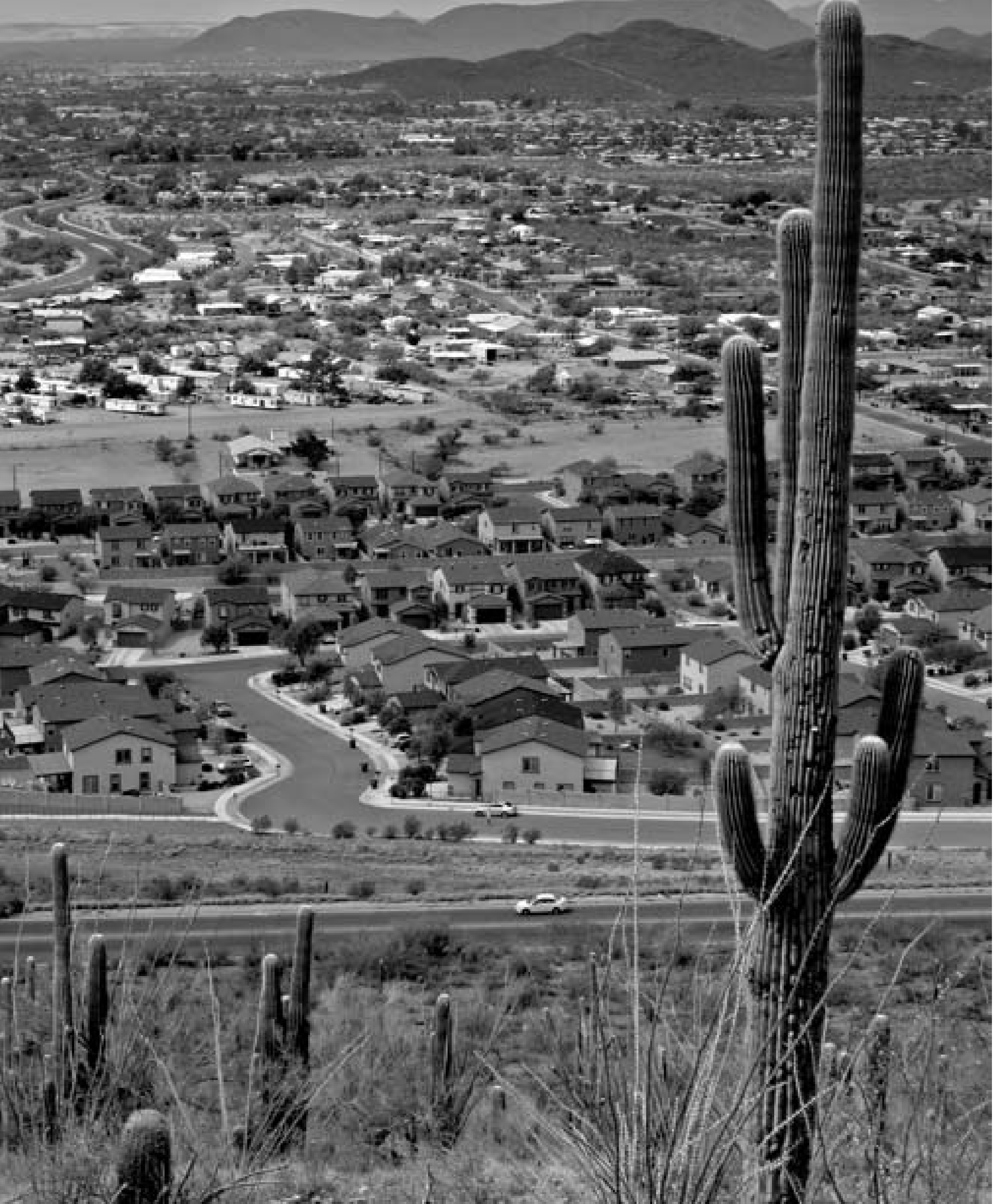

Lost in Translation: Resilience, Social Agency, and Water Planning in Tucson, Arizona

Majed Akhter, Kerri Jean Ormerod
and Christopher A. Scott

This paper critically assesses urban water planning and the quest for resilience by examining social-ecological systems theory in the context of Tucson, Arizona, where real estate-led growth fuels the economy and exerts powerful influence over public decision making. Water planning in Tucson is analyzed through a case history of the Central Arizona Project and an ongoing inter-jurisdictional water 'sustainability' planning initiative. While certain elements of ecological resilience are considered, this planning process fails to acknowledge the political contests that shape every aspect of socio-ecological systems. By considering the role of social agency in shaping social-ecological systems, planners would be better equipped to move towards resilient urban water systems.

The quest for sustainability and urban resilience is a pressing concern for urban planners and scholars (Hamin and Gurran 2009; Godschalk 2003). As the impacts of explosive population growth, resource scarcity, global warming, and pollution pit societal demands against environmental quality, simple yet serious questions confront planners and policy-makers: how do we understand the environment, our interactions with it, and our ability to adapt to the uncertainty of natural and human systems? Ecologists and social scientists have found it useful to approach these questions through the concept of *resilience* (Scoones 1999). Increasingly, planners are also turning towards resilience theory to meet the ecological challenges of urban management. As actors in diverse professional and disciplinary settings engage with the theory of resilience, a 'translation', or reinterpretation occurs, where some aspects of the theory are accentuated and others marginalized. This paper examines how the concept of resilience is utilized in planning discourses through a case study of water planning in Tucson, Arizona. We argue that in the translation from ecology to urban planning, the data collection, measurement, and forecasting aspects of resilience have been emphasized. On the other hand, the social contingency of outcomes, an integral part of the resilience theory we review, has been downplayed or even erased from water planning discourses in Tucson. The political implications of this translation are that 'growth' in Tucson as a political process remains unquestioned.

In the southwestern United States, a combination of extremely dry climactic conditions and one of the fastest growth rates in the country portends an environmental crisis (Morehouse 2000; U.S. Department of Interior 2005). The possibility of a water-related crisis in Arizona stems from a confluence of natural hazards (e.g., biophysical/ecological factors, droughts, extreme variability) and vulnerabilities (e.g., socio-political factors, institutional arrangements, population growth). The Colorado River provides the lifeline for arid

Southwestern cities and roughly 30 million people rely on its flow including the residents of Los Angeles, Las Vegas, Phoenix, and Tucson (Hirt, Gustafson, and Larson 2008). The Colorado River flows 1,400 miles and with a drainage area that stretches over seven Western states (Wyoming, Utah, Colorado, Nevada, Arizona, New Mexico, and California) en route to the Gulf of California in Mexico (Figure 1). The Lower Colorado Basin (Arizona, California, and Nevada) is the most precariously positioned in terms of balancing growth and water supply. Taking the ratio of annual consumptive water use to the annual renewable supply (precipitation and imports, subtracting evapotranspiration and exports) provides a rough "index of the degree to which the [water] resource has already been developed" (Asano et al. 2007, 21). The consumptive use for the Lower Colorado Basin is slightly above 100% (made possible by mining nonrenewable groundwater). The next highest ratio, by contrast, in the Rio Grande Basin, is only 70% (Asano et al. 2007).

Legendary political conflicts over Colorado River supplies ultimately resulted in hierarchical, inflexible water sharing agreements among the seven Colorado Basin states. In the event of a shortage being declared in the Lower Basin, Arizona will be the first to be cut off from Colorado River water (Hirt, Gustafson, and Larson 2008). Today, a shortage in the Lower Basin is considered an increasingly likely scenario given long-term variability and drought. This, and the fact that Colorado River water provides the bulk of municipal water in Tucson, makes the city uniquely vulnerable to supply interruptions from extended drought, and therefore provides an excellent case study for examining the role of resilience in urban planning discourses (Morehouse 2000).

Located in the Sonoran Desert, Tucson is the second largest city in the state and has experienced significant population growth since the post World War II era (Logan 1995). Before the importation of Colorado River supplies via the Central Arizona Project (CAP) water delivery system in the 1990s, Tucson was the largest city in the nation entirely dependent on groundwater. Despite physical limits imposed by the semi-arid climate, the Tucson region has been able to sustain population growth by diversifying the municipal water portfolio to include imported Colorado River water and reclaimed water supplies, as well as by significantly ratcheting down urban use through conservation measures (Gelt et al. 1999). The City of Tucson is well-known for its strong conservation ethic and local water activism (Logan 2002; Tarlock and Van de Wetering 2007; Western Resource Advocates 2003). Nonetheless, ongoing population growth in the context of projected water scarcity keeps the goal of resilience at the center of water policy and planning debates in Tucson.

This paper offers a critical and constructive assessment of water planning in Tucson through the theoretical lens of ecological resilience. Resilience has its origins in ecosystems theory, but has spread and been reinterpreted across many disciplines including engineering, planning, ecology, and human-environment studies (Medd and Chappells 2007). While the theory itself can have quite radical interpretations, we find its translation into planning discourses elides concerns of conflict and uneven social power. This translation is not without political implications, and prioritizes continued growth over other social concerns.

Figure 1. Map of the Colorado Basin. Source: Dettinger 2004

The outline of the paper is as follows. First, we provide the context of these issues by tracing the interlinked histories of water and urban growth in Tucson. We then briefly contextualize the emergence of resilience as a central and influential tenet of ecosystems theory. Next, we critically analyze historical and ongoing water planning initiatives in Tucson, and relate these to resilience theory. We discuss the history of large infrastructure projects and conservation efforts in Tucson, and analyze documents from the ongoing jointly convened city-county Water and Wastewater Infrastructure, Supply, and Planning Study (WISP).[1] We argue that the concept of resilience as it is used in the study should be more attuned to the existence of multiple equilibria in social-ecological systems, social agency in determining outcomes, and the inescapably political nature of urban growth. By social agency we mean the capacity of organized actors to intentionally affect change in a socio-ecological system. We suggest a synthesis of selected aspects of planning and social-ecological resilience as a productive way forward for planners concerned with creating resilient urban communities.

Growth and water in Tucson, Arizona

Tucson Water, a municipally owned utility, is run by Mayor and Council, who have the responsibility to establish water policy within a state-led regulatory and water rights administration framework. The utility has been grappling with water supply and demand gaps for over a century, largely through conservation strategies and technological investments (such as imposing irrigation restrictions, constructing new pumping plants, putting new well fields into production, and importing water) (Kupel, 2003). Explosive population growth in Tucson, like in other urban centers in the western United States, took off in the post World War II era with subdivisions expanding the physical size of the city beyond the official city limits (McPherson, Gregory, and Haip 1989). Post-war urban expansion in Tucson led to increased groundwater consumption and overdraft conditions, where groundwater is extracted beyond the rate of natural recharge (Kupel 2003).

Growth in Tucson from the mid 1940s to the mid 1970s corresponds closely to broader trends in the urban west, where "the wheels of economic growth were the scientific-military complex, the maturing of automobile and air transportation, and the postwar housing boom" (Abbot 2008, p. 165). In Tucson, the increasing local economic importance of Davis-Monthan Air Force Base and the establishment in 1950 of the Hughes Aircraft plant fit this trend.

In urban planning discourses, growth is usually conflated with urban expansion. Historically, there has always been consensus between government, planners, and businessmen in Tucson that urban expansion is an unqualified good. Until the nationwide real-estate crash of 2008, housing developments were being built at a furious pace in the Tucson metropolitan region, and it is clear that the real-estate community will continue to be influential in shaping economic growth and urban expansion. The main thrust of this group has always been that growth must go on – and water policy should revolve around making this happen (Abbot 2008; Morgan 1995; Waterstone 1992).

This section has sketched trends of urbanization in Tucson. Before turning to a more thorough case study of water, growth, and resilience in the region, we review the socio-ecological systems concept of resilience.

Social-ecological systems, resilience, and planning

A major shift in the thinking of academics, managers, and modelers around the nature of equilibrium in dynamic systems occurred in the 1970s. The critique against equilibrium models, leveled by the non-equilibrium theorists, was that they did not fully capture the dynamic and complex nature of the socio-ecological systems they claimed to represent. Empirically, these systems displayed characteristics that deviated wildly from the models' assumptions and predictions (Scoones 1999). Insights from ecology, based on years of studying landscapes and ecosystems, not only complemented non-equilibrium theory, but also grounded much of the abstract mathematical theory in observations from the field, leading to theory building through empirical enquiry (Gunderson, Allen, and Holling 2010).

The concept of resilience, as developed in social-ecological systems (SES) theory, has attracted much attention as a metric, concept, and a way of thinking. Although there are many working definitions of resilience in the literature, the classic one characterizes resilience as the ability to "absorb change and disturbance and still maintain the same relationships between populations or state variables" (Holling 1973, 14). The focus is on the *relationships* between components of a system, as opposed to a more fixed 'stability' or 'engineering resilience' view based around a steady state, or equilibrium, of the system, and the time it takes to return to that static condition after a disturbance (Holling and Gunderson 2002; Holling 1973).

Holling and Gunderson (2002) stylize ecological systems as sets of nested adaptive cycles. Ecological processes of exploitation, conservation, release, and reorganization characterize the cyclical motion of ecosystems. Exploitation and conservation are processes that respectively emphasize periods of "rapid colonization" and the "slow accumulation of energy and material" (p. 33). SES theorists argue from decades of observations that rapid breakdown and dissolution of established systems is part of the cyclical motion of ecosystems. The possibility of a rapid shift to alternate stable states suggests an ecological phase of release, analogous to Schumpeter's creative destruction in the capitalist economy, where a "tightly bound accumulation of biomass and nutrients becomes increasingly fragile until suddenly released" (Holling 1973, 34). Reorganization, the phase that connects the periods of rapid breakdown and slow accumulation, is "essentially equivalent to [a phase of] innovation and restructuring in an industry," where strong "pioneer species" expand their presence in the system (p. 35). We signal the reader here to the conflict and struggle to establish social dominance that is lurking beneath the innocuously named "reorganization phase," to return to it below. Resilience of a system expands and contracts depending on which of the four ecological processes are dominant at any given time. The reorganization phase, when novelty and experimentation are the norm, is the most resilient phase of the adaptive cycle. Adaptive cycles and transitions from one phase in the cycle to another are central to SES theory. Walker and Salt assert that "resilience thinking is about envisioning a system in relation to thresholds", and that any socio-ecological system should be seen as "a set of linked adaptive cycles" (p.113).

Holling (2002) lists four properties of ecosystems observed by ecologists and resource managers that have serious implications for the way we think about human and coupled human-natural systems. These properties are: the episodic (as opposed to gradual) nature of change in ecological systems, the non-linearity of social and ecological processes across scales, the existence of multiple equilibria, and the impossibility of accurate prediction.

This brief outline by no means captures the nuance or full complexity of the SES approach to resilience, but does allow an initial evaluation of its usefulness to planners concerned with successfully meeting ecological challenges. Uncertainty and the existence of multiple equilibria are issues central to SES, and are concepts that challenge traditional planning practices. Urban planners must confront the inevitability of their ideal-scenario designs not coming to fruition as planned. Planners could see uncertainty as not something to be eliminated or even minimized, but rather as a necessary and integral part of any social-ecological system. In the next section, we analyze resilience in regional water planning with special attention to the current WISP study in the context of the historical geography of water and growth in Tucson.

Case study: Tucson, Arizona

Our case study takes an in-depth look at water planning in Tucson by 1) relating the intertwined histories of the Central Arizona Project (CAP) and conservation in Tucson and 2) an analysis of the ongoing Water and Wastewater Infrastructure, Supply, and Planning Study (WISP) study. The history of CAP demonstrates how socio-ecological systems are influenced, sometimes decisively, by social agency. We suggest that this is a historical moment that corresponds to the 'reorganization' phase of SES adaptive cycles. The WISP study provides insight into how water planning discourses incorporate the concept of resilience.

The Central Arizona Project and its discontents

The battle of Arizona's 'water elite' to attain federal funding for the construction of the CAP, which transports water from the Colorado River 336 miles east and uphill nearly 3,000 vertical feet to its terminus in Tucson is summarized below (for a detailed account, see Hirt, Gustafson, and Larson 2008; Sheridan 1995).

The most expensive federally funded water development project in U.S. history, the CAP was completed at a cost of over $4 billion dollars in 1993. Originally developed as an agricultural water resource, the CAP was a dream held by powerful Arizonans for many years before it was built, despite being harshly contested by environmentalists, federal authorities, a skeptical President Jimmy Carter, and California politicians worried about their own allocation of Colorado River water. Ultimately, farmers declined to utilize CAP water due to high costs and water quality (salinity) concerns. As a *quid pro quo* for federal financing, the Groundwater Management Act (GMA) was signed into law in 1980 by Governor Bruce Babbitt. By strictly limiting groundwater pumping in the urban areas of the state, the GMA forced new urban users to purchase CAP water (Kupel 2003). Water sources for agriculture remain largely undiversified and farmers rely heavily on groundwater. Statewide agriculture in Arizona accounts for 80% of total water use, while the municipal sector accounts for 16% (USGS 2004).

In Arizona, water use and land use have historically been planned independently of each other; the GMA loosely ties water to land-use through regulated Active Management Areas (AMA) and associated assured water supply rules. The stated goal of the GMA is to eliminate groundwater overdraft by the year 2025 through management plans and assured water supply rules. The Act established the Arizona Department of Water Resources, long-range management goals, and ensured the completion of the CAP. The overriding aim of statewide urban water conservation efforts is focused on the metric of water use per capita, or gallons per capita per day (GPCD), managed at the municipal water utility level. The management goal for the Tucson AMA is to achieve 'safe-yield', defined as a long-term balance between groundwater withdrawals and natural and artificial recharge. Tucson Water is the largest municipal water utility in Pima County and in the Tucson AMA. The GMA stipulates that in safe-yield AMAs water suppliers and developers must demonstrate a one-hundred-year assured renewable supply of water for all new development. The mandated restrictions on groundwater pumping represented a dramatic change for municipal water management and planning (Gelt et al. 1999).

The CAP continued to draw fire even after it was built, albeit directed more towards its operation rather than its existence. Faced with a continuous population boom facilitated by CAP deliveries, the City of Tucson acquired the largest municipal entitlement of CAP water (144,000 acre-feet per year). However, initial problems with the quality of CAP water delivered through an aging distribution network to Tucson residents led to a voter initiative in 1995 that blocked the direct delivery of CAP water. As a means to work within this citizen mandate, CAP water is now indirectly supplied by first being recharged to local aquifers. A blend of minimally treated groundwater and CAP water is then delivered to customers (Hirt, Gustafson, and Larson 2008; Sheridan 1995; Wilson, Matlock, and Jacobs 1998). The allocated supplies are considered more than adequate to meet current demand and currently excess CAP water is also recharged underground for future recovery and use.

In November 2007, a signature-led ballot initiative sought, among other things, to limit future water connections and prohibit reclaimed water (highly treated municipal wastewater) from being used as drinking water. Although the initiative did not pass, the concerns it raised motivated City of Tucson and Pima County leaders to embark on the WISP study in early 2008. The ultimate goal of this on-going study between the city (water utility) and county (wastewater utility) is to assure sustainable water supplies given the pressure of continued population growth in the region, defined roughly as the 800,000 residents within City/County obligated service areas for water supply and wastewater reclamation.

Conservation

Prior to the GMA and arrival of CAP to the region, Tucson Water initiated conservation campaigns that attempted to link land-use and water supply. Tucson pioneered conservation efforts beginning in the late 1970s, after a period of drought and heightened sense of water scarcity (Logan 2002). In the 1970s, Tucson's slow-growth and environmentalist movement opposed irrigated landscaping in favor of desert adapted species, favored infill over sprawl, and protested the construction of the CAP in favor of greater conservation and controlled growth. Slow-growth reform City Council Democrats enacted a new rate structure and charges to cover the additional pumping costs of delivering water to outlying customers at higher elevations. The new water policies, and the significantly higher rates for some users, drew fire immediately and ultimately resulted in the "most spectacular example of water politics intruding into electoral patterns of the community", when three city council members were recalled for their efforts (Logan 2002, p. 215). Over thirty years later, the ratepayer revolt continues to influence water policy decisions for elected officials in Tucson.

In the wake of divisive water politics, water conservation was something Tucsonans could agree on and conservation became part of Tucson's cultural identity. By the late 1970s, desert landscaping was considered an "economic necessity" in Tucson and an "unlikely coalition of business people and environmentalists joined the local utility in promoting water conservation and desert landscaping" (McPherson, Gregory, and Haip 1989, 446). Tucson Water's conservation tactics include inclining potable water rate structure (the more you use the more you pay per unit), discounted reclaimed water rates (subsidized by potable rates), and more than thirty years of education and efficiency programs.

The general public continues to exercise the power to influence water projects and policy directly through political processes including ballot initiatives and lawsuits, and indirectly, such as through the normalization of environmental values (Kupel 2003). Policies aimed at conservation contribute to the city having one of the lowest levels of per capita water consumption in the southwest (Western Resource Advocates 2003) and individual voluntary conservation has allowed the utility to accommodate population growth without the subsequent rise in aggregate water demand.

The arrival of the CAP and conservation efforts in Tucson have been rife with social struggle and contest (Logan 1995). We noted above that political contestation is a part of the 'reorganization' phase of an adaptive socio-ecological cycle. However, as we discuss below, this aspect of socio-ecological system resilience is not satisfactorily incorporated in the WISP study.

Water and Wastewater Infrastructure, Supply, and Planning Study

In what follows, we trace strategies of resilience in the WISP study. We then offer a critique based on the lack of critical incorporation of certain social processes, specifically the idea of multiple possible equilibria, which can result from social contingencies.

The WISP study is a multi-year collaborative effort that began in 2008. A twelve member Oversight Committee appointed by the elected representatives of the city and county consists of a range of professional backgrounds including hydrology, planning, engineering, community development and environmental consulting. Out of a total of five planned phases for the study, at the time of writing Phase I and Phase II are complete, and in January 2010, results and recommendations were presented to the Tucson City Council and Pima County Board of Supervisors. In January 2010, Pima County passed a resolution (Pima County Resolution 2010-16) endorsing and taking measures to implement recommendations in Phase II of the WISP study. One month later, the mayor and council endorsed the report (Mayor and Council Resolution No. 21478). The resolutions call for integrated land use and water planning, directed urban form, consideration of the environment as a water user, a diversified water supply portfolio, increased use of rainwater and reclaimed water ('locally renewable supplies'), and sensitivity to uncertainties on the Colorado River that might emerge from climate change.

Phases I and II of the study focus on the service areas of Tucson Water, the largest single water provider in Tucson, and the Pima County Regional Wastewater Reclamation Department.[2] Phase I's scope of work was identified as providing an inventory and assessment of agreed upon basic facts regarding the capacity of water and wastewater infrastructure in the region, as well as highlighting factors that were critical to water sustainability in the region. Phase II is a discussion and synthesis of community values as they relate to water and the environment that culminates in fourteen technical papers, with topics ranging from stormwater management to drought to urban growth.

The first phase of the study concludes that although there is uncertainty on a variety of fronts regarding future water supplies, such as drought and the level of flows on the Colorado River, "Tucson Water has a reliable and renewable water supply for the near term," (City of Tucson and Pima County 2009c, 26). Caution is urged with regard to uncontrolled population and economic growth in the area, and looming issues that demand careful planning are given special attention, including regional watershed cooperation, the enormous financial cost of upgrading wastewater and water supply infrastructure, and the untapped potential of locally renewable water resources.

Specific strategies emerge from the documents that constitute the plan for resilience in the Tucson region. The main resilience strategy is the full utilization of sources that have been designated renewable, especially Colorado River water and reclaimed water. This implies the conservation of groundwater and the banking of surplus renewable supplies in local aquifers for use in case of serious shortages of Colorado River flow. There is also stress on adaptive management practices, especially on data collection and forecasting. In what follows, we summarize and critique the concept of resilience that undergirds the WISP study.

The proximate goal of water conservation efforts as articulated by the WISP study is to prevent continued groundwater overdraft by increasingly utilizing renewable supplies. Colorado River water, although heavily dependent on Rocky Mountain snowmelt and requiring huge energy expenditures to deliver it to Tucson (Scott et al. 2007), is seen as a renewable resource whose utilization should be maximized. As the joint study white paper on drought remarks, "in essence, the City's CAP allocation has transformed the focus of the Utility [Tucson Water] from a local one to that of the regional Colorado basin," (City of Tucson and Pima County 2009a, 4; City of Tucson and Pima County 2009b). Colorado River supplies and reclaimed water are attractive supply-substituting resources for cities because urban users are the primary new users of water where existing (mostly groundwater) supplies are already tightly allocated. Arizona is heavily dependent on the supply of Colorado River water, as it is the source of roughly one third of all water used in the state. Colorado River water is an ostensibly renewable resource, and its use in Arizona, especially Tucson, has reduced withdrawals from non-renewable groundwater resources.

One adaptation strategy used in Tucson to counter uncertainty in future Colorado River flows is storage, carried out under the Arizona Water Banking Authority (AWBA). The AWBA is authorized to bank, or recharge to the aquifer, up to 400,000 acre-feet of Colorado water per year for later use. The authors of the drought technical paper claim that "the conjunctive use of groundwater and CAP water supplies…provides a great deal of resiliency for the Tucson water supply system during times of local drought," (City of Tucson and Pima County 2009a, 7). The technical paper urges the adoption of an "adaptive management" approach to drought, which means a reliance on expert cooperation and coordination, flexible scenario planning, and constant monitoring and updating of data.

Effluent, or reclaimed water, forms another major plank in Tucson's resilience strategy. It is currently utilized in Pima County in one of three ways: for landscaping irrigation, discharged to the (otherwise dry) Santa Cruz River bed, or in limited cases to artificially recharge depleted groundwater. The reclaimed system currently utilizes 38 percent of the City/County entitled effluent, largely by serving large-volume turf irrigators: golf courses, schools, and parks. The reclaimed water technical report offers decision-makers advice on how to expand their reclaimed customer base by overcoming financial and regulatory obstacles and working cooperatively. However, the main point of the paper is to link efficient effluent utilization to a broader resilience strategy. The report argues that while other utilization options for effluent are attractive, such as expanding the reclaimed system to include more golf courses and individual homes, "aquifer augmentation provides the most flexibility for future use because it can be withdrawn at any time and used for various purposes," (City of Tucson and Pima County 2009e, 3). The report's authors argue that long-term aquifer augmentation shields the utility from uncertainty and provides for environmental restoration (since key desert habitats depend on high water tables).

Another strategy almost universally urged in the WISP is the collection of information that situates the current position of the system, and gives clues as to the changing effects and relationships of factors within any given SES. This approach to management and policy formulation can also be called adaptive management (Ostrom 2007), and incorporates many of the lessons of uncertainty from SES theory. The water study states that "there is less need for certainty in forecasts than there is for a regularly monitored credible range of possibilities that the utilities and the community can prepare for" (City of Tucson and Pima County 2010, 27).

Longstanding conservation ethics are emphasized in the WISP technical paper on conservation. The report boasts "this community, indeed this entire region, had a conservation ethic long before having a conservation ethic was cool," (Little 2009, 1) and continues, "for the most part there is nothing being done in the U.S. that hasn't been done, or at least considered for this region" (p.9). While discussing larger matters of sustainability, the conservation technical paper makes the important but often overlooked point that water cannot be viewed in isolation from energy issues. They note that conservation may reduce energy use and subsequent greenhouse gas emissions that are the primary drivers of climate change (City of Tucson and Pima County 2009d). All water delivered in Tucson, whether groundwater, CAP, or reclaimed water, is pumped uphill. As a result, the water and wastewater systems are enormously energy consumptive. For example, nearly 90 percent of the natural gas and electricity used by the municipal government is utilized for water and effluent production and distribution. Similarly, potable water supply and treatment account for more than half of the City's greenhouse gas emissions (Little 2009). The functional implications of current dependence on renewable (CAP and effluent) supplies in Tucson are intensive energy use. The report acknowledges that the future costs of both water and energy are likely to increase, especially as air and water quality regulations increase over time. The white paper also drives home the point that conservation should not be seen solely as a vehicle to allow continued growth, but as a means of "preserving options for the future," (p. 27). By conserving water now, time is bought for planners to gather data, arrange financing, and lay out careful plans for arranging new sources of water.

Discussion

What emerges from the documents are specific strategies that constitute a plan for resilience in the Tucson region. The main adaptation strategy is the full utilization of sources that have been designated 'renewable', such as CAP water, effluent, and natural recharge to the aquifer. Conservation, interpreted problematically as lower per capita consumption, ideally lowers the impact Tucson has on its immediate surroundings. Conserving groundwater in the local aquifer prepares Tucson for drought conditions in the future, as the water is nearby and easily accessible.

The issue of drought highlights the role that scale and definition of region play in thinking about sustainability and resilience. Since resilience to Tucson water planners means the maximization of renewable sources of water, making full use of CAP water becomes a major step in attaining resilience. This however does not take into account the increased vulnerability of Tucson to climactic changes in the larger Colorado Basin, or the fact that only a portion of the Colorado River total flow should be considered truly 'renewable' (Hirt, Gustafson, and Larson 2008). Even if the Colorado River is seen as a renewable supply of water, it makes Tucson vulnerable to events in a larger geographic context than if it were utilizing local sources alone. The Colorado River water that ties Tucson to a larger ecological scale also enmeshes it in a larger political web. It is important to underscore the role of social agency in establishing the system parameters. The river is a resource shared with the other six Colorado River Basin states, and per interstate negotiations regarding the construction of the CAP, Arizona agreed to junior rights status among competing states in times of declared shortage. Simply put, the fact that Arizona's water supplies will be disproportionally affected by a shortage on the Colorado River is a feature of the system that resulted from political jockeying among the Colorado Basin states and the federal government.

On a related note, the casting of reclaimed water as a local source of renewable water is problematic. Despite the fact that more than 60 percent of water in Tucson comes from the Colorado River (City of Tucson and Pima County 2009c), reclaimed water is still viewed as local and renewable resource. If we track the geography of water in Tucson, from its roots several hundred miles to the northwest, it is difficult to argue that effluent is a locally controlled water source. The scale of resilience solutions is masked by the labeling of certain sources of water as renewable.

Conservation efforts in Tucson, although lauded nationally as progressive and innovative, must be viewed in broader political terms. Tucson Water has a long history of demand reduction on the customer side. However conservation imposed by per capita limits only symbolically addresses aggregate conservation. Simply put, balancing per capita consumption with population growth has not decreased overall demand in Arizona. Instead conservation has allowed for growth. Waterstone (1992, 482) notes that by failing to limit overall municipal use, GPCD as a measure "certainly bears little, if any, relationship to the stated, long-term goal of safe yield." The fixation on lowering GPCD as the target of conservation efforts marks a major departure from the resilience approach. By focusing on a per capita rate, as opposed to absolute levels of use, the existence and possibility of crossing ecological thresholds is downplayed. Furthermore, the management goal of safe-yield applies only to groundwater use within the AMAs, or essentially the urban areas of the state, leaving agricultural and industrial users to continue to mine non-renewable groundwater. The artificial bounding of urban water supplies carries over to the WISP study documents as well. The original intent of the GMA has been thwarted through the use of loopholes and 'paper water' (as opposed to 'wet water') credits that allow construction of new development units unabated (Hirt, Gustafson, and Larson 2008; Parsons and Mathews 1990).

Finally, it must be noted that the WISP study is already generating controversy and bitterness. The City resolution on the study, for example, explicitly calls for further analysis of financial costs, definition of the service area for Tucson Water for planning purposes, economic and environmental impacts, and identification of opportunity costs before implementation of the report's recommendations. Within the text of the Phase II report is a Committee member's expression of extreme unease with the report's lack of rigorous economic analysis supporting the recommendations of rainwater harvesting, dedicated environmental flows, and the directed control of urban form in Tucson.

Another key point of contention is how to determine who is included in a 'regional' planning study, which is essentially a question of scale. The unincorporated populations of Pima County, as well as the small

but rapidly growing outlying towns of Marana, Oro Valley, and Sahuarita have been excluded from the conversation. Smaller municipal entities are wary about entering any planning exercise with much larger entities likely to dominate the process. Other points of contention are the 'environmentalist' language of the report and the economic wisdom of setting aside water for conservation purposes. There is also debate around specific measures and recommendations in the WISP report – our purpose here however is to present a general overview of the report and how it relates to theories of ecological resilience.

Translating resilience

Parallels can be observed between resilience planning in Tucson and the SES approach. Most significantly, a holistic view of water is favored over a single-factor optimization approach. Water is positioned as an integrated component within a larger array of factors that need to be considered, such as environmental flows, infrastructure networks, growth patterns, urban form, and public service provision. Further, the documents discuss the idea of the environment as both a water provider and a water user, and that future water use must serve both social and environmental needs. System optimization, a favorite tool of economists and engineers, is susceptible to critique from the SES approach and its use in the WISP study is carefully qualified and contextualized. Walker and Salt (2006) note that "the more you optimize elements of a complex system of humans and nature for some specific goal, the more you diminish that system's resilience" (p. 6). Second, given climate change and historical drought patterns, the report envisions a water future that looks very different from the recent water past and stresses diversity, flexibility, and technical innovation. Third, the study acknowledges problems of definition, accepting that important concepts, for example drought, do not mean the same thing to everyone and it is important to establish common ground across disciplines.

The most powerful implication of the SES literature, the existence of multiple temporarily stable states that can be shaped by social and political action, is the one least visibly embraced by water planners in Tucson. It has been lost in translation. Despite the thoughtful, thorough, and sensitive nature of the writing, at least one major overarching assumption underlies the entire study. This is the portrayal of growth as an inevitable, apolitical and necessary process of social systems. Problems associated with growth are acknowledged, though not in a way that attempts to understand growth as a social and political process. Phase I of the report argues that Tucsonans must "plan for and direct growth considering a wide array of factors, of which water is one, albeit critical, factor" (City of Tucson and Pima County 2009c, 29). Growth itself is taken for granted, and is not broken down to its constitutive components. The imagined possible steady states of the Tucson SES are limited to those that feature continuous economic and population growth. We find the most important lesson of the SES approach is not genuinely engaged in the study; this is true of water planning in the arid western U.S. in general (Tarlock and Van de Wetering 2007).

If growth is seen as a social process that is actively constituted instead of as a fixed aspect of the landscape, thorny questions arise as to the true resilience of water planning in Tucson. By not acknowledging the social and political nature of scarcity and growth, questions of resilience and sustainability are transformed in such a way as to evade their purported intent or full explanatory value. Taking growth for granted deters the potentially transformative role of resilience thinking in planning. Instead of seriously interrogating the social practices that form the relationship between social and ecological systems, resilience as a concept is used to actually serve and perpetuate a certain type of growth. In Arizona, economic growth is largely dependent on real-estate development, courting mobile and wealthy population groups from other parts of the country. While it may seem that new housing units would be firmly regulated by strict groundwater management laws, upon closer examination a different story comes to light. For example, while the GMA is touted as progressive and a presumably resilience-enhancing water policy, it actually is quite effective in promoting expansion of housing development. The role of 'water elites', or those interests with disproportionate influence on water policy, must be incorporated into any study of how resilience is framed in local contexts. Larson, Gustafson and Hirt (2009) demonstrate for the Phoenix AMA how the original progressive intent of the GMA has been thwarted over the past three decades by amendments, loopholes, and toleration of noncompliance in practice.

Examining the use of resilience in the WISP study allows general reflection on SES and resilience. For example, knowledge about current location and past trajectory within the adaptive cycle is a central tenet of resilience theory and strategy. Indeed, knowledge of possible system stable states and determining the current position of the system is the necessary first step in planning for urban resilience and sustainability. Based on these data, policy makers can search for sites of intervention, identify and attempt to avoid undesirable steady states, or even, if the situation is beyond modification, simply accept transformation and abandon adaptation (Walker and Salt 2006). Inevitable uncertainty about the way that multiple nested social and ecological systems will interact with each other, both in the present and in the future, leads to a planning strategy that emphasizes adaptive management. The emphasis here is not on developing and implementing a single 'panacea' for planning sustainable communities, but rather on a continuous social process of monitoring and learning about dynamic social-ecological systems (Ostrom 2007).

Furthermore, the style and purpose of much SES analysis is descriptive, rather than explanatory. The ecological tradition of descriptive and empirical study emphasizes resilience as a feature of SESs determined by parameters such as diversity, flexibility, and openness to innovation (Walker and Salt 2006; Perrings 2006). While the theoretical framework demands an empirical effort to determine and measure system parameters and relationships, there is no impetus within this framework to determine why or how the system came to be this way. While adaptive cycles, and the cyclical ecological functions that SES theory sketches are useful metaphors to understand interlinked long-term and short-term processes that cause rapid system change, they are not useful for asking how the system came to acquire certain features and consequently how the context for evaluating resilience is set.

The difference between description and explanation is neither trivial nor semantic, as serious political and social issues are hidden when explanatory questions go unasked. This is problematic for planners who are concerned with making cities sustainable, because SESs are shaped by political processes that are crucial in determining system paths and outcomes. There is room, of course, in Hollings and Gunderson's (2002) framework to bring in social agency. In terms of the system sketch based on ecological functions above, political contest emerges in the transition between the reorganization and conservation phases, where the dominant 'species' or system components actually establish their dominance. The existence of thresholds and multiple equilibria in the system, furthermore, assures that this dominance is not permanent but is vulnerable to breakdown and contest. The SES, in other words, is examined as a social construct with some stability, but one that is vulnerable to changes in linked social and ecological processes. By acknowledging the role of social agency in establishing system parameters, this approach makes envisioning alternate equilibria in the system possible. However, these are precisely the elements of SES and resilience that are underemphasized or even erased as it is used in water planning discourses in Tucson. As we have seen, resilience as it is deployed in water planning discourses in Tucson does not delve into questions of political conflict and uneven power relations.

Conclusions

For water policy in Tucson, by leaving the black box of growth unexamined, the most pertinent resilience questions have become: "How can we make Tucson's growth trajectory resilient to ecological constraints or alternative social conceptualizations? Does integrated water planning make Tucson resilient *for* continued growth, or resilient *to* uncertainties including growth?" In other words, the network of relationships that is being guarded against shock is not one of social community or ecological functionality, but rather of unbridled economic and population expansion based on new housing developments (Hirt, Gustafson, and Larson 2008; Parsons and Mathews 1990).

The acknowledgement of system thresholds and multiple steady states in planning demands analyses that are sensitive to the power of social agents, and the interests motivating them. Resilience planning in Tucson, as represented by the WISP study, makes scalar and growth assumptions that are politically biased towards maintaining the system as it is 'found'. Looking at Tucson historically reveals that other steady states are possible and desirable, and this can lead to a more critical view of planning resilience than is found in the WISP study. Examples of political agents determining system parameters and paths include the building of the CAP, the influence of real-estate lobby on urban form, and the voters' initiative that challenged the direct distribution of CAP water. Acknowledging political potency of social agents in the past makes it easier to envision their playing a role in the future. Indeed, there are strong indications that without the political support of ordinary citizens, resilient planning strategies become extremely difficult to implement (Tarlock and Van de Wetering 2009; Wilson, Matlock, and Jacobs 1998).

This paper has argued that planners concerned with urban resilience would benefit from fully engaging with the political ramifications of the multiple equilibrium and threshold phenomena emphasized by SES theorists, in addition to uncertainty that has been incorporated in the Tucson water planning process assessed above. Drawing on examples of resilience planning from Tucson, we demonstrate how certain assumptions about desired or possible steady-states can creep into otherwise thoughtful and sensitive analysis by not acknowledging political agency in the establishment of system parameters, and the contest those parameters are always subject to. Planning for sustainability is inescapably political and more productive and creative paths for sustainable urban environments can be charted once this is embraced.

Majed Akhter is a Ph.D student at the School of Geography and Development, and a Graduate Research Associate at the Udall Center for Studies in Public Policy, both at the University of Arizona. His research interests are the political economy of water, the history and politics of Pakistan, and issues in development geography.

Kerri Jean Ormeord is a Ph.D student at the School of Geography and Development, and a Graduate Research Associate at the Udall Center for Studies in Public Policy, both at the University of Arizona. Her research interests focus on the American West, urban growth demands, and public perceptions of water reuse, water policy, and regional planning.

Christopher A. Scott is Associate Research Professor of Water Resources Policy at the Udall Center for Studies in Public Policy, and Associate Professor of Geography and Development, both at the University of Arizona. His research addresses adaptive water management and policy, water reuse, the water-energy nexus, transboundary and international water resources.

Notes

1 See http://www.tucsonpimawaterstudy.com

2 Both are public utilities. Phase II recommendations include formally bringing into the planning process other (smaller) utilities, many of which are privately owned.

Acknowledgements

This material is based in part upon work supported by the National Science Foundation under Grant No. EFRI-0835930. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

The authors would like to thank Claude Peloquin, Jamie McEvoy, and the anonymous reviewers for their thoughtful comments.

Lead Photograph

View from Sentinel Peak, commonly known as "A" Mountain, looking south toward the Sierrita Mountains. Photograph by Kerri Jean Ormerod.

References

Abbot, Carl. 2008. *How Cities Won the West: Four Centuries of Urban Change in Western North America*. Albuquerque: University of New Mexico Press.

Asano, Takashi, Franklin Burton, Harold Leverenz, Ryujiro Tsuchihashi, George Tchobanoglous. 2007. *Water Reuse: Issues, Technologies, Applications*. New York: McGraw-Hill Companies, Ltd

City of Tucson and Pima County. City/County water & wastewater infrastructure, supply, and planning study. 2010. *Phase 2 report*. http://www.tucsonpimawaterstudy.com/Reports/Phase2FinalReport/PHASE2_Report_12.09.pdf (accessed December 8, 2009).

——— City/County water & wastewater infrastructure, supply, and planning study. 2009a. *Consolidated drought management plan technical paper*. http://www.tucsonpimawaterstudy.com/Reports/Phase2/Memo%20Report.pdf (accessed December 8, 2009).

——— City/County water & wastewater infrastructure, supply, and planning study. 2009b. *Growth technical paper*. http://www.tucsonpimawaterstudy.com/Reports/Phase2/GrowthReport.pdf (accessed December 8, 2009).

——— City/County water & wastewater infrastructure, supply, and planning study. 2009c. *Phase 1 report*. http://www.tucsonpimawaterstudy.com/Reports/Phase1Reports.html (accessed December 8, 2009).

——— City/County water & wastewater infrastructure, supply, and planning study. 2009d. *Water conservation technical paper*. http://www.tucsonpimawaterstudy.com/Reports/Phase2/Water%20ConservationFIN4Web.pdf (accessed December 8, 2009).

Dettinger, Michael D. 2004. Coping with severe and sustained drought in the Southwest. U.S. Geological Survey. http://geochange.er.usgs.gov/sw/changes/natural/codrought/ (accessed May 8, 2010).

Gelt, Joe, Jim Henderson, Kenneth Seasholes, Barbara Tellman, Gary Woodward, Kyle Carpenter, Chris Hudson, and Souad Sherif. 1999. *Water in the Tucson area: Seeking sustainability*. Tucson, Arizona: A status report by the Water Resources Research Center, College of Agriculture, The University of Arizona.

Godschalk, David. 2003. Urban hazard mitigation: Creating resilient cities. *Natural Hazards Review* 4(3): 136-143.

Gunderson, Lance H., Craig R. Allen and Crawford S. Holling (eds.). 2010. *Foundations of Ecological Resilience*.Washington, D.C.: Island Press.

Hamin, Elisabeth, and Nicole Gurran. 2009. Urban form and climate change: Balancing adaptation and mitigation in the U.S. and Australia. *Habitat International* 33: 238-245.

Hirt, Paul, Annie Gustafson, and Kelli Larson. 2008. The mirage in the Valley of the Sun. *Environmental History* 13: 482-514.

Holling, Crawford S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* 14: 1-23.

Holling, Crawford S., and Lance Gunderson. 2002. Resilience and adaptive cycles. In *Panarchy: Understanding transformations in human and natural systems*, edited by Lance Gunderson and C.S. Holling, 25–63. Washington, DC: Island Press.

Larson, Kelli, Annie Gustafson, and Paul Hirt. 2009. Insatiable thirst and a finite supply: An assessment of municipal water conservation policy in greater Phoenix, Arizona, 1980-2007. *The Journal of Policy History* 21(2): 107-137.

Little, Val L. City/County water & wastewater infrastructure, supply, and planning study. 2009. *Water conservation white paper*. http://www.tucsonpimawaterstudy.com/Reports/Phase2/Val%20Little%20Conservation%20paper.pdf (accessed December 8, 2009).

Logan, Michael. 2002. *The lessening stream: An environmental history of the Santa Cruz river*. Tucson: University of Arizona Press.

———. 1995. *Fighting sprawl and city hall: Resistance to urban growth in the southwest*. Tucson: University of Arizona Press.

McPherson, E. Gregory, and Renee A. Haip. 1989. Emerging desert landscape in Tucson. *Geographical Review* 79, (4) (Oct.): 435-49.

Medd, Will, and Heather Chappells. 2007. Drought, demand, and the scale of resilience: Challenges for interdisciplinarity in practice. *Interdisciplinary Science Reviews* 32(3): 233-248.

Morehouse, Barbara J. 2000. Climate impacts on urban water resources in the Southwest: The importance of context. *Journal of the American Water Resources Association* 36(2): 265-277.

Ostrom, Elinor. 2007. A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences of the United States of America* 104:15181–15187.

Parsons, William, and Douglas Matthews. 1990. The Californiazation of Arizona water politics. *Natural Resources Journal* 30: 341-360.

Perrings, Charles. 2006. Resilience and sustainable development. *Environment and Development Economics* 11: 417-427.

Kupel, Douglas E. 2003. *Fuel for growth: Water and Arizona's urban environment*. Tucson: University of Arizona Press.

Scoones, Ian. 1999. New ecology and the social sciences: What prospects for fruitful engagement? *Annual Review of Anthropology* 28: 479-507.

Scott, Christopher A., Robert G. Varady, Anne Browning-Aiken, Terry W. Sprouse. 2007. Linking water and energy along the Arizona/Sonora border. *Southwest Hydrology* 6 (5): 26-27, 31.

Sheridan, Thomas. 1995. *Arizona: A history*. Tucson: The University of Arizona Press.

Tarlock, A. Dan, and Van de Wetering, Sarah B. 2007. Water and western growth. *American Planning Association Planning and Environmental Law* 59, (5): 3-13.

U.S. Department of Interior. Bureau of Reclamation. 2005. *Water 2025: Preventing crises and conflict in the West*.

U.S. Geological Survey (USGS). 2004. Estimated Use of Water in the United States in 2000, U.S. Geological Survey Circular 1268; see http://water.usgs.gov/watuse/

Walker, Brian and David Salt. 2006. *Resilience thinking: Sustaining ecosystems and people in a changing world*. Washington D.C.: Island Press.

Waterstone, Marvin. 1992. Of dogs and tails: Water policy and social policy in Arizona. *Water Resources Bulletin* 28(3): 479-486.

Western Resource Advocates. 2003. *Smart water: A comparative study of urban water use efficiency across the Southwest*. http://www.westernresourceadvocates.org/water/smartwater.php.

Wilson, L.G., W.Gerald Matlock, and Katherine L. Jacobs. 1998. Hydrogeologic uncertainties and policy implications: The Water Consumer Protection Act of Tucson, Arizona, USA. *Hydrogeology Journal* 6: 3-14.