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Analyzing the Rio Chama Flow Project’s Capacity to Implement Adaptive Management

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Dedication

For Mark- for being the one next to me through this adventure,

&

For my family- for being a constant source of inspiration and providing me with the strength to constantly improve myself.

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Abstract

The Rio Chama is the main tributary to the Rio Grande in New Mexico. Several reservoirs were built on the Rio Chama to store water for downstream users, which has led to the river section becoming highly managed, resulting in negative ecological effects. Approximately 400,000 AF per year of water is conveyed through the system without considerable consumptive amounts, 96,200 AF of which were added with the San Juan-Chama trans-basin diversion, creating more water in the system then historically available. Therefore, the flow between the El Vado and Abiquiu Reservoirs has the potential to be optimized in order to provide environmental and economic benefits. The Rio Chama Flow Project was created in 2010 to identify the optimal flows to enhance social and ecological benefits on the 31-mile stretch between El Vado and Abiquiu Reservoirs.

However, a management strategy is needed in order to formalize the current decision-making process on the Rio Chama. The Rio Chama Flow Project (Project) specifically outlines Adaptive Management (AM) as the management strategy of choice to create a framework in which to operate. A decision key, developed in DOI's *Adaptive Management Technical Guide* (2009), is used to determine the appropriateness of AM for the Project. The decision key will also provide a structure for evaluating the Project and what is still needed for an AM plan. However, current AM literature has identified few successful implementations of AM plans. This project then provides a literature review of common challenges to AM implementation along with how those challenges relate to the Project.

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Acronyms and Abbreviations

ABCWUA	Albuquerque Bernalillo County Water Utility Authority
AF	Acre-feet
AM	Adaptive Management
BLM	Bureau of Land Management
AMP	Adaptive Management Program for Glen Canyon
BOR/Reclamation	Bureau of Reclamation
cfs	cubic-feet per second
The Compact	The Rio Grande Compact of 1938
DOI	Department of the Interior
ESA	Endangered Species Act
ISC	Interstate Stream Commission
MRG	Middle Rio Grande
MRGCD	Middle Rio Grande Conservation District
RCFP/the Project	Rio Chama Flow Project
RERI	River Ecosystem Restoration Initiative
SJC	San Juan-Chama
The Program	Platte River Recovery Implementation Program
USACE	U.S. Army Corps of Engineers

Introduction

The Rio Chama is the main tributary to the Rio Grande in New Mexico. The headwaters of the Rio Chama are located in the San Juan Mountains of Southwest Colorado and then joins the Rio Grande just north of Espanola, New Mexico (Figure 1). There are two dams constructed on the Rio Chama, El Vado (1935) and Abiquiu (1954). Willow Creek, a tributary to the Rio Chama, has Heron Reservoir, constructed in 1974. The three reservoirs were developed in order to provide water storage for downstream users including the two largest water users within the Middle Rio Grande (MRG), the Middle Rio Grande Conservation District (MRGCD) and the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) and flood control. In 1974, the San Juan-Chama (SJC) Project began in fulfillment of New Mexico's part of the Colorado River Compact, which allotted New Mexico 96,200 acre-feet (AF) of water that was to be diverted from the San Juan River into the Rio Chama via Willow Creek and Heron Reservoir. In 1988, the Rio Chama was designated a *Wild and Scenic River* under the National Wild and Scenic Rivers Act of 1968 (Public Law 100-633) (Harris, 2012). Due to the highly managed nature of the Rio Chama to meet human and environmental needs downstream, the river's natural flow has been significantly altered, as illustrated in a hydrograph (Figure 2). The highly altered flow has negatively affected the system's sediment transport, channel dynamics, and ecology.

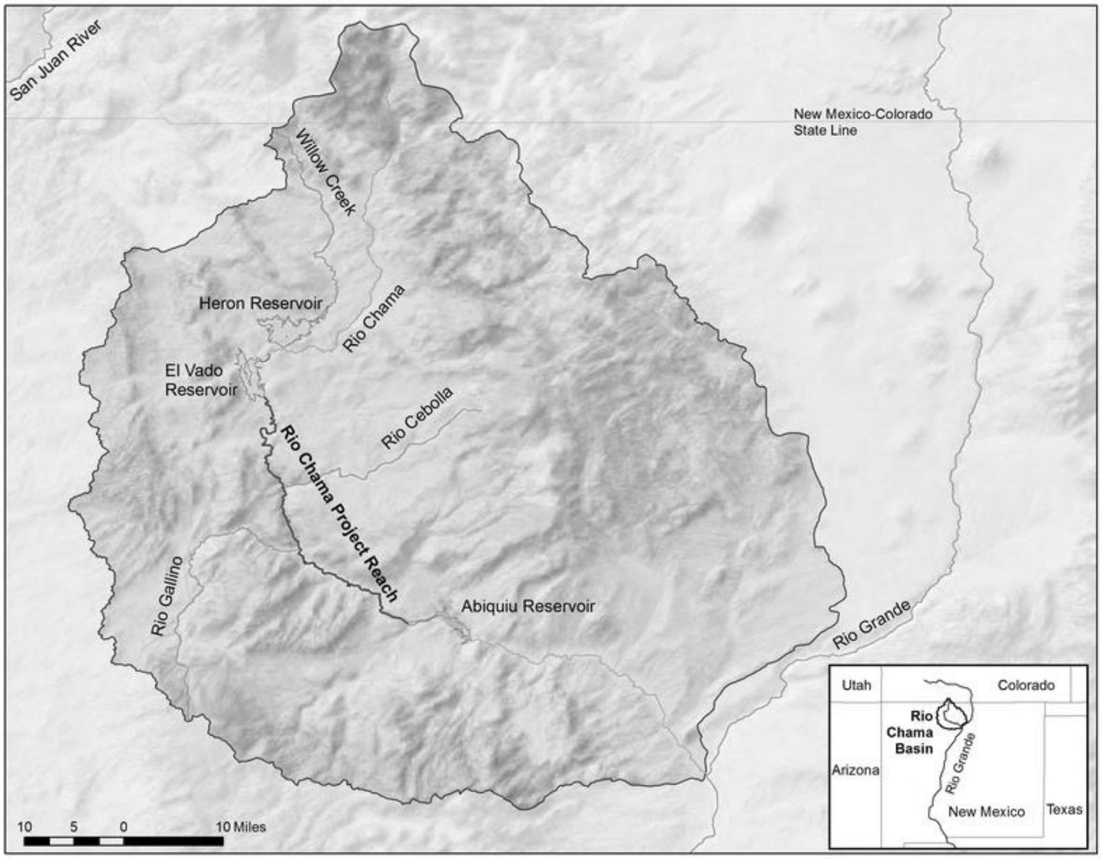

Figure 1: Rio Chama Watershed
Retrieved from https://riverrestoration.wikispaces.com/Rio+Chama+Group+Project

Approximately 400,000 AF per year of water is conveyed through the system without considerable consumptive losses, and 96,200 AF of which were added with the SJC trans-basin diversion, creating more water in the system then historically available (Rio Chama Flow Project [RCFP], 2016). The majority of the water moves though the Rio Chama downstream of El Vado Reservoir and ends up in Abiquiu Reservoir and then downstream to its users. This allows for flexibility in how and when the water is actually moved. Therefore, the flow between El Vado and Abiquiu Reservoirs can be optimized in order to provide the highest environmental and economic benefit, which is one step in managing the various environmental impacts on the Rio Chama (RCFP, 2016).

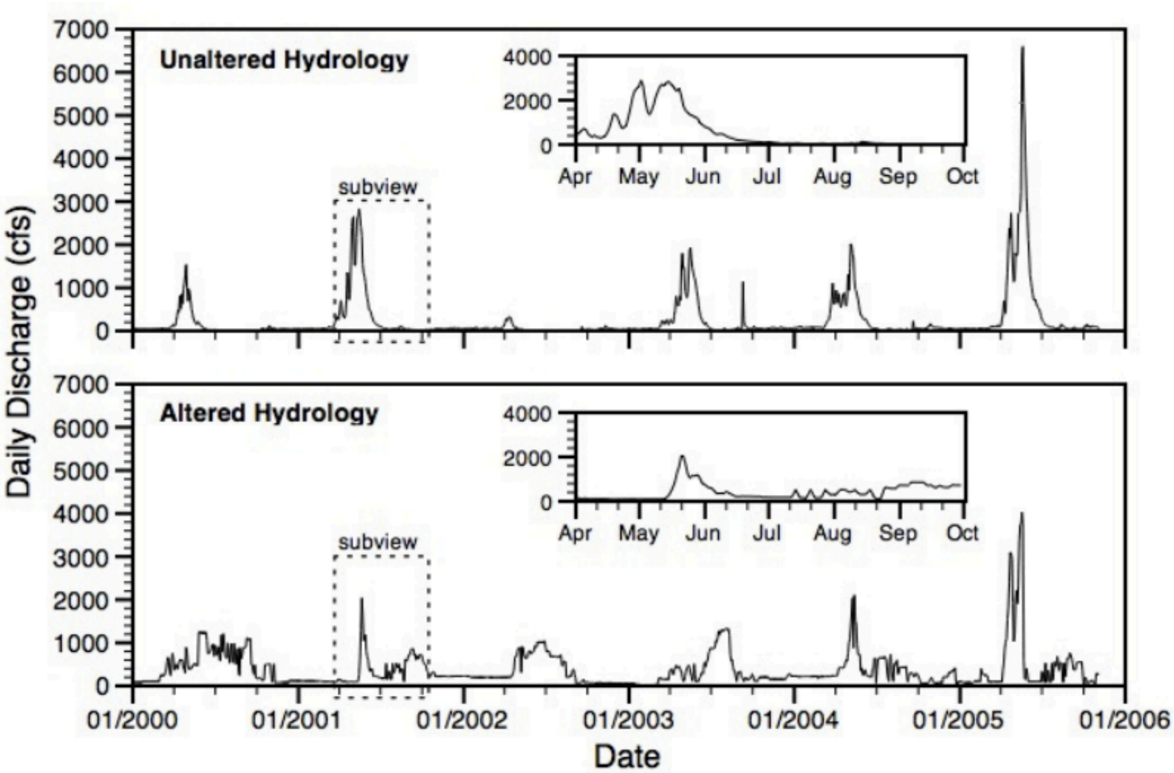

Figure 2: Rio Chama Unaltered and Altered Hydrographs
Reprinted from Stone, Harris, Harvey, Morrison, Gustina, & Benson, 2012

The Rio Chama Flow Project (RCFP or "the Project") was established in 2010 to "identify necessary and obtainable adjustments to operations of El Vado and Heron Reservoirs in order to achieve economic, environmental and recreational improvements in the 31-mile long Wild and Scenic designated reach of the Rio Chama without adversely affecting downstream water users" (RCFP, 2016). The RCFP takes place in the 31-mile stretch of the Rio Chama between El Vado Reservoir and Abiquiu Reservoir and is considered a novel system, which is a system that has developed post-dams and human influence. Therefore, improvements to the system need to occur within the existing framework of dam operations. The current decision-making process for the RCFP is based on informal agreements that are built on the social capital of the system in order to fulfill the Project's management objectives. The goodwill that has been built by stakeholders on the Rio Chama to create environmental flows has allowed for the Project to exist in its current state.

However, a management strategy is needed in order to formalize the current decision-making process to secure what the social capital has built thus far into the system. The Project specifically outlines Adaptive Management (AM) as the management strategy of their choice to create a framework in which to operate. AM involves "decision making in an environment of multiple management objectives, constrained management authorities and capabilities, dynamic resource systems, and uncertain responses to management actions" (Williams, Szaro, & Shapiro, 2009). However, according to literature on AM, there have been very few successful AM plans and programs. By understanding the common areas of failure and examining other similar projects that implemented AM, the RCFP can learn from other AM challenges to inform the development of their AM plan and how they should implement it. The Bureau of Reclamation (BOR or "Reclamation") is responsible for all water within this stretch and management of El Vado Reservoir. However, the RCFP has the expertise to determine the necessary flows to create the highest level of ecological benefits. Therefore, this paper focusses on how an AM plan should be developed for the RCFP, in order for the Project to make flow recommendations to BOR.

First, an introduction on AM will be presented. Then, the appropriateness of AM for the RCFP will be evaluated using a decision key developed in DOI's *Adaptive Management Technical Guide* (2009). The decision key will also provide a structure for evaluating what the Project already has and what is still needed for an AM plan to be developed. The next section will include common challenges in AM that were identified by Allen and Gunderson (2011) and supported by other AM literature, along with an analysis of whether a plan developed by the

RCFP can be successful will be done by reviewing AM common challenges with the RCFP. Examples of BOR projects that have engaged AM, the Glen Canyon Dam and the Platte River, will also be presented due to their similar characteristics with the Rio Chama.

Introduction on Adaptive Management

Adaptive Management was developed in the late 1960s by C. S. Holling and his colleagues at the University of British Columbia's Institute of Resource Ecology in order to reduce uncertainties by incorporating learning into the management process (Walters & Holling, 1990). AM was then adopted by U.S. resource management agencies, especially the Department of the Interior (DOI), including Reclamation. Many resource managers have turned to AM due to its ability to "to address management challenges that involve high degrees of variability and uncertainty" (Benson, Stone, & Morrison, 2013). According to DOI's *Adaptive Management Technical Guide* (2009),

> an adaptive approach involves exploring alternative ways to meet management objectives, predicting the outcomes of alternatives based on the current state of knowledge. Implementing one or more of these alternatives, monitoring to learn about the impacts of management actions, and then using the results to update knowledge and adjust management actions.

Overall, AM is a learning-based process that influences decision making, which reduces uncertainty over time (Figure 3). Due to the attractive nature of AM, AM has become another management alternative for various natural resource issues.

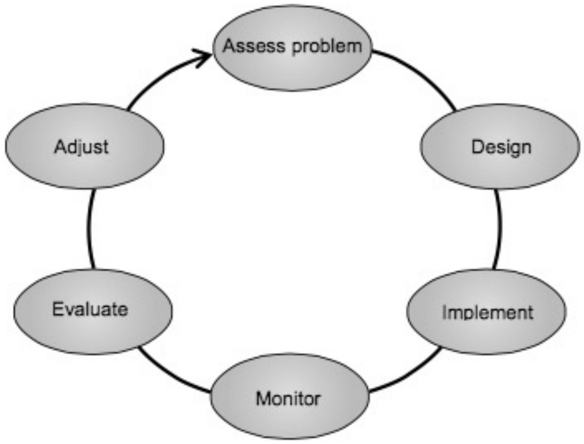

Figure 3: AM Iterative Process

Reprinted from Williams et al., 2009

Three distinct forms of AM have developed: evolutionary, passive, and active. Evolutionary AM is commonly referred to as “trial and error” learning, where there is informal learning from random experiences (Allan & Curtis, 2005). Passive AM “can be any variation of AM that falls along a decreasing continuum of scientific rigor for hypothesis testing” (Fischman & Ruhl, 2015). In passive AM, learning is treated as a byproduct instead of the key factor in decision making and the main focus is implementation (Fischman & Ruhl, 2015). On the other hand, active AM is primarily focused on learning by designing testable hypotheses to better understand uncertainties within the ecological system (Allan & Curtis, 2005). Federal resource management agencies were able to build upon earlier scholarly work to develop AM theory, which lead to these agencies to adopt policies to implement AM. However, due to the various political and fiscal constraints within federal agencies, it has led to most agencies practicing AM-lite, which lacks prior hypothesis development before experimentation and loose responses to observed results (Fischman & Ruhl, 2015).

The implementation of AM involves two phases: the set-up (or deliberative) phase and iterative phase. The two phases constitute the AM framework and contain key structural elements, which are integrated into an iterative cycle of management, monitoring, and assessment (Williams et al., 2009). The set-up phase includes stakeholder involvement, identifying management objectives, determining management options, creating models of the system, and developing monitoring plans and protocols. Once these elements are described and determined, they should be used in a cycle of iterative decision making (Williams et al., 2009). After the set-up phase puts those key elements in place, the iterative phase begins, which includes decision making, follow-up monitoring, and assessment. In addition to the iterative phase continually repeating, the set-up phase should be revisited periodically to maintain social and institutional learning (Figure 4) (Williams & Brown, 2013). Reducing uncertainty and learning occurs by comparing the predictions generated in the set-up phase through models constructed with the data generated during monitoring in order to improve future management actions and decision making (Williams & Brown, 2013).

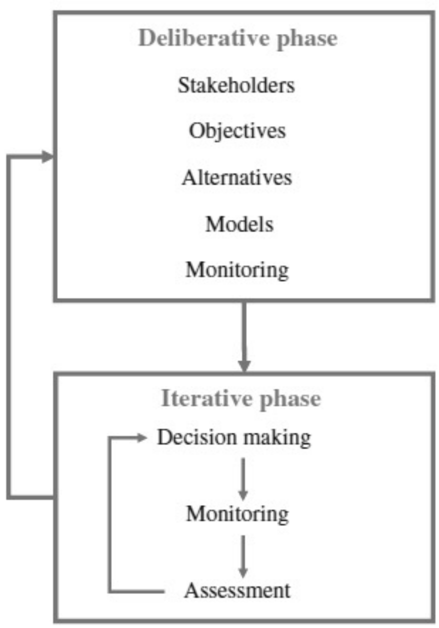

Figure 4: Two Phase Learning in Adaptive Management

Reprinted from Williams & Brown, 2014

Capacity for the Rio Chama Flow Project to Implement Adaptive Management

The best way to determine if AM is the best management strategy for the Rio Chama is to go through the decision key that was developed by the DOI in the *Adaptive Management Technical Guide* (2009) (Appendix A). In addition to using the decision key to determine the appropriateness of AM, the decision key will also provide a structure for evaluating what the Project already has and what is still needed for an AM plan.

Section 1: Management Decisions: is there some kind of decision to be made?

Yes. The Rio Chama is a highly managed system that mainly serves as a beltway to deliver water to downstream users using the reservoir system on the river. The "management decision" for purposes of the project involves integration of an experimental release of water in BOR's annual operating plan. The annual operating plan for the Rio Grande Basin is determined by BOR based on volume forecasts from the Natural Resources Conservation Service along with snowpack, soil moisture and climate forecasts (Bureau of Reclamation [BOR], 2016). Other factors that determine annual operations are Article VII restrictions under the Rio Grande Compact, flood control and channel capacity, requirements of the 2003 Biological Opinion in the MRG, and the timing of water deliveries (BOR, 2016). Once all these factors are considered, the BOR matches the expected volume with a similar volume from a previous year in order to have a baseline for system operations. System operations are then modeled on forecasted data (BOR, 2016). Therefore, environmental flows on the Rio Chama need to be a factor that is also considered during the development of BOR's annual operating plan just like the previously mentioned factors in order to be included in the primary management decisions. Furthermore, the purpose of each reservoir along with the dam operations associated with each reservoir is crucial to understand the current management of the Rio Chama and where there is flexibility for better management to create increased benefits for the system.

Heron Reservoir was constructed in 1971 on Willow Creek with a capacity of 401,300 AF (Langman & Anderholm, 2004). Heron Reservoir is operated by BOR with the sole purpose of storing SJC water, and it is not authorized to store native Rio Chama water. The SJC Project was established in 1962 with Congressional authorization under the Colorado Compact to fulfill a portion of New Mexico's allocation under the Colorado Compact. The SJC Project provides water to SJC contractors, which include the City of Albuquerque, the City of Santa Fe, MRGCD and various others (Figure 5) (Harris, 2012). SJC contractors must take their full amount of water each year due to the inability to carryover water from year to year in Heron; therefore, they must take delivery of their water by December 31st unless they are granted a waiver (Langman & Anderholm, 2004). Contractors will then generally store their water in El Vado or Abiquiu reservoirs.

San Juan /Chama Project Allocation of Water Supply for a Total Firm Yield of 96,200 ac-ft
(category of use shown in parentheses)

48,200 ac-ft	City of Albuquerque, (M&I)
20,900 ac-ft	MRGCD, (irrigation)
6,500 ac-ft	Jicarilla Apache Tribe (M&I)
5,605 ac-ft	City of Santa Fe, (M&I)
5,000 ac-ft	Cochiti Reservoir Recreation Pool, (recreation)
1,200 ac-ft	Los Alamos County, (M&I)
1,030 ac-ft	Pojoaque Valley Irrigation District, (irrigation)
1,000 ac-ft	City of Espanola, (M&I)
500 ac-ft	City of Belen, (M&I)
400 ac-ft	Town of Taos, (M&I)
400 ac-ft	Village of Los Lunas, (M&I)
400 ac-ft	Town of Bernalillo, (M&I)
60 ac-ft	Village of Red River, (M&I)
15 ac-ft	Twining Water and Sanitation District, (M&I)
4,990 ac-ft	Contracts under consideration with:
2,000 ac-ft	San Juan Pueblo
2,990 ac-ft	Taos Area

Figure 5: San Juan-Chama Water Allocations

Reprinted from WRRI Conference Proceedings, 1999

El Vado Reservoir is located on the Rio Chama, approximately five miles below Heron Reservoir. El Vado was completed in 1935 and is authorized to store SJC water for SJC contractors, native Rio Chama water for MRGCD and the six MRG Pueblos, which have “prior and paramount” water rights, and provide power generation for Los Alamos County (Langman & Anderholm, 2004). “Prior and paramount” water rights for the pueblos is defined by Congress as the water necessary to irrigate their 8,847 acres of historic homeland, and the management of which highly influences El Vado dam operations (Benson, Llewellyn, Morrison, & Stone, 2014). El Vado is owned by MRGCD, but operated by BOR for the purpose of managing water for the downstream users (Langman & Anderholm, 2004). The reservoir has a capacity of 180,000 AF, 40,000 AF of which is typically SJC water (Langman & Anderholm, 2004). SJC water can be released from the reservoir when contractors call for it, and native water is generally released during the irrigation season (March-November). However, releases of native water is governed by the Rio Grande Compact, which will be discussed in Section 9.

Abiquiu Reservoir was constructed on the Rio Chama in 1963 primarily for flood and sediment control. Abiquiu is run and operated by the US Army Corps of Engineers (USACE). The maximum capacity of Abiquiu is 1,535,300 AF, with a maximum storage capacity of SJC water of 140,097 AF (Langman & Anderholm, 2004). In 1981, Abiquiu was authorized to store 200,000 AF of SJC water, but the reduced capacity is due to sediment deposition and lack of storage easements (Langman & Anderholm, 2004). In 1988, Abiquiu was authorized to store a maximum of 200,000 AF of native water as long as the storage was not needed for SJC water (Flanigan, 2006).

The dam operations on the Rio Chama play a huge role in creating the current conditions on and around the river. Although there are some legal constraints, particularly on native water, that influence the dam operations, there is some significant flexibility for how and when water can be delivered to the downstream users, even though this has not been generally practiced in the past. There is a capacity to integrate environmental flows into BOR's annual operating plan. Also, dam operations can be changed through Congressional approval to store different types of water in reservoirs that were not previously authorized to do so. Therefore, the greatest management decision to be made is how to manage the flows to create the best ecological benefits without affecting downstream users.

Section 2: Stakeholders: can they be engaged?

Yes. The RCFP has a large stakeholder base due to the importance of the Rio Chama for water managers and recreationists alike. In addition, without complete engagement by MRG water suppliers, principally MRGCD and ABCWUA, the RCFP cannot be successfully implemented. Since those water suppliers technically own the water that will be used to fulfill management goals, their implicit involvement is crucial.

During the formation of the RCFP, Steve Harris, the Project's manager, set out to include everyone who wanted to be included as a stakeholder for the RCFP. In addition, formal letters of support were sent and signed by BOR, USACE, and the Interstate Stream Commission (ISC). Trout Unlimited, Rio Grande Restoration, and Los Alamos County have since signed on as supporting partners in the RCFP (Harris, 2012). Table 1 shows a compiled list of the current stakeholders in the RCFP, but more are added each year as support for the Project grows.

The RCFP project team hosted an ecology workshop in March, 2013 to develop environmental flow recommendations. Those attending the workshop were spilt up into three groups: aquatic, geomorphic, and riparian. The workshops attendees developed the flow recommendation paradigm discussed in Sections 3 and 5.

Stakeholders are engaged annually at the RCFP Advisory Council meetings. The meetings are held in October or November, usually at the Santa Fe Bureau of Land Management (BLM) office. The purpose of the meeting is to review the water operations on the Rio Chama that have occurred up to the date of the meeting and to plan for the next year's spring water operations.

Table 1:

RCFP Stakeholders & Stakeholder Groups
ABCWUA
Abiquiu Landowners
Acequias Nortenos
Adobe Whitewater Club
Anglers
BLM, Taos Field Office
BOR
Christ in the Desert Monastery
City and County of Santa Fe
El Vado Ranch
Enviornmental Groups
Forest Service, Santa Fe National Forest
Ghost Ranch
Jicarilla Apache Nation
Los Alamos County Utilities
MRGCD
New Mexico Trout Unlimited
NM OSE/ISC
Rio Chama Acequia Association
Rio Grande Pueblos
Univeristy of New Mexico
USACE
USFWS
Wild & Scenic Landowners

Section 3: Management Objectives: can they be stated explicitly?

Yes. From the creation of the RCFP in 2010 there has been clear management objectives set forth. The chief objective for the RCFP is to identify adjustments to the current water management on the Rio Chama between El Vado and Abiquiu Reservoirs to achieve economic, environmental, and recreational benefits (RCFP, 2016). The Project hopes to achieve these benefits by prescribing flow recommendations, which will create a more natural hydrograph and hydrologic regime. During the 2013 ecology workshop, the participants created a flow recommendation model to express management objectives (Figure 6). The flow recommendations serve as hypotheses for how modified flow operations will support ecosystem functions.

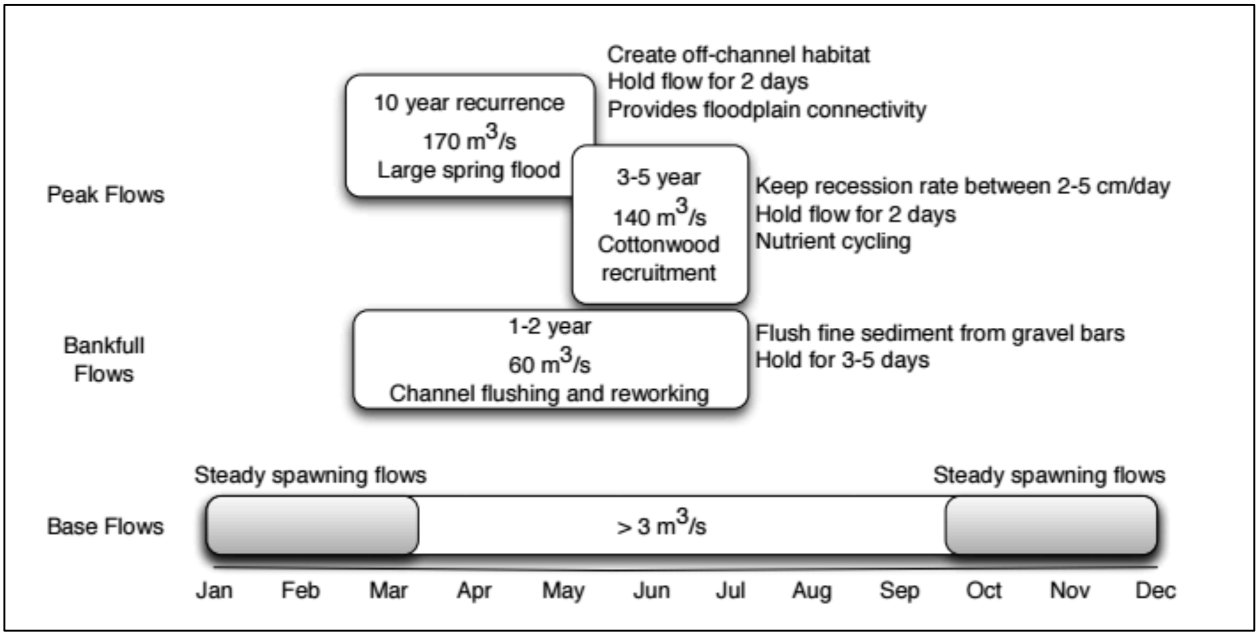

Figure 6: Flow Recommendations developed by Collaborative Workshop, 2013
Reprinted from Morrison & Stone, 2015b

Improving the river's ecology is the principle environmental objective for the Project. The improvements include ecological processes, such as floodplain inundation and cottonwood recruitment, biological resources, water quality, and channel geomorphology. All of these improvement objectives are achievable through the flow recommendations. By changing the timing, magnitude, duration, and rate of stream flows, there are corresponding changes to a river's ecology (Harris, 2010).

Baseline studies for the RCFP were funded through New Mexico's River Ecosystem Restoration Initiative (RERI) Program in 2011 and done by the Technical Group, composed of ecological engineers, riparian ecologists, benthic invertebrate ecologists, geomorphologists, and environmental law experts (RCFP, 2016). The baseline studies were done to assess the Rio Chama's geomorphic, hydrologic, and ecologic conditions (Harris, 2012). Technical Group meetings were also funded with the same RERI grant; however, the grant ran out in 2012, and at which time, the Technical Group meetings ceased, which demonstrates the importance of funding for a Project's continued operation and success.

Section 4: Uncertainty: does it affect decision making about potential management impacts?

Yes. Typically, there is always a certain level of uncertainty within any project, but most managers are averse to uncertainty and, therefore, do not actively engage it. The sources of uncertainty that can exist within a project includes varying ecosystem responses to management decisions, monitoring-data uncertainty, complex relationship between components in the system, and institutional and physical capacities in the system (Benson et al., 2013). Since uncertainty usually exists, AM embraces it and incorporates it into the management plan. The uncertainties within the Rio Chama involve the institutional and physical capacities, which Benson et al. (2013) examined, which cover the operational goals of the Project and are not engaged due to the current informal decision-making process based off of goodwill from the stakeholders.

The institutional uncertainties include interstate compact obligations under the Rio Grande Compact, water allocation and delivery obligations under state law, storage authority in Abiquiu Reservoir, end of the year deliveries for SJC Project water, and changes in hydropower dam operations (Benson et al., 2013). Some of these uncertainties do not need to be addressed if the Project's objectives do not interfere with how they are currently operated; however, it is the changes to the current operations that creates the uncertainty and it is the change to current operations that will achieve the Project's objectives. Therefore, these uncertainties will need to be engaged at various levels in order to fulfill water management goals.

Similar to the institutional capacity of the system, the physical capacities also pose some uncertainty depending on the level that the Project's objectives engage them. The physical capacities include hydropower facility capacity, El Vado spillway capacity, channel capacity near private property in the floodplain, and evaporative losses at reservoirs (Benson et al., 2013). The hydropower facility capacity and the El Vado spillway capacity may not need to be addressed if the recommended flows by the Project do not exceed the discharge capacity or require use of the spillway; however, the flow recommendations go up to about 6,000 cfs, which many believe exceeds channel capacity, but it is uncertain. Therefore, if project objectives are modified to accommodate the current physical constraints on the system, then that will eliminate physical uncertainties.

Section 5: Models: can they represent resource relationships and management impacts?

Yes. Not only do the flow recommendations illustrate management objectives, but they also model system dynamics that assess environmental flow alternatives (Figure 6). The flow recommendations serve as hypotheses for how modified flow operations will support ecosystem functions. The three groups from the 2013 ecology workshop, terrestrial ecology group, aquatic ecology group, and geomorphology group, created the recommendations to improve each group's primary function within the system.

The peak flows were determined to enhance habitat complexity and enhance the river system through sediment transport. The terrestrial ecology group determined that a peak release of 6,000 cfs (170 m^3/s) for at least three days will promote the creation of new off-channel wetlands and new sites for cottonwood seeding establishment (Rio Chama Flow Project [RCFP], 2013). The peak flows entail a rapid ramp-up of the 6,000 cfs flow for the three days every 10 years between March and June (RCFP, 2013). The geomorphology group determined that the peak flows of about 6,000 cfs were needed every two years in the spring during the first five years to break out the existing sediment within the river, followed by similar peak releases with a more gradual ramp up every 5-10 years in the spring to continue the same processes (RCFP, 2013). The peak flows needed for sediment transport will also benefit the aquatic ecology by moving the sediment downstream away from the El Vado Dam tailwaters (RCFP, 2013).

The bankful flows were determined to be important for cottonwood recruitment and reworking the geomorphology of the river. For cottonwood recruitment, a release of about 5,000 cfs (140 m^3/s) once every 3-5 years in late May to early June, with a recession from the peak flow of no more than one inch per day is needed (RCFP, 2013). Here cottonwood recruitment also represents floodplain inundation, which is an important ecological process that is needed and promotes nutrient cycling within the system. By creating more natural floodplain ecology it will create roosting habitat for bald eagles and greater songbird diversity (RCFP, 2013). The bankful flows were also identified as adequate flows to flush fine sediment and to develop gravel bars by having those flows of around 5,000 cfs for 3-5 days every 2-3 years (RCFP, 2013). A reduction of turbidity will also result from the bankful flows by moving sediment with a flow every 4-6 weeks in the summer with a frequency of 1.7 years (RCFP, 2013).

The moderate high flows of 2,100 cfs (60 m^3/s) were identified as maintaining the gravel bars and continuing the flushing of fine sediment through the system. Lastly, a steady, winter spawning flow every year of about 100 cfs (3 m^3/s) was determined to deposit small gravels for the October to March spawning period (RCFP, 2013). The flows determined in this model illustrate the various system dynamics needed to promote many ecological benefits and increase system function.

Ryan Morrison, a member of the RCFP Technical Group, wrote part of his dissertation on Rio Chama system dynamics. For his doctoral work, he created a diagram to illustrate certain aspects of system dynamics of the Rio Chama (Figure 7). This diagram shows the key variables that influence cottonwood recruitment and reservoir storage in the Rio Chama basin (Morrison & Stone, 2015a). The arrows represent connections between variables, and signs next to each arrow represent positive or negative reinforcing (Morrison & Stone, 2015a).

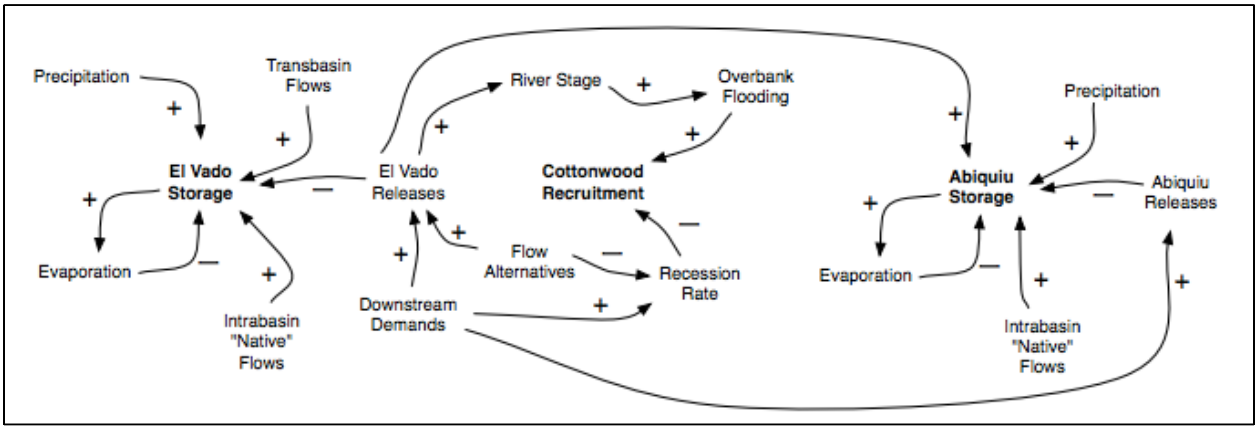

Figure 7: Key variables that influence cottonwood recruitment & reservoir storage
Reprinted from Morrison & Stone, 2015a

Section 6: Monitoring: can it be designed to inform decision-making?

Yes- With adequate funding. Monitoring, like in almost all AM plans, poses the greatest challenge for the RCFP. Both the RCFP's initial "RERI Proposal" (2010) and a subsequent "Basin Study Proposal" (2012) outline processes to determine baseline conditions for the Rio Chama; however, neither proposal sets out specific monitoring plans. The "RERI Proposal" (2010) states monitoring and documenting ecosystem changes as one of its management objectives and considers using stakeholders to review the collected data to identify unintended consequences from alternative flow operations. The "Basin Study Proposal" (2012) expands on the "RERI Proposal" (2010) by delineating specific tasks to be done by members of the Technical Group to create the baseline data. In addition, some of the tasks state more specific monitoring efforts to de done, such as instream water quality monitoring and shallow groundwater monitoring.

Since the Project's inception in 2010, there have been two experimental flow releases. The first was in April 2014 and included a peak flow of 2,050 cfs with the primary objective of mobilizing fine sediments. The second pulse flow occurred in May 2016 and was about 4,000 cfs, which served the objective of floodplain inundation. In addition, an agreement has been made with ABCWUA to keep water in El Vado to be used for winter spawning flows. There has been limited monitoring after both pulse flows due to the constraint of adequate funding for effective monitoring. Annual fish populations have been monitored by New Mexico Game and Fish in cooperation with BLM. In addition, there has been amphibian monitoring occurring for three years in a row. Although there has been limited monitoring on the Rio Chama, there is not sufficient monitoring data of overall system dynamics to influence the flow recommendations yet.

In order for adequate monitoring to occur, a more secure source of funding for the RCFP needs to be established. Although the BOR is the principle agency responsible for water management on the Rio Chama, they do not feel as though they can currently commit the resources needed to monitor (C. Donnelly, personal communication, March 1, 2017). Additionally, it is found that the federal government generally lacks the needed level of commitment and required expertise under current staffing and funding levels (Moir & Block, 2001). Therefore, the expertise within the RCFP would ideally be the best source for monitoring. However, without sufficient funding, it is not feasible for monitoring to occur at the scale needed for it to improve management decisions and to inform the flow recommendations. Many studies have been conducted thus far by Project team members and students at the University of New Mexico; therefore, university students could be a potential source to provide the monitoring needed. Overall, monitoring plans need to be established and followed through with funding sources for an AM plan to be successful.

Section 7: Measuring Progress: can progress in achieving management objectives be measured?

Yes. Progress in achieving management objectives is measurable for the RCFP. The main management objectives are illustrated through the flow recommendations (Figure 6). The flow recommendation model also specifies certain prescriptions that are attached to the specific flows; therefore, by conducting effective monitoring after implementing the recommended flows, there can be an assessment of whether those prescriptions are taking place. Determining the ecological processes that occur after flow recommendations is the most effective way of measuring progress towards achieving management objectives, but effective monitoring needs to take place in order for this step to achievable.

Section 8: Adjusting Management Objectives: can they be adjusted in response to what has been learned?

Yes- If it can be done in a way that still meets the needs of downstream water users. An essential part of AM is the ability to integrate what is learned back into the management objectives. This part is a continuation of Section 7 because if it is determined that the appropriate outcomes of the recommended flows are not occurring then the flows can be adjusted based on what has been learned from the initial flow recommendation.

Since the RCFP is currently responsible for determining the appropriate flows to create the specific ecological benefits, then it is their recommendation that the BOR will take when actually managing the flows on the Rio Chama. The BOR has expressed that they are willing to take the recommendations and work within their constraints to carry out environmental flows using the expertise of the RCFP (C. Donnelly, personal communication, March 1, 2017). If it is determined that a flow is not producing the intended benefits, then the BOR will take that into account for the next year's operating plan with the expressed willingness from the water contactors (C. Donnelly, personal communication, March 1, 2017).

Section 9: Legal Constraints: does the whole process fit within the appropriate legal framework?

Yes. Due to the scale of the RCFP, there are significant legal constraints that must be considered in order to determine if the recommend flows can occur in compliance with any relevant laws or regulations at the federal and state level. Table 2 is a complied list of the legislative history of authorizations and operations for reservoirs in the Rio Grande, including the Rio Chama.

Legislation	Date	Effect on reservoirs in the study area
MRGCD initiative	1935	Completion of El Vado Dam.
Rio Grande Compact	1938	Authorized water delivery obligations between Colorado, New Mexico, and Texas.
Flood Control Act (PL 80-858)	1948	Authorized comprehensive plan for improvement of Rio Grande Basin with a focus on flood control.
Upper Colorado River Basin Compact	1949	Set New Mexico's share of Upper Colorado river water at 11.25 percent.
Flood Control Act (PL 81-516)	1950	Authorized construction of Abiquiu Dam.
River and Harbor and Flood Control Act (PL 86-645)	1960	Set operating criteria for Abiquiu Dam and retention of floodwater during summer months for carryover storage under certain conditions. Authorized construction and operation parameters of Cochiti Dam.
PL 87-483	1962	Authorized SJC Project (including Heron Dam) that allows importing water from San Juan Basin of the Colorado River to the Rio Chama to supply specific municipal and irrigation users in the Rio Grande Basin. Set minimum instream-flow requirements for the Navajo and Little Navajo Rivers and Rio Blanco.
PL 88-293	1964	Authorized permanent pool in Cochiti Lake for recreation, fish, and wildlife.
City of Albuquerque Resolution	1974	Committed the City's allotment of SJC Project water to the establishment of an incidental recreational lake at Abiquiu Reservoir as a result of the annual storage.
Water Supply Storage (PL 97-140)	1981	Authorized the storage of as much as 200,000 acre-feet of SJC Project water in Abiquiu Reservoir.
PL 100-522	1988	Authorized the storage of as much as 200,000 acre-feet of Rio Grande Basin water in Abiquiu Reservoir instead of SJC Project water if space is available.
Wild and Scenic River Designations (PL 100-633)	1988	Designated three reaches of the Rio Chama upstream from Abiquiu Reservoir as wild and scenic river with recreational purposes.

Table 2: Legislative history of authorization and operations for reservoirs in the Rio Grande
Reprinted from Langman & Anderholm, 2004

The primary and overarching legal constraint for the RCFP is the Rio Grande Compact of 1938 (the Compact), which is a binding legal contract between the states of Colorado, New Mexico, and Texas. The Compact is the federal, legal framework for determining the equitable apportionment of the streamflow of the Rio Grande (Langman & Anderholm, 2004). By being a signatory of the Compact, New Mexico is obligated to delivery certain quantities of water to Texas, the downstream state. Therefore, the Compact, particularly Article VII and VIII of the Compact, is the primary determinant for water management on the Rio Grande and Rio Chama. Article VII of the Compact prohibits upstream storage for downstream use in New Mexico when there is insufficient storage in Elephant Butte Reservoir (Benson, Llewellyn, Morrison, & Stone, 2014). Therefore, Article VII is in effect during drought times, when water storage higher up in the system would be beneficial to ecological systems (Benson et al., 2014). Based on New Mexico's status within the Compact (i.e. credit or debit), it will determine the flexibility of water management within the Rio Grande basin. However, even with the Compact in place, it can still allow for the water to be moved through the system to create the best ecological benefits, especially with a more flexible approach to Article VII under the Compact. There should not be a conflict if water that is already going to be moved under Compact compliance can be done in a way that also promotes ecological benefits. Furthermore, changes to the Compact can be made by the U.S. Congress after a negotiation between the signatory states, but to do so would be a monumental challenge and it is unclear whether changes are necessary to implement the Project's management objectives.

Federal and state regulations of dam operations are the next significant legal constraints to be considered. Many of the regulations on dam operations involve delineating the conditions for storage in the reservoirs, which were previously discussed in Section 1. One of the most important aspects of dam operation regulations is the designation between native and SJC Project water. By having two distinct sources of water in the same river, it makes water management more complicated. Nonetheless, both types of water need to move through the system, albeit under different restrictions, and having both types of water has allowed more water in the system then historically before, which can lead to the establishment of environmental flows. A more flexible management of the reservoirs by Reclamation and USACE would create the greatest chance at improving the Rio Chama's system dynamics.

The Wild and Scenic designation is another federal legal constraint within the Rio Chama system. Approximately 21.6 miles of the Rio Chama were designated Wild and about 3 miles were designated Scenic in 1988 under the Wild and Scenic Rivers Act of 1969 (USDA Forest Service, USDI Bureau of Land Management, & US Army Corps of Engineers [USDA], 1990). By being designated a Wild and Scenic River, it imposes certain legal obligations and standards onto the stretch of river that must be adhered to. Through the designation, a corridor was established, from El Vado Ranch boat launch site to just below Big Eddy boat ramp, to be jointly managed by the Secretaries of the Interior and Agriculture, along with the Secretary of the Army on the lower segment due to the USACE's need to manage Abiquiu Reservoir for flood control purposes (USDA, 1990). A management plan was developed in 1990 for the Wild and Scenic section of the Rio Chama and signed by the three managing parties; however, the plan is outdated. The BLM is currently working on a revision. Due to the designation, the Rio Chama corridor must be managed in accordance with the legislation, but enhancing the ecological benefits in and around the river through flow recommendations can only positively serve the corridor and reaffirm its designation.

The other legal constraints that should be considered include: New Mexico state laws governing water administration, Clean Water Act, and the National Environmental Policy Act. Fortunately, there are no currently endangered species on the Rio Chama, which means the Endangered Species Act (ESA) does not have to be engaged. However, the majority of stakeholders on the Rio Chama are also stakeholders in the MRG, which has extensive involvement with ESA legislation; therefore, effectively bringing together stakeholders on the Rio Chama, absent ESA requirements, might allow for better collaboration in the MRG where the stakes are much higher.

Common Adaptive Management Challenges in Literature

There has been a large amount of literature critiquing the implementation of AM by federal agencies and collaborative groups alike (Williams & Brown, 2014). Overall, implementation of AM has been difficult and many programs practice AM in name only or some variant of trial and error management (Allen & Gunderson, 2011; Gunderson & Light, 2006). Allen and Gunderson (2011) outline nine common challenges in AM, which are repeated sources of failure and substantiated by other sources of AM literature. The common challenges include lack of stakeholder engagement, developing experiments over large scales, surprises not being reincorporated back into an AM plan, not having the flexibility to update or change management objectives, spending too much time on the process and not implementation, agencies using AM to placate stakeholders, doing small experiments instead of the critical management objective, lack of leadership or direction, and monitoring and its associated costs. The shortfalls of AM will be discussed below using peer-reviewed literature with some examples from other AM projects. Also, the capability for the RCFP to develop and implement a successful AM plan is based off the determination of the RCFP's capacity and how it relates to the common challenges present in AM literature.

Challenge 1: Lack of Stakeholder Engagement

One of the main criticisms of AM is the lack of stakeholder engagement. According to DOI's *Adaptive Management Technical Guide* (2009), the first step in the set-up phase of developing an AM plan is creating stakeholder involvement. Stakeholder involvement is important in AM design because "stakeholders assess the resource problem and reach agreement about its scope, objectives, and potential management actions, recognizing that differences in opinion about system responses may exist even when there is consensus on these issues" (Williams et al., 2009). Not involving stakeholders from the beginning of developing an AM plan could lead to stakeholders rejecting results that are not in line with their existing expectations of the system, withholding support for the project, or mounting legal challenges (Williams & Brown, 2014). For example, the Glen Canyon AM Working Group charter does not specifically outline all the stakeholders to be involved and leaves it up to the Secretary of the Interior to include parties based on his or her discretion (Susskind, Camacho, & Schenk, 2010). This has led to the stakeholder engagement process to not be transparent or complete, which could greatly affect the validity of the project (Susskind et al., 2010).

The first challenge of a lack of stakeholder engagement is not present in the RCFP. The RCFP has actively engaged its various stakeholders and is constantly trying to bring more into the Project in order to allow for all perspectives on how water management on the Rio Chama can lead to the most benefits. However, there are not currently any stakeholders representing large landowners in the MRG.

Challenge 2: Developing Experiments over Large Scales

Developing experiments, especially over large systems, can be extremely difficult, which is another shortcoming of AM. Large ecosystems typically have large and complex governance structures making the cross jurisdictional nature of projects difficult to maneuver (Allen & Gunderson, 2011). During several case studies conducted by Allan and Curtis (2005), they found a large sense of the need for control among the agencies involved and other stakeholders. By trying to maintain control through hierarchies, this encouraged a narrow focus to develop and compartmentalization, which prevents collaboration and the holistic thinking required for AM (Allan & Curtis, 2005). Also, there is a tendency among scientists to overstate their ability to measure complex functional relationships in large scale systems (Gregory, Ohlson, & Arvai, 2006) In addition to the institutional and ecological complexities created by large scale experiments, opportunity and monitoring costs become exorbitant, especially in the long-run (McLain & Lee, 1996).

The RCFP exists over a relatively smaller scale at 31 miles and is a tributary to the main river system of New Mexico, the Rio Grande. Also the Rio Chama has many of the same stakeholders as the MRG and is absent ESA legislation, which provides an excellent test case for the larger Rio Grande system. Since there are several federal and state agencies involved in the management of the Rio Chama, it could lead to a high level of control by these agencies; however, by having a separate entity like the RCFP, it allows for more trust to be built.

Challenge 3: Surprises not being Reincorporated back into the AM Process

Surprises not being incorporated into the AM process can lead to failure. A surprise can “come in the form of a natural disaster, or as a departure from anticipated human behaviors, or from other sources” (Allen & Gunderson, 2011). When surprises occur, one can learn more from it than if the outcome were predicted by it not conforming to our expectations (Melis, Walters, & Korman, 2015); however, due to human dislike of uncertainty, surprises are usually not reincorporated into the existing AM plan. Previous Secretary of the Interior, Bruce Babbit, commonly referred to "no surprises" when implementing new management policies, illustrating institutional dislike for uncertainty and a policy of suppressing it (Stankey, Clark, & Bormann, 2005). For example, in the Platte River, their habitat restoration along the river, led to the colonization of an invasive reed. There were no management actions outlined in the AM plan for such an occurrence; therefore, some argued to just eradicate the reeds and then continue on with the original plan, but, instead, the management of the invasive reed was incorporated into the AM plan by updating management objectives (Allen & Gunderson, 2011).

Not incorporating surprise into the AM framework is another challenge that many programs face. Another benefit of having the RCFP as a separate entity outside the agencies involved on the Rio Chama, allows for more flexibility in adhering to the AM framework. Since the RCFP is not subject to the same regulations and mandates that agencies are, surprise are less likely to be suppressed. Also the RCFP is not held to the same level of accountability as government agencies; therefore, the RCFP does not have the same aversion to surprises and failures. In addition, it was a "surprise" emergency release of water in 2009 that provided the momentum for the RCFP to get started.

Challenge 4: Not Having the Flexibility to Update or Change Management Objectives

Having the flexibility to update or change management goals throughout the process is essential. When new outcomes come from experiments or during the management process, the new knowledge can either be noted and filed away or rewritten into the AM plan as in the Platte River invasive reed example (Allen & Gunderson, 2011). When the AM process is too fragile either in the stakeholder network or internal organization, it can lead to a lack of flexibility by not wanting to change the management objectives or prescriptions when things occur outside the original plan (Allen & Gunderson, 2011). For AM decision-making a transition from traditional "command and control" tactics to a more collaborative, risk-tolerance, and flexible structure is needed (Williams & Brown, 2014). Therefore, a good AM plan should become obsolete over the plan's time period, indicating new knowledge generation and the group's ability to continually rewrite and adapt the plan throughout the process to include all changes learned within the system (Allen & Gunderson, 2011).

The RCFP has the ability to reincorporate what has been learned back into the AM plan, which is a challenge for other projects. The RCFP does not operate under a "command and control" structure, but is more flexible and less risk averse. Since the BOR would actually be the one to carry out the RCFP's management objectives, the BOR has also expressed their ability to take the expertise of the RCFP and reincorporate that into future operations as long as the water users or water contractors agree.

Challenge 5: Spending Too Much Time on the Process not on Implementation

Spending too much time and resources devoted to the process and not towards implementation is a common mistake. Many can argue for more science during the process of developing an AM plan; however, this can be a common stalling technique and at some point the group will need to push through to the action phase because if all things are known about the system then AM becomes obsolete (Allen & Gunderson, 2011). Moir and Block (2001) argue that most land-management agencies spend a majority of their time, energy, and money on the planning stage of AM development. For over a decade, the Everglades have been planning management actions through numerous workshops and pilot programs, but hypotheses testing is yet to occur; "Everglades management continues to focus on planning and seeking spurious certitude prior to action, rather than confronting the unknowns of such a complex and dynamic system" (Gunderson & Light, 2006).

Many projects implementing AM have spent a majority of their time on the planning phase instead of on implementation. The RCFP has not encountered that challenge because they have yet to actually develop a formal AM plan. Even though a formal AM plan has not been developed, each year since the Project's formation, the Project has had open dialogue with the BOR, and the BOR has taken the Project's environmental flow recommendations into account when determining the year's operating plan. Therefore, a more formal AM plan is needed to go back and fill in steps that have been put aside to allow for better implementation of management objectives in the future.

Challenge 6: Agencies using Adaptive Management to Placate Stakeholders

It is easy for agencies to suggest that they are using AM to placate stakeholders, but continuing business as usual (Allen & Gunderson, 2011). If learning is not used to improve management or modify policy, then a central feature of AM is not being utilized. Therefore, incorporating what has been learned is vital for the success of any AM plan; however, sometimes if the management action that is needed is too politically, economically, or logistically difficult it can end up being ignored (Gregory et al, 2006). Upper-level managers and bureaucrats tend to be attracted to AM because it allows them to postpone difficult decisions that need to be made due to resource constraints and scientific uncertainty (Gregory et al., 2006).

The challenge of agencies using AM only in name while continuing business as usual has not occurred thus far on the Rio Chama because AM has not been formally adopted; therefore, currently, stakeholders are not expecting AM to be actively engaged.

Challenge 7: Doing Small Experiments Instead of the Critical Management Objective

In some instances, small management experiments can be continually undertaken instead of the critical, controversial management objective. This can occur due to decision makers' strong aversion to risk (McLain & Lee, 1996). Allen and Gunderson (2011) argue that endangered species management often falls into this category, in which case AM should probably have never been employed if the risk is too high. If the results from a "worst case scenario" is unacceptable to stakeholders or decision makers then an alternate management strategy should be used (Williams et al., 2009). Active approaches to AM also involve greater risks, especially to sensitive species, which is a reason why agencies practice diluted forms of AM (Gregory et al., 2006).

The RCFP is not conducting small management experiments instead of the larger, main management objective because, once again, the flow recommendations have not been formalized in an AM framework. However, a large pulse flow of approximately 4,000 cfs occurred in May 2016, which is a substantial flow experiment for the Rio Chama. Also, some of the decision makers and stakeholders on the Rio Chama remain averse to risk. A potential risk on the Rio Chama is damage to infrastructure if the flows exceed 6,000 cfs, but the flow recommendations include peak flows that are approximately 6,000 cfs. Therefore, the likelihood of the BOR conducting flow recommendations at that volume is low because of the potential negative effects it would cause.

Challenge 8: Lack of Leadership or Direction

Another common pitfall in AM planning is a lack of leadership or direction. Stakeholders should not be decision makers, but this often happens if a stakeholder group or an individual is particularly outspoken, they can hijack the process (Allen & Gunderson, 2011). Furthermore, group decision-making is least successful when unaided (Irwin & Kennedy, 2008). Therefore, a structured decision-making process with acknowledged direction allows for complex decisions to be made by groups of people, including experts and lay persons alike (Irwin & Kennedy, 2008).

An AM plan for the Rio Chama would not lack leadership because that is the role that the RFCP plays. Since the RCFP is outside of the agencies involved on the Rio Chama and represents all the stakeholders, it allows for better stakeholder engagement and does not allow one group or stakeholder to hijack the process.

Challenge 9: Monitoring and its Associate Costs

Monitoring is commonly listed at one of the greatest challenges to successful AM implementation. Monitoring can be very expensive and it is difficult to achieve adequate funding (Moir & Block, 2001). Not only can monitoring be expensive, but it also takes a large institutional commitment to follow through with the necessary monitoring and evaluation needed for AM (Williams & Brown, 2013). Benson and Stone (2013) found, in a study that surveyed AM practitioners in the United States, that 53.2% of those surveyed "strongly disagreed" that monitoring efforts are adequately funded. However, when asked whether they agreed if once monitoring was conducted that the results were reintegrated into the AM decision-making process, 30.4% responded that they "somewhat agreed" and 23.9% answered that they "agree very much" (Benson & Stone, 2013). If adequately funded, monitoring can be used in the manner in which AM intended it to be.

The RCFP has also experienced a challenge with securing adequate funds to conduct effective monitoring on the Rio Chama. In addition, the RCFP does not have current monitoring protocols established, which will need to be done in order to achieve the monitoring condition of AM. Although the RCFP is lacking adequate funding for monitoring, there has been limited monitoring efforts conducted by RCFP Technical Group members and University of New Mexico students. Monitoring is definitely the greatest challenge for the RCFP.

Due to the common challenges that many AM plans share, there are high chances of failure in the AM process. However, by maintaining the primary objectives of using AM then many of the challenges will be overcome. Recognizing uncertainty is central to an AM plan; therefore, "rather than assume uncertainty away or use it to preclude management actions, adaptive management can help foster resilience and flexibility to deal with an uncertain future" (Allen & Gunderson, 2011). The structured, iterative process of AM is what can reduce uncertainty over time, which fosters learning. Since the RCFP is not faced with many of the common challenges to developing and implementing an AM plan, a formal AM plan for the Rio Chama is more likely to be successful. However, the RCFP will have to overcome the challenge of monitoring and its associated costs by securing adequate funding, which in itself is also a difficult task. It is important to note where potential challenges could arise and how best to avoid them in order for the RCFP's management objectives to be effectively engaged on the Rio Chama.

Examples of Similar Western Adaptive Management Projects

Since the DOI has adopted the use of AM for some of their projects, BOR has also moved forward with incorporating AM into their management strategy. Many of the BOR's western projects use AM, including the Glen Canyon Dam and the Platte River. It is useful to analyze other BOR projects that embrace AM because the BOR plays a vital role in the Rio Chama. Also, if BOR formally adopts an AM plan for the Rio Chama, which is a possibility that would be welcome, then determining how AM was used in other BOR projects would provide needed background information. Some aspects of AM implementation in these projects have been deemed successful, while other aspects could be improved upon. Several articles outline the success and failures of the use of AM in the Glen Canyon Dam and the Platte River projects. It is important to review the analysis of these projects due to the similarities they have with the Rio Chama and to identify key strategies that can be used to create an AM plan for the Rio Chama.

The Glen Canyon Dam Adaptive Management Program began in 1997 to manage the Colorado River through Glen Canyon National Recreation Area and Grand Canyon National Park (Melis et al., 2015). The BOR operates the Glen Canyon Dam mainly for water deliveries for water users downstream. Following the construction of the dam in 1963, flows through the Grand Canyon were drastically modified, which ultimately led to a change in the ecological dynamics. Since 1996, managed experiments on the river have included high flow treatments, modified low fluctuating flows, low summer steady flows, fall steady flows, and trout management flows (Melis et al., 2015). The Adaptive Management Program (AMP) evaluates the experiments done on the river through monitoring and research, which they then use to make recommendations to the DOI for future experiments (Melis et al., 2015).

Part of the set-up phase of creating an AM plan is bringing scientists and mangers together to create an ecosystem model to characterize how the system is believed to operate and how it will respond to various management actions (Williams et al., 2009). The AMP along with the Grand Canyon Monitoring and Research Center created the Grand Canyon Ecosystem Model, which has had some shortcomings. However, Melis et al. (2015) argue that the development of the model "increased understanding about the value of consistent monitoring in areas where data were either previously missing or not adequate to resolve uncertainties". Consistent monitoring led to an increased understanding of the system's uncertainty and demonstrated the success the AM process had in terms of their ability to create a practical ecosystem model.

On the other hand, the Glen Canyon Dam AMP is not immune to criticism. According to an article by Susskind et al. (2010), they argue that despite the concerted efforts and flow modification experiments done in the canyon, the ecosystem within the canyon is still at risk. Susskind et al. (2010) maintain that the post-dam, highly modified ecosystem that the AM plan is trying to repair still remains based on the population of a native fish, the humpback chub that thrives in warm, sediment-rich waters, is still not rebounding to the abundancies land managers would prefer. The Fish and Wildlife Service have found the chub population to be increasing, but without a stronger commitment by the AMP to continue high-flow experiments and to adopt an overall modified flow regime, the increasing numbers of the chub may not be maintained (Susskind et al., 2010).

Overall, it can be argued that the Glen Canyon AM plan has accomplished both successes and failures in the eyes of scholars reviewing the program through more examples then presented. One way to ameliorate some of the failures is to spend more upfront time considering the longer term effects of management actions. Moir and Block (2001) argue that the "limiting 'and then what?' demands an answer, especially from reluctant senior management, as part of up-front monitoring design." Recognition of the slower, longer cycles in ecosystem dynamics is also vital to insuring complete follow through of management objectives, which the Glen Canyon Dam AMP could have done a better job at doing (Moir & Block, 2001).

The Platte River Recovery Implementation Program (the Program) began in 2007 as a joint effort between Colorado, Nebraska, Wyoming, DOI, water users, and conservation groups to address issues of endangered species and habitat loss along the river using AM as the scientific framework (Smith, 2011). Negotiations for the AM plan began in 1997 in response to the Federal Energy Regulatory Commission's conditional relicensing of the Kingsley Dam on the North Platte River (Smith, 2011). Historic use of the river, including water deliveries and land use changes, created severe alterations to the natural ecosystem and lead to four endangered species (Smith, 2011). In order to remedy the declining habitat and endangered species, the Program adopted a proactive restoration approach, including AM.

The governance structure developed for the Program is very different than in other federally funded AM plans. In other projects, the main decision maker is typically the DOI or the representatives from the states that are involved. In the Platte River Program, the decision makers are outside federal or state agencies and even the other stakeholders, i.e. water users and conservations groups (Smith, 2011). This has allowed a higher level of trust among the stakeholders and developed more independence and less bias from the decision makers, which is one of the main challenges that Allen and Gunderson (2011) advocated against (Smith, 2011). The stakeholders then become voting members of the policy body, which is also not typical to have conservation groups and local water users so integrated into the management structure (Smith, 2011). The governance structure is one of the examples of positive implementation of AM; however, which stakeholders to include in the Program is unclear.

Another strength of the Platte River Program is their development of conceptual models. The Program created many models to illustrate how the system functions, which they plan to continually revise as they test the hypotheses laid out in their management plan (Platte River Recovery Implementation Program, 2006). Individual conceptual models were created for the four endangered species, physical processes, and other system functions. Through the development of their models, clear and descriptive hypotheses were created, 42 in total; however, having 42 testable hypotheses is not practical because that many are impossible to test over a normal policy timeline (Smith, 2011). Additionally, the well-constructed conceptual models have allowed for detailed monitoring and data collection protocols to also be developed, which is typically a weak point in many AM plans.

Overall, the Platte River Program created a very robust AM plan, but to move into actual implementation of the plan is another challenge (Smith, 2011). Since the Program's inception, they have made serious headway on their management goals and completed annual monitoring to continually inform the management objectives. It seems as though the Program's AM plan is very comprehensive and a good model to base other AM plans off of due to their unique governance structure and strong development of conceptual models.

Both the Glen Canyon and Platte River examples of AM provide beneficial and cautionary takeaways. It is important to review how other projects develop and implement AM plans in order to provide guidance for the best AM plan for the Rio Chama. Other AM projects can be analyzed in terms of the common challenges identified by Allen and Gunderson (2011) and corroborated by other literature on AM so they can be avoided. Both Glen Canyon and Platte River establish separate positions and organizations within their structure to share the various responsibilities and tasks needed to manage large projects, including a decision making body, scientific body, and independent review panels. The governance structures developed by the two projects provide good examples for the RCFP and how they can develop their governance structure. It is helpful to divide the responsibilities into the different organizations to create functional redundancy, which helps build adaptive capacity within the system. On the other hand, both the Glen Canyon Dam and Platte River have Congressional authorization and very large sources of funding, which enable the two projects to have extensive monitoring and access to a variety of resources. The RCFP is not in the same position in terms of funding as the other two projects, making the RCFP's ability to conduct adequate monitoring a significant challenge. Overall, through literature on AM and the examples of the Glen Canyon and the Platte River, they can help the RCFP build an effective AM plan and program that can become one of the AM successes.

Conclusions

By following the decision key developed in DOI's *Adaptive Management Technical Guide* (2009), all the basic conditions have been met and adaptive management would be appropriate for the RCFP, although the condition of monitoring and securing adequate funding does need further attention for AM to be successful for this Project. Also by comparing what the RCFP has in terms of AM with the common challenges introduced in the literature review, it seems as though the RCFP has and can avoid most of the them, again possibly not the challenge of monitoring. Therefore, if an AM plan for the RCFP is developed and implemented with the challenges developed by Allen and Gunderson (2011) in mind, there may be higher potential for success. Furthermore, the analysis of the RCFP through the decision key becomes more critical because it exposes areas that need improvement. Although the RCFP is weak in a couple of aspects, most notably monitoring, enough criteria have been met to move forward into developing a more formal management plan for the RCFP using AM. A more formal process of AM is required in order to maximize the benefits of any option for land and natural resource management and to achieve long-term objectives (Lessard, 1998). AM literature concerning the need to formalize AM is lacking because most AM projects or problems typically operate under the assumption that the AM framework will be engaged in a formal manner. Small AM projects not implemented through a state or federal agency, which have formal regulations to adhere to, have not been identified; therefore, using AM for the RCFP could be a first and the RCFP does not have institutional regulations that concern the formalization of its decision-making process. A discussion over formalizing the AM plan for the RCFP versus maintaining the current informal decision-making process would be lacking in current AM literature.

In order to formalize an AM plan for the RCFP, first, a more formal agreement will have to be made with the MRG water suppliers. Currently, the RCFP has been operating based on informal agreements that have been possible through the social capital within the system. Without certain people in their current positions, such as Rolf Schmidt-Petersen at the ISC, Carolyn Donnelly at BOR, and Dave Gensler and Mike Hamman at MRGCD, there might not be the ability to engage in environmental flows on the Rio Chama. Also, the social capital that has been built on the science side by using the expertise of Mark Stone, Mike Harvey, and Todd Caplan has also lead to the success of some of the Project's management objectives since the Project's establishment. Therefore, on the reverse side, if any of those involved with the Project and implementing the flow recommendations decided they no longer wanted to be a part of it, then the Project would be at a standstill. Therefore, a more formal arrangement is needed to capture what the social capital has built in order for it to continue if those involved were no longer in their current positions. By not formalizing the AM process, it leaves the RCFP vulnerable to the participation or lack of by stakeholders. However, the social capacity of the Rio Chama system will always play a role because it is the personal relationships that were built over time that gave the Project traction to begin with. New Mexico water management has greatly relied on personal relationships, so a more formal agreement for environmental flows on the Rio Chama will not change that dynamic and, hopefully, allow that dynamic to be translated to the MRG were most of the same stakeholders are engaged in higher stakes water management.

In order to formalize an agreement with the MRG suppliers an incentive might need to be offered. Most of the SJC Project contractors are cities that have ratepayers who pay for the water. The Rio Chama offers many benefits to the people who use the river and surrounding area for recreational purposes, i.e. boating, fishing, hiking, etc. Therefore, the cities have an incentive to move water on the Rio Chama to create the best ecological benefits because their ratepayers will be the people who most receive those benefits. Future work should be done to assess recreationalists' willingness to pay for ecosystem services within the Rio Chama basin through polling or other measures. Those results can then be used to incentivize cities to allow their water to be delivered to them in the most ecological beneficial way possible.

If a more formal management plan were created for environmental flows on the Rio Chama, BOR would be the best agency to carry it out because they are responsible for the releases from El Vado Reservoir. However, there would still need to be formal cooperation with the MRGCD because they are still one of the largest contractors of SJC Project water and are the owners of El Vado Reservoir. Ideally, BOR would be able to commit resources to the Rio Chama and funding to the RCFP to provide the expertise needed to inform the flow recommendations, similar to what they have done on the MRG. However, one of the biggest pieces that needs to be reconciled in order for the Project to move forward is, will the flow recommendations be carried out each year based on an AM plan or will flows always just be subject to what water is available regardless of what the flow recommendations prescribe for that year? Since the Project will never own the water needed to carry out the flow recommendations, it is important that an AM plan will be followed by all the stakeholders in order to fulfill the flow recommendations each year.

As Benson et al. (2014) asserted, the highly managed nature of the Rio Grande watershed through dam operations and other channelizing activities has led to a decline of the overall functional diversity and adaptive capacity of the river system; therefore, a new governance structure is needed to enhance the adaptive capacity needed to endure the system changes occurring. Engaging in AM is a way to improve system resilience on the Rio Chama. In addition, using AM literature and examples of AM plans and programs is helpful to understand common pitfalls and successes. Also, by analyzing what the RCFP currently has in terms of an AM plan, it is evident that AM is a good management choice for the Rio Chama to achieve higher ecological benefits for the river and its surrounding ecosystem. Creating a more formal arrangement between RCFP stakeholders would be the most effective way to successfully implement an AM plan for the Rio Chama.

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Appendix A

Adaptive Management Decision Key

1. Is some kind of management decision to be made?
   No – decision analysis and monitoring are unnecessary when no decision options exist.
   Yes – go to step 2.

2. Can stakeholders be engaged?
   No – without active stakeholder involvement an adaptive management process is unlikely to be effective.
   Yes – go to step 3.

3. Can management objective(s) be stated explicitly?)
   No – adaptive management is not possible if objectives are not identified.
   Yes – go to step 4.

4. Is decision making confounded by uncertainty about potential management impacts?
   No – in the absence of uncertainty adaptive management is not needed.
   Yes – go to step 5.

5. Can resource relationships and management impacts be represented in models?
   No – adaptive management cannot proceed without the predictions generated by models.
   Yes – go to step 6.

6. Can monitoring be designed to inform decision making?
   No – in the absence of targeted monitoring it is not possible to reduce uncertainty and improve management.
   Yes – go to step 7.

7. Can progress be measured in achieving management objectives?
   No – adaptive management is not feasible if progress in understanding and improving management is unrecognizable.
   Yes – go to step 8.

8. Can management actions be adjusted in response to what has been learned?
   No – adaptive management is not possible without the flexibility to adjust management strategies.
   Yes – go to step 9.

9. Does the whole process fit within the appropriate legal framework?
   No – adaptive management should not proceed absent full compliance with the relevant laws, regulations, and authorities.
   Yes – all of the basic conditions are met, and adaptive management is appropriate for this problem.

Adapted from Williams et al., 2009