Arizona Water Management Along the Adaptive Cycle: What can the ebb of water governance teach us about future flows?

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Abstract

The principal challenge for Arizona water managers is sustainable water use in light of the rapid population growth of its cities and the increasing competition for water both inside and outside of the state. If indeed "stationarity is dead" then what framework can water managers use to understand and anticipate change in these systems so critical for life? One useful framework could be adaptive management through a focus on resilience and the adaptive cycle. This paper seeks to explore both the utility of the adaptive cycle in understanding water governance in Arizona over the past 60 years, and examine what types of governance create more adaptive systems of water resource management. To investigate the applicability of these concepts two questions are asked: 1) How does the history of Arizona's water governance follow the adaptive cycle? And 2) Assuming that Arizona is moving into an α (reorganization) phase what can theoretical and empirical studies teach us about how water governance in Arizona might become more adaptive as it reorganizes? The answers to these questions are explored through a discussion of how Arizona water governance has followed the adaptive cycle; a review of theories of adaptive management for water management and social ecological systems; and an examination of how theories of adaptive management currently are used in Arizona and how these theories might guide future changes to water governance.

Introduction

In 2008 Milly et al. proclaimed that “stationarity is dead and should no longer serve as a central default assumption in water-resource risk assessment and planning.” The old paradigm of stationarity, which maintains that natural systems fluctuate within a well defined set of parameters, has been a tenet of water management for decades. This paradigm simply does not hold in the face anthropocentric modification to the water cycle and water supply though climate change. If the “old ways” no longer apply, then what framework can water managers use to try to understand and anticipate change in these systems so critical for life? One useful framework, and the focus of this paper, is adaptive management through a focus on resilience and the adaptive cycle.

The adaptive cycle posits that most natural systems move through four reoccurring cycles: rapid growth, conservation, release and reorganization (Gunderson and Holling, 2002). As systems move along the adaptive cycle they gain and loose connectivity, capacity and resilience to disturbance. (Figure 1) Even though these systems move along a cycle, their future state may not resemble their past because systems can “flip” into entirely new regimes, which may or may not be desirable to the humans that depend upon them. (Holling, 1973) Furthermore, adaptive cycle theory recognizes the importance of scale and the ability of processes at smaller scales to influence and indeed in some cases topple those at a larger scale. The capacity of a system to maintain its original state is a measure of its resilience to both ex-

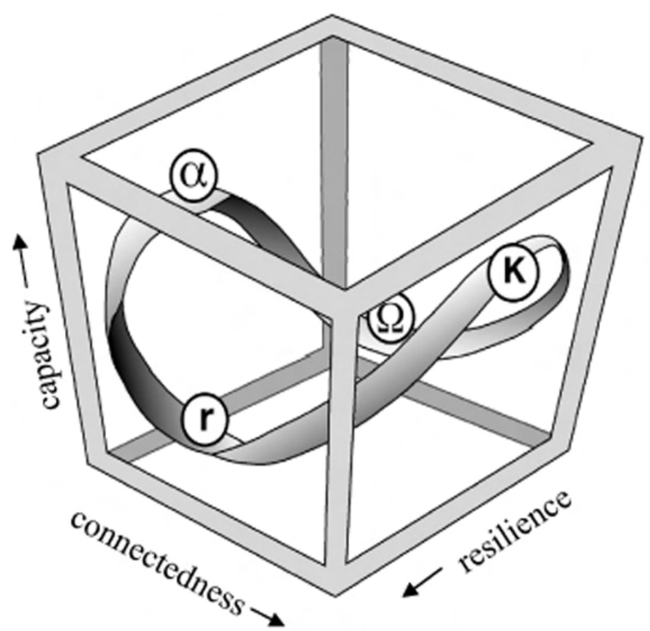

Figure 1 Adaptive Management Cycle in three dimensions showing capacity, connectedness and resilience. Source: Holling and Gunderson, 2002

ternal and internal change.

Adaptive cycle theory was originally applied to ecological systems, but it also is increasingly applied to social-ecological systems (SES), which emphasize the integration of humans into natural systems. SES is based on the concept that the delineation between an ecosystem and a social system is arbitrary and human and ecological systems have significant feedbacks between them. (Berkes and Folke, 1998). Understanding the adaptive cycle may help build the resiliency of SES and may increase the capacity of managers to anticipate and respond to unexpected changes (Folke et al., 2005). This field of study is increasingly important because how people respond to change and how society reorganizes following change are the most neglected and the least understood aspects of resource management and science (Holling and Gunderson, 2002).

In addition to understanding the applicability of the adaptive cycle and the importance of resiliency, there is an increasing focus among researchers on governance. This approach is useful because governance encompasses the entire range of institutions and relationships that affect a SES (Pierre and Peters, 2000) and allows the researcher to examine the full complexity of regulatory processes and their interaction (Pahl-Wostl, 2009).

This paper seeks to explore both the utility of the adaptive cycle in understanding water governance in Arizona over the past 60 years, and examine what types of governance create more adaptive systems of water resource management. Governance, as opposed to institutions alone, is used as the framework in this analysis because the interactions between the many actors and policies involved in Arizona water management cannot be fully understood by examining only institutions. To investigate the utility of the adaptive cycle and resilience in the understanding of Arizona's past and future water management, two questions are asked:

- How does the history of Arizona's water governance follow the adaptive cycle?
- Assuming that Arizona is moving into an α (reorganization) phase what can theoretical and empirical studies teach us about how water governance in Arizona might become more adaptive as it reorganizes?

These questions will first be briefly put into context with short background on Arizona water management. I will then:

1) Discuss how Arizona water governance has followed the adaptive cycle
2) Review theories of adaptive management for water management and SES
3) Examine how theories of adaptive management currently are used in Arizona and how these theories might guide future changes to water governance.

Context and Scope

Arizona is a semi-arid state located in the southwestern United States with a 2010 census population of 6.4 million people. Arizona's most populous county, Maricopa, grew 24% between 2000 and 2010 (U.S. Census, 2011). The principal challenge for Arizona water managers is sustainable water use in light of the rapid population growth of its cities and increasing competition for water both within and outside of the state (Colby and Jacobs, 2007). While there is keen interest in finding the water to fuel future growth, this interest is increasingly tempered by the acknowledgement of the importance of Arizona's rivers and groundwater resources to the natural environment.

Arizona can be divided into three water resource provinces, basin and range lowlands, plateau uplands and central highlands. (Figure 2) Each of these provinces has groundwater supplies but the type and productivity of their aquifers is varied. Surface water supplies are not ubiquitous across the state and perennial supplies occur mostly at higher elevations and within the central highlands province. The renewable surface water supply in the state is largely developed, and there remains little opportunity for further enhancement of this supply. By far the most significant source of surface water for the state is the Colorado River, which runs across the northwestern portion of the state and then south forming the boundary with California. Metropolitan areas in the center of the state, Phoenix and Tucson, depend upon water from the Colorado that is pumped from the river to them via the Central Arizona Project (CAP) canal as well as other surface water supplies from in-state rivers. (Anderson et al, 2007) In 2006, 53% of the statewide water demand was met by surface water, 43% by groundwater and 3% by reclaimed wastewater (ADWR, 2010).

Figure 2 Arizona water resource provinces Source: ADWR 2010

Water governance in Arizona is not uniform and the degree of control that laws and policies have over water quantity in particular is varied. As a western state, all surface waters are subject to the doctrine of prior appropriation whereby the first in time to divert the waters is the first to receive their allocation. One constant throughout the state is a legal divide between surface water and groundwater, and only in select river systems are the hydrological links between the two recognized and incorporated into management. The largest metropolitan areas in Arizona are regulated by a relatively strict groundwater code that was established in 1980 and restricts groundwater pumping. This code sets a target for achieving "safe-yield" of the aquifers by 2025 through the use of renewable supplies and demand management. There are five of these areas, called Active Management

Figure 3: Groundwater Basins and Planning Areas of Arizona. Active Management Areas are in yellow.
Source: ADWR, 2010

Areas (AMAs) in the state (Prescott, Phoenix, Pinal, Tucson and Santa Cruz). (See Figure 3) Outside of the AMAs, groundwater may be pumped according to the beneficial use doctrine whereby any amount of water may be extracted, regardless of the hydrologic effects, provided that the water is put to a beneficial use such as domestic, agricultural or industrial uses.

Over the past 60 years most of the focus of water resource governance in Arizona has been on the AMAs because they were the areas with the most vulnerability. For this reason the focus of this paper and analysis also will be on the water resource management of the state's AMAs. Although this paper will focus on the AMAs, it is important to recognize that the adaptive-cycle dynamics of a system at a state level are influenced by the adaptive-cycle dynamics of linked systems at finer (a groundwater basin) and broader (a nation) scale. (Holling and Gunderson, 2002). For example, shortage on the larger Colorado River Basin system will impact water management within the AMAs that depend upon CAP water. The smaller scale management issues at the AMA or groundwater basin level can also influence management at a larger level, such as the state, where competition for inter-basin transfers of water can influence statewide water management (See Figure 4)

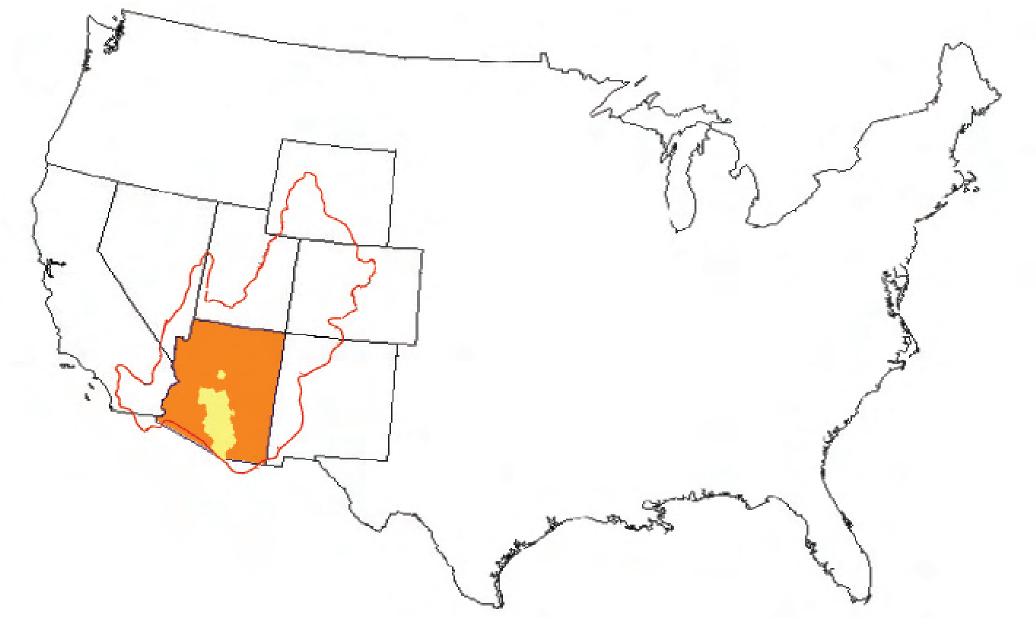

Figure 4 Panarchy in Arizona water governance. Events and processes at the national scale can affect those at the Colorado River Basin scale (red) which can in turn influence those at the state (orange) and AMA (yellow) scales. Smaller scales, such as the AMA, can also impact larger scales such as the Colorado River Basin.

Arizona Water Governance along the Adaptive Cycle

Phases of the Adaptive Cycle

The adaptive cycle has four phases: exploitation (r), conservation (K), release (Ω) and reorganization (α). (Figure 5) In the r phase growth is rapid, resilience to disturbance is high and competition is great. In an r phase the ideas and organizations that developed most rapidly and are most aggressive are those that will persist. It is a time with many start-up organizations and ideas that have "intense activity energized by a pioneers spirit and opened opportunity." (Holling and Gunderson, 2002) The r phase shifts to the K phase when its

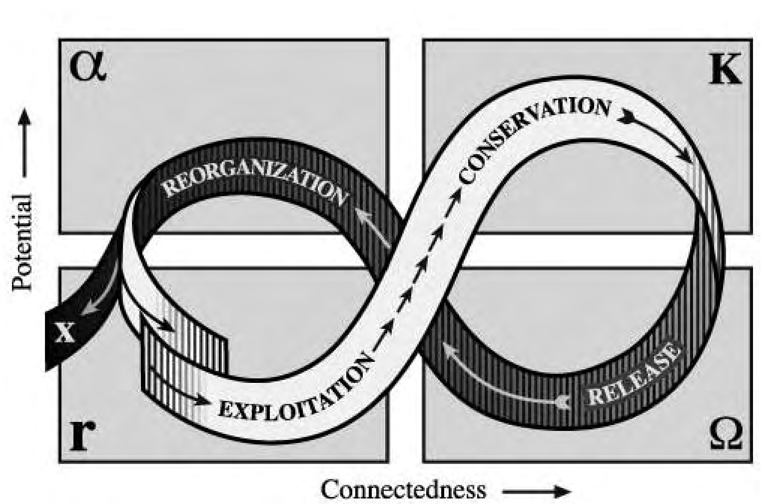

Figure 5: Adaptive cycle
Source: Holling and Gunderson, 2002

organizations and ideas consume ever increasing amounts of the available resources. These resources include human and social capital, financial resources and physical and architectural structures. During the K phase the connection between interrelated organizations and people increases and these connections control external variability in order to ensure their own continued expansion. The competitive edge shifts from those who can adapt the fastest (in the r phase) to those who are best at controlling variability and increasing the efficiency of the existing system, or in bounded systems to those who are most adept at controlling system dynamics themselves. However, this increase in efficiency decreases resilience and makes the system more vulnerable to unexpected events. During a K phase organizations frequently become more bureaucratic, rigid and internally focused, losing the perspective of the world outside the organization. (Holling and Gunderson, 2002) Taken together the r and K phases are considered the fore-loop of the adaptive cycle and are generally occur over the span of years to decades.

The rigidity created by the K phase makes the system very vulnerable to collapse events. In many cases these events would have barely disturbed the system during the r phase but because of the system's connectedness and rigidity a crisis occurs. After the collapse, the Ω phase begins and the capital in the system is released. During this phase the workforce is reduced in an effort to reduce costs, and restructuring begins. As a consequence of this, the system's potential temporarily plummets. After the Ω phase and in the α phase there are fewer resources within the system because the capital has been released. However, the released capital may decide to come together in another form, which can result in novel and unpredictable renewal. As stated by Holling and Gunderson (2002): "It is the time when accidental events can freeze the direction for the future." During the α phase there is low connectedness, high resilience and the resources' potential is more freely available then during the K phase. The Ω and α phases are the back-loop of the adaptive cycle and can progress very rapidly.

First K Phase (1948 – 1977)

I will focus on water governance in the past 60 years although there are many other eras in the history of water governance in the Arizona that we could use to illustrate the adaptive cycle. Sixty years ago Arizona was in a late r phase and moving into a K phase. (See Table 1) In the late 1940s, water was managed by local entities and water governance efforts were focused on finding a way to move Colorado River water from the state's western margin to its center. In 1948, a final feasibility study for the canal from

Table 1: Time line and examples of key events for Arizona water governance in the AMAs along the adaptive cycle

Year	Phase	Event
1948	K	Critical Area Groundwater Code passed
		Final Feasibility Study for the canal from Colorado River to central Arizona approved
1963		*Arizona v. California* decided
1968		Colorado River Basin Project Act passed
1971		Establishment of the Central Arizona Water Conservation District
1973		Construction of the Central Arizona Project canal begins
1977		President Carter begins campaign against western water projects
		Groundwater Management Study Commission formed to develop comprehensive groundwater code.
1979	Ω	Secretary of Interior will not give final approval to CAP without groundwater management reform
		Jarvis v. State Land Department III and *Farmers Investment Company v. Bettway* determine that groundwater may not be transported "off the land"
1980	α	Groundwater Management Act (GMA) passed
		Arizona Department of Water Resources formed
1982	r	*Town of Chino Valley v. City of Prescott* and *Cherry v. Stiener* challenge GMA and fail
1985		CAP deliveries begin in Phoenix
		First management plans for the AMAs are completed
1991		CAWCD funds underground recharge and storage of water through tax monies
		Second management plans for the AMAs are completed
1993		CAP deliveries begin in Tucson
		Central Arizona Groundwater Replenishment District is formed
1995		Rules established for the Assured Water Supply Program
1996		Arizona Water Banking Authority established
1999		Third management plans for the AMAs completed
2000	K	Governor's Water Management Commission formed
2000		Gallons Per Capita per Day program challenged and not implemented
2005		Attempts to form a new AMA in the Upper San Pedro fail
2009	Ω	Arizona Water Institute cut
		ADWR budget cut, is backfilled with funding from the Arizona Water Banking Authority
2010		ADWR cut again, outlying AMA offices close
2011	α?	Water Resources Development Commission forms

the Colorado River was approved and the Critical Area Groundwater Code was adopted. However, a stalemate occurred due to unresolved issues regarding the importation of Colorado River water and no action was taken until 1968 when the Colorado River Basin Project Act was passed (August and Gammage, 2007). By the mid 70s it was widely recognized that the Critical Area Groundwater Code was not effective in reducing groundwater mining and the populations of Phoenix and Tucson were increasingly seeing water level declines and subsidence (Jacobs and Holway, 2004).

Although the Colorado River canal was authorized in 1968, the federal government would not release funds for its planning and construction until a mechanism was developed to reimburse the federal government for the costs of the project. In 1971 this reimbursement mechanism was created through the establishment of Central Arizona Water Conservation District (CAWCD). This organization was initially responsible for overseeing the repayment of federal funds, but eventually became the umbrella organization that operated the Central Arizona Project (CAP) canal as well. Although the construction of the CAP canal had begun by 1973, the governance was narrowly focused on just one goal: bring Colorado River water to central Arizona. This narrow focus resulted in a system that was ripe for a disturbance and collapse, but supplanted by dynamics operating at different spatial (Colorado River Basin) and institutional (federal government) scales.

First Omega to Alpha Phase (1977-1980)

Although construction of the canal began at Lake Havasu in 1973, Arizona was not permitted access to all the necessary federal funds for the project at that time. In 1977 president Jimmy Carter began a campaign against 19 western water projects, threatening Arizona's interests. Also in 1977, the Groundwater Management Study Commission was formed to develop a comprehensive groundwater code, but two years later a code had yet to be proposed. Then, in October 1979, Secretary of the Interior Cecil Andrus informed Arizona that he would not issue final recommendations on CAP allocations until the state could demonstrate a greater commitment to controlling groundwater use. (August and Gammage, 2007) This crisis coincided with another crisis when a lawsuit was filed by an agricultural irrigator seeking to prevent cities and mines from transporting pumped groundwater away from the areas where it had been pumped (Jacobs and Holway, 2004). Because now both the CAP water and additional pumped groundwater supply was in jeopardy, rapid action was needed, creating the stimulus for major change in the way central Arizona managed its groundwater.

The release from the Ω phase reorganized and passed quickly through the α phase with the end result of a new groundwater management regime in central Arizona. This new governance structure began with the 1980 Groundwater Management Act (GMA). The GMA created a new statewide organization, the Arizona Department of Water Resources (ADWR), as well as the Active Management Areas (AMAs). The three primary goals of the GMA were to 1) control groundwater overdraft occurring in central Arizona, 2) facilitate the allocation of the state's limited groundwater resources in order to reflect the changing needs of Arizona and 3) to increase Arizona's groundwater supply through the development of additional water supplies. Although the definitions were slightly different for each AMA, the ultimate goal of the GMA was for each area to reach "safe-yield" of their aquifers by 2025. (Jacobs and Holway, 2004)

R Phase (1981-1999)

The creation of the GMA and the Arizona Department of Water Resources initiated an era of growth and innovation in water governance within the AMAs. Many new rules, policies and organizations were created during this r phase (See Table 1) including the first management plan for each of the AMAs in 1985. These management plans create the first framework, tailored to each AMA, for the areas to reduce groundwater overdraft and increase the use of renewable water supplies. In 1991, the CAWCD successfully initiates a tax to fund "demonstration sites" for underground recharge and storage of CAP water and effluent in order to further ameliorate groundwater overdraft and fully utilize the renewable water supplies available.

Two years later, in 1993, a new organization, under the umbrella of the CAWCD is formed called the Central Arizona Groundwater Replenishment District (CAGRD). The CAGRD was created to facilitate growth within the AMAs while also ensuring that the mandate of the use of renewable water supplies is met. By joining the CAGRD a municipality or subdivision could continue to pump a limited amount of groundwater and pay the CAGRD to replenish that groundwater demand with renewable supplies. This allowed areas that did not have an allocation of CAP water or other surface water supplies to grow, and paved the way for the 1995 adoption of the Assured Water Supply (AWS) rules. The AWS rules, required by the 1980 GMA, were first proposed in 1988 but subsequently withdrawn because of significant opposition from the municipal water demand sector (Holway, 2007).

By the mid-1990s the CAP canal was complete and renewable Colorado River water supplies were flowing to three of the five AMAs. Arizona's utilization of its Colorado River allocation had increased, but was not yet maximized and was less than most planners had originally expected. In 1996 the Arizona legislature created another organization, the Arizona Water Banking Authority (AWBA) to ensure that: the entire Colorado River allocation was utilized to buffer Arizona against future drought, support the settlement of Native American water rights claims and provide for interstate water banking to assist

Nevada and California (Megdal, 2007). The AWBA has been very successful in securing and storing water, with over 3.4 million acre feet of water stored through 2009 (AWBA, 2010). Alongside ADWR, CAWCD and the AWBA were many other groups and organizations working at varied scales in the AMAs during this time. Their roles were varied; some, such as the Arizona Legislature, served to create law regarding water management while others, such as municipal water providers, largely functioned as stakeholders in decision making since they were affected by the laws. (See Table 2)

Table 2: Examples of groups and organizations involved in Arizona water governance in the AMAs, 1980 -2010. This is not meant to be a comprehensive list and not all of the groups have been operating for the entire 30 year period.

Name	Geographic Scope	Type of Group
Agricultural Irrigation Districts	Throughout the AMAs	Non-Governmental Organization
Arizona Corporation Commission	Statewide	Public
Arizona Department of Environmental Quality	Statewide	Public
Arizona Department of Water Resources	Statewide	Public
Arizona Farm Bureau	Statewide	Non-governmental Organization
Arizona Legislature	Statewide	Publically Elected Body
Arizona State Lands Department	Statewide	Public
Arizona Water Association	Statewide	Trade Association
Arizona Water Banking Authority	Statewide	Public
Central Arizona Water Conservation District	Maricopa, Pinal and Pima Counties	Public
Groundwater Users Advisory Councils	One in each AMA	Volunteer group, appointed by the Governor
Homebuilders Association of Central Arizona	Maricopa County	Trade Association
Maricopa County Water Users Association	Maricopa County	Non-Governmental Organization
Morrison Institute	Statewide	University
Municipal Water Providers	Throughout the AMAs	Both Public and Private Utilities
Pima Association of Governments	Pima County	Public
Safe Yield Task Force	Tucson AMA	Volunteer group
United States Bureau of Land Management	Nationwide	Public
United States Bureau of Reclamation	Nationwide	Public
Water Resources Research Center	Statewide	University
Power Companies	Throughout the AMAs	Both Public and Private Utilities

Second K Phase (2000-2006)

With the establishment of the AWS rules in 1995, creation of the AWBA in 1996 and the completion of third management plan for the AMAs in 1999 central Arizona had achieved a relatively robust and complete water governance system. In 2000, Arizona Governor Jane Hull convened a Water Management Commission to review water management in central Arizona to date and to determine what steps were necessary for the future. In December 2001, the Commission released its findings determining that "[T]he goals and legal framework contained in the Groundwater Code are sound and should continue to guide water management decisions and investments in the State's five AMAs." (Arizona Governor's Water Management Commission, 2001) Included with this endorsement of the overall framework of water governance were recommendations for the improvement of code and its operations. To date most of these recommendations have not been implemented.

Another development signaling a conservation phase was weakening of the principal demand management programs within the AMAs. In 1990, Arizona Water Company, a private municipal water provider in Phoenix, filed suit against ADWR to prevent enforcement of the gallons per capita per day (GPCD) program for municipal providers, claiming that the GMA did not impose conservation measures on end users. (Arizona Water Company v. ADWR) This suit was not resolved until 2004. Even after the suit was settled, the program did not receive much attention from ADWR until 2008 when the Modified Non-Per Capita Conservation Program (Modified NPCCP) was initiated. The Modified NPCCP was a significant shift from the original GPCD program and only required enrollment from a limited number of water providers.

Also notable at this time is the absence of a fourth management plan for the AMAs. According to the GMA management plans should be prepared for each AMA in 10 year increments. The first plan (1980-1990) was released in 1985, the second in 1991 (1990-2000) and the third in 1999 (2000-2010). The management plans involve extensive stakeholder review and data analysis and generally are initiated long before the next management period begins. As of 2011 work on the fourth management plan has not begun. However, data analysis of water supply and demand for the five AMAs was completed for 4 of the 5 AMAs by 2011.   These failures are evidence of the increasing connectedness between interested parties and a decrease in potential of the system.

Second Omega to Alpha Phase (2009-Present)

In 2008, the entire United States entered into an economic recession. This downturn resulted in fewer financial resources for Arizona because its economy was largely dependent on growth and an expanding housing market, which was devastated by the recession. In addition, political change resulted in an anti-regulatory sentiment at the state capitol that was just the catalyst needed to propel an already overly connected and low potential water governance in central Arizona into an omega phase. Signs of the omega phase began in 2009 when an novel organization, Arizona Water Institute, that was designed to bring together expertise of the state's universities and state agencies to form innovative research agendas was closed and the first of two major cuts to the ADWR budget were made. The 2009 cuts to the ADWR budget also resulted in less capacity for the AWBA as the budget for ADWR was back-filled by monies from the AWBA (ABWA, 2010). In 2010, further cuts in ADWR's budget were made resulting the elimination of over 50% of the positions at the agency and the closing of all offices outside of Maricopa County.

Due to the loss of most of its human and financial capital, Arizona water governance is now in an α phase, a time when connectedness is low and potential is high. In this phase, we now must ask: what is the potential future for water governance in central Arizona? To answer this question, I will begin with a brief review of theory and empirical findings on adaptive management and resilient natural resource management systems and will then apply the theory to water governance in the AMAs.

Toward More Adaptive Management – Review of Theory and Empirical Findings

Holling and Gunderson (2002) note that the Ω and α phases of the adaptive cycle are a critical time, one in which great change and innovation may occur. To determine the keys to successful adaptive natural resource management of social-ecological systems a literature review was conducted through Web of Science as well as of key journals such as Ecology and Society and Water Resources Research. Search terms included "adaptive management" and "water" or "natural resources", "resilience" and "water governance" and "social ecological systems" and "adaptive management" or "resilience". This review resulted in five reoccurring themes in both the theory and empirical studies leading to more adaptive water, or natural resource, governance: public participation, social learning, polycentric governance, adequate capital and leadership. These five elements are interrelated the keys to their implementation and success often depend upon the presence of related elements. (See Figure 6) Other elements that were mentioned in a few papers that will

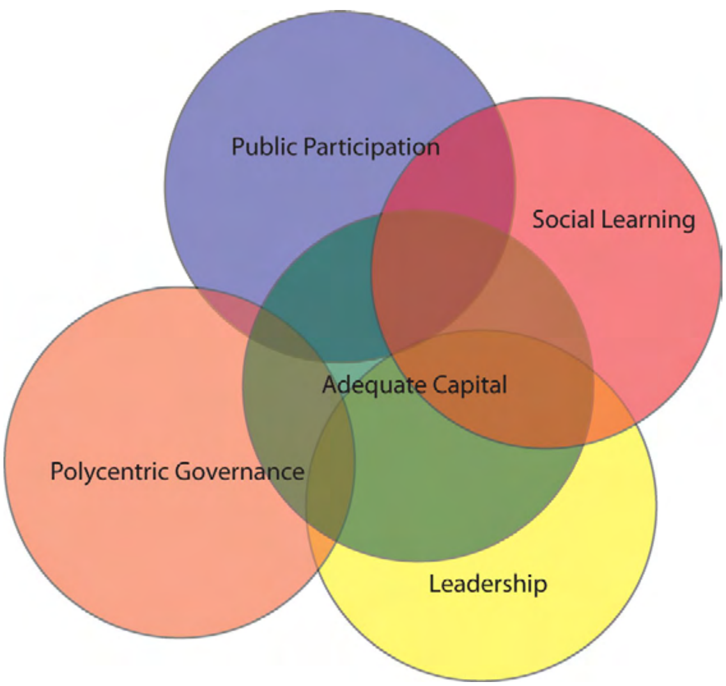

Figure 6: Elements of adaptive governance. Many of the elements are overlapping and interdependent. All elements depend to some degree on the presence of adequate capital.

not be discussed here but should not be disregarded are: an experimental approach to management, institutional memory, accountable authorities and a bioregional approach.

Public Participation

Perhaps the most frequently cited element for a more adaptive approach to natural resource management was the participation of a broad set of stakeholders in governance and decision making. (e.g., Pahl-Wostl, 2009; Lebel et al, 2006; Kumler and Lemos, 2008; Walker et al, 2006; Huitema et al, 2009; Folke et al, 2005) The continued involvement of stakeholders was found to build trust among groups, which thereby improved outcomes. For example, Lebel et al (2006) found through a review of four case studies that the capacity to build networks of trust through effective public participation was fundamental to the types of self-organizing collective action necessary to manage resilience and engender adaptive management. Furthermore, in several U.S. collaborative water-management projects, it was determined that collaborative approaches were better suited to diffuse the complex issues surrounding water management. These approaches, however, are only successful when the process reflects the concerns of all stakeholders and is not unilaterally determined by any one organization (Huitema et al, 2009)

Social Learning

Social learning is defined most simply as the process of learning through interactions, or where members of groups learn from one another (Kumler and Lemos, 2008). It has been identified in both theory and, to a lesser extent, practice as an essential element of adaptive management and more resilient water systems (Carpenter et al. 2001, Folke et al. 2005, Pahl-Wostl 2006, Pahl-Wostl et al. 2007) Social learning is closely related to and often occurs simultaneously with public participation and stakeholder processes. It is also important within the institutions that comprise a governance regime.

In a case study of the Paraiba do Sul River Basin in Brazil it was found that “There has been a synergistic relationship between social learning and Brazil’s water-reform hybrid governance institutions, in which social learning facilitated the implementation of the reform’s new institutions, which in turn enabled further learning in the context of the river basin committee’s decision-making process.” (Kumler and Lemos, 2008) According to the authors, this social learning enabled the newly formed institution to effectively adapt their governance during a severe drought and maintain the innovations and advances achieved up to that point.

Polycentric Governance

Polycentric governance systems are defined as systems in which “political authority is dispersed to separately constituted bodies with overlapping jurisdictions that do not stand in hierarchical relationship to each other” (Skelcher, 2005). In general, polycentric governance systems are more adaptive and resilient that top-down hierarchical governance (Pahl-Wostl et al, 2011; Lebel et al, 2006; Kumler and Lemos, 2008; Walker et al, 2006; Huitema et al, 2009; Folke et al, 2005; Beier et al, 2009) This dispersal of authority creates more adaptive management and resilience in governance because these systems: 1) allow issues with different scopes to be managed at different scales; contain overlap and redundancy of function that decreases vulnerability so that if one portion of the system fails another can take over its functions; and 3) allow for experimentation with novel approaches that can serve as learning tools for other units (Huitema et al, 2009). A case study of adaptive management and resilience in the Tongass National Forest in Alaska found that one of the chief reasons why this system collapsed and struggled to recover was because governance was too driven by a singular management emphasis that was rigidly organized (Beier et al, 2009).

Adequate Capital

The fourth element frequently cited as critical to a systems adaptive capacity is the presence of adequate capital (Baral et al, 2010; Folke et al, 2005; Lebel et al, 2006; Huitema et al, 2009; Abel et al, 2006) There are numerous forms of capital within a governance system including: human, social, natural, financial and physical. Human capital is “the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well being.” (OECD, 2001) Social capital contains elements of human capital and can be defined as human networks, leadership capacity and trust amongst groups (Folke et al 2005). Natural capital is the ecosystems that support humans; physical capital is technology and infrastructure and financial capital is access to money (Abel et al, 2006). The loss of capital is frequently seen as a sign of an Ω phase, and if capital is reduced too drastically during an Ω phase it may prevent the system from reorganizing and create “poverty traps” (Holling et al, 2002).

Leadership

Leadership is an important part of adaptive management and resilience which can be considered a part of social capital although some feel it is so critical that it should warrant its own separate category (Baral et al, 2010; Folke et al, 2005; Kumler and Lemos, 2008; Walker et al , 2006; Leah and Pelkey, 2001). A review of empirical literature on watershed partnerships by Leach and Pelkey (2001) found that effective leadership was the second most critical factor for successful partnerships surpassed only by adequate funding. Leadership is an essential element in providing the innovation and flexibility necessary to deal with ever changing, complex ecosystems (Folke et al, 2005). Within the literature reviewed there is little discussion of what form effective leadership must take. However, it is clear that a lack of leaders can lead to inertia in social-ecological systems (Scheffer et al, 2003) and that leadership needs to be a dynamic process that at times may require leadership changes in order to best respond to prevailing social and biophysical conditions (Walker et al, 2006).

Applying the Theory to Arizona – As Reorganization Begins

According to Abel et al (2006) when a system enters an omega phase there are three possible paths forward, the system can either: 1) reorganize into the same regime that it was in prior to the collapse; 2) shift to a new regime where the feedback processes or the scale of operation changes but the state variables are the same; or 3) transform into a totally new regime where scale, state variables and feedbacks differ from the past. Which of these three occurs, and the degree to which the changes are positive or negative, depends on resilience and adaptability within the system as well as the desired outcome for the system. The most desired outcome might be reorganization into the same regime for a system of governance that has a history of success in meeting the needs of a population and their ecosystem. In contrast, a complete transformation would be the best alternative for a system if adaptation is not possible (Holling and Gunderson, 2002)

Which of the three paths is best for water governance in Arizona is difficult to determine. While the original system originating with GMA has served to decrease groundwater mining and increase the use of renewable supplies, this regime has had numerous shortcomings. These include its failure to consider environmental water demands, lack of connection between surface water and groundwater and inability to actually meet its ultimate goal of “safe-yield” by 2025. Thus, the most desirable and achievable goal for water governance in central Arizona may be a hybrid that falls somewhere between the original system and a complete transformation. Regardless, as it moves from an Ω to an α and perhaps into a r phase again incorporating some, if not all, of the discussed elements of adaptive management and resilience is likely to be beneficial especially since an α phase is often the most opportune time for shifts in governance.

Next, we should consider which of the five common elements in more adaptive and resilient governance of social-ecological systems already exist in Arizona water governance. During the 2010 legislative session a the Arizona Legislature passed H.B.2661 creating the Water Resources Development Commission (WRDC) to assess the current and future water needs of Arizona. The WRDC was appointed by the Director of ADWR, and its membership was to include people with knowledge about various water resource and water management issues in Arizona and representatives from different regions as well as a geographic cross-section of the state. The WRDC began meeting in October of 2010 will meet for one year. The goal of the WRDC is to provide recommendations on areas of the state that currently have unmet water demands or will have unmet demands in the next 100 years. Although it is too early to tell what affect the WRDC will have on water governance in Arizona, there are a few elements to this process that could lead to more adaptive management and increased resilience. Observations on these elements are based on my experience working on WRDC tasks as an employee of ADWR and on the structure and goals of the WRDC.

The first element that shows promise within the WRDC is its public participation element. Although many of the actual commissioners are so called “water buffalo”, those who have worked in water management in Arizona for many decades, some of the participants in the WRDC’s workgroups are relatively new to this process and may be able to bring fresh insights. The WRDC is divided into four committees: finance, water supply and demand, recommendations and environmental. The environmental committee in particular is significant because it has the potential to introduce new concerns and innovations into conversations that are usual focused completely on human supply and demand. The WRDC also opens the door for significant social learning amongst the participants. However, the degree to which this has and will occur is uncertain at this time.

Depending on the path committees take, the WRDC could also serve to regroup much needed financial and human capital. It is too early to know if this potential can be reached since the finance committee will only begin its meetings in earnest once the water supply and development and environment committees have reached their conclusions on unmet demand. Much like the Governor's Water Management Commission in 2000, the WRDC has great potential to increase the capacity for adaptive management and resilience. The success of the WRDC cannot be determined until its final recommendations are released and the water user/management community response to those recommendations is observed. However, wide distribution of the recommendations and consensus among stakeholders will be critical to the implementation of these recommendations and the success of the WRDC.

The GMA, as originally implemented, had some elements of polycentric governance with managers and satellite offices for each of the regional AMAs and the appointing of Groundwater User Advisory Councils (GUACs) composed of knowledgeable citizens outside of ADWR to guide policy-making within the individual AMAs. Likewise, the board for the CAWCD is popularly elected from the three counties that the CAP canal serves. The CAWCD board is responsible for establishing policy and usually meets twice a month in meetings that are open to the public. These elements, however, display more of a geographic dispersion of a still predominantly top down governance structure as opposed to a truly polycentric governance regime. The important elements of polycentric governance, experimental learning and redundancy of function in particular have not been expressed to date. For example, even though the satellite offices of ADWR no longer operate, when they did they were largely subject to hierarchal control by the main office of ADWR in Phoenix and therefore any adaptation of the original policies or goals of the satellite areas did not, in general, vary significantly.

There are aspects of the existing structure, however, that could be improved in order to engender a more polycentric governance structure. One example is the GUACs that continue to operate in each of the AMAs. These five-member groups, which are appointed by the governor for six year terms, were originally designed to advise the Area Director, make recommendations on groundwater management programs and policies for the AMA, and comment to the Area Director and to the Director on draft Management Plans before they are promulgated by ADWR (ADWR, 2011). These groups could be expanded and strengthened in order to provide substantive policy and management decisions and work alongside ADWR as opposed to just as advisors. Doing so could aid redundancy and would certainly help to improve the ability of water governance in central Arizona to be more sensitive to regional issues at varied scales.

It has been noted in other case studies that the key to reorganization is an investment in the “capitals” of the system (e.g., Abel et al, 2006; Baral et al, 2010). During the recent Ω phase much human, social and financial capital was lost. Whether or not this loss was significant enough to create a poverty trap is unclear, however, there are signs of at least a stabilization of the capital that remains. In many cases the human capital that existed prior to collapse has not left the system entirely but has migrated to other organizations. This could create the innovation necessary for a transformation of the governance system. Social capital, in particular trust and leadership, has been eroded but processes such as the WRDC have the potential to rebuild both. Financial capital was lost in some areas, most notably ADWR. However, the CAWCD or for example has not suffered layoffs in the past 3 years. Although a return to pre-collapse funding of more than $25 million is not yet on the horizon, ADWR was able this legislative session to secure a commitment of $7 million in temporary funding through contributions from municipal water providers that will supplement the approximately $2 million in funding it receives from permits and fees.

Finally, and not insignificantly, is the issue of leadership. Since many of the current leaders in Arizona water governance are nearing retirement, new leadership will be needed. This could potentially, open up opportunities for new ideas to emerge and transform the system. New leadership could also arise from older groups that have decided to “come out of retirement” due to recent crises. For example, in 2010 the Tucson AMA Safe-Yield task force began meetings again to determine how the Tucson AMA can achieve safe-yield by 2025. Originally formed in 2000 to advise the Governor’s Water Management Commission, it began meeting again with an eye to revisiting and updating its recommendations in light of ADWR's assessment that the Tucson AMA will not reach safe-yield by 2025 (Metropolitan Water District, 2011). This body is but one example of an arena where new leadership on water governance may emerge.

Conclusion

For many years water governance in the AMAs has been chasing the idea of “safe-yield” of the aquifers. While safe-yield is not synonymous with sustainability, because it allows for diminished surface water flows and localized areas of depletion, it does seek to maintain a long-term balance between the amount of water withdrawn and that replaced into the aquifers of the AMAs (Jacobs and Holway, 2004). Sustainability, however, may not even be an appropriate goal given what we know about both ecological and social-ecological systems today. If stationarity is dead and unexpected change the new norm the idea of sustainability that maintains the stability of current life-styles and production systems may no longer be tenable. Resilience, on the other hand is about change and adaptation. Increasingly scholars of both natural and social systems have found that managing for control and stability in fact engenders the opposite effect, sudden instability and turbulent change. It has therefore been suggested that in our management and governance we should seek less to control all aspects of the system and more to understand the dynamics of the whole system. (Folke et al, 2005) In other words, when governance becomes too driven by a singular management emphasis that is rigidly organized, even the best-laid plans will likely fail (Beier et al, 2009).

In Arizona this speaks to some of the already recognized issues with our water governance, namely the legal disconnect between surface water and groundwater, the lack of incorporation of environmental water needs into policies and practice and the singular focus on regulating groundwater demand with little or no regulation per se of surface water demand. These issues are well known and the need to "fix" them has been the subject of many an academic study. (Colby et al, 2007) What is new here is looking at these problems, and the opportunities provided by a system in the α phase, through the lens of adaptive management and resilience. Perhaps our goal should not be first and foremost to reform water law or regulate surface water demand, but rather to incorporate public participation, encourage social learning, allow for polycentric governance, provide sufficient investment in all forms of capital and foster leadership. With these elements enhanced, the system of water governance may just transform itself and Arizona could once again find its water governance heralded as a leader in progressive water management and planning.

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