are intended to link decision-makers with particular researchers, students and faculty with potential applications areas for their research, etc., can help build a network of people focused on integration.
- Integrators can be required as a component of research that is intended to involve stakeholders/decision-makers.

IV. Mechanisms for Evaluation and Feedback

Assessments

Assessments of social and physical conditions are not always viewed as original research, and they may not get the respect they deserve from academics or scientists. However, assessments of physical conditions within regions, the institutional capacity to handle change, and the expertise and involvement of decision-makers are the most useful way to focus scientific research that is directed toward applications. Assessments also cause integration of science into society, as a by-product of the required interaction between physical and social scientists and the players in a particular area. The National Assessment of the Impact of Climate Change and Variability in the United States, which established regional and sectoral assessments throughout the U.S. (see Scheraga and Furlow, 2001), was possibly the most ambitious step yet in “use-inspired basic research” (L. Gilbert, personal communication, citing Donald Stokes, Pasteur’s Quadrant). Although the process followed for the Assessment varied substantially from region to region and between sectors, varying degrees of true engagement of stakeholders did occur. Encouraging on-going activities of this nature, which result in networks of scientists and stakeholders within communities, has benefits that are difficult to quantify but important for collaborative learning.

Follow-Through

Failure to adequately synthesize and disseminate the lessons learned in collaborative projects has reduced the value of some research and application activities. This is particularly problematic within and between federal agencies, where regular changes in personnel and changing areas of emphasis result in fragmentation of efforts and loss of institutional knowledge. For relatively little additional effort, results of research in applications could be more widely disseminated and useful.

The final product of research that is intended for applications is not a journal publication, but the development of operational products. There is a need for a more robust system to evaluate utility of products and to provide more "value-added" products. This framing of the research findings is critical to whether the products are truly useful.

Developing and documenting demonstration projects, where the utility of particular tools can be tested and potential benefits identified, is a useful way of following through on new ideas that show promise. A good example of this technique is work by K. Georgakakos et al. (the INFORM project) in northern California, where real-time monitors will be set up to show water managers the impacts of using climate prediction information in reservoir management as an alternative to depending on existing rule curves based on historical climate and runoff data. The key to this project is that there is no commitment made by the manager to change operations – they can operate for seasons or years with side-by-side systems, and evaluate benefits of changes in approach, while making no "risky" commitments.

Special Project Management Considerations in Science Applications

- Establish milestones (intermediate goals) and measures of success before programs begin.
- Collect data in an accessible (to all participants) and preferably standardized way, articulate quality control expectations.
- Provide opportunities for decision-makers and stakeholders to manipulate data and test applications of tools themselves.
- Document interactions between scientists and stakeholders, observing ways in which they change over time and why.
- Develop iterative feedback and response mechanisms.
- Require assessments of success from participants, including feedback from participants regarding conclusions.
- Identify lessons learned and ways to improve the approach in subsequent applications.
- Develop and maintain an up-to-date contact list for interested parties in both the research community and the applications community.
- Distribute regular updates on the status of currently funded projects and findings.
- Find avenues for sharing results outside of traditional academic journals, produce derivative "value-added" products that move beyond data sharing to a discussion of policy implications.

V. Measures of Success in Collaboration

Measures of success must be in the context of an objective and a strategic plan. They need to be identified in the context of the project itself. Participatory research as an end in itself is too process-oriented. You need an end condition that you will really know when you see it. (M. Dilley, personal communication.)

Success in Collaboration is in the Eye of the Beholder

Success from the perspective of a social scientist might be development of sustained relationships between scientists and stakeholders and decision-makers, an open and participatory process, incorporation of risk assessment in prioritizing research activities, better scientific understanding of the decision-making process, etc. Success from the perspective of a physical scientist might be an improved understanding of physical processes that results from working with decision-makers who have years of hands-on experience managing resources. From the perspective of a stakeholder, success might be measured in terms of dollars earned from improved crop management decisions, or reduced losses from flooding or fire hazard. All of these measures of success are legitimate, though some are more difficult to document than others. The following table provides suggestions for potential measures of success that can be included in the articulation of expectations for future research activities.

MEASURES OF SUCCESS**

- **In Stakeholder Interaction/Collaboration**
  - Did participants modify behavior in response to information?*
  - Did participants initiate subsequent contacts?*
  - Were contacts/relationships sustained over time and did they extend beyond individuals to institutions?*
  - Was the information received integrated into the user's "world view"?*
  - Did stakeholders invest staff time or money in the activity?
  - Was staff performance evaluated on the basis of quality or quantity of interaction?*
  - Did the project take on a life of its own, become at least partially self-supporting after the end of the project?
  - Did the project result in building capacity and resilience to future events/ conditions rather than focus on mitigation?
  - Were quality of life or economic conditions improved due to use of information generated or accessed through the project?
  - Did the stakeholders claim or accept partial ownership of final products?

MEASURES OF SUCCESS** (cont.)

- **In the Use of Science in Decision-making**
  - Was the process representative (all interests have a voice at the table)?
  - Was the process credible (based on facts as the participants knew them)?
  - Were the outcomes implementable in a reasonable time frame (political and economic support)?
  - Were the outcomes disciplined from a cost perspective (i.e., there is some relationship between total costs and total benefits)?
  - Were the costs and benefits equitably distributed, meaning there was a relationship between those who paid and those who benefited?

- **In Interdisciplinary Work**
  - Are there regular contacts with colleagues in other disciplines?
  - Have inter-disciplinary programs and lecture series been established within agencies or institutions?
  - Are participants publishing integrated analyses in multi-disciplinary journals or journals from other fields?
  - Are participants cited in journals from other fields?
  - Are research projects jointly funded with other agencies or disciplines?
  - Is there a professional reward system (such as merit pay review) that encourages activities outside of the discipline?

* From both the scientist's and the user's perspective
** This table incorporates significant input from B. Morehouse and D. Liverman, personal communication.

VI. Conclusions

There are multiple opportunities to improve the utility of scientific research through developing new kinds of relationships with stakeholders and decision-makers. These efforts to work with stakeholders should not be perceived as being in conflict with the current research agenda of the federal science agencies; rather, relatively minor changes in process and expectations can make a significant difference in utility of products and result in more constituent support for the program. Likewise, there is no need for all scientists to directly engage with stakeholders. The key is developing an appreciation of the constraints and opportunities associated with working in the context of the "real" world, and establishing two-way flows of information with true engagement of stakeholders at one end of the flow, and the researchers at the other. Expanded use of intermediaries and translators can enhance the flow of information where scientists and/or agencies do not engage directly with decision-makers. Additional suggestions for increased integration of science and decision-making include:

- Understanding the context in which decisions are made
- Expanding the range of professional integrators
- Developing and documenting cooperative demonstration projects
- Encouraging institutional change, focusing on interdisciplinary research and applied knowledge (including changing the academic incentive system to reward applied and interdisciplinary work)
- Articulating clear expectations from the beginning and measuring success based on those expectations while providing for iterative learning
- Developing ability of practitioners to manipulate data themselves
- Facilitating long-term relationships and trust between scientists and decision-makers
- Developing synthesis products and mechanisms for evaluation and feedback
- Having people representing different backgrounds and perspectives in the same room

These efforts are important and necessary, and require both financial and institutional support. Evaluation of ways to improve the utility and communication of scientific research is itself a legitimate research objective that will significantly enhance the societal benefits of investments in science. An expanded focus on useful science is likely to result in increased support from constituents, an important outcome for government agencies.

Appendix 1. Differences in Perspective on the Use of Climate Information Between Scientists and Water Managers

(From Jacobs and Pulwarty, in press)

Factor	Scientist's Perspective	Water Manager's Perspective
Identifying a critical issue	•Based on a broad understanding of the nature of water management	•Based on experience of particular system
Time frame	•Variable	•Immediate (operations) •Long-term (infrastructure)
Spatial resolution	•Defined by data availability, funding, modeling capabilities	•Defined by institutional boundaries, authorities
Goals	•Prediction •Explanation •Understanding of natural system	•Optimization of multiple conditions and minimization of risk
Basis for Decisions	•Generalizing multiple facts and observations •Use of scientific procedures, methods •Availability of research funding •Disciplinary perspective	•Tradition •Procedure •Professional judgment •Training •Economics •Politics •Job risks •Formal and informal networks
Expectation	•Understanding •Prediction •Ongoing improvement (project never actually complete) •Statistical significance of results •Innovations in methods/theory	•Accuracy of information •Appropriate methodology •Precision •Save money, time •Protect the public •Protect their job, agenda or institution
Product Characteristics	•Complex •Scientifically defensible	•As simple as possible without losing accuracy
Frame	•Physical (atmospheric, hydrologic, economic, etc.) and societal conditions as drivers •Dependent on scientific discipline	•Safety, well being •Profit •Consistency with institutional culture, policy, etc.
Nature of Use	•Conceptual	•Applied

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