Measuring acequia functionality: developing a tool for assessing New Mexico's community-Based irrigation systems

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MEASURING ACEQUIA FUNCTIONALITY: DEVELOPING A TOOL FOR ASSESSING NEW MEXICO’S COMMUNITY-BASED IRRIGATION SYSTEMS

by

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A Professional Project Report Submitted in Partial Fulfillment of the Requirements for the Dual Degree of:

Master of Water Resources
Master of Community & Regional Planning

The University of New Mexico
Albuquerque, New Mexico
April 2012

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The Master of Water Resources and Community & Regional Planning Professional Project Report of Marcos A. Roybal, entitled Measuring Acequia Functionality: Developing a Tool for Assessing New Mexico’s Community-Based Irrigation Systems, is approved by the committee:

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ABSTRACT

The semi-arid environment of the American Southwest has necessitated creative strategies for the use and management of water resources. In New Mexico and southern Colorado, one such strategy is the acequia irrigation system, which serves the dual purpose of delivering water and shaping community. This professional project provides a synthesis of existing knowledge with respect to acequias, and develops a tool, the Acequia Functionality Assessment, for evaluation of factors that contribute to the operation of acequias. It begins by summarizing the origin, development and use of acequias, and highlights the communal nature of their operation. Second, it briefly describes resilience theory as a lens through which to view the past, present and future of acequias. Third, it outlines the various benefits acequias provide, which include crop irrigation, serving as a cultural resource and important element of rural communities, ecosystem services, and representing an alternative method of natural resource management. Fourth, it discusses the challenges acequias currently face, which range from increasing demands on land and water resources, changing socioeconomic conditions, large-scale agricultural practices, and climate change. Finally, in recognition of the many benefits of acequias provide but the challenges they face, it develops the Acequia Functionality Assessment (AFA) as a planning tool for acequia users, researchers, and funding agencies to document current conditions and needs, monitor project effectiveness and changes over time, and engage youth and other community members. Such use of the AFA can help build the resilience of acequias and likelihood that they will continue to function in the future.
ACKNOWLEDGEMENTS

This project would have been impossible without the support of numerous people. In particular, the guidance and ideas of Bill Fleming, José Rivera, and Bruce Thomson were instrumental in bringing this project to fruition and improving it immeasurably. Also, the feedback from numerous acequiers in the El Rito and Taos areas and the 2010 and 2011 Congresos de las Acequias greatly bolstered the comprehensiveness and utility of the Acequia Functionality Assessment. I would like to give special thanks in this regard to Juan Garcia and Lucas Trujillo in El Rito and Miguel Santistevan in Taos, who devoted substantial time and thought to the effort. I would also like to thank Melinda Benson, Zander Evans, Eytan Krasilovsky, Amy Miller, Sandeep Sabu, and Katie Zemlick for pondering various aspects of this project with me and sharing their valuable ideas, and Lauren Klose, who helped develop early versions of the assessment. Finally, I would like to thank Sheila Castle and Larry and Sarah Roybal for their support and understanding throughout the process.

Additionally, I would like to acknowledge the generous support provided by New Mexico EPSCoR under NSF Grant #EPS-0814449 throughout the two academic years in which this project was developed.

“El que pierde su tierra pierde su memoria”
-Juan Estevan Arellano, 1997
TABLE OF CONTENTS

Chapter 1. Exploring the past, present and future of acequia irrigation systems...........1
  1.1 Introduction.................................................................1
  1.2 A note on terminology and scope........................................3
  1.3 EPSCoR: Context within and contributions to a larger research project.......3
  1.4 Client.................................................................5
  1.5 Roadmap.................................................................5

Chapter 2. Acequias and land grants: an introduction to traditional irrigation and
  land use in New Mexico.......................................................8
  2.1 Acequia description and history........................................8
  2.2 Governance of acequias..................................................11
  2.3 The land grant context...................................................14
  2.4 Current efforts in support of acequias..................................19

Chapter 3. Resilience: a framework for evaluating the trajectory of acequias as a
  social-ecological system.......................................................21
  3.1 An introduction to resilience theory....................................22
  3.2 Applying resilience theory to acequia history..........................24
  3.3 Moving forward with a resilience theme................................30

Chapter 4. “Multifunctional” agriculture: the benefits of acequia irrigation systems........31
  4.1 Acequias as the social and cultural underpinning of rural Hispano
     communities and a source of local knowledge..........................32
  4.2 Economics.................................................................34
  4.3 Policy and management: acequias as a model for alternative resource
     management.................................................................36
     4.3.1 User and resource boundaries.....................................39
     4.3.2 Congruence with local conditions.................................41
     4.3.3 Appropriation and provision.......................................41
     4.3.4 Collective choice arrangements...................................42
     4.3.5 Monitoring..........................................................42
     4.3.6 Graduated sanctions................................................43
     4.3.7 Conflict resolution................................................44
4.3.8 Recognition of rights to organize........................................45
4.3.9 Nested enterprises.................................................................46
4.4 Environment..............................................................................47
4.5 Conclusions..............................................................................50
Chapter 5. Challenges facing contemporary acequia irrigation systems.........51
  5.1 Changing demands on land and water resources..........................51
      5.1.1 Land use change..............................................................53
      5.1.2 Pressures on acequia water rights........................................55
  5.2 Changing socioeconomic conditions........................................57
  5.3 Trends in agriculture...............................................................59
  5.4 Climate change.........................................................................61
      5.4.1 Global climatic factors affecting agriculture...............63
      5.4.2 Extreme weather events..................................................64
      5.4.3 ‘Pest’ behavior.................................................................66
      5.4.4 Effects of elevated CO₂ concentrations: FACE studies........67
      5.4.5 Economic and social effects.............................................68
      5.4.6 Small-scale agriculture......................................................69
      5.4.7 Adaptation.........................................................................70
  5.5 Conclusions..............................................................................71
Chapter 6. The Acequia Functionality Assessment: a tool for planning and
building resilience.........................................................................73
  6.1 Development of the Acequia Functionality Assessment................74
      6.1.1 Sources of inspiration and related efforts.........................74
      6.1.2 Development and refinement of the Acequia Functionality
          Assessment criteria..............................................................76
  6.2 Description of the Acequia Functionality Assessment use and structure......81
  6.3 Description of pages 1 and 4 of the Acequia Functionality Assessment....83
  6.4 Description of the “Physical Characteristics” category of the
      Acequia Functionality Assessment..........................................84
      6.4.1 Amount of flow during irrigation season...........................85
      6.4.2 Duration of useable flow in recent years.............................85
6.4.3 Bank Stability................................................................. 86
6.4.4 Access to acequia easement.............................................. 87
6.4.5 Infrastructure condition and improvements needed.............. 87
6.4.6 Water quality............................................................... 88
6.4.7 Extent of irrigation......................................................... 89

6.5 Description of the “Ecology” category of the Acequia Functionality Assessment........................................ 89
6.5.1 Vegetation structural diversity........................................... 90
6.5.2 Vegetation species diversity.............................................. 91
6.5.3 Presence of noxious weeds.............................................. 92
6.5.4 Acequia bed material..................................................... 92
6.5.5 Wildlife use................................................................. 93
6.5.6 Other ecosystem services............................................... 93

6.6 Description of “Acequia Governance and Community Use” category of the Acequia Functionality Assessment........................................ 94
6.6.1 Meetings of the local acequia association.......................... 94
6.6.2 Acequia bylaws and water transfers................................... 95
6.6.3 Water banking............................................................. 96
6.6.4 Use of acequia water...................................................... 97
6.6.5 Acequia cleaning........................................................... 97
6.6.6 Interest in acequia agriculture within the local community........ 98
6.6.7 Economic viability of farming and ranching....................... 98
6.6.8 Land use trends in the local community.............................. 99
6.6.9 Acequia finances.......................................................... 100

6.7 Analysis and application of the Acequia Functionality Assessment results................................................. 100

Chapter 7. Summary and conclusions: the Acequia Functionality Assessment as a tool for building social-ecological resilience.................................................. 102
7.1 Summary........................................................................... 102
7.2 Future work...................................................................... 106
7.3 Conclusions...................................................................... 107

References............................................................................. 109
Appendix 2. Acequia Functionality Assessment………………………………………………………… 121
Appendix 3. Acequia Functionality Assessment Guidebook…………………………………… 125

LIST OF TABLES

Table 1. “Design principles” characteristic of long-enduring common-pool resource management institutions……………………………………………………………………………… 38
Table 2. Modified “design principles” characteristic of long-enduring common-pool resource management institutions……………………………………………………………………………… 39
Table 3. Riparian Health Assessment criteria………………………………………………………… 74
Table 4. Acequia Functionality Assessment category 1–physical characteristics…………… 78
Table 5. Acequia Functionality Assessment category 2–ecology……………………………… 79
Table 6. Acequia Functionality Assessment category 3–acequia governance and community use…………………………………………………………………………………………………… 80
Table 7. Average functionality ratings for acequia physical characteristics, ecology, and governance/community use…………………………………………………………………………………………………… 82

LIST OF FIGURES

Figure 1. The typical layout of an acequia system……………………………………………… 9
Figure 2. The adaptive cycle……………………………………………………………………………… 23
Figure 3. Panarchy…………………………………………………………………………………… 23
Figure 4. Paisaje del agua in El Rito, NM…………………………………………………………… 40
Figure 5. Hydrologic flow paths in a flood-irrigated acequia system………………………… 48
Figure 6. Population trends in Rocky Mountain states, 1950–2010…………………………… 52
Figure 7. Acequia headgate before and after repair supported by acequia cost share program……………………………………………………………………………………………………………… 88
Figure 8. Four vegetation structural classes: tree, shrub, grasses and forbs………………… 91
CHAPTER 1. EXPLORING THE PAST, PRESENT AND FUTURE OF *ACEQUIA* IRRIGATION SYSTEMS

1.1 Introduction

On an unseasonably warm Sunday morning in March, a motley group assembled at an old adobe house in northern New Mexico. Though small, its members had traveled from as nearby as the house next door and as distant as Pennsylvania. The chatter on the porch ranged from that year’s poor precipitation to why the man from Pennsylvania was wearing two watches (“so I know the time back there and here—at once!”). The group slowly drifted inside, where, once a critical mass was reached, the conversation was transformed into business by Robert’s Rules of Order. The annual meeting of the local acequia association had begun. After the opening formalities and requisite reports, the topic shifted to that year’s major item of business: updating the association’s bylaws to reflect recent changes in New Mexico’s statutes governing acequias’ ability to approve transfer of water rights outside of the system and protect existing water rights from loss due to non-use through banking.

Beginning in the 1980s, the New Mexico legislature, recognizing changing pressures facing the state’s long-standing irrigation institution, adopted a series of statutes granting greater protection to acequias. The first, passed in 1985, allowed for the protest of water right transfer applications that would negatively impact the “public welfare” (NMSA 1978 §72-5-23). The second, passed in 1987, allowed acequias to acquire water rights from *parciantes* (member irrigators) in order to transfer them and protect them from loss due to nonuse through water banking (NMSA 1978 §73-2-22.1). The third, passed in 2003, further provided for temporary allocation of water rights to a water bank (NMSA 1978 §73-2-55.1) and supplied an individual acequia’s commission with the authority to deny water rights transfers that would be “detrimental to the acequia… or its members” so long as the acequia’s bylaws declared this
authority (NMSA 1978 §73-2-21E and §73-3-4.1). Finally, amendment of NMSA 1978 §3-27-1 and §3-27-3 in 2009 prohibited municipalities from condemning acequia water rights to supplement their growth plans (Utton Center 2012).

The discussion in the meeting surrounding updating the bylaws echoed themes characteristic of many of New Mexico’s acequias—fears of water right transfers affecting the overall system’s ability to function, “outsiders” not understanding the value of acequias, frustration with individual parciantes using water out of turn, residual anger flowing from land loss in land grant communities, and concerns over the effects of a changing climate and increasing cultivation of genetically modified vegetable crops. All of these factors were cited as justification for ensuring that this particular acequia’s bylaws were kept up-to-date. Passions were running high by the end of the meeting, but even at the time of this writing, approximately two years later, the bylaws in question have not been updated. This is not for lack of effort; rather, it is a product of a complex suite of factors that have reduced acequias’ capacity to plan and see such visions through to fruition.

This project seeks to address the question of how to mitigate this problem. It proposes that this can be accomplished via use of a tool, the Acequia Functionality Assessment, that parciantes, acequia associations, researchers, and funding agencies can use to assess current conditions and needs in a given acequia system and build the capacity to address these needs in a way that strengthens resilience. This will help ensure not just the survival of acequia communities but also the flourishing of a unique system of water resource management and community development. This project is the culmination of several years of academic interest in the past, present and future roles of acequias in New Mexico, as well as a lifetime of experience in acequia communities. As a result, it provides a perspective on the trajectory of acequias in
New Mexico that is supported not only by a burgeoning body of academic literature but also first-hand exposure to the successes and tribulations of the acequia way of life.

1.2 A note on terminology and scope

Throughout this report, “acequia” refers to both the physical ditch through which water flows during its conveyance to irrigated land and to the complex social institution that has arisen in relation to acequia irrigation (i.e. the associated governance structures, irrigation works, and interactions between parciantes). For example, Cox (2010) describes the acequia as a “community of irrigating farmers.” “Hispano” is used to describe the residents of New Mexico who can trace some degree of their lineage to Spanish or Mexican settlers during the Spanish and Mexican colonial periods (1598–1848) and often possess Native American ancestry as well (Wheelright 2012). Although various terms can be used in different contexts, Hispano is commonly used in this regard (Kosek 2006).

Today, operating acequias are found in northern New Mexico and southern Colorado, particularly within the San Luis Valley. Although this project is generally focused on New Mexico, the discussion and Acequia Functionality Assessment are applicable in Colorado as well.

1.3 EPSCoR: Context within and contributions to a larger research project

This project was conducted under the Experimental Program to Stimulate Competitive Research (EPSCoR) Research Infrastructure and Improvement Phase 3 (RII 3), “Climate Change Impacts on New Mexico’s Mountain Sources of Water.” This program, funded in part by the National Science Foundation Grant #EPS-0814449, began in 2008 and continues for five years.
with the objective of providing “the tools required for quantitative, science-driven discussion of difficult water policy options facing New Mexico in the 21st Century” (New Mexico EPSCoR n.d.). The University of New Mexico is one of several institutions in New Mexico participating in this project, with the UNM Community and Regional Planning Program taking the lead on documenting the customs and traditions of acequia systems in the Rio Hondo and El Rito watersheds during times of climate variability and the effects of this variability on human adaptation. This includes characterizing acequia socio-cultural institutions and the robustness of acequia systems in the face of climatic variation; organizing focus groups and facilitating discussions on the possible climate change impacts on traditional irrigation practices, cropping patterns and land use, water sharing agreements, storage facilities and water conservation; and monitoring riparian health.

This professional project contributes to the goals of New Mexico EPSCoR and the CRP sub-award in several ways. At the state level, it provides a tool for evaluating the current conditions of an important component of New Mexico’s water policy—its acequias. As acequias are often located relatively high in watersheds, their water use is both sensitive to upstream activities and influences the availability of water for downstream users. The Acequia Functionality Assessment was created to allow monitoring changes over time to facilitate planning for uncertain future conditions. This will promote climate change adaptation. At the UNM CRP level, the components of the assessment and supporting discussion are informed by the “ancient customs and traditions of acequia systems” and the assessment provides a means of characterizing acequias’ robustness in the face of climate change. Additionally, many acequias function as riparian systems due to their lengthy presence on the landscape and connectivity to
existing rivers and streams. This assessment evaluates the “functionality” of these systems, which in many cases can be seen as an analogue of riparian “health.”

1.4 Client

As a professional project, this effort is intended to not only represent an academic exercise in the partial fulfillment of the requirements of the degrees of Master of Water Resources and Master of Community and Regional Planning at the University of New Mexico, but also to generate a product with applications outside of the University. In particular, the Acequia Functionality Assessment is targeted at parciantes and local acequia associations and commissions to serve as a planning and educational tool and an instrument for monitoring spatial and temporal changes, and at agencies that work with and provide funding for acequias. As such, Chapter 6 describes the assessment in detail and be adapted into a guidebook that describes use of the assessment and analysis and application of the results (Appendix 3). The project will be provided in its entirety to the New Mexico Acequia Association and other interested parties, and the guidebook portion will be provided to acequia associations in northern New Mexico.

1.5 Roadmap and Project Objectives

The remainder of this project is divided into six sections. Chapter 2 outlines the history of the acequia institution in New Mexico and describes its context within the system of Spanish and Mexican land grants that facilitated settlement of the region. It also describes the current role acequias play. Chapter 3 discusses resilience theory as applied to “social-ecological systems” (SES), and highlights acequia communities in rural New Mexico as a prime example of this type of system. It also uses the resilience framework to evaluate factors that have allowed
acequias to persist for over 400 years in the state and that may affect their viability into the future. Chapter 4 introduces the benefits acequias provide, ranging from simply allowing settlement in a challenging environment to their effects on more complex social and ecological arrangements. Chapter 5 presents challenges acequias currently face and the effects these challenges may have on the resilience of the acequia SES. These include increasing demands on water resources for domestic and municipal uses; land use change; the current nature of agriculture at broad scales; the social and economic environment of New Mexico’s rural communities; and the impacts climate change may have on agricultural systems generally and New Mexico’s mountain sources of water specifically. In recognition of the benefits acequias provide and the challenges they currently face, Chapter 6 presents the development of the Acequia Functionality Assessment as a tool parcientes, acequia associations, researchers and funding agencies can use identify strengths, weaknesses and needs, monitor changes over time, and engage local youth on a given acequia. This assessment is designed to highlight factors that may contribute to the resilience of an acequia with respect to its physical components, ecological services, and governance and community use. This chapter outlines the methods undertaken in developing the assessment, describes each of the assessment’s components, guides analysis of the resulting data, and proposes potential applications of the assessment. Much of the material in this chapter is also formatted as a guidebook for use of the functionality assessment that can be distributed to parcientes and acequia associations (Appendix 3). Finally, Chapter 7 summarizes the elements of this project and outlines the assessment’s potential role in strengthening the resilience of New Mexico’s rural social-ecological systems.

On the whole, in addition to developing a planning, evaluation and educational tool for use by parcientes and others interested in acequias, this project serves as a synthesis of a
growing body of literature surrounding the history, function, and current and future status of acequias in New Mexico. Furthermore, framing these issues using resilience theory represents a relatively new method of analysis.
CHAPTER 2. ACEQUIAS AND LAND GRANTS: AN INTRODUCTION TO TRADITIONAL IRRIGATION AND LAND USE IN NEW MEXICO

This chapter provides a general description of the anatomy and function of acequias, and summarizes their evolution as an irrigation institution in New Mexico. As a part of this, it will outline the system of land grants that guided the establishment of many communities in the state and describe the implications that land tenure changes associated with the adjudication of these grants have had for rural Hispano communities. This adjudication is criticized by many as having been unjust and at many times fraudulent (e.g. Briggs and Van Ness 1987, Ebright 1994, Gonzales 2003, Benavides and Golten 2008, Correia 2009), and has had lasting impacts on New Mexico’s rural communities (Kosek 2006, Garcia 2008, Trujillo 2009). This chapter closes by describing the current use of acequias in New Mexico and efforts being made to promote their continued viability.

Understanding the history, use and governance of acequias and surrounding systems of land tenure is critical to setting the context for acequias’ current status in New Mexico. These topics have been addressed in detail by numerous authors (e.g. Hutchins 1928, Lovato 1975, Meyer 1984, Clark 1987, Crawford 1988, Rivera 1998, Rodríguez 2006, Fernald et al. 2007, Rivera and Martinez 2009) and are briefly summarized here.

2.1 Acequia description and history

Acequias are irrigation ditches used for conveying water to fields, orchards and gardens (Figure 1). They typically consist of a main ditch (*acequia madre*) that is diverted from a stream or river by means of a small dam (*presa* or *atarque*) that can be temporary or permanent and constructed of local materials such as brush and rock or imported materials such as concrete and metal. From the diversion dam, the *acequia madre* flows generally parallel to the stream, and
Irrigated areas are typically located between the ditch and the stream (Rivera 1998). These ditches are often earthen, but may be lined with concrete to increase efficiency or eliminate seepage or erosion in problem areas (M. Santistevan, personal communication, May 2010). Water is diverted from the *acequia madre* by means of a headgate (*compuerta*) into smaller lateral ditches (*sangrias*) that carry the water into the area to be irrigated (Rivera 1998).

Irrigation is traditionally done by hand by surface flooding; however, alternative methods such as drip or gated pipes are gaining popularity, but these have shown mixed results regarding efficiency (García Petillo 2009).

The history of irrigation in the American Southwest predates the earliest Spanish settlement by as much as 900 years. The Ancestral Puebloans (Anasazi) and various other Native American groups constructed complex water storage, conveyance and conservation systems.
infrastructure, using it to provide water to extensive agricultural works (Meyer 1984). In the northern Rio Grande area, early Spanish explorers were impressed by the extent of the irrigated agriculture of the various Pueblo groups (Hutchins 1928, Rivera and Martínez 2009). When Spanish settlement began in the late 1500s, abandoned Native American irrigation works were often used as the foundation for new infrastructure (Rivera 1998). The Spanish settlers also brought irrigation practices from Spain, where a similar climate necessitated active irrigation to support agriculture. Spanish irrigation practices are thought to be rooted in Arabic and Roman traditions that were brought to the Iberian Peninsula; in fact, the word “acequia” is derived from the Arabic as-saquiya, irrigation ditch. When transferred to the American Southwest, these Old World irrigation traditions melded with Native American customs, Mesoamerican agricultural practices and locally unique physical and climatic features to form the basis for the modern-day acequia system. Acequias were often the first public works projects constructed in a new settlement (Rivera 1998, Rivera 2011), and their construction, operation and maintenance were typically communal affairs with parciantes contributing in proportion to the benefits they received (Rivera and Martínez 2009). This pattern of communal use and management of water fit within the larger communal relationship to natural resources seen in community land grants, as discussed in Section 2.3.

New Mexico became part of Mexico in 1821 and the United States in 1848, but acequias generally continued to function as they did under Spanish rule. A territorial law passed in the early 1850s guaranteed priority of water use for irrigation and codified the authority of existing ditch rules to govern the management of acequias; this pattern continued until New Mexico territory adopted its Water Code in 1907. This Code vested authority to manage water resources in the Territorial Engineer, and by centralizing water management reduced the overall
sovereignty of acequias. When New Mexico became a state in 1912, both state and federal administration of water expanded. Bureau of Reclamation projects and the advent of water conservancy districts further complicated the availability of water for acequias (Rivera and Martínez 2009). More recently, a variety of factors, including a reduction in local agriculture for food production, have reduced the role acequias play in day-to-day life in rural New Mexico, but they continue to function to varying degrees in numerous communities.

2.2 Governance of acequias

One of the most significant features of acequias is their communal nature, wherein labor and available water are shared among the irrigators (Rivera 1998, Rodríguez 2006). This stands in contrast with the doctrine of prior appropriation, which developed in Colorado and was codified in the mid to late 1800s, is now common in most of the western United States, and is generally based on the premise that a person who puts a certain amount of water to “beneficial use” at a certain time (priority date) establishes a right to the continued use of that amount of water. In times of shortage, water allocation is determined by the seniority of priority dates, with the water user holding the most senior date entitled to the full measure of his or her water right prior to the next most senior user (Tarlock et al. 2009). Furthermore, under prior appropriation water rights are viewed as a commodity that can be bought and sold, whereas Hispano communities traditionally viewed land and water as inseparable entities (Rivera 1998). Among other things, the commodification of water rights threatens the continued operation of acequias that rely on a certain amount of available water and community participation to function; this is explored in greater detail in Chapter 5.
Until the 1880s, the general governing authority in acequia operations fell almost entirely on the *mayordomo*, or ditch superintendent. The *mayordomo* was typically elected by the *parciantes* and charged with distributing water to *parciantes*, organizing the annual spring cleaning (*limpia*) and occasional repairs to the ditch infrastructure, guarding against waste and inappropriate water use, and settling disputes between irrigators. During these times written rules were usually absent, so familiarity with local customs was crucial for effective administration. In 1880, the New Mexico legislative assembly provided for the election of a three-member commission for larger ditch systems, and in 1895 mandated such a commission for all acequias. Under this system the *mayordomo* retained the authority to allocate water, but the commission, composed of a chairman, secretary and treasurer, was in charge of creating the general policies that governed the operation of the acequia (Rivera 1998). In 1907 the territorial legislature passed the “Acequia Act” (NMSA 1978 Chapter 73, articles 2 and 3), which standardized criteria for officers and membership, election protocol, and duties of the officers (Utton Center 2012).

Throughout acequias’ history in New Mexico, various strategies have been employed to share water (known as *repartimiento*) among acequia users and between ditches and communities in the same stream system. These agreements (*arreglos*) are particularly important in times of shortage, which are common in the state’s semi-arid environment (Meyer 1984, Levine 2000). Individual agreements reflect local customs and conditions, and can be altered to meet changing needs. In El Rito, for example, water is chronically short and a method of water sharing called the *tiempo* system has developed. The tradition of water sharing is quite clear under this system, with the bylaws for the El Rito Ditch Association describing it as “a community based structure for water sharing and distribution… [that] does not anticipate that
any ditch or user has priority over another… [or] attempt to fix [water] quantity to a particular place, but anticipates that the available water will be shared by all parciantes making efficient use of water during chronically short periods” (El Rito Ditch Association 2007, p. 4). The tiempo system serves as a “book-keeping system to ensure the collection of adequate acequia dues; a means of determining the amount of water that each parciant is entitled to during times of shortage; and a system of assessing the labor each parciant is required to provide to the association for the maintenance of the ditch” (Levine 2000, p. 8). Under the system, parciantes receive water on a rotational basis with two six-hour tiempos during the day and one 12-hour tiempo at night, and tiempos are rotated between the 11 ditches that comprise the El Rito system. The time allocated to parciantes to receive water is determined by their location on the ditch and on streamflow. Tiempos do not correspond to the amount of land owned, and parciantes can own multiple tiempos. Tiempos have been bought and sold separately from particular parcels of land, but cannot be divided into units less than one tiempo. The number of tiempos owned does not determine the number of votes to which a parciant is entitled, but each parciant pays dues in accordance to the number of tiempos he or she owns. Under the tiempo system more than one parciant can irrigate at once if adequate water is available, and if water is abundant it is not distributed on a rotational basis and parciantes are able to irrigate as needed (Levine 2000, El Rito Ditch Association 2007).

In contrast to the tiempo system employed in El Rito, which has been in place for many years and depends on the judgment of the ditch officials and a simple rotation system, three of the communities within the Rio Hondo watershed north of Taos (Des Montes, Valdez and Arroyo Hondo) recently adopted a more quantitative flow sharing agreement that allocates water in fixed percentages to the three communities on a sliding scale based on measured streamflow
in the Rio Hondo. The Rio Hondo and all diversions from it are to be gauged, and in low-flow conditions flow is to be reported at least bi-weekly. In addition to mayordomos on individual acequias, operations among the participating communities are overseen by three “Mayordomos de la Comunidad,” who are comprised of one mayordomo or commissioner from each of the three communities subscribing to the agreement (Rio Hondo Acequias 2006a & b).

2.3 The land grant context

Acequias represent one element of a larger system of communal land tenure and agropastoral tradition that existed in New Mexico for several hundred years and formed the basis for many of its modern day rural communities: land grants. Acknowledging acequias’ context within the land grant system is vital to understanding their development and issues New Mexico’s rural communities face today. The patterns of land use that developed during the land grant period reflect complex interactions between human communities, uplands, and irrigated lowland areas. These patterns remain evident in the social, economic, physical and psychological makeup of many of northern New Mexico’s rural communities today. This section outlines New Mexico’s land grant history, and describes its lasting impacts on the state’s rural landscape and communities. Much of this material is summarized from Roybal (2011).

The first permanent Spanish settlement in New Mexico was established in 1598 near the confluence of the Rio Chama and Rio Grande (Rivera 1998, Torrez and Trapp 2010). From that point forward, with the exception of a period in the late 1600s following the Pueblo Revolt, European occupation of the territory expanded, and its position on the northern frontier of New Spain necessitated an organized method of ensuring it remained a bastion against encroachments from the north. Prior to the Pueblo Revolt in 1680, land grants in New Mexico took the form of
scattered, large properties that were given to Spanish military leaders and operated on the *encomienda* system of forced Indian labor. Abuses associated with this system helped precipitate the Pueblo Revolt, and subsequent resettlement was more community-oriented and guided by the *Recopilación de Leyes de los Reynos de las Indias*, the Laws of the Indies, of 1681 (Ebright 1994). This body of law outlined everything from the criteria governing the location of settlements to the development of public infrastructure, including acequias (Ebright 1994, Rivera 1998).

Following the Spanish reconquest of the territory in 1692 and proceeding through the remainder of the Spanish (1598-1821) and Mexican (1821-1848) territorial periods, the Spanish and Mexican governments awarded grants of land to individuals, groups of settlers, towns, or indigenous communities for the purposes of promoting frontier development, settling sparsely populated areas, rewarding administrative leaders, and buffering populated areas from “hostile tribes” (Gonzales 2003). Although grants to individuals and Pueblos are important to New Mexico’s history, some of the most contentious debate has surrounded the grants to larger groups of people, referred to as “community grants.” These allotments of land were typically composed of individual parcels for housing and farming surrounded by relatively large expanses of common land (*ejido*) used for hunting, pasturage, wood and herb gathering, quarrying, and watering. The individual parcels could be bought and sold, but the *ejido* could not (GAO 2001).

Petitions for community land grants were often made by several individuals on behalf of a larger group. Such petitions were brought before the territorial governor or a local governing official (alcalde), who would evaluate whether the land in question was being claimed or used by others, the adequacy of the petitioners’ qualifications, and the availability of natural resources such as pasture, water and firewood. In many cases, grantees were required to occupy and
cultivate their lands for a certain period of time (typically four to five years) in order to perfect the title.

The distribution of land grants ended in 1848 with the acquisition of New Mexico by the United States via the signing of the Treaty of Guadalupe Hidalgo, at which point the U.S. was faced with the need to adjudicate existing land claims in its new territory. Initially, Article X of this treaty required the U.S. to recognize the validity of all land grants that had fulfilled the requirements for legitimacy set forth by the Spanish or Mexican governments. Prior to ratification of the treaty, however, the U.S. Senate deleted Article X (Ebright 1994) and the U.S. was free to create a land adjudication system of its own. The one it devised placed the burden of proof of land ownership and the validity of land grants on New Mexico’s Spanish-speaking inhabitants, who rarely had the resources and legal expertise to adequately defend their claims (Correia 2009). This opened the door to decades of land speculation and dubious political and legal maneuvering, which in the end resulted in the expropriation of millions of acres of land by speculators and the U.S. government.

Scholarly opinion on the reasons for this expropriation is somewhat divided. Some (e.g. Ebright 1994, Gallegos 2009) attribute the losses of land primarily to fundamental differences between Spanish and Mexican land use law and customs and those of the U.S. In a system so heavily reliant on private property regimes, they say, it is a natural consequence that land held in common by local communities was either privatized or added to the public domain of the U.S. Others (e.g. Correia 2006, Correia 2008a) argue that the dispossession of land grants was a colonial process on the part of the U.S. driven by the inability of the capitalist system to accommodate the subsistence-level land use that characterized many land grant communities, particularly in a region that held a relatively untapped wealth of natural resources. Land grants
stood in the way of “progress,” which was measured in terms of the conversion of natural resources into material wealth.

It is likely that the processes of dispossession are rooted in aspects of both theories. Regardless of where the emphasis should lie, it is clear that the mechanisms the United States developed to adjudicate Spanish and Mexican land claims, the Office of the Surveyor General and the Court of Private Land Claims, frequently legitimized the speculation and self-serving actions on the part of lawyers, politicians, businessmen, and the U.S. government that resulted in the improper adjudication of large expanses of grant land in New Mexico.

Congress established the New Mexico Office of the Surveyor General (SG) in 1854 and charged it with receiving claims to Spanish and Mexican grants and making recommendations to Congress regarding their validity. Congress would then approve these claims on an individual basis (Correia 2008a). However, Congress provided the SG with few resources with which to perform its duties and did not allow adversarial land claims to be made, and Hispano landholders often distrusted or simply did not understand the system (Ebright 1994). To worsen matters, the processes used by the SG lacked transparency and thus facilitated rampant land speculation. Correia (2008a) summarizes tactics used under the SG system that resulted in dispossession. One involved lawyers petitioning for a grant to begin the adjudication process and purchasing (or claiming to have purchased) rights from only the named grantees, and then acquiring SG approval of the grant as a private or tenancy-in-common land claim. This was possible due to confusion surrounding the distinction between private and community grants, the SG’s unfamiliarity with Spanish and Mexican land law, and the fact that the Surveyors General were often active land speculators themselves. Another tactic involved speculators claiming that
community grants were private grants and purchasing deeds from heirs of the settlers. This was directly facilitated by confusion surrounding Spanish and Mexican property law (Correia 2008a).

In response to the significant inadequacies of the Office of the Surveyor General, Congress created the five-judge Court of Private Land Claims (CPLC) in 1891. The CPLC addressed some of the greatest shortcomings of the SG, such as allowing petitioners to make adversarial claims (Correia 2008a). However, with the new process came new challenges for Hispano landholders and additional opportunities for land speculation. For example, lawyers often offered their services for a one-third stake in the common property of a grant. Although under Spanish and Mexican law common property could not be bought or sold, an 1876 territorial statute allowed a part owner of a common property claim to isolate his or her interests through a partition suit. This would force the sale of all common property involved, which was often acquired by speculators at low prices (Ebright 1994, Correia 2008a). Another challenge to landholders was that the CPLC process heavily favored the U.S. government. The burden of proving the validity of a grant was placed on the claimant, and land grant lawyers frequently did not diligently pursue cases from which they did not stand to benefit directly. The U.S. government, on the other hand, was thorough in its challenging of each case and often appealed decisions on highly technical grounds (Ebright 1994).

The end result of the period of land grant adjudication in New Mexico lasting from 1854 to the early 1900s was an enormous reduction in the land base of the state’s land grant communities. According to the GAO (2004), of the 131 non-Pueblo community grants identified, only 20 were properly confirmed as community grants, 64 were confirmed in a non-community ownership pattern, and 47 were not confirmed at all. Of the 64 community grants not properly adjudicated, 30 were confirmed as private grants, 27 were confirmed as tenancies-
in-common, and seven were stripped of their common lands. The number of community grants that would have been confirmed as they were recognized by the Mexican government is uncertain, but would likely be far more than 20 (Benavides and Golten 2008).

To this day, many of New Mexico’s land grant heirs feel that a great injustice was done by the United States in its adjudication of land grants. The expropriation of the lands that historically supported northern New Mexico’s rural communities physically and spiritually has resulted in a strong sense of loss in their residents and a weakening of the region’s economic base, both of which have been cited as causes of the drug abuse and poverty that are prevalent in the region today (Garcia 2006, Kosek 2006, Garcia 2008). However, one element of communal resource management present in many land grant communities that has persisted is the acequia system, suggesting it possesses strong resilience and adaptability and potentially represents a culturally-rooted foundation for future community development that seeks to remediate some of the negative legacies of land grant adjudication.

2.4 Current efforts in support of acequias

The final section of this chapter briefly describes contemporary efforts to study and strengthen New Mexico’s acequias. Today, about 900 acequias are active in New Mexico and southern Colorado; approximately 800 of these are located in New Mexico (Rivera 2012). Acequias have received considerable attention in both academic and popular contexts. In academia, recent research has addressed the hydrologic (e.g. Fernald and Guldan 2006, Fernald et al. 2007, Helmus et al. 2009) and ecological (Fernald et al. 2007) benefits of acequias, the social-ecological dynamics of acequia systems (Cox 2010), the impacts of land use change on acequia landscapes (Ortiz 2007), the effects of water rights transfers on the public welfare of
acequia communities (Klein-Robbenhaar 1996), and the non-market values of acequias (Archambault and Ulibarri 2007, Raheem 2008). This literature generally recognizes the uniqueness of acequias as a long-standing community-based resource management institution with various benefits in addition to supporting agriculture.

Other efforts to promote acequias’ continued survival have been led by the New Mexico Acequia Association (NMAA), which describes its mission as “sustain[ing] our way of life by protecting water as a community resources and strengthening the farming and ranching traditions of our families and communities” through “community education, community organizing and policy advocacy” (New Mexico Acequia Association 2012a). NMAA programs include workshops and conferences related to funding, legal and policy issues, acequia governance, and other agricultural issues; providing technical assistance to individual acequia associations; and projects such as Sembrando Semillas (which is aimed at building agricultural knowledge and engagement in youth) and the Mayordomo Project (which is aimed at documenting and transmitting knowledge held by mayordomos; New Mexico Acequia Association 2012b). Local acequia associations have also played an important self-advocacy role and are vital in ensuring that their governing documents incorporate the protections granted by New Mexico state statutes.
CHAPTER 3. RESILIENCE: A FRAMEWORK FOR EVALUATING THE TRAJECTORY OF ACEQUIAS

While acequias in other portions of the American Southwest have disappeared, those in New Mexico and southern Colorado have persisted for over 400 years. This, against the backdrop of social and political changes that have occurred in the area over the same period, suggests adaptability, a measure of insulation from outside influences, and a particular tenacity of their associated social and cultural traditions. A body of work that has emerged in recent years that forges an explicit link between human and ecological systems and facilitates conceptualization of their dynamics is termed resilience theory or resilience thinking (e.g. Walker and Salt 2006). Resilience theory offers a new perspective for understanding the persistence of acequias in New Mexico, which represent a prime example of a system with strongly linked social and ecological components. Furthermore, it allows for exploration of the future adaptability of acequias in the face of changing climatic, social, and economic regimes, but also of factors that have contributed to current challenges they face.

This chapter provides an introduction to resilience theory, and then explores the history of acequias using the framework it provides. Recently, Cox (2010) used such an approach in his study of the acequias in the Taos area; the discussion here will expand upon this work. The resilience of acequias in the face of contemporary challenges is explored in Chapter 5, and application of resilience concepts to acequias is revisited in Chapter 7, which summarizes the ability of the Acequia Functionality Assessment to identify factors that impact the resilience of acequias and tipping points that could result in changes in the arrangement of these social-ecological systems.
3.1 An introduction to resilience theory

Resilience theory is an emerging systems-based way of thinking about natural resource management and other challenges (Roybal and Benson, in review). Resilience was first linked to the behavior of ecological systems by Holling (1973), who defined the term as “a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations and state variables.” He contrasts this to stability, “which represents the ability of a system to return to an equilibrium state after a temporary disturbance” (p. 14). This latter definition can also be equated to engineering resilience (Peterson et al. 1998). Discussions of resilience following Holling’s definition in 1973 generally focused on its role in ecological systems, but the last 15 years have seen an increase in its application to linked social and ecological systems (e.g. Levin et al. 1998, Adger 2000, Peterson 2000, Walker and Lawson 2006, Davidson 2010), such as acequias (Cox 2010). In linked social-ecological systems (SES) resilience has been defined in a number of ways (Brand and Jax 2007), but generally can be viewed as (1) the amount of change a system can undergo and still retain the same controls on structure and function; (2) the degree to which a system is capable of self-organization; and (3) the ability of a system to build the capacity to learn and adapt (Carpenter et al. 2001, p. 766). Resilience theory eschews the notion that social and ecological systems tend toward equilibrium or a stable state; instead, it views these systems in terms of an “adaptive cycle.” The adaptive cycle (Figure 2) is generally composed of four phases: rapid growth and exploitation of resources and opportunities (r); conservation (K), wherein energy is stored and complexity and rigidity of structure increase; collapse or release (Ω), where some disturbance exceeds a system’s resilience and the system comes undone; and renewal or reorganization (α), where novelty, innovation and experimentation shape a newly emerging system state (Carpenter
et al. 2001, Walker and Salt 2006). Resilience theory recognizes the importance of scale in interactions across system components and between different systems, which it conceptualizes as a hierarchy of interacting adaptive cycles, or panarchy (Figure 3).

Figure 2. The adaptive cycle (adapted from Walker and Salt 2006)

Figure 3. Panarchy (adapted from Walker and Salt 2006)
Many discussions of SES resilience are largely conceptual in nature, but identifying indicators of resilience is key to understanding their behavior (Carpenter et al. 2001). Various authors have proposed factors that contribute to the resilience of SESs. For example, Folke et al. (2003) proposed four factors critical to building resilience: (1) learning to live with change and uncertainty; (2) nurturing diversity for reorganization and renewal; (3) combining different types of knowledge; and (4) creating opportunities for self-organization. Ostrom (2009) emphasized the importance of the ability of users of natural resource systems to engage in collective action to self-organize. Walker and Salt (2006) listed nine elements that are key to a “resilient world”: (1) biological, landscape, social and economic diversity; (2) ecological variability; (3) modularity; (4) acknowledgement of slow variables; (5) tight feedbacks; (6) social capital; (7) innovation; (8) overlaps in governance; and (9) incorporation of ecosystem services in development proposals and assessments (p. 145–148). In an acequia-specific context, José Rivera has proposed that the resilience of acequias as a community irrigation institution can be attributed to (1) the customs of mutual aid (ayuda mutua) common to Hispano communities; (2) rules of governance that are place-based, adaptable, and community-guided; (3) local control and discretionary authority over water management; (4) the capacity to adapt to and recover from stresses such as drought; and (5) the power and solidarity of community characteristic of acequia communities (Rivera 2011, J. Rivera, personal communication, 23 February 2012). The following section will examine the history of acequia systems using the context provided by resilience theory.

3.2 Applying resilience theory to acequia history

Cox (2010) examined the resilience and robustness (defined as “the maintenance of some desired system characteristics despite fluctuations in the behavior of its component parts and
environment;” Carlson and Doyle 2002) of acequias in the Taos area from a historical perspective using the framework set forth by Ostrom (2007), which conceptualizes SESs as multitier interactions between resource systems, resource units, governance systems and resource users. Cox’s historical analysis of acequia resilience focused primarily on drought, in which one of the major challenges is mitigating upstream-downstream conflict. Cox found that both social and biophysical factors contributed to the successful mitigation of such conflict. From a social standpoint, the “relatively decentralized, multi-tiered governance system” of acequias, consisting of a *mayordomo* and several commissioners for individual or small groups of acequias, allowed for water allocation to groups of a manageable size, and also allowed for water allocation decision making between acequias. This helped minimize transaction costs by breaking a larger system into smaller components, with each being able to reach internal agreement that then facilitated governance of the larger system (p. 64).

From a biophysical standpoint, Cox found upstream-downstream conflict to be mitigated by the *desagüe* that returns unused waters (*sobrantes*) to the river and by seepage from unlined ditches into shallow aquifers, with both factors extending the retention of unused water in the local hydrologic system. Furthermore, acequias are often the first diversion in a watershed, allowing for rapid adaptation to seasonal changes in streamflow (Rivera 2011). Cox’s argument can be further supported using the factors contributing to resilience described above. Such a governance structure promotes dealing with uncertainty by providing a flexible framework for allocating varying amounts of water (Folke *et al.* 2003), and provides an example of collective action and self-organization (Folke *et al.* 2003, Ostrom 2009). Finally, individual acequias represent modular components of a larger system, social capital is evident in the interactions that are required in its communal structure, and overlaps in governance are clear (Walker and Salt
Taken together, these factors, along with the fact that acequias have persisted in many communities to this day, suggest that in the face of drought, they have historically been both robust and resilient. However, today they appear to be challenged by changing social, cultural, and economic conditions.

The historical (i.e. pre-20th century) analysis of the resilience and robustness of acequias provided by Cox (2010) primarily addresses drought. As such, it generally does not examine the impact of other historical disturbances on the past—and current—resilience of the acequia institution. However, such disturbances have punctuated acequias’ 400-year history. These include changes in government at the national level; changes in economics and land tenure associated with the adjudication of land grants in the late 19th and early 20th centuries; land use and economic change, particularly associated with the advent of the railroad; and significant migration out of rural communities associated with various wars in the 20th century and efforts to seek employment and education (Torrez and Trapp 2010, J. Rivera, personal communication, 7 February 2012). The remainder of this section explores the persistence of acequias in the face of these historical disturbances, and will discuss the impacts they have had on the resilience of the contemporary acequia institution. These impacts have a direct bearing on the current status of acequias in New Mexico and the issues they face, which is explored in greater detail in Chapter 5.

When Hispano settlers constructed the first acequias in New Mexico, the area was under control of the Spanish government. This government promulgated various laws guiding the establishment of settlements, which often encouraged residents to engage in agricultural pursuits (Rivera 1998). The isolated conditions of these settlements necessitated strong self-reliance, which laid the foundation for the agricultural tradition present in northern New Mexico today.
(deBuys 1985, Rivera 1998). It was within this context that acequias developed their present structure of governance, which, as described in Chapter 2, operated at relatively small scales in a repeating pattern across the landscape. The area became part of Mexico in 1821, and in 1824 and 1826 the legislative council adopted formal statutes governing acequias throughout the state (Rivera 1998). These essentially codified the status quo, and had minimal impact on the on-the-ground operation of acequias. A similar pattern occurred when the area was annexed by the United States. Although the persistence of acequia traditions following these two significant shifts in governance was allowed in large part by minimal efforts at reform by territorial legislatures, the fact that the legislatures passed acequia-related laws shortly after each jurisdictional change (in 1824/1826 and 1851-1852) suggests that lawmakers were not ignorant of acequias’ role in local governance and community function. Their early codification of the status quo likely reflects their acknowledgement that the system generally worked well as it was, which is a direct product of its resilience. Furthermore, the decentralized, modular nature of acequia systems throughout the state would have made enforcement of any major reforms a Herculean task, suggesting lawmakers’ recognition that legislatively forcing a regime shift would have been futile. However, as described in Chapter 2, the legislative, social and economic context of acequias began shifting more rapidly in the 20th century. The impacts of these changes on the resilience of acequias are likely to be significant in the future, and are already finding expression in commodification of water rights and changes in land use and the social status of acequias. These factors will be explored in greater detail in Chapter 5.

As described in Chapter 2, the adjudication of Spanish and Mexican land grants following the acquisition of New Mexico by the United States resulted in significant land tenure and economic changes in the state’s rural communities. In many cases the forested uplands that
comprised the *ejido* of community land grants entered the public domain of the U.S. via the adjudication process itself or the inability of villagers to pay property taxes on confirmed lands under the American system of monetary taxation (Raish 2000). Additionally, in some cases, such as that of the Vallecito de Lovato grant in Rio Arriba County, the residents’ claims to the grant were rejected outright and the entire area, home sites included, became public domain (Bowden 1969, Correia 2009). Although the loss of common lands did not necessarily directly affect irrigation institutions due to the frequent preservation of private property rights encompassing irrigated bottomlands, it compromised access to a large part of the land and resource base that traditionally supported rural Hispano communities. This contributed to the eventual erosion of the small-scale, subsistence-based economies that characterized these communities (Correia 2005).

From a resilience perspective, the actions of slow variables (Walker and Salt 2006) are of particular importance in examining the effects of land grant adjudication on New Mexico’s rural communities and acequias. This adjudication process spanned half a century, and the relatively isolated nature of land grant communities provided insulation from immediate change. Furthermore, land grant residents were often not at first aware that their title to land had changed or been nullified. Finally, as the following discussion illustrates, economic change in rural New Mexico is ongoing. The actions of these variables have likely negatively affected the integrity of acequia communities, but acequias’ persistence is a testament to the resilience provided by structures such as mutual aid; flexible, locally-based governance; local control of resources and discretionary authority in their allocation; adaptive capacity; and strong communal relationships (Rivera 2011, J. Rivera, personal communication, 23 February 2012).
The assimilation of New Mexico into the United States initiated a process of gradual economic change in its rural communities (Correia 2005, Correia 2008b, Rivera 2010). This began in the 1870s and 1880s, with Anglo-American businessmen and investors turning their attention to the natural resources the state had to offer. In particular, the construction of the Denver and Rio Grande Railroad and other rail systems increased New Mexico’s connectivity with external markets and bolstered its attractiveness to foreign as well as domestic investors (Correia 2008b, Rivera 2010, Torrez and Trapp 2010). The economic importance of timber and livestock increased dramatically, and mining, manufacturing, and commercial agriculture expanded as well. Rather than benefitting from this economic expansion, however, New Mexico’s rural Hispano residents were, at best, seen as a source of cheap labor, or, worse, looked at as little more than barriers to economic “progress” driven by outside interests. Low-wage labor jobs in southern Colorado and other areas provided employment for relatively brief periods, but the mechanization of farm equipment and competition from migrant laborers in the early 20th century depressed wages and resulted in periods of unemployment (Rivera 2010).

The shortage of jobs promulgated by shifts from agropastoralism to wage labor economies, together with compromised access to the land base that once provided the agropastoral basis of New Mexico’s rural communities, have also resulted in periods of out-migration as residents have been forced to seek education and employment elsewhere. Of particular note are the periods surrounding World Wars I and II, when numerous rural residents turned to military service. This resulted in a substantial drain of able-bodied residents (Torrez and Trapp 2010, J. Rivera, personal communication, 16 February 2012). The trends of economic depression and out-migration undoubtedly had negative impacts the human capital of New Mexico’s acequia communities, but mechanisms of social capital such as mutual support
societies facilitated the persistence of their social, cultural and economic traditions (deBuys 1985, Rivera 2010 & 2011). Furthermore, these groups represent well-developed examples of community self-organization and collective action, key elements of SES resilience (Folke et al. 2003, Ostrom 2009).

3.3 Moving forward with a resilience theme

Resilience as described here presents a useful framework for viewing the current status of acequias—both their strengths and weaknesses—and exploring potential future trajectories that place acequias at the center of increasing the broader social and ecological resilience of New Mexico’s communities. Chapter 4 discusses the long known but only relatively recently documented role acequias play in increasing the resilience of both social and ecological systems in New Mexico. Despite these beneficial effects, today acequias face a variety of challenges, many of which are legacies of the factors described in this chapter. Chapter 5 examines these challenges and highlights key ways in which they may impact the resilience of the acequia institution. Finally, the Acequia Functionality Assessment is presented in Chapter 6 as a means of elucidating factors that contribute to or detract from acequia resilience and identifying key tipping points that could result in shifts to less desirable states.
CHAPTER 4. “MULTIFUNCTIONAL” AGRICULTURE: THE BENEFITS OF ACEQUIA IRRIGATION SYSTEMS

For hundreds of years, acequias have increased the viability of agriculture in an area where it would otherwise be difficult, if not impossible. This was key in New Mexico’s early history, as the isolation of its rural communities necessitated robust self-sufficiency (deBuys 1985). However, users of acequias have long recognized the benefits this system provides in addition to supporting agriculture. These include recharging shallow groundwater and supporting a diversity of flora and fauna (Rivera 1998, Hicks and Peña 2003, Fernald et al. 2010a). Despite this long-held knowledge, attempts to rigorously quantify these and other benefits have occurred only recently. This has in part been driven by the concept of “multifunctional” agriculture gaining traction in recent years (e.g. Boody et al. 2005, Groenfeldt 2009a & b), which is based on the notion that agriculture can provide many benefits to the land, economy, and social structure in addition to the production of food and fiber (Boody et al. 2005).

This chapter synthesizes the literature related to the multifunctionality of acequias. First, it discusses the social and cultural impacts of acequias, with a particular focus on their importance to the maintenance of traditions in northern New Mexico. Second, it explores the economic values of acequias. Although from a purely market perspective arguments for the benefits of acequias may be tenuous, the other benefits they provide contributes to their nonmarket value. Third, it examines the lessons acequias can teach as an alternative form of natural resource management that is driven by communal ownership and community control of water resources. Fourth, it describes the variety of physical and ecological benefits acequias provide. Finally, it illustrates how these factors combine to form the paisaje de la acequia or paisaje del agua, “a constructed artifact where water is the principle tool of landscape modification for human use
and benefit” (Rivera and Martínez 2009, p. 2) and contribute to the overall resilience of the acequia institution.

4.1 Acequias as the social and cultural underpinning of rural Hispano communities and a source of local knowledge

Acequia users and supporters are often quick to note that water is the lifeblood of New Mexico’s rural communities (e.g. New Mexico Acequia Association 2012c) and that acequias are the veins that carry it. As described in Chapter 2 and by authors such as Rivera (1998), acequias have often served as the glue that binds communities together via their collective governance and structures of water sharing. The springtime limpias represented not only a physical cleaning of the acequia but also a renewal of the community as a whole—an opportunity to settle disputes that arose during the year and to regenerate social connections that may have weakened. Furthermore, times of scarcity necessitated the community to come together in order to ensure its own survival; this scarcity precipitated the creative and diverse strategies of repartimento, or water sharing (Rivera 1998), practiced by acequias.

As the social and economic climate changed under the transition to governance by the United States, perceived threats and resultant hardships were mitigated by mutual aid groups aimed at protecting and promoting customs and traditions that had developed in New Mexico’s remote rural communities (Rivera 2010 & 2011). The connection to the landscape wrought by a dependence on what it could produce developed in its residents a strong sense of place, or, more appropriately, querencia, “a place on the ground where one feels secure, a place from which one’s strength of character is drawn” (Lopez 1990 p. 39, Arellano 1997). The social capital, self-organization and adaptive capacity that developed by necessity in acequia communities are now key to their resilience, but the maintenance of acequias and other connections to the land is vital.
to the persistence of these factors. Indeed, diminished connections between residents and their land—and thus a loss of *querencia*—have been linked to the problems with addiction that are rampant in northern New Mexico (Garcia 2006, Kosek 2006, Garcia 2008, Trujillo 2009). However, in cases where these connections are allowed to persist and are encouraged, meaningful social and economic development can result (e.g. Sargent *et al.* 1991). In many communities acequias are an essential element of this connection (Rivera 1998, New Mexico Acequia Association 2012c).

The connection to place that acequias have helped create has generated a rich body of knowledge about local ecology, hydrology and agronomy, as well as techniques of managing common-pool resources. Additionally, the acequia institution represents an important element of the rich cultural landscape in the Southwestern United States. Amidst increasing calls to integrate local and indigenous knowledge with conventional science in environmental policymaking and natural resource management (e.g. Ballard *et al.* 2008, Berkes *et al.* 2009, Ascher *et al.* 2010, Bohensky and Maru 2011), acequia communities have the potential to contribute a wealth of information to discussions regarding natural resource management and adaptation in the face of social, economic, and climatic change. However, as Arellano (1997) points out, “we need to return to the past and mine that rapidly disappearing knowledge, to understand our privileges and responsibilities” (p. 35). The knowledge contained within acequia communities is great, but is at risk of being lost as the *ancianos*, or old-timers, pass on and younger generations move away to pursue different employment, education, and lifestyles (L. Trujillo, personal communication, 16 October 2010). The instability from which they flee can potentially be reversed with the proper application of integrated knowledge to existing social and cultural frameworks and land use patterns in northern New Mexico. The New Mexico Acequia
Association’s *Mayordomo* Project (New Mexico Acequia Association 2012b) is one example of this, but much work remains to be done. The Acequia Functionality Assessment presented here is one contribution toward this effort, as it is a product of integrated knowledge that seeks to both document traditions and highlight future needs.

4.2 Economics

Acequias have been a key component of rural northern New Mexico’s economic and physical landscape for centuries. In their functional form, they promote sustainable economies, which can be defined as those which maintain “mutually beneficial and equitable relationships internally, that is, within the community, and externally, with the larger society and economy” (Sargent *et al.* 1991, p. 182). Internally, acequias historically required equitable use of water and distribution of benefits due to scarcity and isolation. This took the form of sharing water, labor and agricultural products. Externally, they allowed for trade in agricultural goods between communities, which was key in a landscape where a factor as simple as being located in a narrow valley shortened the growing season, thereby lessening available produce. Furthermore, the governance structure of acequias was traditionally reliant on local control of resources, which Sargent *et al.* (1991) list as a key element of sustainable economic development. Finally, each acequia system represented a somewhat modular component of the larger agricultural landscape in northern New Mexico, with physical barriers such as mountain ranges separating individual systems from each other. This decreased the chances that localized disturbances such as fire or pest outbreaks and small-scale variability in precipitation would negatively impact agriculture regionally, and also allowed for development of a greater diversity of plant cultivars across the
landscape. This modularity and diversity (Walker and Salt 2006) contributed to the overall historical functional and economic resilience of acequias.

In short, acequias made locally based, sustainable agricultural economies possible in New Mexico’s rural villages. However, from the perspective of a traditional market economy, today the productivity of water and land under the system of acequia irrigation is substantially less than the productivity of these resources when applied to urban and industrial uses (Archambault and Ulibarri 2007). Time can also be added to this equation, as the inputs of time required in traditional methods of acequia farming will generally yield a much lower financial return than similar investments of time in other occupations, particularly in more urban settings. In light of this fact, a purely market-based evaluation of the economic benefits of acequias would likely come up short. However, two recent studies (Archambault and Ulibarri 2007, Raheem 2008) have found that acequias produce substantial nonmarket benefits that should be accounted for in their valuation.

Archambault and Ulibarri (2007) conducted a stakeholder analysis in order to examine the cultural and environmental factors that contribute to the nonmarket value of acequias. They found that stakeholders typically assign value to acequias “based on their unique social structure, cultural and traditional heritage, and actual and potential environmental contributions” (p. 493). Conversely, they found that inefficient use of water, particularly with regard to its potential ecosystem effects, and conflicts with urban and industrial development had the potential to diminish their nonmarket value. They concluded by proposing activities that could improve the nonmarket value of acequias, including decreasing water consumption via ditch infrastructure improvements and increasing the efficiency of irrigation methods, capitalizing on cultural values.
by promoting tourism that emphasizes their unique cultural heritage, and recognizing the potentially beneficial effects proximity to an acequia could have on residential property values.

Raheem (2008) employed a contingent valuation survey to measure attitudes toward acequias, and found that residents of New Mexico’s San Miguel County place positive nonmarket values on acequia culture, and that there was a willingness to pay for a program designed to promote acequia culture. He also found that irrigators generally did not rely on agriculture for income, but, conversely, several made their entire income from agriculture.

It is clear that a purely market-based economic argument for the preservation of acequias would be tenuous. However, the limited research on the topic indicates that acequias possess substantial nonmarket values that are based in their cultural uniqueness and environmental effects. Despite this, the continued persistence of acequias will likely require a bolstering of their market values. Archambault and Ulibarri (2007) and Rivera (1998) propose tourism as one means of increasing acequias’ economic value, but their original purpose—enabling agriculture, provides a promising option as well. Several successful examples (such as the Santa Cruz Farm in the Española Valley; AgMRC 2012) of using acequia agriculture in combination with modern technologies such as heated vegetable beds, hoop houses and drip irrigation can serve as models for deriving greater market value from traditional acequia practices.

4.3 Policy and management: acequias as a model for alternative resource management

Natural resource management in the United States has, for much of its history, been conducted in a top-down, command-and-control fashion. Such an approach seeks to reduce variability and increase the predictability of system behavior in order to bolster the effectiveness (often defined in economic terms) of management. Examples of command-and-control
management can be found in a variety of resource systems, including water. However, as resilience theory demonstrates, social-ecological systems are dynamic and do not tend toward an equilibrium that is appropriate for command-and-control management. Command-and-control management of such systems will result in unexpected results for both their human and natural components. These can include collapse of the resource or related socio-economic systems, biodiversity loss, and human conflict (Holling and Meffe 1996). The overall result is what Holling and Meffe (1996) term the “pathology of natural resource management”—“when the range of natural variation in a system is reduced, the system loses resilience” (p. 330). In order to move away from this pathology, these authors call for natural resource management that seeks to increase the resilience of ecosystems and the flexibility of natural resource managers, self-reliance of industries, and the knowledge of citizens.

In recognition of the often unsustainable results of command-and-control natural resource management, scholars, resource management agencies, and communities are seeking alternative strategies that can inform natural resource management. One such strategy is community-based resource management (e.g. Pretty 2003, Fernandez-Gimenez et al. 2008, Fleming and Fleming 2009, Cox et al. 2010, Larson et al. 2010) and resource co-management (e.g. Berkes et al. 2009), both of which vest a greater degree of decision making authority in local communities than would be present in a purely command-and-control approach. Under community-based resource management local communities possess varying amounts of management authority, whereas co-management generally combines management by communities with management by agencies. Allowing local communities a greater role in natural resource management is a direct acknowledgement of the valuable perspectives local and indigenous knowledge and an attachment to place can contribute in such efforts (Berkes et al. 2009).
Although the success of community-based resource management around the world is mixed (e.g. Leach et al. 1999, Berkes et al. 2009), Ostrom (1990) argues that in some cases common-pool resource (CPR) management can in fact be quite successful and endure for long periods. She describes eight “design principles” that characterize “long-enduring” common-pool resource institutions (Table 1). Cox et al. (2010) evaluated application of these principles in the context of 91 studies, and found them to be “well supported empirically.” They then applied the 20 years of lessons learned from these studies to a reformulation of Ostrom’s rules (Table 2). Acequias are indeed “long enduring” community-based resource management institutions, and display many similarities to those examined by Ostrom (1990). The remainder of this section will focus on describing acequias in the context of Cox et al.’s reformulation of Ostrom’s rules in order to illustrate the elements that have contributed to the endurance of this institution of communal water management. Many of these have been codified in New Mexico statutes.

Table 1. “Design principles” characteristic of long-enduring common-pool resource management institutions (from Ostrom 1990, p. 90)

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Clearly defined boundaries: Entities who have rights to use the resource must be clearly defined, as must the boundaries of the resource itself.</td>
</tr>
<tr>
<td>2</td>
<td>Congruence between appropriation and provision rules and local conditions: Appropriation rules restricting time, place, technology and/or quantity of resource units are related to local conditions and to provision rules requiring labor, material, and/or money.</td>
</tr>
<tr>
<td>3</td>
<td>Collective-choice arrangements: Most individuals affected by the operational rules can participate in modifying these rules.</td>
</tr>
<tr>
<td>4</td>
<td>Monitoring: Monitors, who actively audit resource conditions and user behavior, are accountable to the users or are the users themselves.</td>
</tr>
<tr>
<td>5</td>
<td>Graduated sanctions: Users who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offense) by other users, by officials accountable to the users, or both.</td>
</tr>
<tr>
<td>6</td>
<td>Conflict resolution mechanisms: Resource users and their officials have rapid access to low-cost arenas to resolve conflicts among users or between users and officials.</td>
</tr>
<tr>
<td>7</td>
<td>Minimal recognition of rights to organize: The rights of users to devise their own institutions are not challenged by external governmental authorities.</td>
</tr>
<tr>
<td>8</td>
<td>Nested enterprises: For resource systems that are part of larger systems, appropriation, provisioning, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.</td>
</tr>
</tbody>
</table>
Table 2. Modified “design principles” characteristic of long-enduring common-pool resource management institutions (from Cox et al. 2010, p. 15)

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td><em>User boundaries</em>: Clear boundaries between legitimate users and nonusers must be clearly defined.</td>
</tr>
<tr>
<td>1b</td>
<td><em>Resource boundaries</em>: Clear boundaries are present that define a resource system and separate it from the larger biophysical environment.</td>
</tr>
<tr>
<td>2a</td>
<td><em>Congruence with local conditions</em>: Appropriation and provision rules are congruent with local social and environmental conditions.</td>
</tr>
<tr>
<td>2b</td>
<td><em>Appropriation and provision</em>: The benefits obtained by users from a common-pool resource (CPR), as determined by appropriation rules, are proportional to the amount of inputs required in the form of labor, material, or money, as determined by provision rules.</td>
</tr>
<tr>
<td>3</td>
<td><em>Collective-choice arrangements</em>: Most individuals affected by the operational rules can participate in modifying the operational rules.</td>
</tr>
<tr>
<td>4a</td>
<td><em>Monitoring users</em>: Monitors who are accountable to the users monitor the appropriation and provision levels of the users.</td>
</tr>
<tr>
<td>4b</td>
<td><em>Monitoring the resource</em>: Monitors who are accountable to the users monitor the condition of the resource.</td>
</tr>
<tr>
<td>5</td>
<td><em>Graduated sanctions</em>: Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and the context of the offense) by other appropriators, by officials accountable to the appropriators, or both.</td>
</tr>
<tr>
<td>6</td>
<td><em>Conflict-resolution mechanisms</em>: Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.</td>
</tr>
<tr>
<td>7</td>
<td><em>Minimal recognition of rights to organize</em>: The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.</td>
</tr>
<tr>
<td>8</td>
<td><em>Nested enterprises</em>: Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.</td>
</tr>
</tbody>
</table>

4.3.1 *User and resource boundaries*

Under principles 1a & b, “clear boundaries between legitimate users and nonusers must be clearly defined” and “clear boundaries are present that define a resource system and separate it from the larger biophysical environment” (Cox et al. 2010, p. 15). In acequia systems, boundaries between users and nonusers are typically clear. These are often described in bylaws for a particular acequia association and based on land ownership. This distinction is further supported by New Mexico statutes, which state, “…no person or persons who may desire to use the waters of… acequias… shall be allowed to do so without the consent of a majority of the
owners of such acequias…” (NMSA 1978 §73-2-7). Historically, the physical boundaries of the resources system were clear, as the isolated nature of New Mexico’s rural communities allowed them to function as discrete units. Within these communities, the landscape influenced by the acequia (paisaje del agua) was clear. Today, the paisaje del agua remains well defined (Figure 4) and the organization of acequias into distinct local institutions is codified by their status as corporations (“All community ditches or acequias shall… be considered as corporations… And… beginning at the dam or entrance of the water, in continued course to the end of the same, shall be considered as one ditch or acequia only…” [NMSA 1978 §73-2-11]) and political subdivisions of the state (NMSA 1978 §73-2-28). However, the boundaries of the resource itself, water, have been blurred by increasing demands within and outside of acequia communities for non-agricultural uses. At the local scale these issues can be mitigated by water sharing agreements (as discussed in Chapter 2), but at broader scales this presents a significant problem to the continued operation of acequias. This is further discussed in Chapter 5.

Figure 4. The paisaje del agua is clearly defined by green fields in El Rito, NM (image: Google Earth)
4.3.2 Congruence with local conditions

Under Principle 2a, “appropriation and provision rules are congruent with local social and environmental conditions” (Cox et al. 2010, p. 15). Because few acequias have or had substantial water storage infrastructure, their function is limited by the local availability of water. Although New Mexico statutes declare that the “apportionment and distribution of the water shall be made in accordance with the rights of each ditch, and in proportion to the lands irrigated by each ditch” (NMSA 1978 §73-2-49), on the ground, shortages are often mitigated by water sharing agreements such as the tiempo system in El Rito, the flow sharing agreement in Rio Hondo, and by local custom.

4.3.3 Appropriation and provision

Under Principle 2b, “the benefits obtained by users from a common-pool resource, as determined by appropriation rules, are proportional to the amount of inputs required in the form of labor, material, or money, as determined by provision rules” (Cox et al 2010, p. 15). Factors controlling a parciante’s ability to use water from an acequia are generally determined by local custom. Some acequias provide water on the basis of acreage owned (with the understanding that greater acreage requires greater inputs of time, material and labor), while others allocate water on a time-controlled basis. Regardless, New Mexico statutes require contribution of labor or money in proportion to land ownership to support maintenance of acequias and infrastructure improvements (NMSA 1978 73-2 §34, 38, 39, 44, 52, 56; NMSA 1978 §73-3-5).
4.3.4 Collective-choice arrangements

Under Principle 3, “Most individuals affected by the operational rules can participate in modifying the operational rules” (Cox et al. 2010 p. 15). Historically, the rules governing acequia operation were set and modified by the users of the ditch (Rivera 1998). Today, although the commissioners of each acequia association are generally in charge of setting the rules that govern acequia operations, the commissioners are elected to office by the general membership. Votes can either be allocated to parciantes in proportion to the interest of the voter in the ditch or water, or in proportion to the number of water rights he or she owns (NMSA 1978 §73-2-14). Furthermore, amendments to the bylaws that govern acequia operations typically require approval by the parciantes.

4.3.5 Monitoring

Under principles 4 a & b, “Monitors who are accountable to the users monitor the appropriation and provision levels of the users… and the condition of the resources” (Cox et al. 2010, p. 15). The use of acequia waters has long been monitored by acequia users and ditch official alike. For example, Ebright (1994) documents the extensive legal battle between two parciantes over the reconstruction of a dam in 1832, indicating that neighbors kept close tabs on each other’s water use. More recently, the mayordomo has typically been charged with monitoring water use and the overall conduct of the parciantes. State statutes give the mayordomo “superintendence of all work [on the acequia], the distribution of the waters thereof and the collection of fines, if any, and of amounts to be paid in lieu of fatigue or task work” (NMSA 1978 §73-2-21) and the ability to request parciantes to furnish laborers, assist in maintenance and repairs, and assess fines to those who fail to do so or who otherwise illegally
use water or encroach on the rights of other *parciantes* (NMSA 1978 73-2 §30, 31, 34, 36, 39, 40, 43-45, 52, 53-55, 64; NMSA 1978 §73-3-5).

Another less codified duty of *mayordomos*, commissioners and *parciantes* alike is monitoring the physical condition of acequia infrastructure as well as climatic trends that will affect water availability throughout the irrigation season. A constant watch for blockages in the ditch, weak spots in the bank, and malfunctioning infrastructure allows for identification of problems before they become serious. Because acequias are sensitive to variations in streamflow, careful accounting of available water is crucial to promoting acequia function throughout the season. Often, the first topic of conversation at the annual *limpia* is how the preceding winter’s precipitation and the mountain snowpack will impact water availability that year (Rivera 1998).

**4.3.6 Graduated sanctions**

Under Principle 5, “appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and the context of the offense) by other appropriators, by officials accountable to the appropriators, or by both” (Cox et al. 2010, p. 15). Historically, a variety of punishments were levied for offenses including water theft and damage to irrigation infrastructure or crops (Ebright 1994, Rivera 1998). Today, state statutes allow for fines, legal suits and other sanctions (usually water use restrictions) related to interference with a ditch easement (NMSA 1978 §73-2-5), improper *mayordomo* behavior (NMSA 1978 73-2 §20, 29, 46, 50; NMSA 1978 §73-3-8), failure to complete work or pay fees (NMSA 1978 73-2 §26, 34; NMSA 1978 §73-3-6), use of water after failure to complete required work or pay fees (NMSA 1978 §73-2-25), failure to furnish laborers as required by the *mayordomo* (NMSA 1978...
73-2 §31, 39, 40; NMSA 1978 §73-3-5), abandonment of work (NMSA 1978 §73-2-37), failure to provide payment for infrastructure maintenance or improvement (NMSA 1978 §73-2-45), neglect of duty on the part of the commissioners (NMSA 1978 §73-2-50; NMSA 1978 §73-3-9), illegal water use or water use without consent (NMSA 1978 73-2 §53, 54, 64), and interference with any acequia or associated infrastructure (NMSA 1978 §73-2-64). The severity of sanctions generally corresponds with the severity of the offense. For example, the penalty for abandonment of work is a fine paid to the local commission that can range from $5 to $10 (NMSA 1978 §73-2-37), whereas interference with an acequia or its infrastructure is classified as a misdemeanor with a penalty that ranges from $300 to $1,000 and/or five to 30 days in prison upon conviction, as well as the potential for the acequia to file a civil complaint for up to $5,000 (NMSA 1978 §73-2-64). However, the fine amounts reflect the era in which they were adopted (sometimes the late 1800s) and are often trivial by modern standards. As a result, they should be updated to reflect contemporary values.

4.3.7 Conflict resolution

Under Principle 6, “appropriators and their officials [should] have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials” (Cox et al. 2010, p. 15). Ebright (1994) and Rivera (1998) document the early history of conflict resolution related to acequia use, which typically ranged from simple verbal settlement of disputes to legal action or executive intervention by county- or state-level governing officials. Although intervention by governing officials generally no longer occurs, the courts and less formal arenas remain important venues for conflict resolution today. Many issues can be
resolved in-house by an acequia, which keeps costs to a minimum, but state statutes provide for legal intervention for the more serious offenses described in the previous section.

4.3.8 Recognition of rights to organize

Under Principle 7, “the rights of appropriators to devise their own institutions are not challenged by external governmental authorities” (Cox et al. 2010, p. 15). As Rivera (1998, 2009) documents and Chapter 2 describes, both the Mexican and American territorial legislatures were quick to pass laws that essentially codified the existing extent and operation of acequias in New Mexico. These broad liberties were legislatively diminished over the periods of U.S. territorial jurisdiction and then statehood, but current state statutes still allow for substantial protection of the general acequia institution (Rivera and Martínez 2009, Utton Center 2012). In fact, it appears that, to an extent, the New Mexico legislature has embraced the ability of acequias to self-organize, as reflected in state statutes. This is likely key to their persistence, and without these protections it is probable that outside interests such as the land speculators and investors of the late 19th century would have severely compromised acequias’ viability. Today, groups such as the New Mexico Acequia Association (NMAA) possess substantial social and political influence in the state, which promotes the continued self-organization capacity of the acequia institution. The passage of the water banking and water right transfer approval statutes in 2003, for example, occurred in large part due to advocacy by NMAA, and represents official recognition on the part of the state government of acequias rights to self-organize and self-govern (Rivera 2012).
4.3.9 Nested enterprises

Acequias can be seen to exist at three main scales: the individual acequia or small groups of acequias functioning under a single association, groups of interacting acequia associations (such as those sharing a common stream system, e.g. the Rio Hondo), and as a state-level institution, as codified in state statutes and advocated by NMAA. The subsections above describe application of principles 1–7 described by Cox et al. (2010) at the individual acequia level. Although several provisions in state statutes govern interactions between different acequias (NMSA 1978 72-2 §47-51, 54, 55), water sharing agreements such as those described in Chapter 2 generally guide operations that jointly affect ditches that are parties to the agreements. Although the language and provisions of these agreements vary, they provide an additional layer of support for the principles described in this section. Finally, state-level statutes provide relatively specific rules that govern acequia function equally.¹ This allows for state-level application and understanding of acequia rules in the contexts described by principles 1–7.

The preceding discussion illustrates that acequias possess many of the “design principles” of long enduring common-pool resource management institutions. This recognition is key not only to focusing future efforts at strengthening the acequia institution, but also to deriving lessons on how elements of the management of acequias and other common-pool resource regimes can be applied to other natural resource management situations where, perhaps, past command-and-control approaches have yielded little success at managing the resource to its benefit or that of the human communities dependent upon it.

¹ With small exceptions in procedure provided by the distinction between “Article 2” acequias (described in NMSA 1978 72-2) and “Article 3” acequias (described in NMSA 1978 72-3)
4.4 Environment

Acequia users have long touted the environmental benefits of their irrigation works, claiming they play crucial roles in recharging shallow groundwater; supporting useful plants such as *capulin* (chokecherry; *Prunus virginiana*), *ciruela* (wild plum; *Prunus* spp.), and *jara* (willow; *Salix* spp.); and providing wildlife habitat (Rivera 1998, Hicks and Peña 2003, L. Trujillo, personal communication, 16 October 2010). However, it was not until relatively recently that attempts have been made to quantify acequias’ environmental effects. This section summarizes the results of this ongoing research, which focuses primarily on hydrology but addresses water quality and ecology as well.

The EPSCoR project “Climate Change Impacts on New Mexico’s Mountain Sources of Water” has supported substantial research conducted by New Mexico State University regarding the hydrologic effects of acequias, much of which has been completed at the Sustainable Agriculture Science Center in Alcalde, New Mexico. Though ongoing, so far this work has found that seepage from ditches and flood-irrigated fields recharges shallow groundwater (Fernald et al. 2007, 2007, 2010b; Ochoa et al. 2007 & 2009; Helmus et al. 2009), with flood irrigation acting as a surrogate for historical floodplain inundation during peak discharge periods (Fernald et al 2007). This recharges wells located in the shallow aquifer and alters the river hydrograph by dampening flashiness (Fernald et al. 2010b) and extending flows into the late summer and early fall (Fernald et al. 2006, 2007, 2010b). Furthermore, acequia irrigation helps retain water in the watershed (Fernald et al. 2007) and potentially reduces evapotranspiration (ET) losses by increasing shallow aquifer (versus surface) storage (Fernald et al. 2010b). Figure 5 depicts the various paths water follows in an acequia irrigation regime. Overall, these studies found the following accounting of water diverted for irrigation: seepage from the ditch accounted
for between 5% and 16%, percolation (once the water was applied to a field) accounted for 21%, surface return flow for 59%, and crop ET for only 7%. It must be noted that all of the above studies were conducted in the same general area. Ochoa et al. 2009 emphasize the differential effects of soil type on the percolation and transmission of irrigation water, and it is likely that this, as well as other site-specific factors, would change the overall water balance and hydrologic behavior in other locations. However, these studies are likely indicative of general trends in the hydrologic effects of acequia irrigation systems. In El Rito, for example, seepage from acequias and flood irrigation is critical in recharging shallow aquifers that supply numerous domestic wells in the community (L. Trujillo, personal communication, 16 October 2010).

![Hydrologic Flow Paths](image)

Figure 5. Hydrologic flow paths in a flood-irrigated acequia system (Fernald et al. 2007, p. 161. Used with permission.)

Acequia irrigation has also been shown to positively affect water quality. Seepage into shallow aquifers through unlined ditches and flood-irrigated fields dilutes shallow groundwater constituents such as nitrates and other ions (Fernald et al. 2007, 2007, 2010b; Helmus et al. 2009), and may also dilute agricultural chemicals and septic tank effluent. Furthermore, groundwater transmitted to streams and rivers cools the temperatures of these surface water
bodies (Fernald et al. 2007 & 2010b), and the additional riparian vegetation that acequia irrigation supports traps contaminants that may otherwise be transmitted to streams and rivers by surface flow (Fernald et al. 2007, Hicks and Peña 2003).

The ecological benefits of acequias are more readily apparent, as they can be seen in the green swath that comprises the paisaje del agua in irrigated valley bottoms. First and foremost, as “agroecosystems” acequias support a diversity of both wild and domestic vegetation. This helps preserve crop genetic diversity and heirloom varieties; provides a variety of plants useful for food, medicinal purposes, handicrafts and other applications; and reduces the need for chemical inputs to control weeds and insect pests through intercropping, use of allelopathic plants, and companion planting (Hicks and Peña 2003). Second, the network of ditches and laterals that comprises the physical makeup of acequias resembles the more complex channels of braided stream systems (Fernald et al. 2007), which supports a greater extent of riparian vegetation and may attenuate flood flows (Hicks and Peña 2003). In many areas this complexity would have otherwise been lost through channelization of rivers and streams and residential and other urban development on floodplains. This overall extension of the riparian corridor has a number of associated benefits, including water quality mitigation, maintenance of soil stability, and creation of wildlife habitat and travel corridors (Hicks and Peña 2003, Fernald et al. 2007). Third, acequias create wetland areas that provide wildlife habitat, regulate water flow, and mitigate water quality (Hicks and Peña 2003). Fourth, the slow release of shallow groundwater to streams and rivers bolsters in-stream flows, particularly in late summer and early fall, when discharge would otherwise be low. This is particularly important in areas containing threatened and endangered species, or where in-stream flows are valued for aesthetic reasons (Rivera 1998, Fernald et al. 2007). Finally, the community management of acequia systems and the close ties
to local ecology that are necessary for their operation promotes a land ethic that is transmitted from generation to generation (Arellano 1997, Hicks and Peña 2003). This is particularly important in the face of the continued distancing of many human systems from their ecological context (e.g. Louv 2005).

4.5 Conclusions

Taken together, the factors described in this chapter—acequias’ support of small-scale, local agriculture; their deep social and cultural roots and contributions to sense of place in the rural residents of New Mexico and southern Colorado; their current nonmarket benefits, potential for future market value and contributions to sustainable economies; their lessons in alternative forms of natural resource management; and their myriad environmental benefits—comprise a large part of the justification proponents of acequias set forth in support of their continued survival as an irrigation institution. These factors combine to form the paisaje del agua, which describes the landscape affected by acequia irrigation and operation. This landscape embodies the multifunctionality of agriculture. Although production of food and forage is the primary goal, the diversity of factors described in this chapter provides a wide variety of social and environmental services. These factors also lie at the core of what contributes to acequias’ resilience, as they variously bolster the diversity, adaptive capacity, tendency to self-organize, and connectivity crucial to this system property (Folke et al. 2003, Walker and Salt 2006, Ostrom 2009). Despite these strengths and benefits to society, the acequia institution as it exists today is compromised by a number of factors. The next chapter discusses these and the impact they may have on the continued viability of this centuries-old institution.
CHAPTER 5. CHALLENGES FACING CONTEMPORARY ACEQUIA IRRIGATION SYSTEMS

As the previous chapters have illustrated, acequias have been faced with substantial adversity throughout their history. This has come in the forms of harsh climates and landscapes, geographic and political isolation, changes in governance, and economic exploitation. Such adversity has undoubtedly presented challenges, but has also necessitated adaptability, creativity and cooperation. These characteristics have turned out to be some of acequias’ greatest strengths, and have contributed to their resilience and thus their persistence for over four centuries. However, acequias currently face a suite of challenges that may compromise their future viability. These include increasing demands on land and water resources imposed by competing entities (Rivera 2012), evolving socioeconomic conditions in New Mexico’s rural communities, an increasingly homogenized and consolidated system of agricultural production, and the “no analog” future (Ruhl 2008) socio-ecological systems may be entering via a changing climate. These challenges are particularly acute because of their complex ties to large-scale (state, national and global) economic, social, cultural and climatic systems. This chapter outlines these challenges, and discusses their potential implications for the future viability of the acequia institution.

5.1 Increasing demands for land and water resources

The population of the Rocky Mountain region of the western United States (which includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah and Wyoming) has increased substantially since 1950 (Figure 6). According to U.S. Census data, population growth between 1950 and 2010 ranges from a 67% increase in Montana to 1,590% increase in Nevada, with the total population of this region (plus Texas) increasing by 270% during this period.
Between 1950 and 2010 the population of New Mexico has increased by slightly more than 202% (Appendix 1). This growth is placing increasing strain on the West’s natural resources, particularly land and water. Numerous entities such as Native American tribes, cities, industry, commercial agriculture, recreational users, and the environment compete for the resources on which acequias rely (Rivera 2012, p. 91). Although this has numerous implications for the region’s social-ecological systems, from the standpoint of acequias the most consequential are likely the conversion of arable land to residential and urban development (Rivera 1998, Ortiz 2007, Ortiz et al. 2007) and increasing demands on water resources for domestic and municipal water supply, protecting threatened and endangered species, and satisfying interstate compact obligations (Klein-Robbenhaar 1996, Rivera 1998, Hicks and Peña 2003, Cox 2010). Additionally, the extent of tribal water rights is often uncertain, and could encompass substantial
portions of water rights present in New Mexico’s river basins (J. Rivera, personal communication, 23 February 2012)

5.1.1 Land use change

As the population of the West grows, agricultural land and other undeveloped areas are converted to residential development. For example, Ortiz (2007) and Ortiz et al. (2007) examined land use change in and around Alcalde, NM between 1962 and 2003. Alcalde is a small rural community located approximately six miles north of Española along the Rio Grande. These studies found that during this period, land area for orchards decreased by 69%, row crops decreased by 53%, and residential development increased by 533%. Part of the decrease in orchards and row crops can be accounted for by a 47% increase in pasture, but it is clear that the increases in residential development were substantial (Ortiz 2007, Ortiz et al. 2007). This pattern can be seen throughout northern New Mexico. Conversion of agricultural land and open space to residential development has the potential to negatively impact the acequia institution. This can occur by removing land area from irrigated agricultural uses (Sargent et al. 1991), increasing non-agricultural water use, affecting water quality, and changing the social and economic makeup of rural communities.

The most obvious effect of reducing the arable land base is decreasing the area available for agricultural production. As discussed in Chapter 4, the agricultural production component of acequia systems often lacks efficiency from a purely economic standpoint, and reducing the area from which economic benefits can be derived further compromises an area’s economic viability from the standpoint of agriculture. Additionally, agricultural land, particularly that which supports small-scale agriculture, produces a variety of ecosystem and social services beyond
Crop production (Swinton et al. 2007, Groenfeldt 2009). These include maintenance of soil fertility; nutrient cycling; regulation of pollinators, pests, pathogens and wildlife; carbon sequestration; aesthetics; landscape diversity, cultural heritage; and allowing for rural lifestyles (Sargent et al. 1991, Swinton et al. 2007). Reducing agricultural land will compromise the provision of these services (on which the rural Hispanic culture in northern New Mexico is strongly based). This will likely substantial social and cultural impacts (e.g. Garcia 2008, Trujillo 2009).

Land use change also alters water quality and patterns of water use. In northern New Mexico, rural residential development typically utilizes on-site septic systems for sewage disposal. Expansion of residential development increases the risk of shallow aquifer contamination by nutrients. In Alcalde, Ortiz et al. (2007) used a geographic information systems (GIS) analysis to determine the risk of groundwater contamination due to residential development, and found agricultural land to generally be the highest risk. This is due to low slope, soil characteristics, and water table depth. Regarding water use, although domestic applications account for a small fraction of the total water used in northern New Mexico (e.g. approximately 4% in the Rio Chama basin [La Calandria Associates 2006] and 5% in the Taos area [DBS&A 2008]), domestic water uses decrease the overall water availability for acequia operation. Of particular concern are the effects that increased groundwater pumping will have on surface water systems. In the Rio Chama basin, for example, groundwater supplies 90% of all water for domestic and commercial purposes (La Calandria Associates 2006). These wells are often relatively shallow (the average domestic well in New Mexico is less than 200 feet deep) and located near streams or rivers. This can result in the drawdown of aquifers that are hydrologically connected to surface water systems, reducing the amount of water available for
surface diversion (Maddock and Barroll 2012). However, given the small scale of domestic water use within northern New Mexico’s rural communities, a more pressing concern is the effects that increasing demands for water in more urbanized areas will have on acequias. The following section will discuss these effects.

5.1.2 Pressures on acequia water rights

Prior to the 1960s, the market for water rights in New Mexico was relatively weak and had little effect on acequia agriculture. However, beginning in the 1960s, municipal growth, an expanding industrial sector, increasing recreation and tourism, and residential development in rural areas began to increase the market value of land and water rights in many parts of New Mexico. As discussed previously, land and water use by acequias tended to rate low in terms of pure economic value, presenting an appealing resource base from which to supply changing needs. The first large-scale test cases involving transferring water from acequia uses came in the form of two proposed projects in northern New Mexico, the El Llano Unit, which would divert water from the Rio Grande upstream of several rural communities to Española to fuel future growth, and the Indian Camp Dam, which would be built on the Rio Grande near Taos to supply water to a proposed conservancy district (Rivera 1998). These projects were met with substantial opposition by local farmers (with the latter project and associated social effects of its proposal captured in spirit by John Nichols in *The Milagro Beanfield War* in 1974) and did not go through, but the tone was set for the emergence of one of the most substantial ongoing challenges to the acequia institution: increasing downstream demands for water.

Acequia users traditionally viewed water as an “asset in place” (Hicks and Peña 2003, p. 400), inseparable from the land on which it was used (Rivera 1998). This stands in contrast to
the doctrine of prior appropriation, which was imposed on the acequia communities of New Mexico and southern Colorado when they were subsumed by the United States and views water rights as discrete entities that can be transferred to different places and uses through sale or, more recently, leases (e.g. Broadbent et al. 2009, Broadbent et al. 2012). Under prior appropriation acequia water rights often have a priority date junior only to Native American rights, which increases their economic value. The sale or lease of water rights does not affect their priority date (NMSA 1978 §72-5-23). This fact, combined with acequia users traditionally not viewing water as a commodity, has created substantial concern among acequia advocates that the growing thirst of downstream municipalities, including those in adjacent, will result in the sale of water rights from acequia systems. Market pressures in the form of increasing land and water rights values will likely further catalyze such transfers. The potential effects of such sales are twofold. First, the revenue an acequia collects and the labor that is provided to maintain its infrastructure are proportional to the number of parciantes that use the ditch. Each parciante that sells land or water reduces the base of support, thereby increasing the financial and physical burden on the remaining members (Rodriguez 1987). Second, a certain amount of water is needed in the acequia system to ensure that flows are adequate to reach the parciantes furthest downstream. Transfers outside of the system compromise this functionality, as they reduce the amount of water flowing through the ditch (La Calandria Associates 2006).

Despite these fears, history generally seems to favor the preservation of acequia water rights. The El Llano Unit and Indian Camp Dam were unsuccessful at least in part because of widespread protest, a condominium project that would have transferred water rights from an agricultural parcel near Taos was blocked, and a proposed transfer of water from the Anton Chico land grant to supply water to a conference center was denied (Klein-Robbenhaar 1996,
Rivera 1998). The inclusion in the New Mexico water code in 1985 that the Office of the State Engineer must consider whether a water right transfer application would be “detrimental to the public welfare” (NMSA 1978 §72-5-23) provides an additional measure of protection for acequia water rights, but in water right transfer protests the burden of proving public welfare injury falls on the protesting party (Klein-Robbenhaar 1996). Further, as described in the introduction to this document, more recent statutory provisions provide acequias with the ability to acquire water rights, protect rights from loss due to nonuse through banking, and directly deny water rights transfers that would be “detrimental to the acequia… or its members” (NMSA 1978 §73-2-21E, NMSA 1978 §73-3-4.1). NMAA has also been instrumental in protecting acequia rights to water. However, as the regional population continues to grow, demands on water resources will increase. Additionally, climate change may further stress the region’s water resources, as is discussed at the end of this chapter. In light of these trends, it is likely that the challenges posed to New Mexico’s acequias by outside demands on water rights are only beginning, and it is not safe to assume that the past tendency for water transfer cases to be decided in favor of acequias is an indicator of future trends.

5.2 Changing socioeconomic conditions

As described in Chapter 3, the second half of the 20th century saw substantial changes in the social and economic structures of northern New Mexico’s rural communities. Many residents moved away in an effort to pursue employment, education, military service, or a different lifestyle. At the same time, these communities experienced an influx of newcomers attracted to the remoteness, slow pace, beauty, and self-sufficiency of northern New Mexico. In the 1960s and 1970s these newcomers were a mixed blessing, with some bringing new
perspectives, ideas and energy and an interest in embracing and documenting the traditional ways of life (e.g. van Dresser 1972, deBuys and Harris 1990) but others brought problems more frequently associated with urban cultures such as illegal drug use (L. Roybal, personal communication, 3 May 2011). Local economies continued on the trajectory set by the application of capitalist ideals on top of a history of agropastoral subsistence—small-scale farming and ranching continued to comprise a deeply set component of Hispano identities, but yielded a meager income. Furthermore, the economic gap between rural residents and the rest of the state continued to widen as localized rural economic vitality was sapped by continued land loss, substance abuse, and large employers such as Los Alamos National Laboratories capturing human capital (Atencio 2001, Atencio 2004, Kosek 2006, Garcia 2008). More recently, as described in the previous section, the wave of newcomers has grown, placing additional stresses on land and water but also exposing acequia customs to a new generation of immigrants.

Acequias have thus far survived these changes, but some acequia members feel the outlook is bleak. Knowledge of farming practices and traditional ways of life is often held by the old-timers in the communities, who worry that “you look over your shoulder and no kids are following in your footsteps” (L. Trujillo, personal communication, 16 October 2010). There is often a feeling that interest in farming and ranching in younger generations is diminishing, as it often makes for a marginal existence at best. Furthermore, the continuing trend of rural residents leaving their communities for work and to pursue a formal education represents a significant drain on human capital. Indeed, it is rare to see acequia meeting attendees under the age of 40. In an effort to prevent the gradual atrophy of acequia customs, groups such as the New Mexico Acequia Association are working to document traditional ways of life and inspire a new generation of acequia farmers. These programs appear spirited and successful, but likely require
expansion in order to garner the broad-based support that is necessary to ensure the continued viability of acequias.

As with keeping water rights in acequia agriculture, the fight to expand the economic vitality and interest in maintaining acequias is likely just beginning. The odds will be increased by building social capital within agricultural communities and developing the capacity to adapt to ever-changing social and economic environments. This will require concerted efforts to capture knowledge held by long-time acequia farmers, and to inspire interest in acequia agriculture in younger generations. Accomplishment of this latter feat will require strong economic incentives to engage in acequia agriculture, otherwise the trend of migration out of rural communities will continue. Providing such incentives may not be possible under the current paradigm of globalized production of agricultural and other goods, as Section 5.3 describes, but increasing transaction costs associated with a changing climate, particularly with respect to energy, may necessitate a shift back toward a paradigm of more locally-based patterns of existence.

5.3 Trends in agriculture

An in-depth analysis of national and global agricultural trends and their relationship to acequias is beyond the scope of this project. However, it is important to note the general implications these trends have for the current and future status of acequias. The second half of the 20th century saw rapid increases in the mechanization, homogenization and globalization of agriculture (Boody et al. 2005, Groenfeldt 2009a). This resulted in increases in farm size, decreases in the number of people working in agriculture, and numerous environmental effects associated with soil erosion, decreased biodiversity, long-distance transportation of agricultural
products, and the use of pesticides, herbicides and fertilizers (La Trobe and Acott 2000, Horrigan et al. 2002). In the United States, these trends have been supported by government subsidies for a small set of agricultural commodities, namely corn, wheat, soybeans, cotton and rice (Boody et al. 2005). Additionally, the increasing use of genetically modified organisms containing proprietary technology has raised a suite of ethical, social, legal, environmental, and health concerns (Horrigan et al. 2002, New Mexico Acequia Association 2011). This combination of factors has made it increasingly difficult for small farms to compete with the large-scale agribusiness that has come to characterize food production in the industrialized portions of the modern world (New Mexico Acequia Association 2010a). This presents a significant economic challenge for acequia farmers, who rarely possess the resources or infrastructure to be competitive in larger food markets.

As discussed above, although the nonmarket value of acequias may be great, increasing the economic viability of acequia agriculture will be vital in protecting its future. However, the current food production system has created substantial hurdles in the path of accomplishing this goal. A shift in the food production and consumption paradigm will likely be necessary, which may be driven by two factors. The first is the already established niche market for locally-produced and/or organic goods. As concerns about the health implications and negative externalities of conventional agriculture grow, this market will likely expand and provide additional opportunities for acequia farmers to market their products. The second, which is addressed in the following section, is climate change. A changing climate will likely have substantial effects on the systems that surround the production and consumption of farm commodities, which may necessitate the reorganization of these systems in a way that
accommodates higher market and nonmarket costs associated with production, processing, transportation and consumption.

5.4 Climate change

Climate variability has been a defining factor in acequias’ function for the entirety of their existence. The development of mechanisms to accommodate this variability and the associated uncertainty—flexibility in governance, locally-based customs, mutual aid, and adaptive capacity—represent key factors that contribute to the resilience and thus persistence of this institution of irrigation. However, the possibility of what Ruhl (2008) terms a “no-analog” future due to global anthropogenic climate change—one in which natural and human systems and the processes that drive them are altered in such a way that prediction of future behavior based on historical experience is impossible—poses a substantial challenge for acequias. The uncertainty associated with climate predictions makes anticipating specific effects difficult, and, although it is possible that strategies acequias have developed for coping with variable conditions will allow for their persistence under a changing climate, it is likely that climate change, coupled with the other pressures described above, will pose novel challenges that negatively impact their survival. This section describes current climatic trends in New Mexico, future predictions, and their possible implications for agriculture generally and acequias specifically. This discussion is central to EPSCoR’s emphasis on exploring climate change effects.

In New Mexico, tree ring analysis indicates that precipitation and streamflow have historically been variable, with instances of both high moisture and drought recurring throughout the past 1,000 years (Sheppard 2002, Hurd and Coonrod 2008, Gutzler 2012). However, the
global trend of continued radiative forcing of the atmosphere due to elevated greenhouse gas concentrations yields a “reasonable expectation” that this natural variability will be exceeded in the future (Hurd and Coonrod 2008 p. 2-3). In the Southwest as a whole, an analysis of 49 climate projections provided by 19 models revealed only three projections that indicated a shift toward a wetter overall climate in the region. Generally, these models suggested a transition toward a drier climate that begins in the late 20th and early 21st centuries, with precipitation decreasing on average. During the winter precipitation is expected to decrease while evaporation is expected to remain unchanged or increase slightly, whereas during the summer both precipitation and evaporation are expected to decrease. Furthermore, unlike historical multiyear droughts in the Southwest, which were typically associated with variations in sea surface temperatures in the tropics (e.g. La Niña), future dry periods will likely be caused by rising humidity in the tropics increasing moisture divergence, which will alter atmospheric circulation in a way that expands the subtropical dry zones poleward (Seager et al. 2007).

Across New Mexico and the Southwest, mean annual temperatures have increased at a rate exceeding global averages by nearly 50% since the 1970s (Enquist and Gori 2008). In New Mexico, mean annual temperatures have increased 0.6°F per decade in this period, with the most substantial increases occurring in the winter and spring. Trends in precipitation have been more variable, with approximately half of the state experiencing wetter conditions, 41% experiencing drier conditions, and 5% showing no change between 1991 and 2006 compared to 1961–1990. Warmer, drier conditions have been the most pronounced in mid- to high-elevation forests and woodlands (Enquist and Gori 2008). This has resulted in 93% of New Mexico’s watersheds experiencing moisture stress between 1970 and 2006, with snowpack in New Mexico’s major mountain ranges generally declining over the past 20 years. Furthermore, peak streamflow from
snowmelt in New Mexico has, on average, occurred one week earlier than in the mid-20th century (Enquist et al. 2008). These trends are expected to continue (Gutzler 2012), with temperatures potentially increasing by more than 5°F by the end of the 21st century; the overall snow season decreasing, with delay in the arrival of the first snowfalls, snowpack increasing in elevation and decreasing in water content, and snowmelt accelerating in the spring; springtime flood events occurring earlier and in a more extreme fashion; increasing evaporative losses from streams, reservoirs and soil and increasing evapotranspiration by agricultural and riparian plants; and decreasing soil moisture content (New Mexico Office of the State Engineer 2006).

The effects that a changing climate will have on agriculture will vary both spatially and temporally, and will have differential impacts on agricultural systems based on the nature of the systems themselves and the adaptive capacity of their associated populations. The following discussion describes these effects and their potential impacts on the practice of agriculture and the societies and economies built around it.

5.4.1 Global climate factors affecting agriculture

Temperature, precipitation and runoff are three major drivers that have both direct and indirect effects on agricultural activities, and climate change predictions indicate variable changes in these factors across the globe. High latitudes in the northern hemisphere, particularly the polar regions of continents, are expected to experience the greatest surface warming throughout the next 90 years. Possible changes in precipitation are more complex, but models generally agree that, in relation to 1980-1999, subtropical areas will experience decreases and high latitudes will experience increases by the end of this century. Predictions of future runoff patterns are also less certain, but in general models indicate that the southwestern United States,
the Mediterranean region (including parts of Europe, Africa and Asia), southern Africa, and parts of South America and Australia will experience decreases in runoff upwards of 40%. Runoff is predicted to increase at higher latitudes in the northern hemisphere (IPCC 2007a).

Because of the spatial variability of effects of climate change on temperature and hydrologic regimes, impacts on agriculture will vary regionally. In general, it is predicted that at mid to high latitudes moderate increases in temperature (2°F to 5°F) will benefit cereal crops slightly, but further increases will have negative impacts. At low latitudes, simulations predict that even moderate increases in temperature will negatively impact the yield of cereal crops (IPCC 2007b, Rosenzweig et al. 2000). Similarly, northern portions of the United States may experience increases in crop yields due to higher temperatures and longer growing seasons (Rosenzweig et al. 2000). These increases will likely decline and possibly become negative in the southern, particularly southwestern, part of the country, where runoff and precipitation are generally predicted to decrease. A warming climate has the potential to lengthen the growing season in temperate regions such as northern New Mexico. Although this may increase production it also increases water demand (B. Thomson, personal communication, 10 April 2012), which, in light of predicted decreases in the snowmelt runoff upon which many acequia systems rely, may negatively impact the viability of acequia agriculture.

5.4.2 Extreme weather events

In addition to broad-scale warming and changing precipitation regimes, climate models predict an increase in the frequency and severity of smaller-scale disturbances such as extended periods of heat, drought, excessive precipitation, tropical cyclone activity and high sea levels.
On local scales, these events tend to negatively impact agricultural output by reducing crop yields and interfering with cultivation activities.

Different crop species and varieties require a certain range of temperatures for proper growth and development. When this range is exceeded, heat stress results and developmental processes such as flowering or fruiting are negatively influenced or occur prematurely, which reduces crop yield (Rosenzweig et al. 2000). Drought, which is often associated with extended periods of heat, contributes to water stress in plants. This can lead to land degradation, lower crop yields, and crop failure (IPCC 2007a). Conversely, excessive precipitation can result in crop damage due to waterlogging, soil erosion, heightened incidence of pest infestations and disease, and increased difficulty of activities such as planting, irrigation and harvest (IPCC 2007a, Rosenzweig et al. 2000). Tropical cyclones, in addition to delivering large amounts of precipitation, can also physically damage crops and agricultural infrastructure. Raised sea levels, resulting both from storm activity and melting polar ice, may inundate coastal agricultural land, making it unusable, and increase the salinity of water used for irrigation (IPCC 2007a).

An important characteristic of extreme weather events is their lack of long-term predictability. Because agriculture, particularly low-diversity systems like those present in much of the United States, is highly dependent on a predictable environment, the decreased predictability caused by more frequent extreme events will, in addition to affecting crops’ physiological processes, hinder human activities associated with crop cultivation such as planting, irrigation, pest management, and harvest. However, reductions in yield will originate not only from physical factors but also from movement of farmers out of agriculture and into activities with a greater degree of stability, a trend that has already become evident in the United States (Rosenzweig et al. 2000). Abandonment of agriculture reduces diversity in method,
cropland and, particularly in small-scale systems, crop species. Such diversity is key to resilience (e.g. Walker and Salt 2006), and its reduction will reduce humans’ ability to adapt to the results of a changing climate.

5.4.3 ‘Pest’ behavior

Closely tied to climate warming and increases in extreme weather events are changes in crop ‘pest’ (weed, insect, fungus, and pathogen) behavior, namely increased activity and subsequent damage to crops (Rosenzweig et al. 2000). Weather conditions play a large role in determining the distribution and proliferation of pest species, and instances of pest outbreaks have been associated with extreme events (e.g. a 1999 locust outbreak in Mexico corresponding with drought and fungal epidemics in corn, soybean, alfalfa and wheat in the Midwestern United States associated with the flood of 1993). Specifically, warm, humid conditions tend to encourage the spread of pest species. Warmer spring temperatures promote their earlier establishment, and longer growing seasons provide greater opportunity for crop damage. Higher winter temperatures reduce pest die-off, which increases rates of development and decreases time between generations. This effect can be seen in North America in European corn borer populations, which experience up to four generations per year in the (warm) southern United States and only one in the (cooler) northern U.S. and southern Canada. In addition, the ranges of several other crop pests in the U.S. have expanded since the 1970s, potentially as a result of climate change (Rosenzweig et al. 2000).

While the amount and toxicity of insecticide applied to crops in the United States increased by a factor of 10 from the 1940s to the 1990s, crop losses to pests actually increased by 7% over the same period. This may partially be a result of overall higher crop yields and
therefore greater total losses, but, as discussed above, the mainstream agricultural system in the U.S. is becoming increasingly dominated high fertilization rates, monocultures with low genetic diversity, and production of crops in warmer, more humid regions that favor crop pests. All of these factors reduce crop resistance to infestation (Rosenzweig et al. 2000). A warming climate will likely exacerbate these effects, but certain practices such as reduced reliance on pesticides and cultivating a greater diversity of crops, both of which are practices often employed in acequia agricultural systems, may help to mitigate them (Santistevan 2008).

5.4.4 Effects of elevated CO$_2$ concentrations: FACE studies

In recent years, certain groups have made claims about the possible benefits of increased atmospheric CO$_2$ concentrations ([CO$_2$]; e.g. Carlisle 2001). CO$_2$ is of course a necessary component of photosynthesis, so they conclude that increasing CO$_2$ concentrations will promote greater plant growth. Over the past two decades, numerous free air CO$_2$ enrichment (FACE) studies have been conducted to assess the effects of elevated [CO$_2$] on plant growth. These studies did find a positive plant response to elevated [CO$_2$], but noted differences in the magnitude of the response based on species, growth stage and photosynthetic pathway (Ainsworth and Long 2005). Woody vegetation was generally more responsive than non-woody species, and C$_3$ plants tended to demonstrate greater increases in growth than C$_4$ plants (IPCC 2007b, Ainsworth and Long 2005). Increased growth of crop species was less than predicted by prior studies (which utilized CO$_2$-enriched enclosures rather than a free-air environment), with yields of C$_3$ crops increasing 10–20% and yields of C$_4$ crops increasing 0–10% under a CO$_2$ concentration of 550 ppm (IPCC 2007b, Ainsworth and Long 2005). Of the four crop species (cotton, wheat, rice and sorghum) analyzed by Ainsworth and Long (2005), only cotton, a woody
crop, demonstrated significantly increased yields under conditions of elevated [CO₂]. Rice and wheat exhibited statistically insignificant increases, and sorghum yield was unaffected. It is therefore difficult to make broad generalizations about the effects of increased [CO₂] on plants, and, although data are limited, it does not appear that crop species will benefit from increased [CO₂] to the degree once predicted.

One of the problems with claims such as those made by Carlisle (2001) is the benefits of increased [CO₂] are inferred in isolation, ignoring other effects of a warming climate. The IPCC’s Third Assessment Report (2001) discusses numerous studies that indicate the temperature and precipitation regime changes associated with a warming climate will often limit direct CO₂ effects on plants (cited in IPCC 2007b). In relation to crops, temperature increases, altered precipitation patterns, and greater incidence of pest outbreak will, in many places, have an overall negative effect on crop yields, which will reduce the beneficial effects of increased [CO₂].

5.4.5 Economic and social effects

Under scenarios of moderate warming (+2°F to +5°F), food production on a global scale is predicted to increase, but warming beyond this range is expected to decrease production (IPCC 2007b). Greater production at moderate levels of warming will likely lead to a reduction in cereal prices, but temperature increases ≥ 10°F are expected to increase food prices by 30% (IPCC 2007b). Regional-scale effects will be more variable, with benefits expected for mid- to high latitudes (under moderate warming) and negative effects for low latitudes. Rosenzweig et al. (2000) report that in the United States, climate change could have an overall negative impact on agricultural production and contribute to significant economic losses, which may reduce the
country’s role as the “leading international exporter of major agricultural commodities” (p. 38).

Indeed, although agricultural productivity in the U.S. has increased since the 1970s, interannual variability of crop yields, prices, and farm income has also increased. Such unpredictability translates to higher operating costs and impacts on numerous agriculture-related sectors (Rosenzweig et al. 2000).

The social effects of climate change impacts on agriculture will be complicated (and in some cases overshadowed) by developments in global socioeconomic systems (IPCC 2007b). Some social effects resulting from greater unpredictability in the agricultural sector have already been discussed, but others are possible. For example, climate change scenarios predict decreased water availability in some regions (including New Mexico), which affects agricultural practices, food preparation, and human health. Conversely, a transition to a wetter climate in other areas may damage crops and increase crop losses due to pests and the incidence of water-borne disease. Sea level rises may inundate coastal areas, making them useless for cropland in addition to displacing large numbers of people. Climate change is also predicted to increase the dependence of developing countries on food imports, and will likely shift the greatest incidences of food insecurity from Asia to sub-Saharan Africa (IPCC 2007b).

5.4.6 Small-scale agriculture

Small-scale agriculture can be defined as “rural producers… who farm using mainly family labor and for whom the farm provides the principal source of income” (IPCC 2007b, p. 281). This definition describes the traditional pattern of acequia agriculture. Small-scale agriculturalists are vulnerable to a variety of social and environmental stressors (IPCC 2007b, p. 278), but because of the complexity of their social and agricultural systems it is difficult to
predict the magnitude and direction of the climate change-related effects they will experience. Like larger producers, small-scale agriculturalists will be affected by changes in temperature, water availability and pest activity, but the impact of these changes may be reduced by the relatively high variety of crop species and cultivation practices they tend to employ (IPCC 2007b). As with commercial agriculture, regional-scale effects will be variable for small-scale operations, with some areas experiencing more negative climatic and environmental stresses (e.g. sea level rise in coastal areas or greater temperature increases) than others.

It is argued (e.g. LaSalle 2008, Santistevan 2008) that the diversity and lower environmental impact practices present in many small-scale agricultural systems such as acequias can serve as a model for future sustainability in the agricultural sector. Proponents of small-scale agriculture (primarily in ‘developed’ countries) suggest that it can be used as both a means of mitigating the causes of climate change (e.g. by promoting carbon storage in soil; LaSalle 2008) and of adapting to its effects (e.g. by providing farmers with crops diverse enough to allow cultivation over a variety of environmental conditions; Borron 2006, Santistevan 2008). Although a complete reversion to small-scale agriculture on a broad scale is likely infeasible, farmers can employ characteristics of it to increase their adaptive capacity by adopting technologies, methods and crops appropriate for small-scale agriculture.

5.4.7 Adaptation

Although agriculture could suffer negative consequences due to climate change, historical patterns have shown that it has a high capacity for adaptation to climatic variability (IPCC 2007b). As discussed previously, in New Mexico and southern Colorado, this capacity is evident in acequia systems. In order to prevent serious damage to the agricultural sector,
agriculturalists must improve their capacity to adapt to novel climate change-driven challenges. The IPCC’s Fourth Assessment Report (2007a, p. 294–296) proposes a number of adaptation strategies at both the individual and societal level. Individual (“autonomous”) adaptations include planting a diversity of crops that are suited to the environment in which they grow and watering/fertilizing according to their dynamic needs; employing strategies aimed at the harvest, conservation and better management of water resources; diversifying farm income; improving pest management strategies; and utilizing seasonal forecasting to decrease production risk. Societal (“planned”) adaptations include improving education about the reality and effects of climate change; improving agriculture-related climate change research capabilities; developing technology better suited to a changing climate; governmental support of societal changes (such as migration and land use change) to reduce negative environmental impacts; developing infrastructure, policies and institutions better suited to addressing climate change and its impacts; and improving adaptive capacity. Acequias have strong potential to contribute to these adaptations in New Mexico, but their core purpose, enabling agriculture, may be compromised by the climate change effects discussed above. Furthermore, acequias’ ability to adapt to future conditions is challenged by uncertainty surrounding the effects of climate change and synergistic relationships that may arise between a changing climate and other pressures.

5.5 Conclusions

The challenges acequias currently face have the potential to impair the future function and viability of this centuries-old irrigation institution. Increasing demands on land and water resources by a variety of entities may erode the land base available for agriculture and deplete the water available for acequia operation. The social and economic conditions in New Mexico’s
rural communities may no longer provide the human, social and fiscal capital necessary for acequia function. Agricultural trends in the United States have compromised the competitiveness of small-scale farms. Climate change will likely impact agricultural systems in a variety of ways, with increased overall aridity and altered precipitation and runoff patterns in New Mexico potentially decreasing water availability to acequia communities. Finally, synergistic relationships between these factors may result in surprises that have serious implications for the continued function of acequias. These surprises, however, can be lessened through good planning that is aimed at increasing overall system resilience. The next chapter introduces the Acequia Functionality Assessment as a tool to facilitate such planning.
CHAPTER 6. THE ACEQUIA FUNCTIONALITY ASSESSMENT: A TOOL FOR PLANNING AND BUILDING RESILIENCE

As the preceding chapters illustrate, acequias are a long-standing element of northern New Mexico’s rural communities that, due to the resilience imparted by their structures of governance and the adaptability of their users, have persisted in the face of substantial climatic, social and economic adversity. Furthermore, they provide a variety of benefits, ranging from community cohesion to offering lessons in alternative forms of natural resource management and supporting ecosystem services. However, numerous pressures, some of which have been developing for decades and others that have become evident relatively recently, have the potential to compromise the future integrity and viability of the acequia institution. In light of this but also in recognition of the strong desire on the part of many acequia users and researchers to facilitate acequia preservation, this project creates an “Acequia Functionality Assessment” (AFA) that can be used to track changes over time, identify needs, engage youth, and plan future activities to increase the resilience of acequias to the challenges presented in Chapter 5. This chapter discusses the AFA. It begins by outlining the process undertaken in developing the assessment, and then describes the use of the assessment and provides a rationale for including each of the criteria. Finally, it address analysis of the results of the assessment and explores possible uses of these results. Much of the material in this chapter is included in the *Acequia Functionality Assessment Guidebook*, which provides instructions for the use of the AFA and analysis and application of results. A copy of this guidebook can be found in Appendix 3.
6.1 Development of the Acequia Functionality Assessment

6.1.1 Sources of inspiration and related efforts

The structure and community-based application of the AFA was inspired by a rapid appraisal approach to evaluating the health of riparian ecosystems (Riparian Health Assessment) designed by Fleming and Henkel (2001). The Riparian Health Assessment (Table 3) evaluates 12 criteria on a 1–4 scale, with 4 representing “excellent” conditions, 3 representing “good” conditions, 2 representing “fair” conditions, and 1 representing “poor” conditions with respect to certain characteristics of each of the criteria.

Table 3. Riparian Health Assessment criteria (from Fleming and Henkel 2001)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>4 Excellent</th>
<th>3 Good</th>
<th>2 Fair</th>
<th>1 Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streamflow (m³/sec)</td>
<td>&gt;0.05</td>
<td>0.03–0.05</td>
<td>0.01–0.03</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Streambed geology: Composition (proportion of rock material – boulders, cobbles, and gravel)</td>
<td>&gt;50%</td>
<td>25–50%</td>
<td>10–25%</td>
<td>&gt;75%</td>
</tr>
<tr>
<td>Streambed geology: Embeddedness (proportion of rock material below streambed surface)</td>
<td>&lt;25%</td>
<td>25–50%</td>
<td>50–75%</td>
<td>&gt;75%</td>
</tr>
<tr>
<td>Width/depth ratio (ratio of bankfull channel width to mid-channel depth)</td>
<td>&lt;7:1</td>
<td>8–15:1</td>
<td>15–25:1</td>
<td>&gt;25:1</td>
</tr>
<tr>
<td>Bank stability (area w/o vertical, unvegetated banks)</td>
<td>&gt;90%</td>
<td>70–90%</td>
<td>50–70%</td>
<td>&gt;75%</td>
</tr>
<tr>
<td>Riffle/pool ratio (ratio of distance between riffles to stream width)</td>
<td>&lt;7:1</td>
<td>7–15:1</td>
<td>15–25:1</td>
<td>&gt;25:1</td>
</tr>
<tr>
<td>Buffer width (vegetation coverage adjacent to channel)</td>
<td>&gt;18m</td>
<td>12–18m</td>
<td>6–12m</td>
<td>&lt;6m</td>
</tr>
<tr>
<td>Vegetation: Species diversity (number of species w/in riparian zone)</td>
<td>&gt;10</td>
<td>5–10</td>
<td>3–5</td>
<td>&lt;3</td>
</tr>
<tr>
<td>Vegetation: Structural diversity (number of height classes)</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1 sparse</td>
</tr>
<tr>
<td>Vegetation: Cover (proportion of riparian area covered)</td>
<td>&gt;90%</td>
<td>70–90%</td>
<td>50–70%</td>
<td>&lt;50%</td>
</tr>
<tr>
<td>Canopy shading (mix of sun and shade)</td>
<td>Mixed sun/shade</td>
<td>Sparse canopy</td>
<td>Mostly sun or shade</td>
<td>No shade</td>
</tr>
<tr>
<td>Aquatic insects (presence of selected macroinvertebrates)</td>
<td>Stoneflies, mayflies, and caddisflies</td>
<td>Mayflies and caddisflies</td>
<td>Mayflies or caddisflies</td>
<td>Only midges or leeches</td>
</tr>
</tbody>
</table>
After evaluating these criteria in a stream, a composite “riparian health” score can be calculated by averaging the condition scores for all of the criteria. The Riparian Health Assessment is designed to be simple to use, as it is based on factors that are easily measured and require little in the way of specialized instrumentation or knowledge. As a result, it provides a technique that is accessible to diverse stakeholders, including youth, for assessing riparian conditions in their local watershed (Fleming and Henkel 2001). Although many acequias possess riparian-like characteristics due to their long presence on the landscape, only several of the criteria contained in the Riparian Health Assessment are truly relevant to acequias because the purpose of an acequia is to provide water for agriculture, not create an aquatic ecosystem. As a result, the content of the Riparian Health Assessment as presented by Fleming and Henkel (2001) has limited application to acequia systems. However, the assessment’s structure, accessible nature, and community-based orientation are highly compatible with the assessment of acequia “functionality,” so the AFA carries these characteristics forward.

Additional inspiration for the structure of the AFA came from the Agricultural Appraisal Method (AGRAM) developed by Villar (2009). This method is similar to the Riparian Health Assessment, but its criteria evaluate 27 elements of Hispano land grand communities in the broad categories of land, water, agricultural products, institutional capacity, and support services with the goal of enhancing the “sustainability, preservation, and community benefits of agriculture” (Villar 2009). Although these criteria capture many of the social dynamics of land use in rural Hispano communities, their scope is relatively broad, so their utility for detailed assessment and planning at the acequia level is somewhat limited. Furthermore, AGRAM is presented as a survey to be conducted by an outside researcher, whereas an intent of the AFA is to present acequia users with a tool that can be used independently and with relative ease.
The New Mexico Historic Preservation Division has created the “Historic Acequia Inventory Form” to determine eligibility for listing of an acequia on the National Register of Historic Places or the State Register of Cultural Properties. This form is generally focused on the physical infrastructure of acequias and is relatively technical, so it is likely of limited utility in facilitating on-the-ground planning at the acequia level (New Mexico Historic Preservation Division n.d. a & b).

Finally, the AFA fits within the context of a variety of assessment tools for evaluating the condition of infrastructure in urban and rural settings. Examples include checklists for examining the walkability of neighborhood environments (e.g. NHTSA n.d.), an instrument for characterizing green infrastructure (Weber et al. 2006), and a method of rating the sustainability of urban infrastructure systems (Sahely et al. 2005). However, such a tool does not appear to exist for assessing the condition of irrigation systems. The AFA offers one method for assessing acequia irrigation infrastructure.

6.1.2 Development and refinement of the Acequia Functionality Assessment criteria

The AFA is a product of discussions with acequia researchers at the University of New Mexico and acequia users, feedback at conferences and meetings, the author’s personal familiarity with the operation of acequias, and multiple field tests. In its earliest form, the AFA closely resembled the Riparian Health Assessment created by Fleming and Henkel (2001). In May 2010 an initial evaluation of this assessment was conducted on an acequia near Taos, NM in cooperation with an acequia farmer, University of New Mexico students in the School of Architecture and Planning and the Biology Department, and a UNM professor. During and after the assessment, the applicability of the criteria and the overall structure of the survey were
discussed and substantial modifications were made to the criteria. Following this initial modification, the AFA was discussed with various acequia users and researchers and field tested several times throughout late summer and early fall 2010. Each discussion and field test yielded further modifications to the criteria and structure of the assessment. Most of these modifications focused on increasing the specificity of the criteria toward acequias, for example altering the “streamflow” criterion in the Riparian Health Assessment to capture the timing and amount of water flow in an acequia in relation to a community’s irrigation needs and the length of the growing season. Additionally, whereas the criteria in the Riparian Health Assessment are presented in one group, several logical categories of criteria began to emerge in the AFA. These are physical characteristics of the acequia system, ecological considerations, and acequia governance and community use.

In late fall 2010 a poster describing the AFA was presented at New Mexico Acequia Association’s 11th Annual Congreso de las Acequias in Santa Fe, NM. Feedback on the assessment was solicited from conference attendees, and the AFA was refined further. An updated poster regarding the AFA was then presented at the 3rd Annual EPSCoR Tri-State Western Consortium Meeting in Santa Ana Pueblo, NM in early April 2011, where additional feedback was solicited from the attendees and poster judges. In late April 2011 the AFA was presented at a focus group attended by acequia farmers and community members in El Rito, NM, where the criteria and structure of the assessment were discussed in detail and, subsequently, modified further. A nearly final version of the AFA was presented at the New Mexico Chapter of the American Planning Association Western Planners/Four Corners Conference in September 2011 in Santa Fe, and again in poster format at NMAA’s 12th Annual Congreso de las Acequias in Santa Fe in November 2011. The AFA was then finalized in early 2012 through multiple
discussions with UNM professors with expertise related to water resources and acequias. The final criteria of the AFA are presented in tables 4, 5 and 6, and are located on pages 2–3 of the assessment. The full version of the AFA can be found in Appendix 2. The following five sections will describe the use, structure, and components of the AFA in greater detail.

Table 4. Acequia Functionality Assessment category 1 – physical characteristics

<table>
<thead>
<tr>
<th>Criterion</th>
<th>4 Points</th>
<th>3 Points</th>
<th>2 Points</th>
<th>1 Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of flow during irrigation season in recent years</td>
<td>Meets all irrigation needs</td>
<td>Meets most irrigation needs</td>
<td>Meets less than half of irrigation needs</td>
<td>Little or no water</td>
</tr>
<tr>
<td>Duration of useable flow in recent years</td>
<td>Entire growing season or more</td>
<td>Majority of growing season</td>
<td>Approximately half of growing season</td>
<td>Less than half of growing season</td>
</tr>
<tr>
<td>Bank stability</td>
<td>No erosion evident</td>
<td>Erosion evident in a few places</td>
<td>Erosion evident in a few places and seems to be increasing</td>
<td>Substantial erosion, and/or amount of erosion is in-creasing rapidly</td>
</tr>
<tr>
<td>Access to acequia easement</td>
<td>Adequate for maintenance along entire ditch</td>
<td>Adequate for maintenance along most of ditch</td>
<td>Accessible along less than half of ditch</td>
<td>Generally not accessible</td>
</tr>
<tr>
<td>Infrastructure condition and improvements needed (presa, headgates, main ditch, etc.)</td>
<td>Little or no improvement needed</td>
<td>Less than 25% of infrastructure needs improvement</td>
<td>About 50% of infrastructure needs improvement</td>
<td>More than 50% of infrastructure needs improvement</td>
</tr>
<tr>
<td>Water quality</td>
<td>Water appears clean with no trash</td>
<td>Water appears clean; some trash</td>
<td>Considerable trash present</td>
<td>Water appears dirty and has lots of trash</td>
</tr>
<tr>
<td>In general, what proportion of fields in your area is irrigated?</td>
<td>More than 75%</td>
<td>50-75%</td>
<td>25-50%</td>
<td>Less than 25%</td>
</tr>
</tbody>
</table>
Table 5. Acequia Functionality Assessment category 2 – ecology

<table>
<thead>
<tr>
<th>Criterion</th>
<th>4 Points</th>
<th>3 Points</th>
<th>2 Points</th>
<th>1 Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation structural diversity along ditch bank (4 vegetation classes = trees, shrubs, grasses, and forbs)</td>
<td>All 4 vegetation classes are present</td>
<td>3 vegetation classes are present</td>
<td>1-2 vegetation classes are present</td>
<td>Little or no vegetation is present</td>
</tr>
<tr>
<td>Vegetation species diversity along ditch bank</td>
<td>Many species present</td>
<td>Dominated by a few species</td>
<td>Dominated by one or two species</td>
<td>Little or no vegetation present</td>
</tr>
<tr>
<td>Presence of noxious weeds along the ditch</td>
<td>Not present</td>
<td>Very few present</td>
<td>Numerous present, but not spreading</td>
<td>Numerous present; appear to be spreading</td>
</tr>
<tr>
<td>Acequia bed material</td>
<td>Mostly earthen and natural</td>
<td>Less than half lined or piped</td>
<td>More than half lined or piped</td>
<td>Entirely lined or piped</td>
</tr>
<tr>
<td>Wildlife use (mammals, birds, reptiles, amphibians, insects)</td>
<td>Many species; seen frequently</td>
<td>Many species; seen occasionally</td>
<td>Few species; seen frequently</td>
<td>Few species; rarely seen</td>
</tr>
<tr>
<td>What other ecosystem services does acequia provide? (riparian area, groundwater recharge, water quality, etc.)</td>
<td>3 or more ecosystem services are provided</td>
<td>2 ecosystem services are provided</td>
<td>1 ecosystem service is provided</td>
<td>No ecosystem services are provided</td>
</tr>
</tbody>
</table>
Table 6. Acequia Functionality Assessment category 3 – acequia governance and community use

<table>
<thead>
<tr>
<th>Criterion</th>
<th>4 Points</th>
<th>3 Points</th>
<th>2 Points</th>
<th>1 Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meetings of local acequia association</td>
<td>Regular and well attended</td>
<td>Irregular but well attended</td>
<td>Regular but poorly attended</td>
<td>Irregular and poorly attended</td>
</tr>
<tr>
<td>Do bylaws require proposed water rights transfers be approved by commission?</td>
<td>Yes</td>
<td>No, but bylaws are being updated</td>
<td>No, but bylaws are otherwise complete</td>
<td>No, and there are no plans to update bylaws</td>
</tr>
<tr>
<td>Water banking to protect unused water rights (Is procedure for water banking included in bylaws? Yes _____ No____)</td>
<td>Water banking always practiced with un-used water rights (or there are no unused water rights)</td>
<td>Water banking occasionally practiced with unused water rights</td>
<td>Water banking not practiced but is included in bylaws</td>
<td>Water banking never practiced and is not included in bylaws</td>
</tr>
<tr>
<td>What does acequia water irrigate? (Food crops include home gardens and orchards)</td>
<td>Food crops, hay fields, pasture</td>
<td>Hay fields and pasture</td>
<td>Just pasture</td>
<td>Untended or unused lands</td>
</tr>
<tr>
<td>Who cleans the acequia?</td>
<td>Mostly parciantes</td>
<td>Mostly labor hired by parciantes</td>
<td>Crew appointed by mayordomo</td>
<td>Acequia not regularly cleaned</td>
</tr>
<tr>
<td>Interest in acequia agriculture within the local community</td>
<td>Strong interest across multiple generations</td>
<td>Moderate interest across multiple generations</td>
<td>Strong interest but mostly in older generations</td>
<td>Little or no interest remaining</td>
</tr>
<tr>
<td>Economic viability of farming and ranching in the local community</td>
<td>Farming and ranching yield livable incomes</td>
<td>Farming and ranching often yield a portion of income</td>
<td>Farming and ranching yield little income but are done as hobbies</td>
<td>Farming and ranching are rarely practiced in the community</td>
</tr>
<tr>
<td>Land use trends in the local community</td>
<td>Land is generally remaining in agriculture (ag)</td>
<td>Minor shifts from ag land to other uses, but existing ag lands remain operational</td>
<td>Land is generally shifting away from ag uses, but existing ag lands remain operational</td>
<td>Land is rapidly shifting away from ag uses; existing ag uses appear to be negatively affected</td>
</tr>
<tr>
<td>Acequia finances</td>
<td>Money collected covers all operation costs</td>
<td>Money collected covers most operation costs</td>
<td>Money collected is often insufficient</td>
<td>Parciantes do not contribute funds to acequia</td>
</tr>
</tbody>
</table>

Professional Project 80  Marcos A. Roybal
6.2 Description of Acequia Functionality Assessment structure and use

This section provides instructions for use of the AFA. The AFA is presented in datasheet format and divided into three main sections. Page 1 contains general information about the acequia, observers, and assessment being done, pages 2–3 present criteria related to evaluating the acequia’s physical characteristics, ecology, and governance and community use, and page 4 provides space for attachment of photographs, sketches, or maps of the assessment area or other relevant features (Appendix 2). To perform the assessment, a portion of the acequia should be chosen that is of greatest interest. This may, for example, be the entire length of an acequia, a section of the ditch that is known to be susceptible to problems or needs special attention, or the portion of the ditch passing through a private landowner’s property. The person conducting the assessment (the observer) should then fill out the material on page 1 at the beginning of the assessment, and proceed to assign ratings to the 22 criteria presented on pages 2–3. Some of these criteria pertain to the entire length of the ditch or the community through which it flows, while some can be limited to a smaller portion. If the observer is sufficiently familiar with the acequia he or she should be able to quickly assign ratings to all of the criteria, but if the observer is less familiar with the physical conditions of the acequia, the community in which it is located, and the governance of the acequia’s operations, consultation with somebody who has greater familiarity with the system may be necessary.

In assigning ratings to the 22 criteria in the assessment, 4 points are given for each criterion that is generally in excellent condition with regard to the specific category in which it resides (physical characteristics, ecology, or governance and community use), 3 points for good condition, 2 points for fair condition, and 1 point for poor condition. After assigning a score to each criterion, the scores for the criteria in each category are totaled and entered in the
Functionality Ratings table at the bottom of page 3. Each of these totals is then divided by the number of criteria in each category (7 for physical characteristics, 6 for ecology, and 9 for governance and community use) to yield an average functionality rating for each category.

Table 7 lists the overall functionality ratings that can be applied to each category.

<table>
<thead>
<tr>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5–4</td>
<td>Excellent</td>
</tr>
<tr>
<td>2.5–3.49</td>
<td>Good</td>
</tr>
<tr>
<td>1.5–2.49</td>
<td>Fair</td>
</tr>
<tr>
<td>&lt;1.5</td>
<td>Poor</td>
</tr>
</tbody>
</table>

The criteria in the AFA are divided into three categories and evaluated separately because rating acequia “functionality” on a poor–excellent scale is subjective and dependent on the goals and perspectives of the individual(s) conducting the assessment. For example, if the efficiency of water delivery is the main goal, a rating of “good” or “excellent” in the physical characteristics and potentially governance/community use categories would be desired, whereas high ratings in the ecology category may adversely impact the efficiency of water delivery via seepage losses through unlined ditches and evapotranspiration by vegetation on the acequia banks. However, from the standpoint of evaluating the overall functionality of the acequia system as explored, for example, by Fernald et al. (2007), which would account for ecological as well as physical and social considerations, the functionality of all three categories would be of interest.

Finally, this assessment is designed to guide evaluation of acequia conditions and planning future activities related to the acequia. Its criteria are intended to be broadly applicable to acequias throughout New Mexico and southern Colorado. However, it is important to
recognize the uniqueness of each acequia system that has developed through differences in local
custom, needs, and landscape. As a result, the AFA should be viewed as a living tool that can be
modified to fit the goals and purposes of individual acequia users, associations, and groups of
acequias. As such, the criteria can be changed, supplemented or omitted as necessary. It must
be noted, however, that changing the assessment criteria or omitting certain criteria will impair
the ability to directly compare assessment results over time or between acequias. In the case of
use of the AFA by funding agencies to identify trends in New Mexico’s acequias or potential
areas of assistance, the AFA should not be modified. This will ensure consistency of its
application across acequias.

6.3 Description of pages 1 and 4 of the Acequia Functionality Assessment

The first page of the AFA asks for general information regarding the assessment and the
acequia. The individual(s) conducting the assessment should write their names on the
“observer(s)” line and record the date, time and location (GPS coordinates if available, otherwise
a verbal description) of the assessment. This information is crucial to ensuring repeatability and
consistency of data collection in the future, as the time of year, location, and observer can affect
the ratings assigned to the criteria. The observers should then record general information about
the acequia—its name, the community through which it flows, the stream or river from which it
is diverted, its estimated length, the approximate number of parciantes using its water, the length
of the growing season, and the current mayordomo. Finally, the observers should record any
additional information relevant to the assessment—for example, their goals in conducting the
assessment (e.g. identifying needs, monitoring changes over time, prioritizing certain elements of
functionality, etc.) and notable changes in the community recently (e.g. increased residential
development on agricultural land, sale of water rights, changes in forest or range management in the surrounding uplands, changes in local or state acequia policy, etc.). This information will facilitate analysis and application of the results of the assessment, as such changes have the potential to impact the acequia function.

Page 4 of the AFA provides space for the attachment of photographs of the assessment area or other features of interest, as well as maps and illustrations that may be relevant to the assessment. Additional graphics can be attached as necessary. Photos, maps and illustrations can be used to visually document changes over time or highlight areas in need of specific attention. In the case of photos intended to illustrate changes over time, it is best to establish a permanent photo point that can easily be revisited in the future. This facilitates duplication of the photos so direct comparisons can be made. A fence post, tree, or unique, permanent feature of the ditch can be used to designate a photo point, or a marker such as a stake can be installed to establish a photo point.

6.4 Description of the “Physical Characteristics” category of the Acequia Functionality Assessment

The Physical Characteristics category of the AFA is oriented toward evaluating the physical functionality of the acequia system. This category evaluates seven criteria: (1) the amount of flow in the acequia during the irrigation season; (2) the duration of useable flow in the acequia in recent years; (3) erosion of acequia banks and channel; (4) the acequia easement; (5) the condition of acequia infrastructure and improvements needed; (6) water quality; and (7) the extent of irrigation in the overall valley. These criteria and possible interpretations of their conditions as observed during the assessment are described below.
6.4.1 Amount of flow during irrigation season

This criterion addresses the extent to which the amount of water flow in the acequia in recent years has been adequate for meeting irrigation needs. Four points are assigned if the flow meets all irrigation needs; three if the flow meets most irrigation needs; two if the flow meets less than half of the irrigation needs, and one if, in recent years, the acequia has contained little or no water. Water availability is obviously crucial to acequia function, and without it irrigation of agriculture is either impossible or must be supported by other means, such as groundwater withdrawals for center pivot sprinklers. As an acequia’s ability to irrigate gardens, orchards and fields declines, its ability to support the community from a market standpoint is decreased. Lower water availability can also discourage people from farming, which reduces the overall integrity of the acequia system. Reductions in flow can stem from factors including drought, a changing climate, changes in watershed conditions, increasing groundwater pumping, and transfers of water rights outside of the acequia system. A timeframe of “in recent years” is specified for this criterion so as to allow for variations in precipitation from year to year, but, as monitoring is repeated in subsequent years, comparisons can be made to earlier surveys in order to detect changes in water availability.

6.4.2 Duration of useable flow in recent years

This criterion addresses the duration of useable flow in the acequia in recent years in relation to the growing season. Four points are assigned if useable flow is present for the entire growing season or more, three if useable flow is present for the majority of the growing season, two if useable flow is present for approximately half of the growing season, and one if useable flow is present for less than half of the growing season. With this criterion, it is important to
note that some acequia systems have never provided flow through the entire growing season. If this is the case it should be noted on the assessment. This criterion is particularly useful for monitoring alterations in flow availability over time that may stem from changes in the use of land and water in and around the local community and, potentially, a changing climate. As with the criterion examining the amount of flow, a timeframe of “in recent years” is specified for this criterion so as to allow for variations in precipitation from year to year, but, as monitoring is repeated in subsequent years, comparisons can be made to earlier surveys in order to detect changes in water availability.

6.4.3 Bank stability

This criterion addresses whether or not erosion of the acequia banks or channel is evident. Four points are given if no erosion is evident, three if erosion is evident in only a few places, two if erosion is evident in a few places but appears to be increasing, and one if substantial erosion is present and/or the amount of erosion is increasing rapidly. Erosion is an important factor in evaluating acequia functionality because it directly affects an acequia’s ability to deliver water. Severe erosion can result in bank failure, failure of the acequia to deliver water, loss of water, and damage to nearby structures and property. Additionally, associated sedimentation can impair the function of diversion structures and headgates. Repairing these problems can be costly and time consuming. Increased erosion can be a product of a lack of maintenance, a sudden increase in flow through the acequia, or changes in land use such as the establishment of a road near an acequia. Roads can concentrate stormwater if improperly engineered and cause substantial erosion (Zeedyk 2006).
6.4.4 Access to acequia easement

This criterion addresses the accessibility of the easement along the acequia. Four points are given if access to the easement is adequate for maintenance along the entire ditch, three if access to the easement is adequate for maintenance along most of the ditch, two if the easement is accessible along less than half of the ditch, and one if the easement is generally not accessible. According to New Mexico state statutes, an acequia has a legal easement as long as it has been used at least five continuous years since its establishment. This easement “shall be adequate to allow for reasonable maintenance, use and improvements to the ditch” (NMSA 1978 §73-2-5; New Mexico Acequia Association 2010b). Access to this easement is crucial for routine and emergency maintenance and for the mayordomo to perform his or her duties. Willful obstruction of an acequia easement is legally punishable, so it is well within an acequia association’s purview to ensure accessibility to the ditch’s easement. Easement access problems can stem, for example, from lack of recognition by landowners that an easement exists, a landowner’s refusal to allow access, or construction of buildings, fences or other structures that prevent access. An acequia should establish a clear definition of its easement and access needs, and educating community members about the easement is key to ensuring access.

6.4.5 Infrastructure condition and improvements needed

This criterion addresses the state of repair of acequia infrastructure such as the diversion dam (presa or atarque), headgates, laterals, and the ditch itself. Four points are given if little or no improvements to the infrastructure are needed, three if less than 25% of the infrastructure needs improvement, two if approximately 50% of the infrastructure needs improvement, and one if more than 50% of the infrastructure needs improvement. Good repair of ditch infrastructure is
crucial to proper function and efficient water delivery. Poor repair can be a product of neglect or insufficient funds on the part of the acequia association or individual *parciantes*. Documenting infrastructure needs can provide justification for funding assistance, which can be used for a variety of purposes, including headgate repair (Figure 7).

Figure 7. Acequia headgate before (left) and after (right) repair supported by an acequia cost share program (photos by Marcos Roybal)

6.4.6 Water quality

This criterion addresses the quality of water present in the acequia with respect to visual appearance and trash. Four points are given if the water appears clean and contains no trash, three if the water appears clean but some trash is present, two if considerable trash is present, and one if the water appears dirty and contains substantial amounts of trash. Trash was chosen as a primary metric of water quality because of its ease of identification; other constituents such as nutrients require special instrumentation and analysis to identify. Additionally, trash can physically obstruct water flow, particularly at culverts. Assessment of the visual appearance of water can also indicate problems; for example, high sediment loadings, which is indicated by unusually turbid water, can impair the function of diversions and headgates. Problems with
water quality can originate from neglect or poor maintenance, but a sudden change in water quality can indicate disturbance or land use changes somewhere in the upstream watershed.

6.4.7 Extent of irrigation

This criterion addresses the extent of irrigation occurring in the agricultural area supported by the acequia. Four points are given if more than 75% of fields in the area are irrigated, three if 50–75% are irrigated, two if 25–50% are irrigated, and one if less than 25% are irrigated. The irrigated portion of a valley comprises a large part of the *paisaje del agua*, the area affected and shaped by acequia irrigation. The full use of the water to which the acequia system is entitled is not only critical to the protection of water rights under the system of prior appropriation but also to protecting the agricultural land base. Long periods of non-irrigation can result in reversion of fields to patches of willow or sagebrush that require substantial modification to support agriculture. Non-use of water rights can result in their loss under the prior appropriation system. A decrease in the irrigated acreage in a valley can be indicative of conversion of agricultural land to residential development, or of people shifting away from agricultural ways of life.

6.5 Description of the “Ecology” category of the Acequia Functionality Assessment

The ecological benefits of acequias, such as recharging shallow aquifers, supporting riparian vegetation, and providing habitat for wildlife, have long been understood by acequia users (Rivera 1998). Recently, this ancient wisdom has been supported in the scientific literature (e.g. Hicks an Peña 2003, Fernald et al. 2007, Rivera 2012). The ecology category of the AFA is designed to assess the degree to which an acequia provides or supports various ecosystem
services. This category evaluates six criteria: (1) vegetation structural diversity along the ditch bank, (2) vegetation species diversity along the ditch bank, (3) the presence of noxious weeds and/or undesirable invasive species, (4) the acequia bed material, (5) wildlife use of the acequia, and (6) other ecosystem services the observer feels the acequia provides. These criteria and possible interpretations of their conditions as observed during the assessment are described below.

6.5.1 Vegetation structural diversity

This criterion addresses the vegetation structural diversity along the ditch bank. Vegetation can be seen as existing in four structural classes: trees, shrubs, grasses, and forbs (Figure 8; forbs include non-woody flowering plants that are not grasses). Four points are given if all four vegetation classes are present, three if three vegetation classes are present, two if one to two vegetation classes are present, and one if little or no vegetation is present. The structural diversity of vegetation reflects the complexity of the ecosystem an acequia supports, with greater diversity creating better wildlife habitat and contributing to overall ecosystem resilience. Furthermore, diverse vegetation cover contributes to the stability of an acequia’s banks, thereby preventing erosion. Finally, vegetation along the ditch serves aesthetic functions, increasing the visual attractiveness of an area. Low vegetation cover can be a product of intentional removal, soil quality issues, or low seepage from the ditch.
6.5.2 Vegetation species diversity

This criterion addresses the number of different plant species along the ditch bank. Four points are given if many species are present, three if the vegetation along the ditch is dominated by a few species, two if the vegetation along the ditch is dominated by one or two species, and one if little or no vegetation is present. A diversity of plant species is generally indicative of a healthy ecosystem and provides a variety of habitat options for wildlife. Additionally, as with the vegetation structural diversity criterion, a rich variety of vegetation contributes to bank stability and visual attractiveness. This criterion does not require identification of individual plant species as this necessitates a relatively technical knowledge of botany. However, those with an interest in specific plant species could append lists of species observed to the assessment; this information could then be used to track changes in specific plant species over time that may result from changing moisture regimes, climate, or land use.
6.5.3 Presence of noxious weeds

This criterion addresses the presence of noxious weeds along the ditch. Four points are given if noxious weeds are not present, three if very few noxious weeds are present, two if numerous noxious weeds are present but do not appear to be spreading, and one if numerous noxious weeds are present and appear to be spreading. This criterion requires some ability to identify noxious plant species; local extension agents can provide substantial information about common species and identifying characteristics. Some common species in northern New Mexico include hoary cress (Cardaria draba), field bindweed (Convolvulus arvensis), yellow toadflax (Linaria vulgaris), and Siberian elm (Ulmus pumila). Noxious plant species are a particular problem along acequias because they can easily be spread by running water or disturbance associated with routine cleaning and maintenance. Increases in noxious weeds can be indicative of disturbance. Early identification and treatment of noxious weeds can prevent their spread, but extension agents should be consulted to determine appropriate treatment measures, as some chemical options are not appropriate for use near water.

6.5.4 Acequia bed material

This criterion addresses the composition of the acequia bed. Four points are given if the acequia bed is mostly earthen and natural, three if less than half of the length of the ditch either as a whole or in the assessment area is piped or lined with concrete or other impervious material, two if more than half of the ditch either as a whole or in the assessment area is piped or lined, and one if the entire ditch is piped or lined. Studies such as that by Fernald et al. (2007) have shown that seepage from the ditch plays a valuable role in recharging shallow aquifers and supporting vegetation and wildlife. Piping or lining a ditch will largely eliminate these benefits.
However, piping or lining the ditch in areas such as road crossings or where ditch seepage may be problematic for buildings or other structures is often necessary, so the rating of four points allows for lining or piping as necessary in situations such as these.

6.5.5 Wildlife use

This criterion addresses the use of the acequia and surrounding area by wildlife (including mammals, birds, reptiles, amphibians and insects). Evaluation of this criterion can include wildlife observed at the time of the assessment, or a culmination of wildlife observations over a period of time. Four points are given if many wildlife species are present and are seen frequently, three if many species are present but are seen infrequently, two if few species are present but they are seen frequently, and one if few species are present and they are rarely seen. Wildlife use of the acequia is an indicator of a functioning ecosystem, and monitoring changes in wildlife use over time can highlight the effects of land use or climatic change in the area. As with plants, a diversity of wildlife will contribute to ecosystem resilience and potentially impart aesthetic or scientific benefits as well.

6.5.6 Other ecosystem services

This criterion addresses other, specific ecosystem services that the acequia is known to provide. These include, but are not limited to, increasing riparian areas, recharging shallow aquifers, improving water quality, improving air quality, providing for carbon sequestration, facilitating nutrient cycling, supporting pollinators, etc. Four points are given if the acequia is known to provide three or more ecosystem services, three if it is known to provide two ecosystem services, two if it is known to provide one ecosystem service, and one if it provides no
known ecosystem services. This criterion is largely aimed at capturing the observer’s perceptions of ecosystem services the acequia provides. This is important in identifying known services (for example, the acequias in El Rito, NM are known to play an important role in recharging the shallow aquifers from which many domestic wells draw their water) and potentially highlighting areas in which an acequia’s ability to provide ecosystem services could be improved.

6.6 Description of “Acequia Governance and Community Use” category of the Acequia Functionality Assessment

One of the most unique elements of acequias is their community-based governance structure. However, without continued community engagement and investment, acequias may cease to function. The governance and community use category of the AFA is aimed at evaluating nine social and economic elements that affect acequia operations: (1) meetings of the local acequia association, (2) protections provided by acequia bylaws, (3) the use of water banking to protect unused water rights, (4) the type of uses to which acequia water is put, (5) who cleans the acequia, (6) interest in acequia agriculture within the local community, (7) the economic viability of farming and ranching in the local community, (8) land use trends in the local community, and (9) acequia finances. These criteria and possible interpretations of their conditions as observed during the assessment are described below.

6.6.1 Meetings of the local acequia association

This criterion addresses the frequency of and attendance at acequia association meetings. Four points are given if the meetings are regular and well-attended, three if the meetings are irregular but well attended, two if the meetings are regular but poorly attended, and one if the
meetings are irregular and poorly attended. New Mexico state statutes require meetings of the acequia membership to elect acequia officials every other year (NMSA 1978 §73-2-12, §73-2-15, and §73-3-1). However, many acequias meet annually. In addition to statute compliance, these meetings are crucial to discussing problems and needs, planning activities, collecting dues, and ensuring the continued function of the association. Poor attendance at meetings may be indicative of low interest in acequia operations or a shrinking membership, both of which have the potential to negatively impact acequia function.

6.6.2 Acequia bylaws and water transfers

This criterion addresses whether or not the acequia’s bylaws require proposed water rights transfers to be approved by the local acequia commission. Four points are given if the bylaws include this provision, three if the bylaws do not include this provision but are in the process of being updated to do so, two if the bylaws do not include this provision but are otherwise complete, and one if the bylaws do not include this provision and there are no plans to update them. New Mexico statutes provide that proposed changes in the point of diversion or place or purpose of use of a water right related to an acequia are subject to the approval of the acequia’s commissioners, and that such a change may be denied if it is found that it would be “detrimental to the acequia… or its members” (NMSA 1978 §73-2-21E and §73-3-4.1). However, an acequia’s bylaws or governing rules must specify this authority in order for the acequia to take advantage of it. Transfers of water rights away from an acequia can negatively impact the acequia in at least two ways. First, they reduce the amount of water that flows through the system, which may compromise its ability to deliver water to irrigators located on the downstream end of the ditch. Second, since acequia membership is typically contingent on
owning water rights, transfers of water rights out of the system have the potential to reduce acequia membership and thus reduce contributions of money and labor toward its operation and maintenance. In order to prevent the potentially detrimental effects of water rights transfers, individual acequias must ensure their bylaws include a water rights transfer approval provision.

6.6.3 Water banking

This criterion addresses whether or not a procedure for water banking is included in an acequia’s bylaws and if water banking is practiced to protect water rights from loss due to nonuse. Four points are given if water banking is always practiced with unused water rights or if there are no unused water rights in the system, three if water banking is occasionally practiced with unused water rights, two if water banking is not practiced but is included in the bylaws, and one if water banking is never practiced and is not included in the bylaws. New Mexico statutes allow for establishment of a water bank by an acequia to protect water rights from loss due to non-use (NMSA 1978 §73-2-55.1). Establishment of a water bank and placement of water rights in the bank under this provision does not require proceedings before the State Engineer or approval by the Interstate Stream Commission or State Engineer. Although acequias are not required to include a water banking provision in their bylaws to take advantage of this allowance, outlining a clear water banking procedure in the bylaws will facilitate use of the water bank and alleviate confusion over how to do so. It is crucial that acequias bank unused water rights, as unused rights are subject to loss under the system of prior appropriation.
6.6.4 Use of acequia water

This criterion addresses the uses to which acequia water is put. Four points are given if the acequia is used to irrigate food crops (which include home gardens and orchards), hay fields and pasture; three if the acequia is used to irrigate just hay fields and pasture; two if the acequia is used to irrigate just pasture; and one if the acequia water is turned on to untended or unused lands to preserve water rights. Putting acequia water to a diversity of uses not only increases its utility to the community as a whole, but also increases its potential to build economic viability. Although irrigating pasture and hay fields is important, food crops have the potential to feed people directly. Maintaining a diversity of agricultural land uses in the community is important for building economic vitality and increasing resilience.

6.6.5 Acequia cleaning

This criterion addresses who cleans the acequia. Four points are given if the acequia is cleaned by mostly parciantes, three if it is cleaned by mostly labor hired by parciantes, two if it is cleaned by a crew appointed by the mayordomo, and one if the acequia is not regularly cleaned. The limpia, or annual acequia cleaning, has traditionally been completed by parciantes or labor hired by the parciantes. Annual cleaning is vital to ensuring efficient water flow, but also provides an opportunity for community members to work together and address issues that have arisen throughout the year. In many areas, recent times have seen a decrease in community participation in acequia cleaning, and often the mayordomo must hire a crew to complete the task due to lack of community participation. Although this is preferable to the acequia not being cleaned at all, it represents the weakening of an element of the acequia institution with deep communal roots and may indicate waning community interest in the acequia.
6.6.6. Interest in acequia-supported agriculture within the local community

This criterion addresses the extent of interest in acequia-supported agriculture at the time of the assessment in the community through which the acequia runs. Four points are given if strong interest in agriculture is present across multiple generations, three if moderate interest in agriculture is present across multiple generations, two if strong interest in acequia agriculture is present but this interest lies mostly in older generations, and one if there is little or no interest in acequia agriculture remaining in the community. Many acequia users voice concern over a perceived lack of interest in acequia agriculture in younger residents, and indeed, many young people as well as their parents have forgone an agricultural way of life in search of education and more profitable and predictable pursuits. In order for acequia culture to persist, a new generation of residents must be poised to fill in as age prevents many of today’s farmers from continuing to irrigate and work the land. Youth should be encouraged to participate in using the assessment; this will not only educate them about what makes for a functional acequia, but will also give them a direct hand in the acequia’s operations.

6.6.7 Economic viability of farming and ranching

This criterion addresses the extent to which, at the time of the assessment, farming and ranching in the community through which the acequia flows are viable means of making a living. Four points are given if farming and ranching can yield livable incomes, three if farming and ranching often yield a portion of people’s income, two if farming and ranching yield little income but are practiced as hobbies, and one if farming and ranching are rarely practiced in the community. The ability to make a strong economic contribution to a community will increase an acequia’s likelihood of receiving ongoing community investment in operation and maintenance.
Although today it is rare that farming and ranching yield livable incomes for many in northern New Mexico, they can certainly augment a household’s income and food supply. Even if they yield little income, these pursuits can be practiced in a way that provides numerous nonmarket benefits. Encouraging farming and ranching will facilitate acequia preservation, and may result in innovations in technique that increase the economic viability of these occupations.

6.6.8 Land use trends in the local community

This criterion addresses land use trends at the time of the assessment in the community through which the acequia flows. Four points are given if land is generally remaining in agriculture, three if there have been minor shifts from agriculture to other uses such as residential development but existing agricultural land remains operational, two if the general trend in the community is a shift away from agricultural land uses but existing agricultural land remains operational, and one if land is rapidly shifting away from agricultural uses in a way that appears to compromise existing agricultural uses. In many parts of northern and central New Mexico, as well as around the United States, agricultural land is being converted to residential and other uses. This has several implications for acequias. First, it reduces the land base available for acequia agriculture. Second, it has the potential to transfer water from agricultural to other uses. Third, it sets the stage for potential conflict over acequia traditions (such as ditch access) that may be seen as infringements on privacy and property rights. Although it is possible that minor shifts away from agricultural land uses will have relatively negligible effects on the overall function of acequia systems, the more land that is changed to other uses the greater the chances that remaining agriculture will be impacted.
6.6.9 *Acequia finances*

This criterion addresses the ability of acequia finances to cover expenses that arise throughout the year. Four points are given if money collected from *parciantes* is adequate to cover all of the acequia’s operational costs, three if money collected from *parciantes* is adequate to cover most of the acequia’s operational costs, two if the money collected is often insufficient, and one if *parciantes* do not contribute funds to the acequia. *Parciantes* are generally required to pay annual dues for acequia membership, and may also be required to provide money in lieu of labor or as payment of fines for violation of acequia rules. Ideally this income will be adequate to cover expenses such as compensation of officers, hiring any labor that may be necessary, and routine and emergency maintenance of the ditch infrastructure. In the worst case scenario *parciantes* do not contribute money to the acequia. This may be a result of low community investment or interest in its operation or ineffective governance and enforcement mechanisms. Although supplemental funding can be acquired from numerous outside sources such as acequia cost share programs with local soil and water conservation districts and federal grants such as the Natural Resource Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP), financial self-sufficiency will increase an acequia’s ability to respond to problems that may arise unexpectedly (ranging from emergency ditch repair to legal defense) and build overall system resilience.

6.7 *Analysis and application of Acequia Functionality Assessment results*

The Acequia Functionality Assessment is intended to serve multiple purposes. It can be used as a planning tool for acequia associations or individual *parciantes* to monitor changes over time; determine needs with respect to maintenance, infrastructure improvements, community
development, education, and changes in governance; and justify requests for funding assistance. Further, it can be used by researchers as a means of evaluating physical, ecological and social conditions related to an acequia of interest or by funding agencies to monitor the condition of acequias and highlight areas in need of assistance. Perhaps most importantly, it can serve as an educational tool to raise awareness of key elements of acequia function and engage local youth. The assessment is designed to be relatively easy to perform, so it can easily be used as a tool to include youth in acequia planning and monitoring.

After performing the assessment, depending on the purpose of the assessment, the results can be examined to determine aspects of the acequia or surrounding community requiring attention (for example, needed infrastructure improvements or low interest in the community with respect to acequia agriculture); the effectiveness of a recent project (such as infrastructure repair); or, in the case of repeated monitoring, trends developing over time. These findings can help inform individual landowners’ management activities, or facilitate project planning at the level of the acequia association. Such projects could include infrastructure improvements, watershed management (such as forest thinning), invasive species removal, community education, bylaws revision, economic development activities, engagement of youth, applications for funding assistance, and further monitoring.

On the whole, the AFA can highlight “tipping points” (J. Rivera, personal communication, 23 February 2012) with respect to the status of elements of the acequia system that may result in transitions to less desirable states, such as reduced local control of resources and a community with little interest in agriculture as an occupation. For example, repeated monitoring over time may indicate waning interest in acequia agriculture in the local community, which would highlight the need for education or development of economic incentives.
CHAPTER 7. SUMMARY AND CONCLUSIONS: THE ACEQUIA FUNCTIONALITY ASSESSMENT AS A TOOL FOR BUILDING SOCIAL-ECOLOGICAL RESILIENCE

7.1 Summary

This project made two contributions to the ongoing discussion about the importance of acequia irrigation systems in New Mexico and southern Colorado. First, it provided a broad synthesis of existing work related to documenting the evolution and current status of acequias, their benefits, challenges they currently face, and how resilience theory can be applied to both understanding their persistence and improving their future viability. Second, it developed the Acequia Functionality Assessment as an instrument acequia users, researchers and funding agencies can employ to evaluate current conditions with respect to an acequia and build their resilience. The assessment can also be used as an educational tool for youth and other community members by engaging them in monitoring acequias and examining factors that contribute to their function.

Chapter 1 began with a scene that has been a feature of winter in New Mexico and southern Colorado for many years: the annual meeting of acequia officers and parciantes to discuss past and future business and emerging needs with respect to their acequia. The proceedings at this meeting highlighted a theme that has become relatively common: recognition on the part of acequia users that a variety of factors have the potential to threaten traditional ways of life and that it is in an individual acequia’s power to develop protections against them, but that the capacity and resources to do so are often lacking. This chapter then described the Experimental Program to Stimulate Competitive Research (EPSCoR), a large, ongoing research endeavor, of which this project is a part, that is aimed at examining the potential impacts of climate change on New Mexico’s mountain sources of water. Acequias are often located
relatively high in New Mexico’s watersheds, which makes them especially sensitive to the changes in snowpack and streamflow that are anticipated under a warming climate. Furthermore, this geographic position gives acequias a relatively strong influence on the delivery of water to downstream users. Finally, this chapter defined key terms and provided a roadmap that outlined the objectives of the project.

Chapter 2 explored the history and current status of acequias in New Mexico. It began by describing acequias as gravity-driven irrigation ditches that evolved from a combination of Spanish, Arabic, Roman, Native American, and Mesoamerican irrigation and agricultural practices and locally unique climate and conditions. It then discussed the modern operation and governance of acequias, and emphasized their community-based management that is rooted in traditions of water sharing and mutual support. Next it described the history of land grants in New Mexico, which formed the basis for systems of land use that persist in rural northern New Mexico and southern Colorado to this day. The adjudication of these land grants by the United States in the late 19th and early 20th centuries was often unjust and resulted in the expropriation of enormous areas of land, which has had ongoing social, economic and psychological implications for rural Hispanos. Finally, this chapter briefly discussed the current status of acequias and efforts being undertaken to promote their viability. Groups such as New Mexico Acequia Association have been instrumental in providing advocacy and technical support for acequias, as well as documenting associated customs and traditions.

Chapter 3 introduced resilience theory as a recent body of work that forges an explicit link between human and ecological systems and facilitates conceptualization of their dynamics. Resilience generally refers to (1) the amount of change a system can undergo and still retain the same controls on structure and function; (2) the degree to which a system is capable of self-
organization; and (3) the ability of a system to build the capacity to learn and adapt (Carpenter et al. 2001, p. 766). This chapter described the elements of resilience theory, which consist of a recognition that social-ecological systems (SES) exist in a dynamic state and behave in non-linear ways, and that interactions among SESs are often complex and scale-dependent. It then outlined a number of factors that contribute to the resilience of SESs generally and acequia systems specifically. Next it applied resilience theory to acequia history, and found that acequias have generally been resilient to a number of climatic, social and economic disturbances. However, some of these disturbances, such as land loss due to land grant adjudication and emigration from rural communities, have likely negatively impacted the current status of acequias. Finally, this chapter presented resilience as a recurring theme throughout the project.

Chapter 4 described acequias as “multifunctional” agricultural systems that provide a variety of benefits beyond growing crops and supporting livestock. These include serving as a foundation for the social and cultural makeup of rural Hispano communities; providing a valuable source of local knowledge regarding agricultural practices and landscapes; yielding a source of economic value from market and particularly nonmarket perspectives; presenting a model for community-based natural resource management that serves as an alternative to the often counterproductive command-and-control approach that has permeated water and other resource management in the United States; and providing a source of numerous environmental benefits, including recharging shallow aquifers, supporting riparian vegetation, improving water quality, and increasing stream channel complexity. These benefits have helped contribute to the resilience of acequia systems, and bolster arguments for preserving acequias as an institution of irrigation.
Chapter 5 outlined the major challenges facing contemporary acequia irrigation systems. These include growing populations in and around New Mexico that increase the demand for land and water for municipal, industrial, and domestic uses; changing socioeconomic conditions in rural communities driven by demographic shifts and a potentially waning interest in acequia agriculture; larger trends in agricultural production such as increasing homogenization, consolidation and mechanization, which greatly decrease the competitive advantage of small-scale producers in larger, more lucrative markets; and climate change, which will likely affect agriculture in a variety of ways and acequias specifically by, among other things, decreasing the overall water availability throughout the year and affecting crops’ physiological processes and resistance to pests and disease. Individually each of these challenges has the potential to negatively impact the continued viability of acequias, and synergistic effects will likely exacerbate this potential. The current resilience of acequias will serve to mitigate negative effects, but building their resilience further will help ensure they continue to function and support rural communities into the future.

Chapter 6 presented the Acequia Functionality Assessment (AFA) as a tool that can help build the resilience of acequias as a social-ecological system. It began by describing the development of the assessment, which was inspired by a rapid appraisal approach for evaluating riparian health developed by Fleming and Henkel (2001) and an agricultural assessment for New Mexico land grant communities developed by Villar (2009). However, the assessment was modified to better reflect factors that contribute to acequia “functionality” following multiple discussions with acequia users, academic experts in the areas of water and acequias; field tests; and the author’s personal experience with acequias. The end product is an assessment tool in datasheet form consisting of 22 criteria determined to be influential in the physical, ecological,
and governance and social functionality of acequias. This chapter described each of these
criteria in detail and provided basic interpretation of certain findings with respect to the criteria.
The AFA can be used by acequia associations, parciantes, youth, funding agencies, and
researchers interested in evaluating conditions on a given acequia. Furthermore, it can be
performed on a regular basis to track functionality in the long term.

7.2 Future work

Several future efforts related to the AFA may be undertaken. First, the assessment
criteria may be refined to increase their applicability to acequias in general or their specificity to
particular acequia systems. Additionally, the criteria may be weighted in order to place greater
value on those deemed to be especially important and less value on those deemed to be of lower
importance. However, as noted above, it is necessary to recognize that modifying the assessment
criteria with respect to a particular acequia will reduce the ability to consistently compare results
across acequias or over time when the original set of criteria have already been used to perform
assessments. Second, formal case studies using the AFA could be conducted. Such studies
could be used to document conditions and trends with respect to a single acequia or a number of
acequias in a region. Finally, the AFA could be incorporated into educational curricula for use in
schools, workshops, field schools, or summer programs. Such curricula could be targeted at
increasing youth engagement with acequias, at building general knowledge with respect to the
function of acequias in the communities in which they are present, or at educating interested
parties about the use of the AFA and interpretation of its results.
7.3 Conclusions

The AFA is intended to serve as a tool that can be used to monitor changes over time, plan for future activities by identifying needs, and educate community members about the factors that contribute to a functional acequia system. A particularly important element in planning is identifying tipping points that may result in undesirable shifts in system state. This is analogous to low resilience. For example, an acequia may have the capacity to withstand the transfer of a certain amount of water rights outside of the system, but when a threshold is crossed with respect to the number of water rights transferred, the system collapses due to insufficient water, decreased support from *parcinates*, or both. Such a tipping point may have detrimental effects for the acequia. If tipping points are identified in conjunction with the use of the AFA, the results of the assessment will indicate whether certain criteria are changing in such a way that moves the system closer to these tipping points. Repeated monitoring using the AFA will illuminate trends in the condition of the criteria that contribute to the functionality of acequias, and highlight areas in need of attention in order to prevent achievement of deleterious tipping points.

With detrimental effects of climate change looming large in the near future, human societies must critically examine their relationships with each other and with the natural world. Are short-term benefits and unending growth worth the sacrifice of environmental quality and alternative perspectives on land and water management? Without question, efforts aimed at achieving a better quality of life cannot be denied. However, the way in which this goal is pursued can be flexible and accommodate a diversity of perspectives. Acequias offer one such perspective, wherein human-environment interactions are readily apparent, robust social relationships are valued, and flexibility is a crucial element of structures of governance. Such
flexibility is key in a world in which “stationarity is dead” (Milly et al. 2008, Craig 2010)—human societies must build the capacity to adapt to ever-changing conditions that may have no historical analog. A “no analog” future (Ruhl 2008), however, does not preclude looking back for inspiration—some past methods of existence may hold valuable lessons for proceeding into an uncertain future. As a changing climate increases energy costs and potentially amplifies the negative externalities of a highly globalized, consumption-driven human society, we may find ourselves looking closer to home for ways to meet our basic needs. Acequias, by merit of their persistence through over 400 years of adversity, possess a resilience that can potentially be applied to future, locally-based approaches to agriculture, land and water management, and community development. It is hoped that this project will contribute to their continued survival and help ensure that their lessons are not lost.
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### APPENDIX 1. POPULATION TRENDS IN THE ROCKY MOUNTAIN REGION AND TEXAS, 1950–2010

<table>
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<td>330,066</td>
<td>332,416</td>
<td>469,577</td>
<td>453,588</td>
<td>493,782</td>
<td>563,626</td>
<td>+94.0</td>
</tr>
<tr>
<td>Total</td>
<td>12,786,192</td>
<td>16,434,737</td>
<td>19,486,631</td>
<td>25,600,713</td>
<td>30,645,286</td>
<td>39,024,115</td>
<td>47,211,012</td>
<td>+269.2</td>
</tr>
</tbody>
</table>
APPENDIX 2. ACEQUIA FUNCTIONALITY ASSESSMENT

This assessment is designed to be a tool for acequia users to evaluate the general functionality of physical characteristics, ecology and governance and community use on their acequia, and to track changes over time. To calculate the “functionality” score for each of these categories, add up the criteria ratings after conducting the assessment. Higher values indicate greater functionality in these areas. More information about the criteria and use of this assessment can be found in the Acequia Functionality Assessment Guidebook.

Assessment Information

Observer(s): 

Date: ___________________________ Time: ___________________________

Location of assessment (GPS or description): ___________________________

Acequia Information

Acequia name: ___________________________

Acequia location (community): ___________________________

Stream or river: ___________________________

Estimated length: _______________ Number of parciantes: __________

Growing season (weeks): ___________________________

Current mayordomo: ___________________________

Notes (For example, what are your goals in conducting this assessment? Have there been notable changes in your community or acequia recently?)

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
## Category 1 – Physical Characteristics

<table>
<thead>
<tr>
<th>Criterion</th>
<th>4 Points</th>
<th>3 Points</th>
<th>2 Points</th>
<th>1 Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of flow during irrigation season in recent years</td>
<td>Meets all irrigation needs</td>
<td>Meets most irrigation needs</td>
<td>Meets less than half of irrigation needs</td>
<td>Little or no water</td>
</tr>
<tr>
<td>Duration of useable flow in recent years</td>
<td>Entire growing season or more</td>
<td>Majority of growing season</td>
<td>Approximately half of growing season</td>
<td>Less than half of growing season</td>
</tr>
<tr>
<td>Bank stability</td>
<td>No erosion evident</td>
<td>Erosion evident in a few places</td>
<td>Erosion evident in a few places and seems to be increasing</td>
<td>Substantial erosion, and/or amount of erosion is increasing rapidly</td>
</tr>
<tr>
<td>Access to acequia easement</td>
<td>Adequate for maintenance along entire ditch</td>
<td>Adequate for maintenance along most of ditch</td>
<td>Accessible along less than half of ditch</td>
<td>Generally not accessible</td>
</tr>
<tr>
<td>Infrastructure condition and improvements needed (presa, headgates, main ditch, etc.)</td>
<td>Little or no improvement needed</td>
<td>Less than 25% of infrastructure needs improvement</td>
<td>About 50% of infrastructure needs improvement</td>
<td>More than 50% of infrastructure needs improvement</td>
</tr>
<tr>
<td>Water quality</td>
<td>Water appears clean with no trash</td>
<td>Water appears clean; some trash</td>
<td>Considerable trash present</td>
<td>Water appears dirty and has lots of trash</td>
</tr>
<tr>
<td>In general, what proportion of fields in your area is irrigated?</td>
<td>More than 75%</td>
<td>50-75%</td>
<td>25-50%</td>
<td>Less than 25%</td>
</tr>
</tbody>
</table>

## Category 2 – Ecology

<table>
<thead>
<tr>
<th>Criterion</th>
<th>4 Points</th>
<th>3 Points</th>
<th>2 Points</th>
<th>1 Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation structural diversity along ditch bank (4 vegetation classes = trees, shrubs, grasses, and forbs)</td>
<td>All 4 vegetation classes are present</td>
<td>3 vegetation classes are present</td>
<td>1-2 vegetation classes are present</td>
<td>Little or no vegetation is present</td>
</tr>
<tr>
<td>Vegetation species diversity along ditch bank</td>
<td>Many species present</td>
<td>Dominated by a few species</td>
<td>Dominated by one or two species</td>
<td>Little or no vegetation present</td>
</tr>
<tr>
<td>Presence of noxious weeds along the ditch</td>
<td>Not present</td>
<td>Very few present</td>
<td>Numerous present, but not spreading</td>
<td>Numerous present; appear to be spreading</td>
</tr>
<tr>
<td>Acequia bed material</td>
<td>Mostly earthen and natural</td>
<td>Less than half lined or piped</td>
<td>More than half lined or piped</td>
<td>Entirely lined or piped</td>
</tr>
<tr>
<td>Wildlife use (mammals, birds, reptiles, amphibians, insects)</td>
<td>Many species; seen frequently</td>
<td>Many species; seen occasionally</td>
<td>Few species; seen frequently</td>
<td>Few species; rarely seen</td>
</tr>
<tr>
<td>What other ecosystem services does acequia provide? (riparian area, groundwater recharge, water quality, etc.)</td>
<td>3 or more ecosystem services are provided</td>
<td>2 ecosystem services are provided</td>
<td>1 ecosystem service is provided</td>
<td>No ecosystem services are provided</td>
</tr>
</tbody>
</table>
### Category 3 – Acequia Governance and Community Use

<table>
<thead>
<tr>
<th>Criterion</th>
<th>4 Points</th>
<th>3 Points</th>
<th>2 Points</th>
<th>1 Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meetings of local acequia association</td>
<td>Regular and well attended</td>
<td>Irregular but well attended</td>
<td>Regular but poorly attended</td>
<td>Irregular and poorly attended</td>
</tr>
<tr>
<td>Do bylaws require proposed water rights transfers be approved by commission?</td>
<td>Yes</td>
<td>No, but bylaws are being updated</td>
<td>No, but bylaws are otherwise complete</td>
<td>No, and there are no plans to update bylaws</td>
</tr>
<tr>
<td>Water banking to protect unused water rights (Is procedure for water banking included in bylaws? Yes [ ] No [ ] )</td>
<td>Water banking always practiced with un-used water rights (or there are no unused water rights)</td>
<td>Water banking occasionally practiced with unused water rights</td>
<td>Water banking not practiced but is included in bylaws</td>
<td>Water banking never practiced and is not included in bylaws</td>
</tr>
<tr>
<td>What does acequia water irrigate? (Food crops include home gardens and orchards)</td>
<td>Food crops, hay fields, pasture</td>
<td>Hay fields and pasture</td>
<td>Just pasture</td>
<td>Untended or unused lands</td>
</tr>
<tr>
<td>Who cleans the acequia?</td>
<td>Mostly parciantes</td>
<td>Mostly labor hired by parciantes</td>
<td>Crew appointed by mayordomo</td>
<td>Acequia not regularly cleaned</td>
</tr>
<tr>
<td>Interest in acequia agriculture within the local community</td>
<td>Strong interest across multiple generations</td>
<td>Moderate interest across multiple generations</td>
<td>Strong interest but mostly in older generations</td>
<td>Little or no interest remaining</td>
</tr>
<tr>
<td>Economic viability of farming and ranching in the local community</td>
<td>Farming and ranching yield livable incomes</td>
<td>Farming and ranching often yield a portion of income</td>
<td>Farming and ranching yield little income but are done as hobbies</td>
<td>Farming and ranching are rarely practiced in the community</td>
</tr>
<tr>
<td>Land use trends in the local community</td>
<td>Land is generally remaining in agriculture (ag)</td>
<td>Minor shifts from ag land to other uses, but existing ag lands remain operational</td>
<td>Land is generally shifting away from ag uses, but existing ag uses appear to be negatively affected</td>
<td>Land is rapidly shifting away from ag uses; existing ag uses appear to be positively affected</td>
</tr>
<tr>
<td>Acequia finances</td>
<td>Money collected covers all operation costs</td>
<td>Money collected covers most operation costs</td>
<td>Money collected is often insufficient</td>
<td>Parciantes do not contribute funds to acequia</td>
</tr>
</tbody>
</table>

### Functionality Ratings

<table>
<thead>
<tr>
<th>Category</th>
<th>Score</th>
<th>Average functionality rating*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Characteristics (out of 28)</td>
<td>Score/7 =</td>
<td></td>
</tr>
<tr>
<td>Ecology (out of 24)</td>
<td>Score/6 =</td>
<td></td>
</tr>
<tr>
<td>Acequia Governance and Community Use (out of 36)</td>
<td>Score/9 =</td>
<td></td>
</tr>
</tbody>
</table>

*3.5–4: Excellent; 2.5–3.49: Good; 1.5–2.49: Fair; <1.5: Poor
Photos, Illustrations or Maps (attach more as needed):

Location and description: ___________________________________________________________

Location and description: ___________________________________________________________
Appendix 3

A Guidebook for Use of the Acequia Functionality Assessment

By
Marcos A. Roybal
University of New Mexico

April 2012
Acknowledgements

Development of the Acequia Functionality Assessment would have been impossible without the support of numerous people. In particular, the guidance and ideas of Bill Fleming, José Rivera, and Bruce Thomson were instrumental in bringing the assessment to fruition and improving it immeasurably. Also, feedback from numerous acequeros in the El Rito and Taos areas and the 2010 and 2011 New Mexico Acequia Association Congresos de las Acequias greatly increased the assessment’s comprehensiveness and utility. Special thanks in this regard is given to Juan Garcia and Lucas Trujillo in El Rito and Miguel Santistevan in Taos, who devoted substantial time and thought to the effort. Thanks is also given to Lauren Klose, who was instrumental in helping develop early versions of the assessment.

Additionally, acknowledgement is given to the generous support provided by New Mexico EPSCoR under NSF Grant #EPS-0814449 throughout the two academic years in which this project was developed.
# Table of Contents

Introduction.......................................................................................................................... 1
Description of Acequia Functionality Assessment Structure and Use................................. 1
Analysis and Application of Results..................................................................................... 3
Description of Assessment Components.............................................................................. 4
   Page 1............................................................................................................................... 4
   Page 4............................................................................................................................... 4
Description of the Physical Characteristics Category...................................................... 4
   Amount of flow during irrigation season........................................................................ 5
   Duration of useable flow in recent years....................................................................... 5
   Bank Stability................................................................................................................ 6
   Access to acequia easement........................................................................................... 6
   Infrastructure condition and improvements needed....................................................... 7
   Water quality.................................................................................................................. 7
   Extent of irrigation......................................................................................................... 8
Description of the Ecology Category............................................................................... 8
   Vegetation structural diversity...................................................................................... 9
   Vegetation species diversity......................................................................................... 9
   Presence of noxious weeds......................................................................................... 10
   Acequia bed material................................................................................................... 10
   Wildlife use................................................................................................................. 11
   Other ecosystem services............................................................................................. 11
Description of “Acequia Governance and Community Use” Category......................... 11
   Meetings of the local acequia association................................................................. 11
   Acequia bylaws and water transfers.......................................................................... 12
   Water banking................................................................................................................ 12
   Use of acequia water.................................................................................................... 13
   Acequia cleaning.......................................................................................................... 13
   Interest in acequia-supported agriculture within the local community..................... 14
   Economic viability of farming and ranching............................................................... 14
Land use trends in the local community.................................15
Acequia finances...........................................................................15
References.........................................................................................17
Acequia Functionality Assessment Datasheets..............................................18
Introduction

The Acequia Functionality Assessment (AFA) is the product of a professional project completed by Marcos Roybal in partial fulfillment of degrees in Master of Water Resources and Master of Community and Regional Planning at the University of New Mexico. It was developed via discussions with acequia users, collaboration with researchers at UNM, feedback at conferences and meetings, field testing, and the author’s personal familiarity with the operation of acequias. The AFA is intended to serve as a tool for acequia users, researchers and funding agencies to track changes in conditions of an acequia over time, identify needs, monitor project effectiveness, engage youth, and plan future activities. Developing a clear picture of current conditions with respect to an acequia is vitally important in the face of increasing demands for scarce water resources by multiple entities, land use shifting away from agriculture, and a changing climate.

This guidebook leads the reader through the use of the Acequia Functionality Assessment. It first describes the structure of the Assessment, and then outlines the process for performing the Assessment and analyzing the results. Finally, it discusses each of the Assessment Criteria in detail and provides a justification for their inclusion. A full version of the AFA can be found at the end of this document.

Description of Acequia Functionality Assessment Structure and Use

The AFA consists of a datasheet divided into three main sections (a full version of the assessment is located at the end of this document). Page 1 contains general information about the acequia, observers, and assessment being done, pages 2–3 present criteria related to evaluating the acequia’s physical characteristics, ecology, and governance and community use, and page 4 provides space for attachment of photographs, sketches, or maps of the assessment area or other relevant features. To perform the assessment, a portion of the acequia should be chosen that is of greatest interest. This may, for example, be the entire length of an acequia, a section of the ditch that is known to be susceptible to problems or needs special attention, or the portion of the ditch passing through a private landowner’s property. The person conducting the assessment (the observer) should then fill out the material on page 1 at the beginning of the assessment, and proceed to assign ratings to the 22 criteria presented on pages 2–3. Some of these criteria pertain to the entire length of the ditch or the community through which it flows, while some can be limited to a smaller portion. If the observer is sufficiently familiar with the acequia he or she should be able to quickly assign ratings to all of the criteria, but if the observer is less familiar with the physical conditions of the acequia, the community in which it is located, and the governance of the acequia’s operations, consultation with somebody who has greater familiarity with the system may be necessary.
In assigning ratings to the 22 criteria in the assessment, 4 points are given for each criterion that is generally in excellent condition with regard to the specific category in which it resides (physical characteristics, ecology, or governance and community use), 3 points for good condition, 2 points for fair condition, and 1 point for poor condition. After assigning a score to each criterion, the scores for the criteria in each category are totaled and entered in the Functionality Ratings table at the bottom of page 3. Each of these totals is then divided by the number of criteria in each category (7 for physical characteristics, 6 for ecology, and 9 for governance and community use) to yield an average functionality rating for each category. Table 1 lists the overall functionality ratings that can be applied to each category.

Table 1. Average functionality ratings for acequia physical characteristics, ecology, and governance/community use

<table>
<thead>
<tr>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5–4</td>
<td>Excellent</td>
</tr>
<tr>
<td>2.5–3.49</td>
<td>Good</td>
</tr>
<tr>
<td>1.5–2.49</td>
<td>Fair</td>
</tr>
<tr>
<td>&lt;1.5</td>
<td>Poor</td>
</tr>
</tbody>
</table>

The criteria in the AFA are divided into three categories and evaluated separately because rating acequia “functionality” on a poor–excellent scale is subjective and dependent on the goals and perspectives of the individual(s) conducting the assessment. For example, if the efficiency of water delivery is the main goal, a rating of “good” or “excellent” in the physical characteristics and potentially governance/community use categories would be desired, whereas high ratings in the ecology category may adversely impact the efficiency of water delivery via seepage losses through unlined ditches and evapotranspiration by vegetation on the acequia banks. However, from the standpoint of evaluating the overall functionality of the acequia system, which would account for ecological as well as physical and social considerations, the functionality of all three categories would be of interest.

Finally, this assessment is designed to guide evaluation of acequia conditions and planning future activities related to the acequia. Its criteria are intended to be broadly applicable to acequias throughout New Mexico and southern Colorado. However, it is important to recognize the uniqueness of each acequia system that has developed through differences in local custom, needs, and landscape. As a result, the AFA should be viewed as a living tool that can be modified to fit the goals and purposes of individual acequia users, associations, and groups of acequias. As such, the criteria can be changed, supplemented or omitted as necessary. It must be noted, however, that changing the assessment criteria or omitting certain criteria will impair the ability to directly compare assessment results over time or between acequias. In the case of use of the AFA by funding agencies to identify trends in New Mexico’s acequias or potential
areas of assistance, the AFA should not be modified. This will ensure consistency of its application across acequias.

Analysis and Application of Results

The Acequia Functionality Assessment is intended to serve multiple purposes. It can be used as a planning tool for acequia associations or individual parciantes to monitor changes over time; determine needs with respect to maintenance, infrastructure improvements, community development, education, and changes in governance; and justify requests for funding assistance. Further, it can be used by researchers as a means of evaluating physical, ecological and social conditions related to an acequia of interest or by funding agencies to monitor the condition of acequias and highlight areas in need of assistance. Perhaps most importantly, it can serve as an educational tool to raise awareness of key elements of acequia function and engage local youth. The assessment is designed to be relatively easy to perform, so it can easily be used as a tool to include youth in acequia planning and monitoring.

After performing the assessment, depending on the purpose of the assessment, the results can be examined to determine aspects of the acequia or surrounding community requiring attention (for example, needed infrastructure improvements or low interest in the community with respect to acequia agriculture); the effectiveness of a recent project (such as infrastructure repair); or, in the case of repeated monitoring, trends developing over time. These findings can help inform individual landowners’ management activities, or facilitate project planning at the level of the acequia association. Such projects could include infrastructure improvements, watershed management (such as forest thinning), invasive species removal, community education, bylaws revision, economic development activities, engagement of youth, applications for funding assistance, and further monitoring.

On the whole, the AFA can highlight “tipping points” (J. Rivera, personal communication, 23 February 2012) with respect to the status of elements of the acequia system that may result in transitions to less desirable states, such as reduced local control of resources and a community with little interest in agriculture as an occupation. For example, repeated monitoring over time may indicate waning interest in acequia agriculture in the local community, which would highlight the need for education or development of economic incentives.

The remainder of this guidebook describes the elements of the AFA.
Description of Assessment Components

This section provides an overview of the components of the Acequia Functionality Assessment. It begins with descriptions of the first and last pages, and then presents the 22 criteria that comprise the body of the assessment, grouped by category (physical characteristics, ecology, and governance/community use).

Page 1
The first page of the AFA asks for general information regarding the assessment and the acequia. The individual(s) conducting the assessment should write their names on the “observer(s)” line and record the date, time and location (GPS coordinates if available, otherwise a verbal description) of the assessment. This information is crucial to ensuring repeatability and consistency of data collection in the future, as the time of year, location, and observer can affect the ratings assigned to the criteria. The observers should then record general information about the acequia—its name, the community through which it flows, the stream or river from which it is diverted, its estimated length, the approximate number of parciantes using its water, the length of the growing season, and the current mayor domo. Finally, the observers should record any additional information relevant to the assessment—for example, their goals in conducting the assessment (e.g. identifying needs, monitoring changes over time, prioritizing certain elements of functionality, etc.) and notable changes in the community recently (e.g. increased residential development on agricultural land, sale of water rights, changes in forest or range management in the surrounding uplands, changes in local or state acequia policy, etc.). This information will facilitate analysis and application of the results of the assessment, as such changes have the potential to impact the acequia function.

Page 4
Page 4 of the AFA provides space for the attachment of photographs of the assessment area or other features of interest, as well as maps and illustrations that may be relevant to the assessment. Additional graphics can be attached as necessary. Photos, maps and illustrations can be used to visually document changes over time or highlight areas in need of specific attention. In the case of photos intended to illustrate changes over time, it is best to establish a permanent photo point that can easily be revisited in the future. This facilitates duplication of the photos so direct comparisons can be made. A fence post, tree, or unique, permanent feature of the ditch can be used to designate a photo point, or a marker such as a stake can be installed to establish a photo point.

Description of the Physical Characteristics Category
The Physical Characteristics category of the AFA is oriented toward evaluating the physical functionality of the acequia system. This category evaluates seven criteria: (1) the amount of flow in the acequia during the irrigation season; (2) the duration of useable flow in the acequia in
recent years; (3) erosion of acequia banks and channel; (4) the acequia easement; (5) the condition of acequia infrastructure and improvements needed; (6) water quality; and (7) the extent of irrigation in the overall valley. These criteria and possible interpretations of their conditions as observed during the assessment are described below.

Amount of flow during irrigation season
This criterion addresses the extent to which the amount of water flow in the acequia in recent years has been adequate for meeting irrigation needs. Four points are assigned if the flow meets all irrigation needs; three if the flow meets most irrigation needs; two if the flow meets less than half of the irrigation needs, and one if, in recent years, the acequia has contained little or no water. Water availability is obviously crucial to acequia function, and without it irrigation of agriculture is either impossible or must be supported by other means, such as groundwater withdrawals for center pivot sprinklers. As an acequia’s ability to irrigate gardens, orchards and fields declines, its ability to support the community from a market standpoint is decreased. Lower water availability can also discourage people from farming, which reduces the overall integrity of the acequia system. Reductions in flow can stem from factors including drought, a changing climate, changes in watershed conditions, increasing groundwater pumping, and transfers of water rights outside of the acequia system. A timeframe of “in recent years” is specified for this criterion so as to allow for variations in precipitation from year to year, but, as monitoring is repeated in subsequent years, comparisons can be made to earlier surveys in order to detect changes in water availability.

Duration of useable flow in recent years
This criterion addresses the duration of useable flow in the acequia in recent years in relation to the growing season. Four points are assigned if useable flow is present for the entire growing season or more, three if useable flow is present for the majority of the growing season, two if useable flow is present for approximately half of the growing season, and one if useable flow is present for less than half of the growing season. With this criterion, it is important to note that some acequia systems have never provided flow through the entire growing season. If this is the case it should be noted on the assessment. This criterion is particularly useful for monitoring alterations in flow availability over time that may stem from changes in the use of land and water in and around the local community and, potentially, a changing climate. As with the criterion examining the amount of flow, a timeframe of “in recent years” is specified for this criterion so as to allow for variations in precipitation from year to year, but, as monitoring is repeated in subsequent years, comparisons can be made to earlier surveys in order to detect changes in water availability.
Bank stability

This criterion addresses whether or not erosion of the acequia banks or channel is evident. Four points are given if no erosion is evident, three if erosion is evident in only a few places, two if erosion is evident in a few places but appears to be increasing, and one if substantial erosion is present and/or the amount of erosion is increasing rapidly. Erosion is an important factor in evaluating acequia functionality because it directly affects an acequia’s ability to deliver water. Severe erosion can result in bank failure, failure of the acequia to deliver water, loss of water, and damage to nearby structures and property. Additionally, associated sedimentation can impair the function of diversion structures and headgates. Repairing these problems can be costly and time consuming. Increased erosion can be a product of a lack of maintenance, a sudden increase in flow through the acequia, or changes in land use such as the establishment of a road near an acequia. Roads can concentrate stormwater if improperly engineered and cause substantial erosion (Zeedyk 2006).

Access to acequia easement

This criterion addresses the accessibility of the easement along the acequia. Four points are given if access to the easement is adequate for maintenance along the entire ditch, three if access to the easement is adequate for maintenance along most of the ditch, two if the easement is accessible along less than half of the ditch, and one if the easement is generally not accessible. According to New Mexico state statutes, an acequia has a legal easement as long as it has been used at least five continuous years since its establishment. This easement “shall be adequate to allow for reasonable maintenance, use and improvements to the ditch” (NMSA 1978 §73-2-5; New Mexico Acequia Association 2010b). Access to this easement is crucial for routine and emergency maintenance and for the mayordomo to perform his or her duties. Willful obstruction of an acequia easement is legally punishable, so it is well within an acequia association’s purview to ensure accessibility to the ditch’s easement. Easement access problems can stem, for example, from lack of recognition by landowners that an easement exists, a landowner’s refusal
to allow access, or construction of buildings, fences or other structures that prevent access. An acequia should establish a clear definition of its easement and access needs, and educating community members about the easement is key to ensuring access.

**Infrastructure condition and improvements needed**

This criterion addresses the state of repair of acequia infrastructure such as the diversion dam (*presa* or *atarque*), headgates, laterals, and the ditch itself. Four points are given if little or no improvements to the infrastructure are needed, three if less than 25% of the infrastructure needs improvement, two if approximately 50% of the infrastructure needs improvement, and one if more than 50% of the infrastructure needs improvement. Good repair of ditch infrastructure is crucial to proper function and efficient water delivery. Poor repair can be a product of neglect or insufficient funds on the part of the acequia association or individual *parciantes*. Documenting infrastructure needs can provide justification for funding assistance, which can be used for a variety of purposes, including headgate repair (Figure 2).

![Figure 2. Acequia headgate before (left) and after (right) repair supported by an acequia cost share program (photo: Marcos Roybal)](image)

**Water quality**

This criterion addresses the quality of water present in the acequia with respect to visual appearance and trash. Four points are given if the water appears clean and contains no trash, three if the water appears clean but some trash is present, two if considerable trash is present, and one if the water appears dirty and contains substantial amounts of trash. Trash was chosen as a primary metric of water quality because of its ease of identification; other constituents such as nutrients require special instrumentation and analysis to identify. Additionally, trash can physically obstruct water flow, particularly at culverts. Assessment of the visual appearance of water can also indicate problems; for example, high sediment loadings, which is indicated by unusually turbid water, can impair the function of diversions and headgates. Problems with water quality can originate from neglect or poor maintenance, but a sudden change in water quality can indicate disturbance or land use changes somewhere in the upstream watershed.
Extent of irrigation
This criterion addresses the extent of irrigation occurring in the agricultural area supported by the acequia. Four points are given if more than 75% of fields in the area are irrigated, three if 50–75% are irrigated, two if 25–50% are irrigated, and one if less than 25% are irrigated. The irrigated portion of a valley comprises a large part of the paisaje del agua (Figure 3), the area affected and shaped by acequia irrigation. The full use of the water to which the acequia system is entitled is not only critical to the protection of water rights under the system of prior appropriation but also to protecting the agricultural land base. Long periods of non-irrigation can result in reversion of fields to patches of willow or sagebrush that require substantial modification to support agriculture. Non-use of water rights can result in their loss under the prior appropriation system. A decrease in the irrigated acreage in a valley can be indicative of conversion of agricultural land to residential development, or of people shifting away from agricultural ways of life.

Figure 3. An example of the paisaje del agua (photo: Marcos Roybal)

Description of the “Ecology” Category
The ecological benefits of acequias, such as recharging shallow aquifers, supporting riparian vegetation, and providing habitat for wildlife, have long been understood by acequia users (Rivera 1998). Recently, this ancient wisdom has been supported in the scientific literature (e.g. Hicks an Peña 2003, Fernald et al. 2007, Rivera 2012). The ecology category of the AFA is designed to assess the degree to which an acequia provides or supports various ecosystem services. This category evaluates six criteria: (1) vegetation structural diversity along the ditch bank, (2) vegetation species diversity along the ditch bank, (3) the presence of noxious weeds and/or undesirable invasive species, (4) the acequia bed material, (5) wildlife use of the acequia, and (6) other ecosystem services the observer feels the acequia provides. These criteria and possible interpretations of their conditions as observed during the assessment are described below.
Vegetation structural diversity

This criterion addresses the vegetation structural diversity along the ditch bank. Vegetation can be seen as existing in four structural classes: trees, shrubs, grasses, and forbs (Figure 4; forbs include non-woody flowering plants that are not grasses). Four points are given if all four vegetation classes are present, three if three vegetation classes are present, two if one to two vegetation classes are present, and one if little or no vegetation is present. The structural diversity of vegetation reflects the complexity of the ecosystem an acequia supports, with greater diversity creating better wildlife habitat and contributing to overall ecosystem resilience. Furthermore, diverse vegetation cover contributes to the stability of an acequia’s banks, thereby preventing erosion. Finally, vegetation along the ditch serves aesthetic functions, increasing the visual attractiveness of an area. Low vegetation cover can be a product of intentional removal, soil quality issues, or low seepage from the ditch.

![Figure 4. Four vegetation structural classes: tree, shrub, grasses, and forbs](image)

Vegetation species diversity

This criterion addresses the number of different plant species along the ditch bank. Four points are given if many species are present, three if the vegetation along the ditch is dominated by a few species, two if the vegetation along the ditch is dominated by one or two species, and one if little or no vegetation is present. A diversity of plant species is generally indicative of a healthy ecosystem and provides a variety of habitat options for wildlife. Additionally, as with the vegetation structural diversity criterion, a rich variety of vegetation contributes to bank stability and visual attractiveness. This criterion does not require identification of individual plant species as this necessitates a relatively technical knowledge of botany. However, those with an interest in specific plant species could append lists of species observed to the assessment; this information could then be used to track changes in specific plant species over time that may result from changing moisture regimes, climate, or land use.
Presence of noxious weeds

This criterion addresses the presence of noxious weeds along the ditch. Four points are given if noxious weeds are not present, three if very few noxious weeds are present, two if numerous noxious weeds are present but do not appear to be spreading, and one if numerous noxious weeds are present and appear to be spreading. This criterion requires some ability to identify noxious plant species; local extension agents can provide substantial information about common species and identifying characteristics. Some common species in northern New Mexico include hoary cress (*Cardaria draba*), field bindweed (*Convolvulus arvensis*), yellow toadflax (*Linaria vulgaris*), and Siberian elm (*Ulmus pumila*). Noxious plant species are a particular problem along acequias because they can easily be spread by running water or disturbance associated with routine cleaning and maintenance. Increases in noxious weeds can be indicative of disturbance. Early identification and treatment of noxious weeds can prevent their spread, but extension agents should be consulted to determine appropriate treatment measures, as some chemical options are not appropriate for use near water.

Acequia bed material

This criterion addresses the composition of the acequia bed. Four points are given if the acequia bed is mostly earthen and natural, three if less than half of the length of the ditch either as a whole or in the assessment area is piped or lined with concrete or other impervious material, two if more than half of the ditch either as a whole or in the assessment area is piped or lined, and one if the entire ditch is piped or lined. Studies such as that by Fernald *et al.* (2007) have shown that seepage from the ditch plays a valuable role in recharging shallow aquifers and supporting vegetation and wildlife. Piping or lining a ditch will largely eliminate these benefits. However, piping or lining the ditch in areas such as road crossings or where ditch seepage may be problematic for buildings or other structures is often necessary, so the rating of four points allows for lining or piping as necessary in situations such as these.
**Wildlife use**

This criterion addresses the use of the acequia and surrounding area by wildlife (including mammals, birds, reptiles, amphibians and insects). Evaluation of this criterion can include wildlife observed at the time of the assessment, or a culmination of wildlife observations over a period of time. Four points are given if many wildlife species are present and are seen frequently, three if many species are present but are seen infrequently, two if few species are present but they are seen frequently, and one if few species are present and they are rarely seen. Wildlife use of the acequia is an indicator of a functioning ecosystem, and monitoring changes in wildlife use over time can highlight the effects of land use or climatic change in the area. As with plants, a diversity of wildlife will contribute to ecosystem resilience and potentially impart aesthetic or scientific benefits as well.

**Other ecosystem services**

This criterion addresses other, specific ecosystem services that the acequia is known to provide. These include, but are not limited to, increasing riparian areas, recharging shallow aquifers, improving water quality, improving air quality, providing for carbon sequestration, facilitating nutrient cycling, supporting pollinators, etc. Four points are given if the acequia is known to provide three or more ecosystem services, three if it is known to provide two ecosystem services, two if it is known to provide one ecosystem service, and one if it provides no known ecosystem services. This criterion is largely aimed at capturing the observer’s perceptions of ecosystem services the acequia provides. This is important in identifying known services (for example, the acequias in El Rito, NM are known to play an important role in recharging the shallow aquifers from which many domestic wells draw their water) and potentially highlighting areas in which an acequia’s ability to provide ecosystem services could be improved.

**Description of “Acequia Governance and Community Use” Category**

One of the most unique elements of acequias is their community-based governance structure. However, without continued community engagement and investment, acequias may cease to function. The governance and community use category of the AFA is aimed at evaluating nine social and economic elements that affect acequia operations: (1) meetings of the local acequia association, (2) protections provided by acequia bylaws, (3) the use of water banking to protect unused water rights, (4) the type of uses to which acequia water is put, (5) who cleans the acequia, (6) interest in acequia agriculture within the local community, (7) the economic viability of farming and ranching in the local community, (8) land use trends in the local community, and (9) acequia finances. These criteria and possible interpretations of their conditions as observed during the assessment are described below.

**Meetings of the local acequia association**

This criterion addresses the frequency of and attendance at acequia association meetings. Four points are given if the meetings are regular and well-attended, three if the meetings are irregular
but well attended, two if the meetings are regular but poorly attended, and one if the meetings are irregular and poorly attended. New Mexico state statutes require meetings of the acequia membership to elect acequia officials every other year (NMSA 1978 §73-2-12, §73-2-15, and §73-3-1). However, many acequias meet annually. In addition to statute compliance, these meetings are crucial to discussing problems and needs, planning activities, collecting dues, and ensuring the continued function of the association. Poor attendance at meetings may be indicative of low interest in acequia operations or a shrinking membership, both of which have the potential to negatively impact acequia function.

_Acequia bylaws and water transfers_

This criterion addresses whether or not the acequia’s bylaws require proposed water rights transfers to be approved by the local acequia commission. Four points are given if the bylaws include this provision, three if the bylaws do not include this provision but are in the process of being updated to do so, two if the bylaws do not include this provision but are otherwise complete, and one if the bylaws do not include this provision and there are no plans to update them. New Mexico statutes provide that proposed changes in the point of diversion or place or purpose of use of a water right related to an acequia are subject to the approval of the acequia’s commissioners, and that such a change may be denied if it is found that it would be “detrimental to the acequia… or its members” (NMSA 1978 §73-2-21E and §73-3-4.1). However, an acequia’s bylaws or governing rules must specify this authority in order for the acequia to take advantage of it. Transfers of water rights away from an acequia can negatively impact the acequia in at least two ways. First, they reduce the amount of water that flows through the system, which may compromise its ability to deliver water to irrigators located on the downstream end of the ditch. Second, since acequia membership is typically contingent on owning water rights, transfers of water rights out of the system have the potential to reduce acequia membership and thus reduce contributions of money and labor toward its operation and maintenance. In order to prevent the potentially detrimental effects of water rights transfers, individual acequias must ensure their bylaws include a water rights transfer approval provision.

_Water banking_

This criterion addresses whether or not a procedure for water banking is included in an acequia’s bylaws and if water banking is practiced to protect water rights from loss due to nonuse. Four points are given if water banking is always practiced with unused water rights or if there are no unused water rights in the system, three if water banking is occasionally practiced with unused water rights, two if water banking is not practiced but is included in the bylaws, and one if water banking is never practiced and is not included in the bylaws. New Mexico statutes allow for establishment of a water bank by an acequia to protect water rights from loss due to non-use (NMSA 1978 §73-2-55.1). Establishment of a water bank and placement of water rights in the bank under this provision does not require proceedings before the State Engineer or approval by the Interstate Stream Commission or State Engineer. Although acequias are not required to
include a water banking provision in their bylaws to take advantage of this allowance, outlining a clear water banking procedure in the bylaws will facilitate use of the water bank and alleviate confusion over how to do so. It is crucial that acequias bank unused water rights, as unused rights are subject to loss under the system of prior appropriation.

**Use of acequia water**

This criterion addresses the uses to which acequia water is put. Four points are given if the acequia is used to irrigate food crops (which include home gardens and orchards), hay fields and pasture; three if the acequia is used to irrigate just hay fields and pasture; two if the acequia is used to irrigate just pasture; and one if the acequia water is turned on to untended or unused lands to preserve water rights. Putting acequia water to a diversity of uses (Figure 6) not only increases its utility to the community as a whole, but also increases its potential to build economic viability. Although irrigating pasture and hay fields is important, food crops have the potential to feed people directly. Maintaining a diversity of agricultural land uses in the community is important for building economic vitality and increasing resilience.

![Figure 6. A diverse garden irrigated with acequia water (photo: Marcos Roybal)](image)

**Acequia cleaning**

This criterion addresses who cleans the acequia. Four points are given if the acequia is cleaned by mostly *parciantes*, three if it is cleaned by mostly labor hired by *parciantes*, two if it is cleaned by a crew appointed by the *mayordomo*, and one if the acequia is not regularly cleaned. The *limpia*, or annual acequia cleaning, has traditionally been completed by *parciantes* or labor hired by the *parciantes*. Annual cleaning is vital to ensuring efficient water flow, but also provides an opportunity for community members to work together and address issues that have arisen throughout the year. In many areas, recent times have seen a decrease in community participation in acequia cleaning, and often the *mayordomo* must hire a crew to complete the task due to lack of community participation. Although this is preferable to the acequia not being
cleaned at all, it represents the weakening of an element of the acequia institution with deep communal roots and may indicate waning community interest in the acequia.

**Interest in acequia-supported agriculture within the local community**
This criterion addresses the extent of interest in acequia-supported agriculture at the time of the assessment in the community through which the acequia runs. Four points are given if strong interest in agriculture is present across multiple generations, three if moderate interest in agriculture is present across multiple generations, two if strong interest in acequia agriculture is present but this interest lies mostly in older generations, and one if there is little or no interest in acequia agriculture remaining in the community. Many acequia users voice concern over a perceived lack of interest in acequia agriculture in younger residents, and indeed, many young people as well as their parents have forgone an agricultural way of life in search of education and more profitable and predictable pursuits. In order for acequia culture to persist, a new generation of residents must be poised to fill in as age prevents many of today’s farmers from continuing to irrigate and work the land. Youth should be encouraged to participate in using the assessment; this will not only educate them about what makes for a functional acequia, but will also give them a direct hand in the acequia’s operations.

**Economic viability of farming and ranching**
This criterion addresses the extent to which, at the time of the assessment, farming and ranching in the community through which the acequia flows are viable means of making a living. Four points are given if farming and ranching can yield livable incomes, three if farming and ranching often yield a portion of people’s income, two if farming and ranching yield little income but are practiced as hobbies, and one if farming and ranching are rarely practiced in the community. The ability to make a strong economic contribution to a community will increase an acequia’s likelihood of receiving ongoing community investment in operation and maintenance. Although today it is rare that farming and ranching yield livable incomes for many in northern New Mexico, they can certainly augment a household’s income and food supply. Even if they yield little income, these pursuits can be practiced in a way that provides numerous nonmarket benefits. Encouraging farming and ranching will facilitate acequia preservation, and may result in innovations in technique that increase the economic viability of these occupations.
Figure 7. Hay grown with acequia irrigation (photo: Marcos Roybal)

Land use trends in the local community
This criterion addresses land use trends at the time of the assessment in the community through which the acequia flows. Four points are given if land is generally remaining in agriculture, three if there have been minor shifts from agriculture to other uses such as residential development but existing agricultural land remains operational, two if the general trend in the community is a shift away from agricultural land uses but existing agricultural land remains operational, and one if land is rapidly shifting away from agricultural uses in a way that appears to compromise existing agricultural uses. In many parts of northern and central New Mexico, as well as around the United States, agricultural land is being converted to residential and other uses. This has several implications for acequias. First, it reduces the land base available for acequia agriculture. Second, it has the potential to transfer water from agricultural to other uses. Third, it sets the stage for potential conflict over acequia traditions (such as ditch access) that may be seen as infringements on privacy and property rights. Although it is possible that minor shifts away from agricultural land uses will have relatively negligible effects on the overall function of acequia systems, the more land that is changed to other uses the greater the chances that remaining agriculture will be impacted.

Acequia finances
This criterion addresses the ability of acequia finances to cover expenses that arise throughout the year. Four points are given if money collected from parciantes is adequate to cover all of the acequia’s operational costs, three if money collected from parciantes is adequate to cover most of the acequia’s operational costs, two if the money collected is often insufficient, and one if parciantes do not contribute funds to the acequia. Parciantes are generally required to pay annual dues for acequia membership, and may also be required to provide money in lieu of labor or as payment of fines for violation of acequia rules. Ideally this income will be adequate to cover expenses such as compensation of officers, hiring any labor that may be necessary, and routine and emergency maintenance of the ditch infrastructure. In the worst case scenario
parciantes do not contribute money to the acequia. This may be a result of low community investment or interest in its operation or ineffective governance and enforcement mechanisms. Although supplemental funding can be acquired from numerous outside sources such as acequia cost share programs with local soil and water conservation districts and federal grants such as the Natural Resource Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP), financial self-sufficiency will increase an acequia’s ability to respond to problems that may arise unexpectedly (ranging from emergency ditch repair to legal defense) and build overall system resilience.
References


Acequia Functionality Assessment

This assessment is designed to be a tool for acequia users to evaluate the general functionality of physical characteristics, ecology and governance and community use on their acequia, and to track changes over time. To calculate the “functionality” score for each of these categories, add up the criteria ratings after conducting the assessment. Higher values indicate greater functionality in these areas. More information about the criteria and use of this assessment can be found in the Acequia Functionality Assessment Guidebook.

Assessment Information

Observer(s): __________________________

Date: __________________________ Time: __________________________

Location of assessment (GPS or description): __________________________

Acequia Information

Acequia name: __________________________

Acequia location (community): __________________________

Stream or river: __________________________

Estimated length: __________________________ Number of parciantes: __________

Growing season (weeks): __________________________

Current mayordomo: __________________________

Notes (For example, what are your goals in conducting this assessment? Have there been notable changes in your community or acequia recently?)

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
### Category 1 – Physical Characteristics

<table>
<thead>
<tr>
<th>Criterion</th>
<th>4 Points</th>
<th>3 Points</th>
<th>2 Points</th>
<th>1 Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of flow during irrigation season in recent years</td>
<td>Meets all irrigation needs</td>
<td>Meets most irrigation needs</td>
<td>Meets less than half of irrigation needs</td>
<td>Little or no water</td>
</tr>
<tr>
<td>Duration of useable flow in recent years</td>
<td>Entire growing season or more</td>
<td>Majority of growing season</td>
<td>Approximately half of growing season</td>
<td>Less than half of growing season</td>
</tr>
<tr>
<td>Bank stability</td>
<td>No erosion evident</td>
<td>Erosion evident in a few places</td>
<td>Erosion evident in a few places and seems to be increasing</td>
<td>Substantial erosion, and/or amount of erosion is increasing rapidly</td>
</tr>
<tr>
<td>Access to acequia easement</td>
<td>Adequate for maintenance along entire ditch</td>
<td>Adequate for maintenance along most of ditch</td>
<td>Accessible along less than half of ditch</td>
<td>Generally not accessible</td>
</tr>
<tr>
<td>Infrastructure condition and improvements needed</td>
<td>Little or no improvement needed</td>
<td>Less than 25% of infrastructure needs improvement</td>
<td>About 50% of infrastructure needs improvement</td>
<td>More than 50% of infrastructure needs improvement</td>
</tr>
<tr>
<td>Water quality</td>
<td>Water appears clean with no trash</td>
<td>Water appears clean; some trash</td>
<td>Considerable trash present</td>
<td>Water appears dirty and has lots of trash</td>
</tr>
<tr>
<td>In general, what proportion of fields in your area is irrigated?</td>
<td>More than 75%</td>
<td>50-75%</td>
<td>25-50%</td>
<td>Less than 25%</td>
</tr>
</tbody>
</table>

### Category 2 – Ecology

<table>
<thead>
<tr>
<th>Criterion</th>
<th>4 Points</th>
<th>3 Points</th>
<th>2 Points</th>
<th>1 Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation structural diversity along ditch bank</td>
<td>All 4 vegetation classes are present</td>
<td>3 vegetation classes are present</td>
<td>1-2 vegetation classes are present</td>
<td>Little or no vegetation is present</td>
</tr>
<tr>
<td>Vegetation species diversity along ditch bank</td>
<td>Many species present</td>
<td>Dominated by a few species</td>
<td>Dominated by one or two species</td>
<td>Little or no vegetation present</td>
</tr>
<tr>
<td>Presence of noxious weeds along the ditch</td>
<td>Not present</td>
<td>Very few present</td>
<td>Numerous present, but not spreading</td>
<td>Numerous present; appear to be spreading</td>
</tr>
<tr>
<td>Acequia bed material</td>
<td>Mostly earthen and natural</td>
<td>Less than half lined or piped</td>
<td>More than half lined or piped</td>
<td>Entirely lined or piped</td>
</tr>
<tr>
<td>Wildlife use (mammals, birds, reptiles, amphibians, insects)</td>
<td>Many species; seen frequently</td>
<td>Many species; seen occasionally</td>
<td>Few species; seen frequently</td>
<td>Few species; rarely seen</td>
</tr>
<tr>
<td>What other ecosystem services does acequia provide?</td>
<td>3 or more ecosystem services are provided</td>
<td>2 ecosystem services are provided</td>
<td>1 ecosystem service is provided</td>
<td>No ecosystem services are provided</td>
</tr>
</tbody>
</table>
### Category 3 – Acequia Governance and Community Use

<table>
<thead>
<tr>
<th>Criterion</th>
<th>4 Points</th>
<th>3 Points</th>
<th>2 Points</th>
<th>1 Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meetings of local acequia association</td>
<td>Regular and well attended</td>
<td>Irregular but well attended</td>
<td>Regular but poorly attended</td>
<td>Irregular and poorly attended</td>
</tr>
<tr>
<td>Do bylaws require proposed water rights transfers be approved by commission?</td>
<td>Yes</td>
<td>No, but bylaws are being updated</td>
<td>No, but bylaws are otherwise complete</td>
<td>No, and there are no plans to update bylaws</td>
</tr>
<tr>
<td>Water banking to protect unused water rights (Is procedure for water banking included in bylaws? Yes ____ No____)</td>
<td>Water banking always practiced with un-used water rights (or there are no unused water rights)</td>
<td>Water banking occasionally practiced with unused water rights</td>
<td>Water banking not practiced but is included in bylaws</td>
<td>Water banking never practiced and is not included in bylaws</td>
</tr>
<tr>
<td>What does acequia water irrigate? (Food crops include home gardens and orchards)</td>
<td>Food crops, hay fields, pasture</td>
<td>Hay fields and pasture</td>
<td>Just pasture</td>
<td>Untended or unused lands</td>
</tr>
<tr>
<td>Who cleans the acequia?</td>
<td>Mostly parciantes</td>
<td>Mostly labor hired by parciantes</td>
<td>Crew appointed by mayordomo</td>
<td>Acequia not regularly cleaned</td>
</tr>
<tr>
<td>Interest in acequia agriculture within the local community</td>
<td>Strong interest across multiple generations</td>
<td>Moderate interest across multiple generations</td>
<td>Strong interest but mostly in older generations</td>
<td>Little or no interest remaining</td>
</tr>
<tr>
<td>Economic viability of farming and ranching in the local community</td>
<td>Farming and ranching yield livable incomes</td>
<td>Farming and ranching often yield a portion of income</td>
<td>Farming and ranching yield little income but are done as hobbies</td>
<td>Farming and ranching are rarely practiced in the community</td>
</tr>
<tr>
<td>Land use trends in the local community</td>
<td>Land is generally remaining in agriculture (ag)</td>
<td>Minor shifts from ag land to other uses, but existing ag lands remain operational</td>
<td>Land is generally shifting away from ag uses, but existing ag lands remain operational</td>
<td>Land is rapidly shifting away from ag uses; existing ag uses appear to be negatively affected</td>
</tr>
<tr>
<td>Acequia finances</td>
<td>Money collected covers all operation costs</td>
<td>Money collected covers most operation costs</td>
<td>Money collected is often insufficient</td>
<td>Parciantes do not contribute funds to acequia</td>
</tr>
</tbody>
</table>

### Functionality Ratings

<table>
<thead>
<tr>
<th>Category</th>
<th>Score</th>
<th>Average functionality rating*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Characteristics (out of 28)</td>
<td>Score/7 =</td>
<td></td>
</tr>
<tr>
<td>Ecology (out of 24)</td>
<td>Score/6 =</td>
<td></td>
</tr>
<tr>
<td>Acequia Governance and Community Use (out of 36)</td>
<td>Score/9 =</td>
<td></td>
</tr>
</tbody>
</table>

*3.5–4: Excellent; 2.5–3.49: Good; 1.5–2.49: Fair; <1.5: Poor
Photos, Illustrations or Maps (attach more as needed):

Location and description: __________________________________________________________

Location and description: __________________________________________________________