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Adaptive management on the central Platte River – Science, engineering, and decision analysis to assist in the recovery of four species

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ABSTRACT

Active adaptive management is the centerpiece of a major species recovery program now underway on the central Platte River in Nebraska. The Platte River Recovery Implementation Program initiated on January 1, 2007 and is a joint effort between the states of Colorado, Wyoming, and Nebraska; the U.S. Department of the Interior; waters users; and conservation groups. This program is intended to address issues related to endangered species and loss of habitat along the Platte River in central Nebraska by managing land and water resources and using adaptive management as its science framework. The adaptive management plan provides a systematic process to test hypotheses and apply the information learned to improve management on the ground, and is centered on conceptual models and priority hypotheses that reflect different interpretations of how river processes work and the best approach to meeting key objectives. This framework reveals a shared attempt to use the best available science to implement experiments, learn, and revise management actions accordingly on the Platte River. This paper focuses on the status of adaptive management implementation on the Platte, experimental and habitat design issues, and the use of decision analysis tools to help set objectives and guide decisions.

1. Introduction

Adaptive management (AM) has long been an intriguing concept for resource managers and decision makers working in complex ecosystems and facing a high degree of uncertainty. Adaptive management emerged as an application of the scientific method to resource management, closely tying management to science learning through experimental actions (Holling, 1978; Walters, 1986). In three decades of application, however, examples of successful adaptive management implementation are few and conflict remains over how to achieve the most essential elements of a true adaptive management approach (Gregory et al., 2006) – a rigorous process of learning by designing management actions as experiments. Generally, AM is considered a six-step process (assess, design, implement, monitoring, evaluate, adjust). In the case of large-scale ecosystem rehabilitation efforts, the application of adaptive management as a guiding framework for science has had mixed success (Walters et al., 1992; Lee, 1993; Zellmer and Gunderson, 2009).

AM is the science framework of a major species recovery program currently underway on the central Platte River in Nebraska. The Platte River Recovery Implementation Program (Program) initiated on January 1, 2007 and is the result of a negotiating process that began in 1997 between the states of Colorado, Wyoming, and Nebraska; the U.S. Department of the Interior; waters users; and conservation groups. Program managers intended to address issues related to the Endangered Species Act and loss of river habitat along 90 miles of the Big Bend Reach of the Platte River in central Nebraska (Fig. 1). By managing land and water resources and applying science in an AM framework the Program is to provide benefits for four target species: the endangered whooping crane (*Grus americana*), interior least tern (*Sternula antillarum*), and pallid sturgeon (*Scaphirhynchus albus*); and the threatened piping plover (*Charadrius melodus*).

An adaptive management plan (AM Plan) provides guidance for Program science and offers a systematic process to test priority hypotheses and apply the information learned to improve management on the ground (Platte River Recovery Implementation Program, 2006a). The AM Plan, guided by conceptual models and multiple hypotheses developed jointly by Program partners, reflects different interpretations of river processes and species' responses to management actions. The cooperative nature of these multiple hypotheses represents a shared attempt on the part of Program

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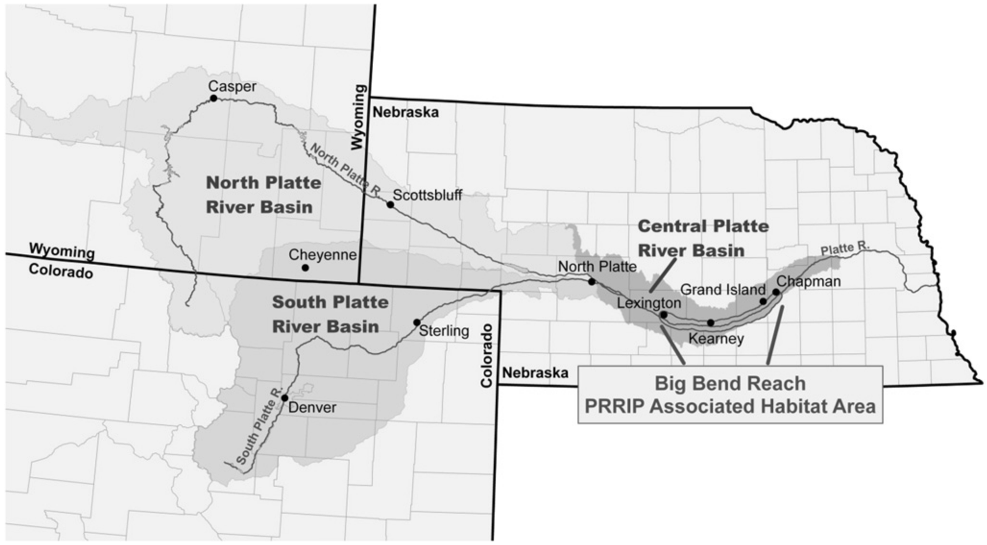

Fig. 1. Platte River Recovery Implementation Program (Program or PRRIP) spatial scale. The Program is focused on species use of habitat and management actions within a 90-mile section of the Big Bend Reach of the Platte River between Lexington and Chapman in central Nebraska. In Program terminology, this is called the "associated habitat". The mainstem Platte River is formed by the confluence of Colorado's South Platte River and Wyoming's North Platte River near North Platte, Nebraska.

cooperators and partners to use the best available science in an agreed-upon manner to implement action as experiments, learn, and revise management actions to reach a common goal – recovery of the target species.

The Program will implement several management actions in 2010 and 2011 to begin the process of testing hypotheses and assessing species response to those actions. Dam releases, sediment augmentation, island building, and other management actions are all part of the Program's experimental design and are planned according to management objectives and key science questions. Here, I discuss the components of the Program, the organization of the Program's science learning efforts, decision analysis tools and strategies utilized to guide the application of science, and the use of independent science review.

2. Program framework

The Program's goals, objectives, and each of its components are the result of intense negotiations that began in 1997 on the heels of the Federal Energy Regulatory Commission's conditional relicensing of Kingsley Dam on the North Platte River near Ogallala, Nebraska. Deliberations for the relicensing effort and the development of the Program centered on use of the central Platte River by the target species and the alteration of habitat that occurred over the course of several decades associated with water diversions, land-use changes, and other basin alterations. The U.S. Department of the Interior and the three states urged all parties to negotiate a plan to address species' concerns and Endangered Species Act requirements cooperatively rather than through litigation.

The Program represents a proactive approach to addressing species recovery and applying AM. While most large-scale species recovery or ecosystem rehabilitation programs are generally the result of litigation, Platte River managers sought to avoid the uncertain outcome of legal remedies. Instead, the resulting Program is an attempt to link management and science learning and engage a broad representation of entities in decision-making about species recovery and river management and policy. This is a unique method not yet fully repeated in places where water shortages and endangered species conflicts exist, though managers of systems like the Middle Rio Grande River in New Mexico are looking to the Program as a model for their own work on species recovery.

The central focus of negotiations revolved around two main objectives: 1) reduce the shortage of flows in the central Platte River by 130,000 to 150,000 acre-feet per year on average and 2) protect or restore 10,000 acres of habitat in the central Platte River basin. The water objective is essentially one-third of the 417,000 acre-feet of annual flow deficit as calculated by the U.S. Fish and Wildlife Service in the mid-1990s. For the land objective, acres will be considered for acquisition, lease, or easement generally based on the concept of five, 2000-acre "complexes" that can be managed to meet important habitat criteria such as channel width, sandbars, and unobstructed width (Platte River Recovery Implementation Program, 2006b). Agreement on these two objectives led to the development of the Program, formed the basis for land and water acquisition and management, and provided the context for adaptive management as the Program's process of science-based learning. The Program is authorized for a 13-year first increment that began in 2007 and is estimated to cost roughly $325 million, in 2005 dollars, with the monetary portion of that being $187 million. The federal government and the three states equally share the total cost in terms of cash, water, and land.

One of the unique aspects of the Program is its governance and management structure. Decisions are the ultimate responsibility of the Governance Committee, which consists of representatives from the Bureau of Reclamation; the U.S. Fish and Wildlife Service; the states of Colorado, Wyoming, and Nebraska; upstream and downstream water users; and conservation groups. The Governance Committee is assisted by several standing advisory committees made up of technical representatives of Program agencies and institutions and is organized by land, water, and AM issues. Thus, stakeholder involvement is a hallmark of Program governance. Day-to-day operations of the Program are the responsibility of the executive director and staff. The Governance Committee hired an independent executive director not affiliated with any of its entities. Staff members also operate independently from the partner agencies. The executive director and staff organize all Program meetings; provide management for the Program budget, lands, water, and implementation of the AM Plan; and provide a common link between the Governance Committee and the advisory committees.

The Program's approach to governance is much different from other well-known adaptive management programs such as those in the Everglades and on the Colorado River where federal agencies are in the lead in terms of both staffing and decision-making. In those systems, U.S. Army Corps of Engineers and U.S. Department of the Interior employees staff the programs but are also ultimately in charge of making policy decisions. On the Platte, the executive director and staff are independent of the U.S. Department of the Interior, the states, the water users, and the conservation groups. This builds in a certain level of independence and lack of bias that so far has proven useful in moving Program projects forward and building trust across all levels of Program participants. In terms of AM, it is highly valuable to utilize professional staff to manage data collection, analysis, and synthesis and to provide scientific guidance through the six-step adaptive management cycle to ensure decision makers are receiving thorough and useful science information to consider in the decision-making process. This governance model is unique and serves as an alternative to how most species recovery and ecosystem rehabilitation programs are currently organized and managed.

In addition, stakeholders such as water users and conservation groups are voting members of the policy body and are represented with state and federal agency representatives. Again, this is a major difference from other AM programs where stakeholders may be involved in the process at various levels but do not have the opportunity to help make management or policy decisions. The Program's construct is more in line with a social learning process that is inherent in true AM implementation and engages stakeholders at a decision-making level to build trust and provide a broader context for experimental management actions (Lee, 1993).

3. Program components and AM

The principal components of the Program are the land, water, and adaptive management plans. The processes of acquiring land and water rights and using AM to focus science learning efforts are spelled out in these individual plans; however, cross-linkages between these components are critical to successful implementation of the overall Program (Final Program Document, 2006b). The land plan is the guiding document for acquisition and management of Program land interests during the first increment, while the water plan provides similar guidance for acquisition and management of Program water. The AM Plan provides direction on how to learn about species and river responses to management actions.

The Program's AM Plan builds on the foundational principles of adaptive environmental assessment and management (Holling, 1978; Walters, 1986). The Program's AM Plan (Platte River Recovery Implementation Program, 2006a) defines adaptive management as "…a systematic process administered by the Governance Committee for continually improving management by: 1) designing certain Program management activities to test alternative hypotheses, and 2) applying information learned from research and monitoring to improve Program management. The process also includes the flexibility to use information and experience from all sources."

The Program's "learning by doing" approach embodies the classic tenets of active adaptive management – identify key questions in relationship to multiple hypotheses, develop and utilize predictive tools to evaluate management action choices, design and implement management "experiments", conduct linked monitoring and research, evaluate results, and reassess hypotheses and management actions (Walters and Holling, 1990). Monitoring and research link to key questions related to species response to management actions, as well as the response of river processes such as sediment transport and sandbar formation to management actions. Data collection and analysis are closely tied to assessing Program hypotheses and management objectives and revising conceptual models, all of which feed information into management decision-making.

Program AM implementation is built on a foundation of interdisciplinary science through information related to conceptual models, hypotheses, management strategies, and monitoring activities through a feedback loop that ties outcomes and learning (performance measures) to management objectives. This applied science framework, similar to an approach developed for dealing with science questions and challenges in the Everglades (Busch and Trexler, 2003), provides guidance for core monitoring, research, and experimental activities as well as direction for quantitative modeling and other predictive efforts. Science learning in the Program squarely focuses on "need to know" as opposed to "nice to know" information – what are the decisions, and what data is necessary to help make those decisions? Monitoring and research generate information to help make Program decisions and time, effort, and monetary resources are pushed toward that priority information instead of on activities that might provide general scientific knowledge but do not illuminate Program questions.

AM on the Platte River focuses on achieving four management objectives – 1) improve production of interior least terns and piping plovers on the central Platte River; 2) contribute to the survival of whooping cranes during migration; 3) avoid adverse impacts from Program actions on pallid sturgeon populations; and 4) provide benefits to non-target listed and unlisted species.

Management objectives serve as the desired outcomes of implementation of the two management strategies indentified in the AM Plan (Platte River Recovery Implementation Program, 2006a). One strategy attempts to rehabilitate the Platte River toward braided channel morphology through pulse flows, sediment augmentation, and mechanical actions such as channel widening and flow consolidation (Flow-Sediment-Mechanical or "Clear/Level/Pulse"). The second strategy employed to achieve the management objectives is mechanical creation and maintenance of habitat without the use of flows or sediment augmentation (Mechanical Creation and Maintenance or "Clear/Level/Plow"). AM actions on the Platte River during the first increment center on implementation of these two strategies through a suite of management actions and progress toward the management objectives will be assessed based on the results of these efforts.

4. Independent scientific review

Independent scientific review is an integral part of implementing adaptive management on the Platte River and will help provide assessments vital to measuring success. In December 2008, the Governance Committee appointed six members to the Program's Independent Scientific Advisory Committee. The science committee will play a critical role for the Program during the first increment by providing important external scientific review and advice on strategies to implement the AM Plan with a robust science program. The science committee will not be a part of implementing adaptive management; rather, the committee will provide independent counsel on experimental design, the overall adaptive management approach, and the methods utilized to integrate science into decision-making.

In addition, several external peer review panels have been assembled to review specific Program monitoring protocols associated with terns and plovers, forage fish, water quality, and geomorphology and in-channel vegetation. Independent peer review was utilized to review a protocol for tern and plover habitat selection research, and additional documents summarizing monitoring and research activities will be subjected to peer review during the first increment to ensure scientific rigor.

5. Experimental design

Application of science in the Program begins with conceptual models. Each conceptual model is a broad representation of physical processes or species behavior that provide the basis for assessing responses related to Program actions. The conceptual models are merely models of how people believe the Platte River system functions and, as in other systems, are used as planning tools to organize ecological thinking and develop specific hypotheses (Ogden et al., 2005). Conceptual models of tern, plover, and whooping crane response to management actions, as well as how river processes such as bank and bed erosion, bed scour, and sediment transport are influenced by the same management actions, served as the starting point for developing hypotheses that are more specific. As Program actions are implemented and learning occurs, the conceptual models will be revised and updated to incorporate new understanding.

The second step to applying science is the development of a set of more specific hypotheses that provide the context for measuring species response to management actions (Fig. 2). The Program has 42 priority hypotheses that address issues related to each target species or river processes such as sediment transport. Program participants developed hypotheses through the negotiation process and each includes an alternative hypothesis. The hypotheses are labeled “priority” because they represent the negotiated set of key questions the Program hopes to assess during the first increment, and they stem from a much larger set of hypotheses filtered out through negotiations over feasibility and relevance to key Program questions and objectives. In the process of developing the Program, negotiators generally agreed to set their value systems and thoughts on how to apply management actions aside and built an AM Plan that incorporates competing views of how the Platte River works (competing hypotheses) and different methods to assess species response (two management strategies). This is a hallmark of adaptive management – the application of actions through a science learning process that improves knowledge and management and bridges entrenched beliefs and fear of uncertainty (Walters, 1997).

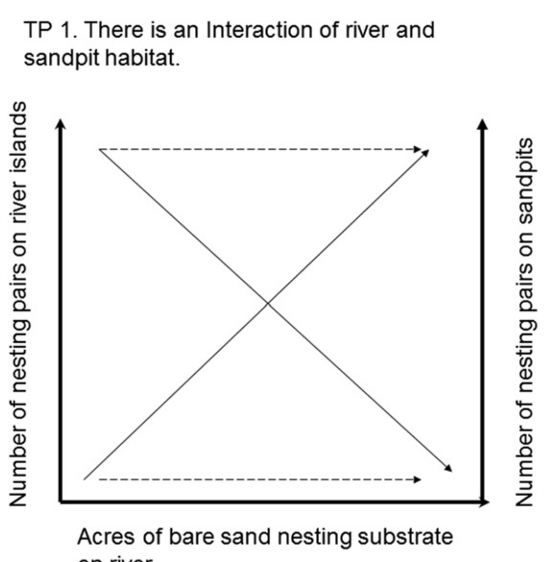

Fig. 2. Program’s tern and plover (TP) priority hypothesis #1, represented as an X–Y graph. This hypothesis postulates that as river nesting habitat (bare sand area on the *X* axis) increases, the number of nesting pairs of terns and plovers in the 90-mile study area will: 1) remain the same on river islands (*Y* axis on left side) and sandpits (*Y* axis on right side); 2) increase on river islands and remain the same at sandpits; or 3) increase on river islands and decline at sandpits.

The breadth of the Program’s AM Plan, however, also breeds challenges. A set of 42 hypotheses is almost impossible to test in normal policy timelines, especially within the thirteen-year limitation of the first increment. The two management strategies being applied on the ground are very similar in terms of individual actions (major differences include the use of augmented flow and sediment) and all work will be conducted within the confines of a single linear river system (water releases will affect the entire study area). Natural events such as precipitation-driven flows, ice scour, and broad climatic factors like drought further confound these factors. The confusing mix of controlled and natural events influencing the response of the target species and river processes in question further heighten the temporal restrictions already placed on Program implementation and render typical experimental tenets of control, randomness, and replication difficult to achieve.

As with many system-oriented ecological efforts, adaptive management actions in the Program are being implemented in way more akin to a *quasi-experiment* where spatial and temporal controls are utilized, but other aspects typical of experimental design are not available in most cases (Williams et al., 2002). Since Program science is built on an adaptive management framework and intends to investigate competing hypotheses, the science is still framed around the notion of strong inference (Platt, 1964). Information will never be complete and uncertainty will never be completely mitigated. In addition, small sample sizes for species like the tern, plover, and whooping crane strain the limits of statistical power. But, by prioritizing and sequencing hypotheses, developing clear decision criteria and supporting decision with predictive tools, and conducting sound monitoring and research, science learning through management experiments will result in robust and useful information to assess multiple hypotheses and provide a scientific foundation for decision-making.

As such, the specifics of Program science, in terms of monitoring and research, focus on questions, *a priori* hypotheses, and objectives that are of most interest to the Program. To that extent, monitoring protocols are being developed and implemented as conservation monitoring as opposed to surveillance monitoring with effort focused on collecting data most important for assessing key hypotheses (Nichols and Williams, 2006). Research is directed at significant questions and is closely managed by the Program to yield critical results – thus, “need to know” instead of “nice to know” research.

With these principles in mind, the Program has developed a set of experimental actions that will allow for the collection of data relevant to the most important hypotheses. In short, the management actions outlined in the AM Plan for the two management strategies will be applied in three general experimental categories:

5.1. Bird response

On Program lands throughout the 90-mile study area, an effort will be made to let the bird target species – least terns, piping plovers, and whooping cranes – tell the Program what habitat is most appealing on the central Platte River through habitat selection studies (e.g. sandbar elevation, sandbar area, distance to trees, channel width, etc.). These studies are paired with annual, intensive occurrence and productivity monitoring. For terns and plovers, islands of different elevations, sizes, and other parameters will be constructed and bird use will be monitored to determine selection through a multi-model inference framework. For whooping cranes, parameters will include channel and unobstructed-view widths and management actions will include widening the channel and removing trees.

5.2. Paired design

A feature of the central Platte River landscape is sandpits, which provide broad expanses of clean sand for nesting terns and plovers off the main channel. At each location where the Program constructs in-channel nesting islands, the Program will also construct new or manage existing off-channel nesting habitat to evaluate differences in productivity. The paired design will provide insight as to whether terns and plovers select or are more productive on one type of habitat versus the other.

5.3. Flow-sediment-mechanical “proof of concept”

The flow-sediment-mechanical strategy includes flow releases, sediment augmentation, and a need to consolidate flow into a single channel to increase stream power. The difficulty of implementing these actions, particularly flow consolidation, makes it difficult to implement this strategy and extract useful data. For example, flow consolidation is likely to entail the movement of material in or around the channel, thus requiring a permit, and downstream landowners are concerned about any flow diversions upstream. There is, however, one location on the river adjacent to an existing Program habitat complex with existing consolidation because old dike structures exist on the banks. Experimental actions at this location will include leveling macroforms in the channel to a pre-determined elevation as well as augmenting flow and sediment to determine the extent of sandbar formation and maintenance, vegetation control, channel width, and other parameters. Implementing research in this reach of river will help determine whether hypothesized sandbar heights or vegetation changes occur with this management strategy.

6. Decision analysis and data synthesis

As AM emerged, the use of increasingly robust decision analysis tools to assist with quantifying and evaluating alternative actions and ultimate policy decisions did also. The value of techniques such as structured decision-making (Gregory and Keeney, 2002), simple model development (Starfield, 1997; Nicolson et al., 2002), and quantification of multiple experimental options and outcomes (Alexander et al., 2006) are increasing as ecologists and managers work through the allocation of resources such as land and water to influence species and ecosystem responses. Decision analysis strategies alone are not adaptive management; rather, they are important tools used in the application of adaptive management to assist with the development of decision criteria and to predict outcomes of actions. The U.S. Department of the Interior adopted many of these tools in its adaptive management training modules and its involvement with management decision-making processes such as determining annual waterfowl harvest rates (Williams et al., 2007).

While the management objectives in the AM Plan provide broad guidance as to implementation priorities and an approach to evaluate the effectiveness of the two management strategies, it is necessary to identify “means objectives” for individual adaptive management experiments on the central Platte River and how information obtained from those experiments relates to priority hypotheses and management objectives. In 2009, the Independent Scientific Advisory Committee delivered their first report to the Program on the progress of AM Plan implementation and key issues the Program should address through its science actions (Marmorek et al., 2009). The Independent Scientific Advisory Committee indicated our approach to experimental design was sound so the Program is now focused on utilizing and building decision tools, predictions, and analysis methods to ensure our actions maximize learning and generate sufficient data to guide future management decisions. Marmorek et al. (2009) also recommended that the Program spend time prioritizing and sequencing the 42 hypotheses in order to develop a smaller subset of hypotheses that could reasonably be tested during the first increment. In addition, the Independent Scientific Advisory Committee provided guidance on developing a decision analysis tool to compare alternative experimental outcomes and developing a more detailed data analysis plan to determine toward the beginning of Program implementation how data will be used to assist the science–policy interface and complete a full cycle of adaptive management.

To this point, the Program has utilized decision analysis tools to help guide the direction of experimental investigations and to focus data collection. One tool is structured decision-making, a process to structure a complex decision to ensure that all objectives, actions, consequences, and tradeoffs are considered (Gregory and Keeney, 2002). An initial workshop in 2008 helped to develop specific objectives for assessing differences between the two management strategies and was paired with rapid prototype modeling, a process of developing very simple models to predict the consequences of different management decisions (Starfield, 1997). Workshop participants developed objectives and specific measurements tied to Program hypotheses to help frame key questions and focus model building on parameters that could be measured and that also could be used to monitor change. The workshop resulted in two simple models (one for terns and plovers and one for whooping cranes) that link available habitat and management actions with subsequent bird response. The two models are now being used to provide direction and pace for management actions and to provide a template for linking monitoring and research data back to our objectives. The models resulted in various tern, plover, and whooping crane responses to four modeled scenarios, all of which are built on varying degrees of Program management as represented by habitat availability and other performance measures (Tyre et al., 2009). Habitat parameters are processed in simple Excel spreadsheet models that were developed by workshop participants. While these simple models do not account for other decision parameters (i.e., cost) or include decision triggers (what level of increase in bird response indicates success), the models and the results are a starting point for using simple predictive tools to help guide management decisions. Model complexity is often an obstacle in gaining stakeholder trust and arriving at predictions that can be understood and utilized at the decision-making level. By developing simple models with a variety of stakeholder interests, trust issues can be avoided and model results can be more easily explained and actually integrated into the decision-making process. Decision analysis tools developed to date are being used at the technical level of the Program to help think through experimental design issues and data collection and analysis challenges.

To assist with moving science learning to the management and policy level, and at the suggestion of the Independent Scientific Advisory Committee (Marmorek et al., 2009) the Program is now developing a “mock report” to combine scientific data (e.g. tern and plover numbers, amount of water and sediment) with other important parameters (e.g. cost of water, time) to develop a decision tool to enable Governance Committee members to consider possible species’ response outcomes associated with different allocations of land, water, and other resources. Decision analyses of this nature have been developed to some degree in other systems (Alexander et al., 2006), but creating a tool that is functional at the appropriate scale for the Platte River will be a new endeavor that should provide useful results for decision-making and potentially for the application of AM in other large-scale systems.

The Program's specific work plan for adaptive management is equivalent using a strategic science plan as a support tool for implementation of adaptive management. This approach is modeled after a similar document developed for the Glen Canyon Adaptive Management Program (U.S. Geological Survey, 2009). The Program's AM Plan provides direction on implementation of the two management strategies and related management actions. Application of these management strategies and actions, along with targeted experiments to acquire "need to know" information, constitute the Program's "management experiments" which is consistent with the active adaptive management paradigm (Walters, 2007). The science plan provides the "means objectives" and action details for those experiments and identifies information needs, data gaps, necessary monitoring and research activities, and a framework for using conceptual and predictive models as decision-support tools.

7. Conclusions

The Program's AM Plan is a robust document that contains all of the elements of a true active adaptive management approach, offering tremendous potential for the ability to learn through experimentation and guide management based on that learning. The difficulty now lies in turning this document into sand and water – putting management actions on the ground in a way that allows for assessment of hypotheses and management objectives. With the bulk of implementation still to come, it remains uncertain as to whether the decision analysis tools used to date and still under development, the pieces of experimental design, and current assessment strategies are adequate to tell the Program's adaptive management story. In particular, work remains to connect science learning to decision-making. However, the AM Plan foundation is in place and Program staff and participants are building forward from this foundation in a way that should allow the Program to complete a significant iteration of the AM six-step cycle. In particular, the development of a mock report in 2010 may prove not only useful for ensuring AM implementation results translate into management changes on the Platte but may also become an instructive tool for other AM and ecosystem rehabilitation programs.

A unique governance structure that includes independent staffing and involves stakeholders in decision-making supports this science framework. Compared to other AM programs, this approach offers the prospect of more robust decisions with wider buy-in than in situations where decision-making is exclusive to a lead federal agency. The size of the Program Governance Committee and its range of views and priorities may seem to pose a large hurdle to decision-making. However, while major policy decisions such as the allocation of water resources are still to come, the functioning of the Governance Committee has been strong and careful deliberations seem to be a direct result of extensive input and shared decision-making. Large-scale recovery efforts are complex and demanding, but the architecture of the Program's independent staffing provides constant, direct implementation action and affords an additional layer of independence from Program governing entities. In the case of governance and management, the Platte River Recovery Implementation Program provides a template worth exploring for other systems.

Carefully designing and implementing adaptive management experiments, collecting data over the long term, and finally using the data to inform management actions remains a constant challenge on the Platte River. Program partners are working hard to accomplish adaptive management in its truest sense – hard thinking for a long time, but constantly advancing learning for more robust management. Many common examples of AM programs have some components similar to the Platte's AM approach, but few, if any, of them can clearly point to working through a full iteration of AM. The trick always seems to be taking exhaustive data, synthesizing that information into an AM story, telling that story to decision makers, and then seeing management or policy change as a result. The prospect for success in this regard on the Platte River is high, but innovation in decision-support and constant attention to moving through the AM cycle will be critical to achieving that success.

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