Chapter 1. The Changing Context

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1.1 INTRODUCTION

Increasingly frequent headlines such as “UN Calls Water Top Priority” (*The Washington Post, January 25, 2008*), “Drought-Stricken South Facing Tough Choices (*The New York Times, Oct 15, 2007*), “The Future is Drying Up” (*The New York Times, October 21, 2007*), coupled with the realities of less available water, have helped to alert decision makers, from U.S. governors and mayors to individual farmers, that climate information is crucial in future planning. The past quarter-century has also seen significant advances in the ability to monitor and predict important aspects of seasonal to interannual variations in climate, especially those associated with variations of the El Niño Southern Oscillation (ENSO) cycle. Predictions of climate variability on seasonal to interannual time scales are now routine and operational, and consideration of these forecasts in making decisions has become more commonplace. Some water resources decision makers have already begun to use seasonal, interseasonal, and even longer-time scale - climate forecasts and observational data in assessing future options, while others are just beginning to realize the potential of these resources. This report is meant to show how climate and hydrologic forecast and observational data are being used, or neglected, by water resources decision makers and suggests future pathways for increased use.

The Climate Change Science Program (CCSP) included a chapter in their 2003 Strategic Plan that described the critical role of decision support in climate science; it was included because previous assessment analyses and case studies had highlighted the importance of assuring that climate information and data would be used by decision makers and not be produced in a vacuum. Since that time, there has been an increase in interest and research in decision support science including for organizations using seasonal to interannual forecasts and observational data in future planning. Five years since the release of the Strategic Plan, one of the main purposes of CCSP continues to be to "provide information for decision-making through the development of decision-support resources[1]." (2008 Our Changing Planet) As a result, CCSP has charged this author group to produce a Synthesis and Assessment report that directly addresses decision support experiments and evaluations in the water resources sector.

The authors of this product have concentrated their efforts on discussing seasonal to interannual forecasts and data products, though in some cases, longer-range forecasts are

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[1] According to this same document, "Decision-support resources, systems, and activities are climate-related products or processes that directly inform or advise stakeholders to help them make decisions."

discussed because they have simply become a part of the decision making process and separating them would cloud the examples given. We have provided a range of domestic case study examples, referred to as “experiments and/or evaluations”, but have provided some international examples, where appropriate.

1.2 INCREASING STRESS AND COMPLEXITY IN WATER RESOURCES

Under conditions of global warming and with an ever-accelerating demand for abundant water supplies, the management of water may become increasingly politically charged throughout the world in the coming century. Emerging challenges in water quantity, quality, pricing, and seasonal climate fluctuations may all increase as the demand continues to rise. Though it may well be the case that the total volume of water on the planet is sufficient for societies’ needs, the largest portion of this water is geographically remote, misallocated, wasted, or degraded by pollution (Whiteley *et al*., 2008). At the same time, there are shifts in the use to which it is put, the value given by society to natural systems, and the changing laws that govern management of the resource. Accordingly, the impact of climate on water resource management and the needs of people has far-reaching implications for everyone from the farmer who may need to change the timing of crop planting/harvesting or the crop type itself to citizens that may have to move because their potable water supply has disappeared.

In the U.S., water resource decisions are made at multiple levels of government and increasingly by the private sector. There is no national water policy, but rather a patchwork of policies, amended by degree over decades. “Water” is controlled/guided/governed by a gamut of Federal agencies overseeing various aspects from quality (U.S. Environmental Protection Agency [EPA]) to quantity (U.S. Geological Survey [USGS], Bureau of Land Management [BLM]). This is complicated by state, regional, and jurisdictional boundaries and responsibilities. Defining a "decision maker" is equally difficult given the complexity of water's use and the types of information that can be used to make decisions. Our challenge in writing this report is to reflect the diverse models under which water is managed and the diverse character of decisions that comprise water management. To illustrate: the term "water management" encompasses decisions by a municipal water entity about when to impose outdoor water restrictions; decisions by a federal agency about how to operate a storage facility; decisions by the Congress about funding of recovery efforts for an endangered species; and decisions by a state government about water purchases necessary to ensure compact compliance.

These types of decisions may be based on multiple factors, such as cost, climate (past trends and future forecasts), community preferences, political advantage, strategic concerns for future water decisions, *etc.* Further, water reflects many different values including economic, security, opportunity, environmental quality, lifestyle, and a sense of place (Blatter and Ingram, 2005). Information about climate variability can be expected to affect some of these decisions and moderate some of these values; for others it may be of remote interest or viewed as entirely irrelevant.

The rapidly-closing gap between usable supplies and rising demand is being narrowed by a myriad of factors, some of the most important include:

- Demand for water is increasing with population growth in terms of potable drinking water, agricultural/food requirements, energy needs, *etc*.
- Recreational and environmental interests in rivers have received greater representation in the political processes, with attendant success in protecting stream waters.
- Groundwater development enabled the expansion of western agriculture and is the basis for the development of several urban regions. As groundwater reserves are mined, pressure increases on other water sources.
- Water quality is a problem that persists, despite decades of regulations and planning.

Most well-documented of these pressures is population growth, which is occurring in the U.S. as a whole, and especially in the sunbelt states where water resources are also among the scarcest. Because water sources were developed and rights created in much earlier time periods, new uses must search for additional supplies. Las Vegas, Nevada is a case study of the measures required to provide water in the desert, but Phoenix, Albuquerque, Denver, Los Angeles and a host of other western cities provide comparable examples. In the Southeastern United States, rapid growth of cities, such as Atlanta, combined with growing environmental concerns that require water to sustain habitat, and poor management, have all lead to serious shortages.

Recreational and environmental interests also have a direct stake in how waters are managed. For example, fishing and boating have increased with importance as the economic basis of our economy has changed.

Groundwater mining is a wild card in national water policy. Water resource allocation is generally a matter of state, not federal control, and each state has different policies with respect to groundwater. Some have no regulation; others permit mining (also referred to as groundwater overdrafting). Because groundwater is not visible, it was less likely to be regulated than surface water use. The effects of groundwater mining become evident when regions must search for alternative sources of water.

These increasing demands for water are not likely to be met with the development of major additional sources of water supply, although some additional storage likely will be developed. The nation engaged in an extended period of construction (cite USGS on dams and reservoirs) in which most of the appropriate sites for construction were utilized. Further, as rivers are fully appropriated, or over appropriated, there is no longer “surplus” water available for development. Environmental and recreational issues are implicated in further development of rivers, making these alternatives more susceptible to challenge.

In response to these challenges, jurisdictions are developing alternatives such as water reuse utilizing groundwater storage and recovery, which avoids reservoir siting issues; conservation and improved efficiency, which has contributed to steady declines in per capita consumption; desalinization of water, and conjunctive management of ground and surface water. Pipelines, which have been used for decades, are suggested as the solution to one region's water shortages, only to be met by resistance from the area of origin.

The most appealing water management solutions, then, are the most modest. Water conservation, which may rely on incentives or regulation, often is the least expensive way of meeting demand. Water pricing has been heralded by generations of economists as the means of ensuring that water choices are wisely made. Transfers of water from one use to another, commonly from agricultural to urban uses in the western U.S., are becoming more common as a means of adjusting to changing economic realities. However, these modest solutions that have lead to more efficient water allocation have also reduced flexibility to adapt to climate variation and change.

The mosaic of water use may be viewed through another lens, which is the relative flexibility of each demand. Municipal and industrial demands can be moderated through conservation or temporary restrictions on use, but these demands are relatively fixed. In contrast, agricultural uses, which still comprise the largest users by volume, can be restricted in times of drought. The increasing connection between water and energy may limit this flexibility. For example, greater reliance on biofuels both increase competition for scarce water supplies and divert irrigated agriculture from the production of food to the production of oilseeds such as soybeans, corn, rapeseed, sunflower seed, and sugarcane among other crops. While parts of China and India have already breached the limit of sustainable water use, without the added strain of trying to grow significant quantities of biofuels, to a lesser but still serious extent, the reliance upon growing corn for ethanol has changed the pattern of agricultural water use also in the U.S (Whiteley *et al.,* 2008).

Rationalization of U.S. policies concerning water has been a goal for many decades. Emergent issues of increased climate variability and change may be the agents of transformation for U.S. water policies as many regions of the country are forced to examine the long term sustainability of water related management decisions.

1.2.1 The Evolving Context: The Importance of Issue Frames

In order to fully understand the context in which a decision is made, those in the decision support sciences often look at the "issue frame" or the factors influencing the decision makers including the general frame of mind of society at the time. A common denominator for conceptualizing a frame is the notion that a problem can be understood or conceptualized in different ways (Dewulf *et al*., 2005). For the purpose of this report, an issue frame can be considered a tool that allows us to understand the importance of a problem (Weick, 1995). Thus, salience is important part of framing. It is fair to categorize most water resources decisions in previous decades as low salience issues, the kind that do not attract much public notice. This low visibility is associated with the widespread perception that the adequate delivery of acceptable water is within the realm of experts and that an adequate understanding and contribution to decisions takes time, commitment, and knowledge that few possess or seek to acquire as water appears to be plentiful and is available when needed. It is understood that considerable variations in water supply and quality can occur, but it is accepted that the water resources establishment knows how to handle variation.

A series of events and disclosures of scientific findings have profoundly changed the framing of water issues and the interaction between such framing and climate variability and change. As illustrated in Figure 1.1, natural disasters, including Hurricane Katrina and recent sustained droughts in diverse sections of the United States, have disturbed the public perception of well-being. Such events raise awareness of the vulnerability of society to flood, drought, and degradation of water quality. Such extreme events come in addition to mounting evidence in professional journals and the popular press that water quantity and quality, fundamental components of ecological sustainability in many geographical areas, are threatened. The February 2007 Intergovernmental Panel on Climate Change, Working Group 1, report reinforced the high probability of significant future climate change and more extreme climate variation affecting many sectors, including water resources. The report received high press coverage and generated increased concern among the public and policy makers. Instead of being low visibility issue, the issue frame for water resources has become that of attention-grabbing risk and uncertainty about such matters as rising sea levels, altered water storage in snow packs, and less favorable habitats for endangered fish species sensitive to warmer water temperatures. Thus, global warming has been an emerging issue-frame for water resources management.

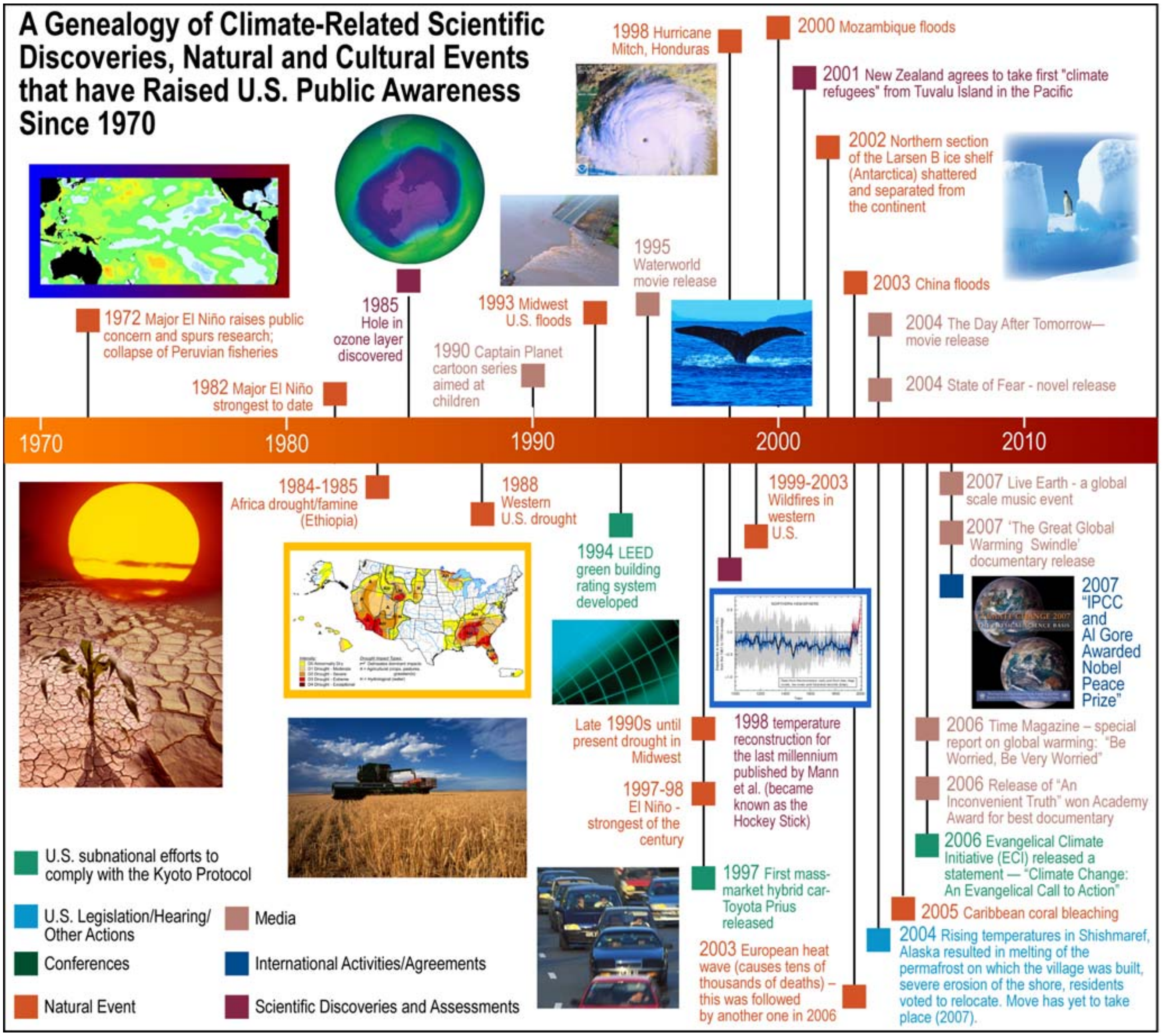

Figure 1.1 Timeline from 1970 to present of key natural and cultural events contributing to a widespread change in context for increasing awareness of climate issues

Figure 1.2 Timeline from 1970 to present of key policy events contributing to a widespread change in context for increasing awareness of climate issues

Along with higher visibility of water and climate issues has come greater political and public involvement. At the same time, with an increase in discovery and awareness of climate impacts there has been a deluge of new reports and passage of climate-related agreements and legislation. See Figure 1.2. As is the case with most high salience issues, politicians must compete with one another for status as policy leaders facilitating governmental and private actions to reduce societal vulnerability to climate related variability, although water has up until now taken a back seat to energy in terms of salience. Higher visibility of climate and water variability has put pressure on water managers to behave proactively to respond to expected negative effects of climate variability and change (Hartmann, *et al.*, 2002; Carbone and Dow, 2005). Specifically, in the case of water managers in the U.S., perception of risk has been found as a critical variable for the adoption of innovative management in the sector (O'Connor *et al*., 2005).

Frames encompass expectations about what can happen and what should be done if certain predictions do occur (Minsky, 1980). The emergent issue frame water resource management is that new knowledge (about climate change and variability) is being created that warrants management changes. Information and knowledge about climate variability experienced over the recent historical past is no longer as valuable as once it was, and new knowledge must be sought and put to use (Milly *et al.*, 2008). Organizational and individuals face a context today where perceived failure to respond to climate variation and change is more risky than maintaining the status quo.

1.2.2 Climate Forecasting Innovations and Opportunities in Water Resources

Only in the last decade or so have climate scientists achieved the important innovation of being able to predict aspects of future climate variations one to a few seasons in advance with better skill than can be achieved by simply using historical averages for those seasons. This is a scientific advance fundamentally new in human history (NRC SARP Report, 2007).

BOX 1.1: Seasonal to Interannual Climate Forecasts

Weather forecasts seek to predict the exact state of the atmosphere for a specific time and place at lead-times ranging from nowcasts (*e.g.* severe weather warnings) out to a maximum of two weeks. The accuracy of weather forecasts depends crucially on observations that can be used to accurately characterize the initial state of the atmosphere. In contrast, seasonal to interannual *climate forecasts* seek to predict the statistics of the atmosphere for a region over a specified window of time, typically from one month to a few seasons in advance.

The accuracy of climate forecasts depend crucially on observations of the slowly varying boundary conditions on the atmosphere, including upper ocean temperatures, snow cover, and soil moisture. Climate forecasts can also address the expected probabilities for extreme events (floods, freezes, blizzards, hurricanes, *etc.*), and for the expected range of climate variability. Much of the skill in seasonal to interannual climate forecasts for the U.S. derives from an ability to monitor and accurately predict the future evolution of ENSO, however the actual skill demonstrated is not yet high As a general principal, all climate forecasts are probabilistic. They are probabilistic both in the future state of ENSO and in the consequences of ENSO for remotely influenced regions like the US. For example, a typical ENSO-related climate forecast for the Pacific Northwest region of the U.S. might be presented as follows:

> *Based on expectations for continued El Niño conditions in the tropical Pacific, we expect increased likelihoods for above average winter and spring temperatures with below average precipitation, with small but non-zero odds for the opposite conditions (i.e., below average likelihoods for below average winter and spring temperatures and above average precipitation) in the Pacific Northwest (PNW).*

At lead times of a few decades to centuries, *climate change scenarios* are based on scenarios for changes in the emissions and concentrations of atmospheric greenhouse gases and aerosols that are important for the Earth's energy budget. Climate change scenarios do not require real-time observations needed to accurately initialize the atmosphere or slowly-evolving boundary conditions (upper ocean temperatures, snow cover, *etc.*).

******END BOX*******

It is important to emphasize that seasonal to interannual climate forecasting skill is still quite limited, and varies considerably depending on lead time, geographic scale, target region, time of year, status of the ENSO cycle, and many other issues that are the subject of chapter 2. Even so, the potential usefulness of this new scientific capability is enormous, particularly in the water resources sector, and this potential is being harvested through a variety of experiments and evaluations, some of which appear in this product. For instance, reservoir management changes in the Columbia River Basin in response to seasonal to interannual climate forecast information have the potential to generate an average of $150 million per year more hydropower with little or no loss to other management objectives (Hamlet *et al*., 2002). Table 1.1 illuminates the potential of SI climate forecasts to affect a wide range of water related decisions, potentially providing great economic, security, environmental quality, and other gains.

Table 1.1 Examples of Water Resource Decisions Related to seasonal to interannual Climate Forecasts

Decision/topic	**Agency/organization responsible**	**Activities affected**	**Climate Forecast information relevance**
Dam and reservoir management and reservoir allocation	• US Army Corps of Engineers • US D.O.I., Bureau of Reclamation • Tennessee Valley Authority • FERC and its licensed projects • Federal power marketing agencies • State, local, regional water management entities and utilities, irrigation districts	Distribution of inflows and outflows for: • Agriculture • public supply • industry • power • flood control • navigation • instream flow maintenance • protecting reserved waters for resources/ other needs	• Total reservoir inflow • Long-range precipitation • Long-range temperature • Flow data • Snow melt data • Flood forecasts • Shifts in “phase” in decadal cycles
Irrigation/water allocation for agriculture/aquaculture	• Federal, state and regional facility operators • Irrigation districts • Agricultural cooperatives • Farmers	How much water and when and where to allocate it.	• Long/short-range precipitation • Long-range temperature •
Ecosystem protection/ecosystem services	Federal and state resource agencies, *e.g.*, • US D.O.I., Fish and Wildlife Service • US D.O.A., Forest Service, US D.O.I., Park Service, US. D.O.I., BLM, US D.O.C., NMFS, *etc.* • State, regional and watershed- based protected areas NGOs, *e.g.*, • Nature Conservancy, Local and regional land trusts	• Instream flow management • Riverine/riparian management • Wildlife management	• Climate cycles • Long-term climate predictions

Pubic water supply/wastewater management*	- Municipalities - Special water districts - Private water utilities - Water supply/wastewater utilities/utility districts	Needs for new reservoirs, dams, wastewater treatment facilities, pumping stations, groundwater management areas, distribution systems; Needs for long term water supply and demand management plans; Drought planning.	Changes in temperature/precipitation effect water demand; reduction in base-flows, increased demands, and greater evaporation rates (Gleick *et al*., 2000; Clarkson and Smerdon, 1989). Predictive information at multiple scales and multiple time frames.
Coastal zones	- Regional Coastal zone management agencies - Corps of Engineers - NMFS, other federal agencies - Local/regional flood control agencies - Public supply utilities	Impacts to tidal deltas, low lying coastal plans Changes to fish production/coastal food systems, salt water intrusion Erosion; deterioration of marshes Flood control, water supply and sewage treatment implications	Predicted sea level rise & land subsidence; fluctuation in surface water temperature; tropical storm predictions; change to precipitation patterns; wind & water; storm surges and flood flow circulation patterns (Davidson, 1997).
Navigation	- Harbor managers - River system and reservoir managers, barge operators	- River and harbor channel depth; flow	- Stream flow, seasonality, flooding potential
Power production	- Federal water and power agencies; FERC; private utilities with licensed hydropower projects; private utilities using power from generation facilities	- Water for hydropower - Water for steam generation in fossil fuel and nuclear plants - Water for cooling	- Temperature (and relationships to demand for power) - Precipitation - Stream flow and runoff
Flooding/floodplain management	- Floodplain managers; flood zone agencies; insurance companies; risk managers, land use planners	- Infrastructure needs planning - Emergency management	Short and long-term runoff predictions, esp. long term trends in intensity of precipitation, storm surges, *etc.*

Besides the potential applications suggested in Table 1.1, there are other overarching opportunities for use of seasonal to interannual climate and hydrologic forecasts recently introduced to the water resources sector. Adaptive Management and Integrated Water Resources Management are examples of reforms that are still in relative infancy (see chapters 3 and 4) and could gain considerable traction through fostering continuous feedback from forecasts to changes in practice and improved performance. Adaptive management embraces the need for continuous monitoring and feedback; information provided by forecasts can prompt real time adaptations by public and private agencies and water users. Integrated Water Resources Management is based around the concepts of flexibility and adaptability, using measures that can be easily reversed or are robust to changing circumstances (IPCC Report, 2007 3.6.5). Such potential flexibility and adaptability extends not just to water agencies, but also to the citizenry generally. Advances in climate forecast skill and their application provides an opportunity to convey to the public, all of whom use water in one way or another, a deeper understanding than currently exists about the relationship of climate variability to increased risk, vulnerability, and uncertainty related to water that now tends to be perceived in static terms. In addition, more finely tuning water management to real time climate prediction allows for cutting down the lead time for response to climate variation.

1.2.3 Organizational Dynamics and Innovation

The flow of information among agencies and actors in a complex organizational field like climate forecasting and water resources is not at all like water itself that is ruled by gravity and flows downhill. Even as skill levels of climate and hydrologic forecasts have improved, resistance to their use in water resources management both exists and persists (O'Conner *et al.*, 1999; Rayner *et al.*, 2005; Yarnal *et al.*, 2006). Such resistance to innovation is to be expected according to organizational and management literature that addresses the management of information across boundaries of various kinds that include organizations, disciplines, fields, practices and the like (Carlisle, 2004; Feldman *et al.*, 2006). The same specialization that makes organizations effective in delivery of organizational goals can make them resistant to innovation (Weber, 1947). Creating a product or service requires differences in experience, terminologies, tools, and incentives that are embedded in a specific organization. Because knowledge takes investment such as time, resources, and opportunity costs, it constitutes a kind of "stake", and significant costs are associated with giving it up and acquiring new knowledge (Carlisle, 2002). Further, if the kind of knowledge that needs to be coordinated across boundaries may be so different in kind that a bridge of a common language must be created that allows translation to take place. Finally, the sort of demands made by sharing information across boundaries may be so novel that a fundamental readjustment is needed that challenges the organization to rethink what it knows and how.

Figure 1.3, adapted from Carlisle (2004) portrays the different level, challenge, or gap that must be filled for sharing knowledge across boundaries, and helps convey the challenge of innovation through information sharing across different organizations, levels of government, and public and private actors. At the lowest level of the inverted triangle information transfer is relatively simple such as exists between different climate forecasters located in different organizations. Forecasters have common knowledge and know each others' levels of expertise and respect it regardless of organizational ties. Because a common lexicon exists, knowledge transfer is relatively simple. The usual barriers to smooth information flow apply, including information overload, availability of storage and retrieval technologies and other information processing challenges. Unfortunately, agencies prefer their own terminology and trust information that comes from inside the organization more than information from outside, the adoption of seasonal to interannual climate forecast information in the water resource sector hardly ever fits this simple transfer profile.

At the second or translation level of managing information, shared meanings or resolution of discrepancy of meaning are necessary. This level of information sharing probably typifies the relationships between climate forecasters and water resource forecasters who have long predicted water futures using data such as snowpack, soil moisture, basin and watershed models and the like. This involves a large expenditure of effort that has to be justified within the organization and may well encounter resistance unless offset by some considerable pay off. A common lexicon may need to be invented with common definitions. Effort must be expended to develop shared methodologies, create cross-organizational teams, engage in strategies such as collocation of offices, and employ individuals who can act as translators or brokers. Sometimes translation requires making tacit knowledge explicit, and translation becomes more difficult when information is related to practices that may be very different on either side of boundaries. This level of information sharing probably typifies the relationships between climate forecasters and water resource forecasters who have long predicted water futures using data such as snowpack, soil moisture, basin and watershed models and the like.

The third or transformation level of managing information requires considerable change in the ways in which organizations presently process and use information, such as moving toward co-production of knowledge with outside organizations, interests and entities. These costs negatively impact the willingness of organizations to make such transformational changes and help to explain why organizations continue to follow "path dependent" or business-as-usual practices despite evidence that innovation would be beneficial. For instance, the very large challenges presented to climate forecasters to involve users in the production of climate products explains why they continue to follow what has been termed the "loading dock" model, or simply putting forecasts out with little notion of whether or not they will be picked up (Cash *et al.*, 2006). Knowledge at this level is a transformed mixture of knowledge that is determined to still be of value and the knowledge that is of consequence given new insight on climate variability.

Knowledge at this third level must be created collaboratively rather than delivered and must be salient, credible and legitimate to all engaged actors. Salience or decision relevance is changing, as the context for decisions is changing as discussed above. However, information is likely to be more salient if it comes from known and trusted sources (NRC, 1984, 1989, 2002; Sarp Report, 2006). Credibility is not just credibility of scientists, but also to users. Information is more credible if it recognizes and treats multiple perspectives. Legitimacy relates to even handedness and the absence of narrow organizational or political agendas (Cash *et al.*, 2003; NRC SARP Report, 2006). Almost all of the important applications of seasonal to interannual climate forecasts involve information management at level three.

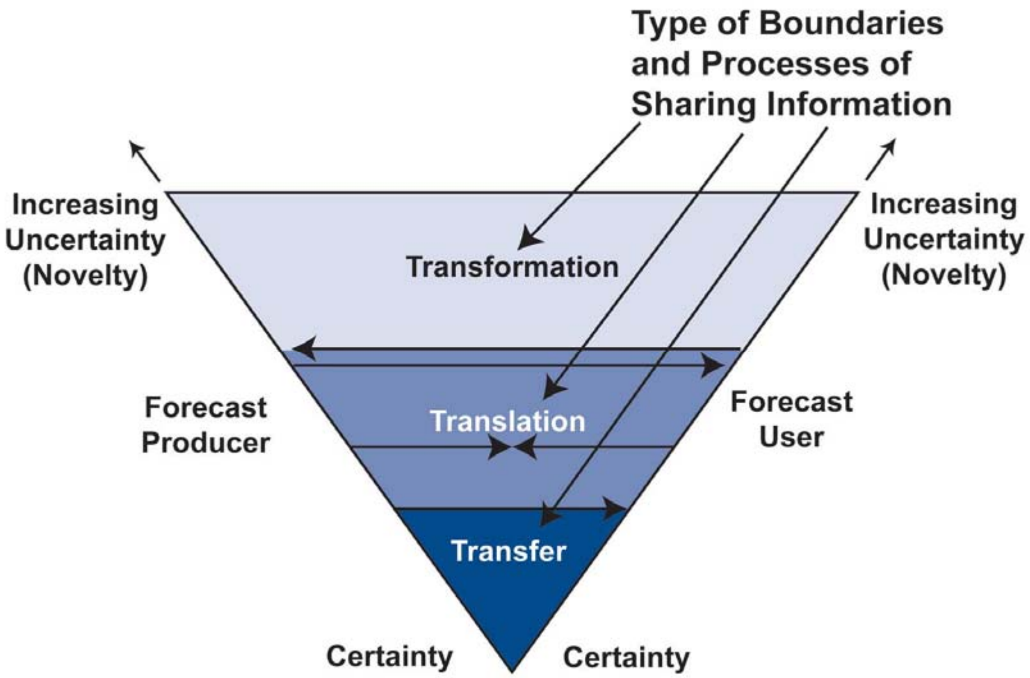

Figure 1.3 Illustration of the processes of information sharing. At the tip of the triangle forecast producers and forecast users are sharing a common syntax and framework and therefore knowledge is simply transferred. As the products and uses become increasingly different and novel, a process of learning has to occur for information to be translated (middle of triangle). Finally, information will need to be transformed in order for knowledge to be accessible to very different parties. Adapted from Carlile, 2003.

1.2.4 Decision Support, Knowledge Networks, Boundary Organizations, and Boundary Objects

A recent National Academy of Sciences Report (2006) observes that decision support is widely used but definitions vary. Following the lead of this report, decision support is defined here as creating conditions that foster the appropriate use of information. This definition presumes that the climate scientists who generate seasonal to interannual climate forecasts often do not know what information they could provide to water resources managers that the managers would find useful, and that water managers do not necessarily know how they could use seasonal to interannual climate forecasts and related information (NAS, 2006). The primary objective of decision support activities is to foster transformative information exchange that will both change the kind of information that is produced and the way it is used (NRC 1989, 1996, 1999, 2005, 2006).

Decision support involves engaging effective two-way communication between the producers and users of climate information (Jacobs *et al*., 2005; 2006; Lemos and Morehouse, 2005; NRC, 1999, 2006) rather than just the development of tools and products that may also be useful though less fundamental. This conception of decision support brings into focus human relationships and networks in information utilization. The test of transformed information is that it is trusted and considered reliable, and is fostered by familiarity and repeated interaction between information collaborators and the working and reworking of relationships. A knowledge network is built through such human interactions across organizational boundaries and creating and conveying information that is end to end useful for all participants ranging from scientists to multiple decision makers.

A variety of mechanisms can be employed to foster the creation of knowledge networks and the coproduction of knowledge that transcends that otherwise available. Among such mechanisms are boundary organizations that play an intermediary role between different organizations, specializations, disciplines, practices, and functions including science and policy (Cash, 2001; Clark *et al*., 2002; Guston, 2001) These organizations can play a variety of roles in decision support that include convening, collaboration, mediation and the production of boundary objects. A boundary object is a prototype, model or other artifact upon which collaboration can occur across different kinds of boundaries during which such collaboration participants may come to appreciate the contribution of other kinds of knowledge, perspectives, expertise or practice and how it may augment, help or modify their own knowledge (Star,1989). A fish ladder is a kind of boundary object since it is an add-on to a dam structure and must be part of structural design. At the same time it serves fish species and needs the insight of biologists for it to work.

1.3 OUTLINE OF THE REPORT AND WHERE PROSPECTUS QUESTIONS ARE ADDRESSED

This Chapter addresses what types of seasonal interannual forecasts related decisions are made in the water community and what role could such forecasts play. It describes the general contextual opportunities and limitations to innovations such as the use of seasonal to interannual forecast information would entail.

Chapter 2 answers the question: what are seasonal and interannual forecast products and how do they evolve from a scientific prototype to an operational product? It also addresses the issue of skill and the impediments to progress in improving skill, and the steps that are taken to ensure that a product is needed and will be used in decision support. It describes the level of confidence about seasonal to interannual forecast products in the science and decision-making communities.

Chapter 3 focuses on the obstacles, impediments, and challenges in fostering close collaboration between scientists and decision makers in terms of theory and observation.

The real world barriers encountered in translation of climate variation forecasting information is explained by a theoretically grounded body of knowledge on why and how resource decision makers use information. Chapter 3 addresses the following kinds of questions: How are hazards and risks related to climate variability perceived and managed? What are the challenges related to finding out and serving the needs of decision makers? It emphasizes the importance of reliability and trust. It suggests how decision support could leverage scientific and technological advances.

Chapter 4 provides examples of a range of decision support experiments in the context of seasonal and interannual forecast information. It describes the limitations on the kinds of information available and the need to employ logical inference. It also discusses how decision support tools can be improved.

Chapter 5 provides an overview of this report, especially identifying overarching themes. It suggests the kinds of research and action needed to improve progress in this area. Finally, it addresses how the knowledge gained in water resources might be useful to other sectors.

The Prospectus for this study contained a series of questions that the Climate Change Science Program Office directed this group to answer within this product. Table 1.2 summarizes the questions and where they are addresses in the report.

Table 1.2 Questions To Be Addressed in Synthesis and Assessment Product 5.3

Prospectus Question	Report Location where Question is Addressed
What seasonal to interannual (*e.g.*, probabilistic) forecast information do decision makers need to manage water resources?	2.1
What are the seasonal to interannual forecast/data products currently available and how does a product evolve from a scientific prototype to an operational product?	2.2
What is the level of confidence of the product within the science community and within the decision making community, who establishes these confidence levels and how are they determined?	2.2
How do forecasters convey information on climate variability and how is the relative skill and level of confidence of the results communicated to resource managers?	2.3
What is the role of probabilistic forecast information in the context of decision support in the water resources sector?	2.3
How is data quality controlled?	2.3
What steps are taken to ensure that this product is needed and will be used in decision support?	2.5
What types of decisions are made related to water resources?	3.2
What is the role that seasonal to interannual forecasts play and could play?	3.2
How does climate variability influence water resource management?	3.2
What are the obstacles and challenges decision makers face in translating climate forecasts and hydrology information into integrated resource management?	3.2
What are the barriers that exist in convincing decision makers to consider using risk-based hydrology information (including climate forecasts)?	3.2
What challenges do tool developers have in finding out the needs of decision makers?	3.3
How much involvement do practitioners have in product development?	4.1
What are the measurable indicators of progress in terms of access to information and its effective uses?	4.3
Identify critical components, mechanisms, and pathways that have led to successful utilization of climate information by water managers.	4.4
Discuss options for (a) improving the use of existing forecasts/data products and (b) identify other user needs and challenges in order to prioritize research for improving forecasts and products.	4.4 and 5
Discuss how these findings can be transferred to other sectors.	5

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