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Water Governance Challenges in New Mexico's Middle Rio Grande Valley: A Resilience Assessment

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WATER GOVERNANCE CHALLENGES IN NEW MEXICO'S MIDDLE RIO GRANDE VALLEY: A RESILIENCE ASSESSMENT

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I. INTRODUCTION.

Decades of detrimental water management practices and imminent shifts in climate regimes are creating unprecedented challenges to traditional forms of water governance in the American Southwest.[1] This Article centers on one watershed struggling to meet these challenges—New Mexico's Middle Rio Grande (MRG).[2] The MRG includes the urban environments of Albuquerque, Santa Fe, as well as surrounding small towns, and rural agricultural communities. The MRG is experiencing the pressures of urbanization, water supply constraints from international treaties and interstate compacts,[3] and a history of highly variable and unpredictable water availability.[4] Long-term climate change projections indicate that New Mexico will experience ongoing drought in the coming decades, with water shortfalls and extended dry intervals expected to become increasingly common.[5]

This Article provides an overview of the MRG as a complex and dynamic social-ecological system (SES) and what challenges may arise under expected hydrologic changes.[6] Employing concepts from resilience theory, it describes the challenges facing water governance in the MRG, placing particular emphasis on the current function and capacity of existing governance structures. After a basic overview of resilience as a paradigm for understanding the dynamics of an SES, it provides a brief overview of the current governance framework for the MRG.[7] It then provides a description of the key social and ecological system elements and their associated interactions.[8] Having identified the key social and ecological elements involved, we discuss possible key interactions among them, including "tipping points"—key thresholds that, if crossed, may threaten the long-term viability of the MRG.[9] We then look at the implications of these interactions and tipping points for natural resource managers and discuss whether the current governance structures

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1. *See generally* Glen M. MacDonald, *Water, Climate Change, and Sustainability in the Southwest*, 107 PROC. NAT'L ACAD. SCI. 21256–62 (2010) (introducing the National Academy of Science Climate Change and Water in Southwestern North America Special Feature).
2. While not exactly in "the middle" of the Rio Grande watershed (it could more accurately be described as occupying the upper reaches of the river), the MRG is the colloquial term for this section of the river in New Mexico.
3. *See infra* notes 35–44 and accompanying text.
4. *See infra* Part IV.B.3.
5. *See infra* Part IV.B.3.
6. *See infra* Part IV.
7. *See infra* Part III.
8. *See infra* Part IV.
9. *See infra* Part IV.C.

are equipped for the challenges ahead.[10] This includes a discussion regarding the potential for and current investment in the use of adaptive management in the MRG.

We conclude with recommendations for water governance in the MRG moving forward. First, more legal and institutional flexibility is needed to build adaptive capacity into the operation of the many dams and reservoirs involved in MRG water supply and allocation.[11] Many of these water operations are authorized for either water storage or flood control, but seldom both. Decisions about how to operate these systems will need to be made on an annual and sometimes month-to-month basis. Second, water allocation strategies must be re-examined.[12] Currently, water allocation is determined by the prior appropriation doctrine based on historical use. This practice hampers water conservation incentive efforts and is too slow to adapt to the projected persistent droughts and ecological needs. In practice, prior appropriation has only limited application in the MRG, and new innovative approaches are ripe for consideration. Third, more aggressive forest management will be needed, both in the MRG's cottonwood riparian system and its upland forest systems.[13] Current practices are not responding quickly enough to the compounding ecological stressors of drought, bark beetle infestation and wild fire, and the corresponding impacts and water quality and supply.[14] Fourth, managers need to embrace a new flood management paradigm, one that better accommodates the flood regimes we can anticipate in the future, including the need to address shifting hydrologic conditions and floodplain needs, with more emphasis on localized flooding risk.[15] Finally, managers must face that, in some situations, ecological regime shifts are occurring, and more adaptive capacity is needed to facilitate transformation when necessary.[16] While the challenges in the MRG watershed are great, this watershed provides an excellent laboratory in which to explore emerging environmental management approaches, which are based on a heightened understanding of the complex relationships among the components of this SES.

II. RESILIENCE: UNDERSTANDING THE DYNAMICS OF SOCIAL-ECOLOGICAL SYSTEMS.

In using the term "resilience" we invoke C.S. "Buzz" Holling's school of ecological resilience, which is increasingly being used to examine both social and ecological system dynamics.[17] Although there are a number of ways within this school

10. *See infra* Part V.
11. *See infra* Part V.A.
12. *See infra* Part V.B.
13. *See infra* Part V.C.
14. *See infra* Part V.C.
15. *See infra* Part V.D.
16. *See infra* Part V.E.
17. *See* Debra L. Davidson, *The Applicability of the Concept of Resilience to Social Systems: Some Sources of Optimism and Nagging Doubts*, 23 SOC'Y & NAT. RESOURCES: AN INT'L J. 1135, 1137–38 (2010). For an examination of the various schools of resilience, including the differences between ecological and engineered resilience and their associated implications *see generally* J.B. Ruhl, *General Design Principles for Resilience and Adaptive Capacity in Legal Systems – With Applications to Climate Change Adaptation*, 89 N.C. L. REV. 1373, 1375–77 (2011).

of defining resilience,[18] this Article invokes the term as used in *Resilience Practice*, in which Brian Walker and David Salt define resilience as "the capacity of a system to absorb a spectrum of disturbance and reorganize so as to retain essentially the same function, structure, and feedbacks—to have the same identity;" it employs the analytic tools provided by the Resilience Alliance in its *Workbook for Assessing Resilience in Social-Ecological Systems: a Workbook for Scientists*.[19] Viewing the MRG as a dynamic SES, the focus is on the amount of *change* the system can undergo while keeping its identity, including the system's adaptive capacity. From a management perspective, promoting resilience involves (1) evaluation of the current trajectory of the system state, and (2) fostering the ability of the system to resist perturbations. The abilities to influence both of these factors are determined by a combination of attributes of both the social and the ecological aspects of the system.[20] Systems with high adaptive capacity are able to re-configure themselves without significant changes to crucial functions, such as primary productivity, hydrological cycles, social relations, and economic prosperity.[21]

Resilience theory also acknowledges the possibility of "surprise,"[22] the unpredictable qualities of SES.[23] A critical component of a resilience orientation is the recognition that regime shifts can occur As a result, a resilience-based approach to management is more realistic than traditional approaches because it acknowledges nonlinear change and provides a way of thinking about how to foster the SES components and dynamics we value and want to protect. The emphasis of resilience-based management is on building adaptive capacity rather than maintaining stationarity.

Where regime shifts occur, transformation results, and the system reconceptualizes itself and creates a fundamentally new system with different characteristics.[24] Intentional transformation involves a conscious and deliberate negotiation from one system state to another. A system's transformative capacity is defined by (1) the degree to which managers of the SES are prepared for a change (as opposed to managers being in a state of denial); (2) the identified options for change (the possible new "trajectories" for the system); and (3) the capacity to change (the ability to make choices from among the possible new trajectories).[25] As will be discussed, the concept of transformation is particularly helpful in cases like the MRG that are

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18. *See generally* Steve Carpenter et al., *From Metaphor to Measurement: Resilience of What to What?* 4 ECOSYSTEMS 765, 765–81 (2001) (providing an extensive summary of definitions of resilience in the literature); RESILIENCE ALLIANCE, *Assessing Resilience in Social-Ecological Systems: Workbook for Practitioners*, http://www.resalliance.org/workbook/ (last visited Jan. 9, 2015).

19. *See* BRIAN WALKER & DAVID SALT, RESILIENCE PRACTICE: BUILDING CAPACITY TO ABSORB DISTURBANCE AND MAINTAIN FUNCTION 3 (2012); *see* RESILIENCE ALLIANCE, *supra* note 18. This definition comes from the Holling School of ecological resilience; *see generally* C.S. Holling, *Resilience and Stability of Ecological Systems*, 4 ANN. REV. ECOLOGY & SYSTEMATICS 1–23 (1973).

20. *See* WALKER & SALT *supra* note 19, at 20.

21. *See id*. at 50, 198–99.

22. Carl Folke, *Resilience: The Emergence of a Perspective for Social–Ecological Systems Analyses*, 16 GLOBAL ENVTL. CHANGE 253, 253–67 (2006); C.S. Holling, *The Resilience of Terrestrial Ecosystems: Local Surprise and Global Change*, *in* SUSTAINABLE DEVELOPMENT OF THE BIOSPHERE 292–317 (William C. Clark & R.E. Munn eds., 1986).

23. *See* Craig R. Allen & C.S. Holling, *Novelty, Adaptive Capacity, and Resilience*, 15(3) ECOLOGY & SOC'Y 24 (2010), *available at* http://www.ecologyandsociety.org/vol15/iss3/art24/.

24. *See* WALKER & SALT, *supra* note 19, at 100.

25. WALKER & SALT, *supra* note 19, at 101.

approaching potential ecological thresholds, providing managers with a framework for approaching impending change.

Adaptive capacity and transformative capacity are related attributes within a SES. These capacities are crucial both when the management orientation is to maintain the current system state *and* when SES dynamics are such that transformation should or will occur. Transformative capacity highlights an important element of resilience theory that is often overlooked in policy discussions. That is, a "resilient" system state is not inherently "good" or "bad."[26] There are many examples of relatively stable and resilient SESs that are not desirable. Any notion of "building resilience" must therefore be followed by the questions—resilience *of* what and *to* what?[27] In other words, it is necessary to first identify overarching systems states we want to keep (referred to as general resilience) and/or elements of the system we want to keep (specified resilience), as well as those that we would prefer to lose. Once the desired outcomes are recognized, managers can perform an assessment of the perturbing factors and disturbances and assess whether they constitute potential or existing threats, as well as their capacity to control those threats.[28] This Article takes the narrower approach, looking at the specified resilience of the MRG's existing water supply and allocation strategies. Resilience theory provides a number of analytical tools for understanding the complexities and dynamics within a SES.

III. CURRENT GOVERNANCE STRUCTURE AND KEY ACTORS.

A. Historical Background.

Understanding the current water supply and allocation strategies in the MRG requires a basic overview of the current governance structure and key actors. It is multi-faceted and involves formal legal mandates and institutions, as well as stakeholder-based and collaborative institutions. The headwaters of the Rio Grande are located in Colorado and northern New Mexico. The river then bisects New Mexico from north to south before exiting the state to form the border between Mexico and Texas. This Article focuses on the 250 km reach in central New Mexico extending from Cochiti Dam to Elephant Butte Reservoir. Figure 1 shows the area with its major watershed features, including the inter-basin transfer from the San Juan River to the Chama River, which is operated in accordance with the Colorado River Compact.

Human occupation of the MRG has a rich and complex history. Several Native American Pueblo communities live in the MRG and have their own, extensive history of water use.[29] In the mid 1500's, the Spanish Conquistadors brought the

26. *See* Sandra Zellmer & Lance Gunderson, *Why Resilience May Not Always Be a Good Thing: Lessons in Ecosystem Restoration From Glen Canyon and the Everglades*, 87 NEB. L. REV. 893, 895 (2009).

27. Carpenter et al., *supra* note 18, at 765 (identifying various definitions of resilience).

28. *See* Stephen R. Carpenter & William A. Brock, *Adaptive Capacity and Traps*, 13(2) ECOLOGY & SOC'Y, 40 (2008), *available at* http://www.ecologyandsociety.org/vol13/iss2/art40/.

29. *See generally* FRED M. PHILLIPS ET AL., REINING IN THE RIO GRANDE: PEOPLE, LAND, AND WATER (2011). The first known human inhabitants of the Rio Grande Valley were likely climate refuges, fleeing drought in other parts of the Southwest. *Id*. at 24–33. The Chaco-Anasazi, ancestors of the modern Pueblo people of the MRG, underwent several significant migrations, as they were plagued by prolonged

first wave of European colonialism.[30] Along with them came Spanish settlements in the form of agricultural communities who were granted large tracts of land by the Spanish Crown.[31] These communities brought with them communal irrigation systems of governance called acequias, resulting in diversions of water from a public waterway, and division of that water among acequia members.[32] For a brief period, the MRG became part of Mexico; the United States gained possession of the landscape with the signing of the Treaty of Guadalupe Hidalgo in 1848.[33]

This led to another wave of Euro-American colonialism—this time spearheaded by Anglo ranchers and farmers arriving on the newly constructed railroad.[34] Anglo settlement in New Mexico followed a pattern familiar across the American West, including the encouragement of settlement by various homesteading provisions and federal water projects supporting the development of large-scale irrigated agriculture.[35] In the MRG and many places in New Mexico, however, this Anglo "homesteading" took place in a landscape that had already been the subject of competing claims—by Pueblo people, Spanish settlers and Mexicans—for hundreds of years.[36] Adjudications of these various claims—along with their associated water rights—upon the signing of the Treaty of Guadalupe Hidalgo has been the subject of controversies that continue to this day.[37]

B. Current Management and Key Players.

Today, the MRG is a stressed system due to the effects of continuing human modifications to the landscape and river system along with both natural and human constraints and demands. As will be discussed *infra*, these stressors include popula-

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droughts that decimated their subsistence corn-based agricultural system. Their style of habitation, in tight, protected communities in some areas and spread across the landscape in others, is a response to the need for access to water, as well as to inflows of other climate refugees. They brought with them sophisticated irrigation practices and adapted these strategies to take advantage of the MRG's monsoonal rain patterns and annual spring flooding events for subsistence agriculture within the floodplain. Today, the MRG is still home to several indigenous Pueblo communities. *Id*. *See also* BILL DEBUYS, A GREAT ARIDNESS: CLIMATE CHANGE AND THE FUTURE OF THE AMERICAN SOUTHWEST 63–71 (2011).

30. *See* PHILLIPS ET AL., *supra* note 29, at 37–65 (providing detailed account of early Spanish influence).

31. *See id*.

32. *See id*.

33. Brigette Buynak & Adrian Oglesby, *Basic Water Law Concepts*, *in* WATER MATTERS! 1-1, 1-2 (Darcy S. Bushnell ed., 2014), *available at* http://uttoncenter.unm.edu/pdfs/water-matters-2014/2014-water-matters-lr.pdf (citing Treaty of Guadalupe Hidalgo of 1848, U.S.-Mex., art III, Feb. 2, 1848, 9 Stat. 922).

34. *Id*.

35. *See generally* DONALD J. PISANI, WATER AND AMERICAN GOVERNMENT: THE RECLAMATION BUREAU, NATIONAL WATER POLICY, AND THE WEST, 1902-1935 2 (2002); *see also* K. Maria D. Lane, *Water, Technology, and the Courtroom: Negotiating Reclamation Policy in Territorial New Mexico*, 37 J. HIST. GEOGRAPHY 300, 301 (2011), *available at* http://www.sciencedirect.com/science/article/pii/S0305748811000065.

36. *See* DAVID CORREIA, PROPERTIES OF VIOLENCE: LAW AND LAND-GRANT STRUGGLE IN NORTHERN NEW MEXICO 114 (2013) (tracing Spanish colonial histories and contemporary struggles over property in what is today northern New Mexico); *see also* John B. Wright, *Land Tenure: The Spatial Musculature of the American West*, *in* WESTERN PLACES, AMERICAN MYTHS: HOW WE THINK ABOUT THE WEST (Gary J. Hausladen ed., 2002).

37. *See* Malcom Ebright, *New Mexican Land Grants: the Legal Background in Land*, *in* WATER AND CULTURE: NEW PERSPECTIVES ON HISPANIC LANDS GRANTS (Charles L. Briggs ed., 1987) (providing a detailed examination of adjudication of land grants in New Mexico).

tion growth, biodiversity loss, and cyclical droughts, all occurring in an over-allocated system under constraints of interstate water compact obligations. The effects of climate change are being felt in the basin, with water demands increasing due to higher temperatures. This impacts are projected to be particularly acute in this region, exacerbated by the over-allocation of the historic water supply.[38]

Any assessment of the resilience of the MRG as a complex SES must account for both its current resource allocation and shortages and the changes projected for the future. In this section, we present a summary of the basic governance structure, beginning with international agreements, interstate compacts and federal agencies and their associated mandates. It then discusses actors at the state and local level, and concludes with the role of collaborative processes and environmental groups.

The Rio Grande is both a *successive* international watercourse, in the sense that it flows from the United States to the international border with Mexico, and a *contiguous* international watercourse, meaning it forms the border between, and is shared by, the United States and Mexico.[39] The International Boundary and Water Commission is a bilateral organization that is primarily responsible for implementation of the treaty between the United States and Mexico regarding use of the Rio Grande.[40]

The MRG is subject to a number of interstate compact agreements between states.[41] Of primary importance are the Colorado River Compacts and the Rio Grande Compact. The states with rights to the Colorado River were divided into two categories—Upper Basin and Lower Basin.[42] New Mexico is part of the Upper Basin, and its allotment of water was determined by the Upper Colorado River Basin Compact of 1948, which granted New Mexico the right to approximately 11.25% of the Upper Basin's water—estimated at approximately 0.84 million acre-feet per year.[43] Major infrastructure has been developed to convey a portion of this water to the MRG.[44] It is referred to as the San Juan-Chama Diversion Project; it is

38. *See infra* Part IV.

39. Margaret J, Vick, *The Rio Grande as an International River*, *in* WATER MATTERS!, *supra* note 33, at 26-1, 26-1.

40. *Id*. at 26–5 (In 1944, the United States signed a comprehensive treaty with Mexico covering all shared watercourses. This treaty added responsibility for border water to the International Border Commission's authority and renamed the organization, the International Border and Water Commission. It consists of an engineer from each country and such advisors as each country chooses) (citing Convention for the Equitable Distribution of the Waters of the Rio Grande, U.S.-Mex., May 21, 1906, 34 Stat. 2953, *available at* http://www.ibwc.state.gov/Files/1906Conv.pdf; Treaty Respecting Utilization of Waters of the Colorado and Tijuana Rivers and the Rio Grande, U.S.-Mex., Feb. 3, 1944, 994 U.S.T. 1); Reclamation Act of June 17, 1902, ch. 1093, 32 Stat. 388).

41. Beth Bardwell & Adrian Oglesby, *Water for New Mexico Rivers*, *in* WATER MATTERS!, *supra* note 33, at 17-1, 17-3 (New Mexico is party to eight interstate stream compacts: Animas-La Plata Project Compact (1968), Canadian River Compact (1950), Colorado River Compact (1922), Costilla Creek Compact (1946), La Plata River Compact (1925) Pecos River Compact (1948) Rio Grande Compact (1939), and the Upper Colorado River Basin Compact (1949).).

42. *Id*. at 17-3.

43. James Hogan, Kimberly Kirby, & Jerry Schoeppner, *Water Quality Regulation*, *in* WATER MATTERS!, *supra* note 33, at 18-1, 18-2 (members of the Navajo Nation use the majority of this allocation).

44. *See generally* Kevin G. Flanigan & Amy I. Haas, *The Impact of Full Beneficial Use of San Juan-Chama Project Water by the City of Albuquerque on New Mexico's Rio Grande Compact Obligations*, 48 NAT. RESOURCES J. 371 (2008), *available at* http://lawschool.unm.edu/nrj/volumes/48/2/07_flanigan_impact.pdf (analyzing the conditions under which the City of Albuquerque can use San Juan-Chama water).

a trans-basin diversion that moves approximately 96,000 acre-feet of water annually from the Colorado River Basin to the Rio Grande watershed to allow the MRG to take advantage of a portion of New Mexico's allocation under the Upper Colorado River Compact.[45]

The other major interstate compact influencing governance in the MRG is the Rio Grande Compact between Colorado, New Mexico, and Texas.[46] The Rio Grande Compact apportions water among the states based on gauged stream flows, and administers the apportionment by assigning interstate delivery requirements within a complex system of debits and credits in water deliveries that carry over from year-to-year.[47] This influences both the amount and timing of water storage in the MRG, which will be discussed further *infra*.[48] Compliance with the Rio Grande Compact is currently the subject of litigation; the U.S. Supreme Court recently granted *certiorari* on a challenge brought by Texas against New Mexico for failure to make deliveries under the Compact.[49]

Tribal agreements are also a major factor in MRG water governance. There are six Native American communities in the MRG. In New Mexico, the determination of water rights for Native American Pueblos is complicated by the fact that the United States did not create reservations for Pueblo communities.[50] Rather, the land ownership of the Pueblos was recognized under the Treaty of Guadalupe Hidalgo in 1848, which provided for recognition of aboriginal rights that were recognized under Spanish and Mexican law and preserved when New Mexico came into the United States. For this reason, the Six MRG Pueblo communities (the Pueblos of Kewa,[51] Cochiti, San Felipe, Santa Ana, Sandia, and Isleta) are recognized as having "Prior and Paramount" rights to water.[52] "Prior and Paramount" is currently

45. Melinda Harm Benson et al., *A Classification Framework for Running Adaptive Management Rapids*, 18(3) ECOLOGY & SOC'Y 30 (2013), *available at* http://www.ecologyandsociety.org/vol18/iss3/art30/.

46. N.M. STAT. ANN. § 72-15-23 (West 2014).

47. *See* Susan Kelly, *New Mexico's Major Reservoirs: An Overview*, *in* WATER MATTERS!, *supra* note 33, at 19-1, 19-7 (The Utton Center explains the role this Compact plays in water storage issues in the MRG: Under Article VII, no storage is allowed in any reservoir upstream of Elephant Butte built after 1929 when the usable project water in Elephant Butte and Caballo Reservoirs falls below 400,000 acre-feet, unless the relinquishment of credit waters in Elephant Butte occurs. Article VII has affected operations in 13 years from 1956 to 2008, or about 25 percent of the time. The provision primarily affects El Vado Reservoir, because the other Rio Grande reservoirs store San Juan-Chama water and/or flood flows, the latter of which are released as soon as downstream conditions safely allow).

48. *See infra* Part IV.B.

49. Texas v. New Mexico, 134 S. Ct. 1783 (2014) (The United States has intervened in this case as a plaintiff); *see also* Darcy S. Bushnell, *Water Litigation in the Lower Rio Grande*, *in* WATER MATTERS!, *supra* note 33, at 23-1, 23-2. The is also a related case involving a 2008 Texas court settlement and an alleged violation of the calculation of New Mexico credit water under the Rio Grande Compact by the Bureau of Reclamation in the United States District Court of New Mexico. New Mexico v. United States, No. CIV 11–0691 JB/ACT, 2013 WL 1657355, at *1 (D.N.M. Mar. 29, 2013). Arguments over the impact of groundwater pumping in New Mexico on surface water deliveries are a key issue in the litigation.

50. *See* Winters v. United States, 207 U.S. 564, 577 (1908); *see also* Michael Osborn & Darcy Bushnell, *American Indian Water Rights*, *in* WATER MATTERS!, *supra* note 33, at 5-1, 5-2 ("When Congress establishes a reservation, it implicitly reserves water in an amount sufficient to meet the purpose of the reservation now and into the future, and that right will have priority as of the date of the reservation.").

51. Also referred to as "Santa Domingo Pueblo."

52. *See* note 172 and accompanying discussion regarding the Rio Grande Compact. *See generally* Joshua Mann, *A Reservoir Runs Through It: A Legislative and Administrative History of the Six Pueblos' Right to Store "Prior and Paramount" Water at El Vado*, 47 NAT. RES. J. 733, 742–43 (2007); Susan

defined by Congress as the water necessary to irrigate their 8,847 acres of historic homeland within the boundaries of the Middle Rio Grande Conservancy District (MRGCD).[53] The full extent of the water rights of the Six MRG Pueblos has yet to be legally determined. However, these rights still play a major role in the MRG, along with their associated right to retain water at El Vado Reservoir, within a calendar year, even when storage restrictions are in effect under the Rio Grande Compact.[54]

At the federal level, the Bureau of Reclamation (Reclamation) and U.S. Army Corps of Engineers (Corps) have numerous responsibilities in the MRG. Reclamation operates two water projects for water storage and delivery: the San Juan-Chama Project, which includes Heron Reservoir, and the Middle Rio Grande Project, which includes El Vado Reservoir.[55] The Corps has primary responsibility for key flood control operations for the MRG, and its network of flood-control dams includes Abiquiu and Cochiti reservoirs.[56] Each of the federal water operations of these agencies has its own statutory mandates and corresponding constraints on management operations.[57]

The U.S. Fish and Wildlife Service, the federal agency primarily responsible for implementation and enforcement of the Endangered Species Act (ESA), is also a key player in the MRG, which is home to two listed species under the ESA—the Rio Grande Silvery Minnow and the Southwestern Willow Flycatcher.[58] As will be discussed *infra*, implementation of the ESA under the limited water supply and water management constraints in the MRG has been a key driver of social system dynamics.[59]

Two other federal agencies are worthy of note. The U.S. Forest Service, as a primary land manager for many of the upland forest areas upstream of the MRG, is also an important player. Finally, the Bureau of Indian Affairs is obligated to ensure the MRG Pueblos receive their allocation of water under tribal water agreements.[60]

Kelly, *New Mexico's Major Reservoirs: An Overview*, *in* WATER MATTERS!, *supra* note 33, at 19-1, 19-7 ("An exception to Article VII is applied in the case of El Vado for the storage of 'Prior and Paramount' water rights for the several Rio Grande Pueblos, because the Compact by its own terms does not affect the water rights of Native American Pueblos and Tribes.").

53. *See* Mann, *supra* note 52, at 738–39 (citing Act of Mar. 13, 1928, ch. 291, 45 Stat. 312). The Pueblos also have an additional 11,074.40 acres of Pueblo land that could be reclaimed as part of their participation in the MRGCD that are not part of the Prior and Paramount allocation. *See id*.

54. *See id*. at 739.

55. *See* Susan Kelly et al., *History of the Rio Grande Reservoirs in New Mexico: Legislation and Litigation*, 47 NAT. RESOURCES J. 525, 525–26 (2007).

56. *See id*. at 526.

57. Table 1 provides a basic overview of key water projects and their current legal and regulatory mandates and constraints.

58. These species were listed in the ESA in 1994 and 1995, respectively. *See* Endangered and Threatened Wildlife and Plants; Final Rule to List the Rio Grande Silvery Minnow as an Endangered Species, 59 Fed. Reg. 36988, 36988–95 (July 20, 1994) (codified at 50 C.F.R. § 17.11(h)); Endangered and Threatened Wildlife and Plants; Final Rule Determining Endangered Status for the Southwestern Willow Flycatcher, 60 Fed. Reg. 10694, 10694–715 (Feb. 27, 1995) (codified at 50 C.F.R. § 17.11(h)).

59. *See infra* Part IV.A.4.

60. The Bureau of Indian Affairs is the federal agency with the obligation to the Pueblos to provide the Prior and Paramount water allocation. It is the "Designated Engineer" that asks Reclamation to detain water in El Vado Reservoir under Article VII of the Rio Grande Compact years discussed *infra* to

At the state level, there are also several key actors. As in many Western states, the Office of the State Engineer is responsible for administration of water in accordance with the prior appropriation doctrine in New Mexico.[61] These duties include, where necessary, the adjudication of water rights in order to "help the State define its existing water rights, meet its interstate compact obligations, manage shortages, and protect the state's waters."[62] To date, however, there has been no adjudication of water rights in the MRG, and the actual administration of water supply is more complex in practice than it would be under strict adherence to the prior appropriation doctrine, as will be discussed *infra*.[63] The New Mexico Interstate Stream Commission, a sister agency to the Office of the State Engineer, has primary responsibility for ensuring that New Mexico meets its obligations and obtains its rights under interstate compact agreements.[64] The New Mexico Environment Department has jurisdiction over issues concerning water quality.[65]

At the local level, the cities of Albuquerque, Santa Fe, and Rio Rancho are all major water users and are key players in land-use management decisions that impact water use in municipal areas. Albuquerque's water is managed by the Albuquerque-Bernalillo County Water Utility Authority (Water Authority). Both the City of Santa Fe and the Water Authority receive water from the San Juan-Chama Project and have drinking water supply projects that divert from the Rio Grande.[66] The Water Authority receives the largest share of San Juan-Chama Project water, with an annual allocation of 48,200 acre feet.[67]

Irrigation districts have a quasi-municipal status as political subdivisions of the state in New Mexico, and no description of MRG governance would be complete without the MRGCD. The MRGCD was created in 1925 to both construct the dams and levees necessary to drain the historic floodplain for agricultural use and to deliver water to district members.[68] It is the largest agricultural water user in the MRG.[69]

The City of Albuquerque is also a key player in the MRG. While water supply and delivery for municipal use is administered by the Water Authority, the city manages the recreational open-space along the Rio Grande riparian corridor

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assure the Prior and Paramount supply for the Six Middle Rio Grande Pueblos and decides the amount that should be detained.

61. *See infra* Part IV.A.2.
62. Buynak & Oglesby, *supra* note 33, at 1-6.
63. *See infra* Part IV.A.2.
64. Buynak & Oglesby, *supra* note 33, at 1-3.
65. N.M. STAT. ANN. § 74-6-4 (West 2014). *See generally* James Hogan et al., *Water Quality Regulation*, *in* WATER MATTERS!, *supra* note 33, at 18-1 (on water quality). New Mexico does not have delegated authority over point source discharges under the Clean Water Act, but like more Western states, nonpoint sources comprise the overwhelming majority of water quality challenges in the site. *See* N.M. ADMIN. CODE § 20.6.4.7(B)(1)(b) (West 2014) (voluntary program for implementation of nonpoint best management practices). *See also* NEW MEXICO ENV'T DEP'T, NEW MEXICO NONPOINT SOURCE MANAGEMENT PROGRAM (2009), *available at* http://allaboutwatersheds.org/library/general-library-holdings/WQCC-Approved2009NPSPlan.pdf.
66. Susan Kelly, *New Mexico's Major Reservoirs: An Overview*, *in* WATER MATTERS!, *supra* note 33, at 19-4.
67. *Id*.
68. *Id*. at 4-6 (There are seventy-two acequias that were subsumed by the MRGCD after its incorporation).
69. *See infra* Part IV.A.2.

through town—locally referred to as the Bosque.[70] In 2011, the city launched the Rio Grande Vision project, a conceptual plan comprised of recreation, conservation, and improvements "that will provide a wider variety of ways for citizens of all ages and abilities to experience and learn about the Rio Grande and the Bosque."[71]

The listing of native species to the MRG as endangered created a need for the federal, state and local entities discussed *infra* to cooperate to meet the needs of the listed species, the Rio Grande silvery minnow (*Hybognathus amarus*) and the Southwestern Willow Flycatcher (*Empidonax traillii extimus*).[72] The Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) coordinates the efforts of the various actors to achieve ESA compliance and funds research related to species recovery efforts.[73] Notably absent from the list of Collaborative Program participants are environmental groups. Environmentalists used litigation as a tool to force species protection efforts under the ESA, bringing a citizen suit enforcement action against Reclamation and the Corps in 1999, which led directly to the creation of the Collaborative Program.[74] But after some initial participation, environmental groups pulled out of the process. Environmental groups are still concerned about species protection, however, and Wild Earth Guardians recently threatened litigation challenging ESA compliance in the MRG, discussed further *infra*.[75]

IV. ASSESSING RESILIENCE: INTERACTIONS AMONG SOCIAL AND ECOLOGICAL ELEMENTS OF THE SYSTEM, AND ASSOCIATED DRIVERS AND DISTURBANCES.

Like in most watersheds in the American West, the SES dynamics of the MRG are driven by the social and ecological stresses placed on the system through imbalances between water availability and demand. This Section describes social (human driven) and ecological (environmentally driven) elements and then highlights key interactions among them, with an emphasis on possible thresholds in MRG that, once crossed, will fundamentally change the SES. As will be demonstrated, it can be difficult to parse the "social" from the "ecological," as they often

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70. Bosque means "forest" in Spanish. See *infra* Part IV.B.1 for a description.

71. *See* Rio Grande Vision: Executive Summary, www.riograndevision.com/wp-content/uploads/2013/09/Executive-Summary.pdf (last visited April 26, 2014).

72. *See* U.S. BUREAU OF RECLAMATION, JOINT BIOLOGICAL ASSESSMENT BUREAU OF RECLAMATION AND NON-FEDERAL WATER MANAGEMENT AND MAINTENANCE ACTIVITIES ON THE MIDDLE RIO GRANDE, NEW MEXICO, PART IV – THE MIDDLE RIO GRANDE ENDANGERED SPECIES COLLABORATIVE PROGRAM RECOVERY IMPLEMENTATION PROGRAM (2013) [hereinafter JOINT BIOLOGICAL ASSESSMENT], *available at* http://www.usbr.gov/uc/albuq/envdocs/ba/MRG/Part4/BA-Part-IV.pdf. The Collaborative Program is a conservation measure proposed to offset the impacts of dam operations in the MRG and has plans to become a Recovery Implementation Program. *Id*. at 7–11.

73. *See, e.g*., TETRA TECH EM, ENDANGERED SPECIES HABITAT RESTORATION ISSUES IN THE MIDDLE RIO GRANDE: EXECUTIVE SUMMARY (2003), *available at* http://www.mrgesa.com/LinkClick.aspx?fileticket=suJviBHUO2I%3D&tabid=263&mid=659; *see generally* U.S. FISH & WILDLIFE SERV., RIO GRANDE SILVERY MINNOW RECOVERY PLAN (2010), [hereinafter RECOVERY PLAN] *available at* http://www.fws.gov/southwest/es/Documents/R2ES/Rio_Grande_Silvery_Minnow_Recovery_Plan_First_Revision.pdf.

74. *See generally* Rio Grande Silvery Minnow v. Keys, 356 F. Supp. 2d 1222 (D.N.M. 2002); JOINT BIOLOGICAL ASSESSMENT, *supra* note 72, at 9.

75. *See infra* Part IV.A.4.

co-emerge and intertwine. For example, the "built systems," including dams, levees, and other human-engineered changes to the Rio Grande river system are *human* in the sense that they were created by and serve social processes but also *ecological* in the sense that they alter the river in physical ways that create new ecological dynamics.

A. Elements of the Current Social System

1. Built Infrastructure: Dams and Levees

Perhaps the most immediate and direct social driver of changes that have occurred to the MRG are the dams and levees that control the amount and location of water and sediment in the river system, which are major determinants of the river system's health and complexity. "Between Cochiti Dam and Elephant Butte Reservoir headwaters, there are 235 miles of levees."[76] Systematic levee construction in the MRG began in the late 1920s as a response to flooding,[77] and spiked in the 1950s with funding support from the Flood Control Act of 1948.[78] Besides the expansion of levees, the Flood Control Act funded additional large flood-control measures in the MRG, including clearing and straightening of the Rio Grande channel, construction of Cochiti Dam, and the installation of bank-stabilization structures in the floodplain.[79] Table 1 outlines the most significant dams and reservoirs influencing the MRG and their current management authorizations. This built infrastructure is necessary for both the agricultural and municipal use of the watershed's historic floodplain. Both water delivery and flood control are dependent on this complex network of ditches, levees, and dams.

Dam / Reservoir	**Current reservoir (manager, water project, construction date, and capacity)**	**Description of current operational authorization-including date and statutory citation**	**Current legal and regulatory mandates and constraints**
Heron Dam and Reservoir	Reclamation (San Juan-Chama Project; completed 1971, 401,320 acre-feet capacity).	1962 PL 87-483. Stores NM allocation under Colorado River Compact. 96,200 acre-feet delivered to 13 contractors plus federal uses on an annual basis.	Filling is subject to water availability in San Juan tributaries and to availability under Colorado River Compact. Undelivered contractor allocations revert to federal pool at end of year.

76. JOINT BIOLOGICAL ASSESSMENT, *supra* note 72, at 9.
77. CLIFFORD S. CRAWFORD ET AL., MIDDLE RIO GRANDE ECOSYSTEM: BOSQUE BIOLOGICAL MANAGEMENT PLAN ix (1993) [hereinafter BOSQUE BIOLOGICAL MANAGEMENT PLAN], *available at* http://www.fws.gov/southwest/mrgbi/Resources/BBMP/Bbmp.pdf.
78. *Id*. at 26.
79. *Id*.

El Vado Dam and Reservoir	Reclamation and MRGCD (Middle Rio Grande Project; completed 1935, rehabilitated in 1950s, storage rights assigned 1963; approx. 190,000 acre-feet capacity remaining).	1927 Conservancy Act, NMSA § 73-14-1 through 73-14-88; Act of 1928, 45 Stat. 312 (appropriating Federal funds for Pueblo share). Store native water for use by Six Middle Rio Grande Pueblos and non-Indian irrigators of the MRGCD. Provide power generation for Los Alamos County.	Subject to Article VII storage restrictions under Rio Grande Compact. Both MRGCD and Reclamation claim title. Regulates flows through National Wild and Scenic Reach of the Rio Chama. Hydropower generation does not dictate flows.
Abiquiu Dam and Reservoir	Corps of Engineers (completed 1962; 551,000 acre-feet capacity for flood and sediment control; 183,099 acre-feet storage of SJC Project water).	Flood Control Act of 1948, PL 81-858; Flood Control Act of 1960, PL 86-645; PL 97-140 (1981) SJC Project storage; PL 100-522 (1988) native storage.	Release limited to 1,800 cubic-feet-per second due to channel capacity restrictions. Storage of native water is legal, but environmental clearances and property-owner permission not yet assured.
Cochiti Dam and Reservoir	Corps of Engineers (completed 1975; 50,000 acre-feet recreation pool refilled with SJC Project water; 590,000 acre-feet flood-control space).	Flood Control Act of 1960, PL 86-645; PL 88-293 (50,000 acre-feet pool for recreation, fish, and wildlife).	Release limited to 7,000 cubic-feet-per second at Albuquerque gauge due to channel capacity restrictions. Must pass all inflow except during flood operations. Floodwaters must be released as soon as practicable.
Elephant Butte Reservoir	Reclamation (Rio Grande Project; completed 1916; approx. two million acre-feet storage capacity for native and SJC Project storage plus flood control).	Rio Grande Reclamation Project, enacted 1905, PL 58-108.	Upper Reservoir pool / delta is critical habitat for endangered Southwestern Willow Flycatcher.
Two additional dams operated by the Corps of Engineers for flood and sediment control, Galisteo Dam and Jemez Canyon Dam, are not listed here. They are also of potential significance to the MRG, although they are smaller structures located on tributaries.			

TABLE 1. Existing dams and reservoirs, and existing operational authorizations and constraints

2. Water Allocation Regimes and Agricultural Practices

Closely related to efforts to tame the river system are the changes made to allow use of its water. Like in many Western states, water allocation in New Mexico is governed by the prior appropriation doctrine.[80] Prior appropriation is a historically based allocation system that anticipates scarcity. The doctrine of prior appropriation states that when shortages occur, the right to use water is determined by the chronological order in which the water was put to beneficial use. "Senior" appropriators are served first; and in a water-short year, "junior" appropriators may receive a reduced amount or no water, depending on the supply.

Water rights are usufructuary and apply only when applied to a beneficial use.[81] In addition, water rights are subject to forfeiture if not used, which creates a general disincentive for conservation strategies.[82] When the prior appropriation doctrine was formally established in New Mexico in 1891, there was no recognition of the values associated with leaving water in stream for wildlife and other uses;[83] and until recently, leaving water in stream for fish and wildlife was not recognized as a beneficial use.[84] Instream flow rights remain relatively limited and, to date, have only been held in the MRG on a temporary leasing basis by Reclamation. Purchase of water rights for instream flow purposes is now authorized under the Strategic Water Reserve by the Interstate Stream Commission, although the Strategic Water Reserve has yet to be put into use for the Middle Rio Grande.[85]

Today, the majority of water use supports agriculture in a traditional system of gravity-fed flood irrigation.[86] Much of this system originated as a network of acequias, which served as local governance structures.[87] Today, over seventy of the individual acequias have been consolidated into the MRGCD, which provides irrigation water for about 53,000 acres of crops, primarily alfalfa, and supports a thriving local dairy industry.[88] Agriculture is mainly small scale and family owned, or associated with the six MRG Pueblos that are members of the irrigation district.[89]

80. "The unappropriated water of every natural stream, perennial or torrential, within the state of New Mexico, is hereby declared to belong to the public and to be subject to appropriation for beneficial use, in accordance with the laws of the state. Priority of appropriation shall give the better right." N.M. CONST. art. XVI, § 2. *See also* Buynak & Oglesby, *supra* note 33, at 1-3.

81. *See id*. at 1-4.

82. *See id*.

83. *See generally* Trambley v. Luterman, 27 P. 312 (N.M. 1891).

84. In 2005, the Office of the State Engineer amended the regulatory definition of "beneficial use" to include "fish and wildlife." *See* Beth Bardwell & Adrian Oglesby, *Water for New Mexico Rivers*, *in* WATER MATTERS!, *supra* note 33, at 17-4.

85. *See* Beth Bardwell & Adrian Oglesby, *Water for New Mexico Rivers*, *in* WATER MATTERS!, *supra* note 33, at 17-4.

86. *See* S. S. PAPADOPULOS & ASSOCS., INC., EVALUATION OF MIDDLE RIO GRANDE CONSERVANCY DISTRICT IRRIGATION SYSTEM AND MEASUREMENT PROGRAM, ES-2 (2002), *available at* http://www.ose.state.nm.us/water-info/MRGCD-efficiency/volume-1-rpt.pdf.

87. *See* PHILLIPS ET AL., *supra* note 29, at 37–52.

88. *See* DOUGLAS W. STRECH & TRACY SCHARP MATTHEWS, MIDDLE RIO GRANDE VEGETATION CLASSIFICATION SUMMER 2000 (August 15, 2001) (on file with author) (this was a joint project between the Middle Rio Grande Conservancy District and the New Mexico Office of the State Engineer / Interstate Stream Commission).

89. *See* S. S. PAPADOPULOS & ASSOCS., INC., *supra* note 86.

3. Urban Growth and Associated Development

Like much of the American West, the MRG has seen a steady increase in population growth, and with that growth, an increasing municipal and industrial water demand.[90] Santa Fe and Albuquerque each rely on both ground and surface water supplies and, while water conservation programs are an important part of the overall supply strategy, both municipalities are constantly seeking new sources.[91] One source of supply is the purchase of senior water rights from willing sellers, and several municipalities in the MRG are purchasing water rights from farmers to meet their growing needs. As a result, there has been a shift in many water rights in the MRG from their original agricultural use to municipal use.[92] Many of these transactions involve purchases of senior surface water rights to offset the impacts to the river of municipal groundwater pumping.[93] Between 1982 and 2011, 21,000 acre-feet of water rights were transferred,[94] most of which were transfers of agricultural rights to cities such as Albuquerque and Santa Fe.[95] The competing demands

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90. *See* Sarah Bates, *Bridging the Governance Gap: Emerging Strategies to Integrate Water and Land Use Planning*, 52 NAT. RESOURCES J. 61 (2012) (discussing need for integrated land use and water planning). In theory, this should not be true in the fully-allocated system of the MRG, where new uses need to be offset by the retirement of existing uses, primarily agriculture. In the absence of adjudication, however, accommodating other municipal water use remains problematic, as will be discussed *infra* Part V.B.

91. For the Albuquerque area, the Water Authority's website explains:

> The Albuquerque area relies on two sources for its drinking water. Ground water from the Santa Fe Group Aquifer and San Juan-Chama surface water diverted from the Rio Grande via the San Juan-Chama Drinking Water Project. Approximately 96 wells combine with the San Juan-Chama project to produce about 33 billion gallons of drinking water for the Water Authority's service area every year..

Your Drinking Water, ALBUQUERQUE BERNALILLO CNTY. WATER UTIL. AUTH., http://www.abcwua.org/Your_Drinking_Water.aspx (last visited Jan. 13, 2015). Conservation programs implemented by the Authority are extensive. *See generally* ALBUQUERQUE BERNALILLO CNTY. WATER UTIL. AUTH., ALBUQUERQUE BERNALILLO COUNTY WATER UTILITY WATER RESOURCE MANAGEMENT STRATEGY IMPLEMENTATION: 2024 WATER CONSERVATION PLAN GOAL AND PROGRAM UPDATE (2013), *available at* http://www.abcwua.org/uploads/files/2024_Water_Conservation_Plan_Update.pdf (considering current water usage, public concerns, and conservation efforts). Santa Fe is even more aggressive with its water conservation strategies and has a number of mandatory requirements; the county recently enacted a Sustainable Growth Management Plan linking water infrastructure to desired growth areas. SANTA FE CNTY. SUSTAINABLE GROWTH MANAGEMENT PLAN (2010), *available at* http://www.santafecountynm.gov/userfiles/SGMP.pdf.

92. *Id*. at 16-1.

93. Darcy Bushnell & Sarah Armstrong, *Groundwater*, *in* WATER MATTERS!, *supra* note 33, at 6-1, 6-6. The Utton Center explains:

> Where groundwater pumping is, or will cause, unacceptable depletions on fully appropriated surface-water resources, the State Engineer can condition any new permit by requiring "offsets." To effect an offset requirement, a proposed appropriator must acquire a senior surface-water right and obtain an OSE permit to transfer it, that is, change the place of use, to the proposed groundwater diversion. The land on which the surface-water was used no longer has an appurtenant water right and the water right is said to be "retired."

Id.

94. "Acre-feet" is the volume of one acre of surface area to a depth of one foot.

95. Darcy Bushnell & Sarah Armstrong, *Groundwater*, *in* WATER MATTERS!, *supra* note 33, at 6-1. A recent memorandum from the New Mexico Office of the State Engineer indicates that of an originally permitted 123,000 acres of irrigated land, only 8,801 acres of Indian land and approximately 21,000 acres of non-Indian lands are still in production using their original water rights. *See* N.M. OFFICE OF THE STATE ENG'R INTERSTATE STREAM COMM'N, 2009-2011 ANNUAL REPORT (2011), *available at* http://www.ose.state.nm.us/Plans/ose%2009-11%20all.pdf.

for a limited water supply in the MRG were highlighted in the Reclamation's 2025 report, which concerned areas of the Western U.S. where existing water supplies are, or will be, inadequate to meet the water demands of people, cities, farms, and the environment even under normal water supply conditions.[96] While there is not enough information to make this determination in the MRG, it is possible that water transfers from agricultural to municipal uses could cumulatively cross an economic threshold whereby the remaining farmers cannot practically continue given lack of remaining infrastructure for buying and selling goods, water delivery, etc.[97]

4. The Endangered Species Act

The ESA is also a major societal factor in the MRG; it is the major driver of ecological restoration efforts in the watershed.[98] Under Section 7 of the ESA, all federal agencies are required to consult with the appropriate wildlife agency to ensure that its actions are not likely to jeopardize the continued existence of listed species or result in destruction or adverse modification of critical habitat.[99] If a jeopardy determination is made, the Fish and Wildlife Service, in its Biological Opinion, seeks to identify "reasonable and prudent alternatives" that would allow the action agency to move forward with the proposed activity while avoiding jeopardy for the species.

In the case of the Silvery Minnow, a jeopardy determination was made in 2003 in the Biological Opinion that covered water operations for Reclamation, the Corps, and a number of nonfederal actors (such as the MRGCD) whose activities are closely linked to federal water operations.[100] Activities that took place under the 2003 Biological Opinion included establishment of ramp-down rates for river flows that facilitate Silvery Minnow spawning; salvage operations for rescuing Silvery Minnow from isolated pools when necessary; establishment by Reclamation of a supplemental water program,[101] in which it leases water on a willing-seller-willing

96. U.S. BUREAU OF RECLAMATION, SECURE WATER ACT § 9503(C), RECLAMATION: CLIMATE CHANGE AND WATER (2011) [hereinafter Reclamation Secure Water Act Report] *available at* http://www.usbr.gov/climate/SECURE/docs/SECUREWaterReport.pdf. *See also* Reed D. Benson, *New Adventures of the Old Bureau: Modern-Day Reclamation Statutes and Congress' Unfinished Environmental Business*, 48 HARV. J. ON LEGIS. 137, 169–72 (2011), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1621758.

97. *See generally* LAWRENCE J. MACDONNELL, PROTECTING LOCAL ECONOMIES: LEGISLATIVE OPTIONS TO PROTECT RURAL COMMUNITIES IN NORTHEAST WASHINGTON FROM DISPROPORTIONATE ECONOMIC, AGRICULTURAL, AND ENVIRONMENTAL IMPACTS WHEN UPSTREAM WATER RIGHTS ARE PURCHASED AND TRANSFERRED FOR USE, OR IDLED AND USED AS MITIGATION, IN A DOWNSTREAM WATERSHED OR COUNTY (2008) (discussing the impact of water transfers on the capacity of communities to continue agricultural economic base and possible legislative solutions).

98. This is the case with many river restoration efforts in the United States. *See* Melinda Harm Benson, *Intelligent Tinkering: The Endangered Species Act and Resilience*, 17 ECOLOGY & SOC'Y art. 28 (2012) *available at* http://www.ecologyandsociety.org/vol17/iss4/art28/ (detailing the role of the ESA in various river basins).

99. 16 U.S.C.A. § 1536 (West 2014).

100. *See* Memorandum from Regional Director, Region 2 to Area Manager, Albuquerque Area Office, Bureau of Reclamation (Mar. 17, 2003), *available at* http://www.fws.gov/southwest/es/NewMexico/documents/BO/2003-0129%20Middle%20Rio%20Grande%20Water%20Ops%20BO.pdf.

101. *See* Wild Earth Guardians v. U.S. Bureau of Reclamation, No. 1:14-cv-00666 (D.N.M. filed July 24, 2014).

buyer basis to enhance instream flow; and further development of the Collaborative Program.[102]

Consultation is currently underway for a new Biological Opinion, and there is some doubt over whether the Corps will continue to participate.[103] On November 26, 2013, the Corps provided notice to the Service of its withdrawal from the ESA Section 7 consultation regarding the Corps' flood control and reservoir management activities in the MRG. In July of 2014, Wild Earth Guardians brought a legal challenge against the Corps and Reclamation, raising, among other claims, the failure of the Corps and Reclamation to meet the ESA's consultation requirement.[104]

Regardless of the outcome of this move by the Corps, it is safe to say that the Silvery Minnow will continue to be a major focus of management efforts, serving as a proxy for the river, representing the environmental degradation that has occurred over the years. The Collaborative Program recently made a decision to boost its efforts with regard to the Silvery Minnow and become a Recovery Implementation Program.[105] Adaptive management is a core component of both the new program and the proposed actions of Reclamation under the new Biological Opinion.[106] However, even with an increased institutional commitment by the Collaborative Program, one of the major challenges moving forward will be finding willing sellers for water transfers in order to increase the amount of water left instream for the Minnow. During the past decade, the Water Authority was one of the main entities leasing water to Reclamation's Supplemental Water Program.[107] That was because it was not yet using its allocation of San Juan Chama Project water—now it is.[108]

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102. *See id*.

103. *See* Letter from Earl H. Stockdale, attorney for the Corps regarding "Reservoir Operations in the Middle Rio Grande Endangered Species Act Consultation" to Fish and Wildlife Serv. (Nov. 28, 2013) (on file with author). While the Corps does not state its legal basis for its decision to withdraw from consultation, its reasoning is likely based on the U.S. Supreme Court's holding in Nat'l Assn. of Home Builders v. Defenders of Wildlife, 551 U.S. 644 (2007), in which the court held that the ESA consultation requirement does not apply to agency actions that are not discretionary. *Id*. at 667–68. *See also* Robin Kundis Craig, *Is There* Really *a Duty to Consult? Section 7 of the Endangered Species Act, Federal Water Management, and the Discretionary Function Requirement*. A.B.A. SEC. ENV'T, ENERGY, AND RES. 31ST ANNUAL CONFERENCE, LAS VEGAS, NEV. (2013), *available at* http://www.americanbar.org/content/dam/aba/events/environment_energy_resources/2013/06/31st_annual_waterlawconference/conference_materials_portal/BestPaper_Craig_Robin-paper.authcheckdam.pdf.

104. *See* Letter from Jen Pelz, attorney for Wild Earth Guardians, to the Corps regarding "Notice of Intent to Sue the U.S. Army Corps of Engineers Pursuant to the Endangered Species Act Regarding its Ongoing Reservoir Operation and Water Management Activities in the Middle Rio Grande, New Mexico" (Jan. 9, 2014) (on file with author. For an extensive history of the Minnow litigation, *see* Susan Kelly & Summer McKean, *The Rio Grande Silvery Minnow: Eleven Years of Litigation*, THE UTTON TRANSBOUNDARY RES. CTR. (2011), *available at* http://uttoncenter.unm.edu/pdfs/Silvery_Minnow_litigation.pdf.

105. *See* Reed D. Benson, *Avoiding Jeopardy, Without the Questions: Recovery Implementation Programs for Endangered Species in Western River Basins*, 2 MICH. J. ENVTL. & ADMIN. L. 473 (2013) (describing the rising influence of Recovery Implementation Programs as an ESA enforcement strategy).

106. *See* JOINT BIOLOGICAL ASSESSMENT, *supra* note 72.

107. *See* Flanigan & Haas, *supra* note 44, at 392–93. From 1999 through 2007, approximately 430,000 acre-feet of SJCP water was allocated to the City. *Id*. Of that amount, the City supplied approximately 163,000 acre-feet to Reclamation to provide flows for the endangered Rio Grande Silvery Minnow under Reclamation's Supplemental Water Program. *Id*.

108. *Id*.

All of these elements—the channelization of the river, withdrawals of water from the river to serve municipal and agricultural water uses, and competing demands for that water from growing cities and endangered species—are stressing the SES. Water allocation approaches are relatively rigid, while the need for more adaptive strategies regarding the use of that water are greater than ever.

B. Elements of Current Ecological System

1. Channelization of the Middle Rio Grande

One dominant ecological driver of change in the MRG is river channelization, a direct result of the flood control efforts within the channel and floodplain accomplished through installation of bank-stabilization structures and construction of levees by Reclamation in the 1950s, and the construction of Cochiti Dam by the Corps in the 1970s.[109] The construction of this infrastructure has led to simplification of the channel and isolation of the channel from the surrounding floodplain. In addition, water management changes to the natural hydrograph for human use eliminate historical early season peak flows in order to provide steady but low summertime flows, further contributing to vegetation encroachment that simplifies the channel.[110] These modifications of the river to meet human needs have fundamentally changed the appearance and structure of the river and riparian system. Figure 2 shows the river and its riparian zone in Albuquerque before and after many of these modifications.

The impacts of channelization are profound. Flood control measures, along with diversions of flows from the river and other changes in the hydrograph, create a reduction in channel complexity and overbank flooding.[111] This results in a transformation of the MRG riparian system, known locally as the "Bosque," from a dynamic patchwork of cottonwoods (*Populous deltoids*) and willows (*Salix exigua*), regularly reworked by spring floods to a continuous, dense, and even-aged cottonwood forest occupying much of the previous river channel and floodplain. Both channel complexity and overbank flooding are important for establishing native vegetation, such as cottonwoods and willows, and the changes in the system dynamics make the system more hospitable for a growing non-native community, including salt cedar (*tamarisk*) and Russian olive (*Elaeagnus angustifolia*).[112]

This riparian system has not experienced significant establishment opportunities for native vegetation since the germination of the existing stands of cottonwoods in the floods of the 1940s. These trees are now close to seventy years old and nearing the end of their lifespan. [113] At the same time, the community of non-native vegetation is expanding.[114] The Bosque has been transformed from a dynamic ecological system, in which frequent flooding and channel migrations created

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109. *See* John P. Taylor et al., *Soil Disturbance, Flood Management, and Riparian Woody Plant Establishment in the Rio Grande Floodplain*, 19 WETLANDS 372, 372 (1999).
110. *See* JOINT BIOLOGICAL ASSESSMENT, *supra* note 72, at 11.
111. *Id*. at. ix.
112. *See* Taylor, *supra* note 109, at 373.
113. *See* William H. Howe & Fritz L. Knopf, *On the Imminent Decline of Rio Grande Cottonwoods in Central New Mexico*, 36 SW NATURALIST 218, 220 (1991).
114. *See* Taylor et al., *supra* note 109, at 372.

uneven and diverse riparian landscapes, to a wide but static swath of even- and old-aged native trees,[115] as well as an expanding community of non-native vegetation.[116]

These changes in the character of the Bosque have also caused biodiversity loss in the region. Most notably, the Silvery Minnow and Southwestern Willow Flycatcher, both endangered species, have suffered due to the human-caused changes to the Rio Grande's riverine and riparian system.[117] The Silvery Minnow has undergone declines in populations[118] and genetic diversity[119] due to loss of riverine habitat and overbank flooding, which supports reproduction. Changes in riparian species and habitat structure have threatened the extinction of the Southwestern Willow Flycatcher.[120] These species, along with others that depend on riverine and riparian habitat of the Rio Grande, will likely be further stressed by warming temperatures and decreased water availability that are occurring as a result of climate change.[121]

2. Upland Forest Systems

Important ecological drivers also are present in the forest upland areas associated with the MRG basin. These high elevation forests are natural reservoirs that capture snow during the winter and release the moisture as runoff in the spring and summer. Two of the most dominant drivers of the recent changes to this system are increased activity of several species of bark beetle, which has killed many acres of pine trees, and an increased vulnerability to catastrophic wildfire, due to current moisture stress in combination with forest management practices of the past century.[122] In 2012 more than 172,000 acres of pinyon pine, ponderosa pine, or Douglas fir forest experienced mortality due to one or more species of bark beetle.[123] The beetle outbreaks cause large areas of upland forest to be susceptible to wildland

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115. *See* Manuel C. Molles, Jr. et al., *Managed Flooding for Riparian Ecosystem Restoration: Managed Flooding Reorganizes Riparian Forest Ecosystems Along the Middle Rio Grande in New Mexico*, 48 No. 9 BIOSCIENCE 749, 750 (1998).

116. *See* Taylor et al., *supra* note 109
, at 372.

117. The Silvery Minnow is the last remaining endemic pelagic spawning minnow in the Rio Grande basin, and it has been steadily declining since it was listed as endangered under the Endangered Species Act in 1994, only eight years ago. Four other pelagic spawning minnow species formerly found in the Rio Grande basin have already gone extinct. *See* Rio Grande Silvery Minnow v. Keys, 356 F. Supp. 2d 1222, 1229 (D.N.M. 2002).

118. *See* Steven P. Platania, *Fishes of the Rio Chama and Upper Rio Grande, New Mexico, with Preliminary Comments on Their Longitudinal Distribution*. 36 SW NATURALIST 186, 192 (1991).

119. Dominique Alò & Thomas F. Turner, *Effects of Habitat Fragmentation on Effective Population Size in the Endangered Rio Grande Silvery Minnow*, 19 CONSERVATION BIOLOGY 1138, 1146 (2005).

120. Juliet C. Stromberg, *Restoration of Riparian Vegetation in the South-Western United States: Importance of Flow Regimes and Fluvial Dynamism*, 49 J. ARID ENV'TS 17, 19 (2001).

121. MEGAN M. FRIGGENS ET AL., U.S. FOREST SERVICE, VULNERABILITY OF SPECIES TO CLIMATE CHANGE IN THE SOUTHWEST: TERRESTRIAL SPECIES OF THE MIDDLE RIO GRANDE (2013), *available at* http://www.fs.fed.us/rm/pubs/rmrs_gtr306.pdf.

122. Craig D. Allen, *Interactions Across Spatial Scales Among Forest Dieback, Fire, and Erosion in Northern New Mexico Landscapes*, 10 ECOSYSTEMS 797, 800–01 (2007).

123. *See* USDA, PR-R3-16-8, FOREST INSECT AND DISEASE CONDITIONS IN THE SOUTHWESTERN REGION, 2011, at 3 (2012), *available at* http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5406441.pdf.

fires,[124] with the greatest wildfire risk occurring shortly after the infestation and dropping off thereafter.[125] When combined with drought conditions currently gripping the Southwest, positive feedback loops are created between bark beetle outbreaks, forest dieback, and forest fires, leading to greater areas of forest mortality.[126] This feedback loop and the threat of fires are expected to increase in intensity due to climate shifts in the future.[127]

The degraded condition of the MRG's forested headwaters has resulted in a dramatic increase in fire frequency, severity, and size over the past decade.[128] A period of rapid forest harvesting around the turn of the century, followed by decades of fire suppression,[129] resulted in tree densities and fuel loads that are drastically higher than they were historically.[130] These high fuel loads combined with stress associated with sustained drought,[131] increased air temperatures, reduced winter snowpack that is melting off earlier in the year,[132] forest dieback,[133] and increased human activity in the wildland/urban interface,[134] have all contributed to this trend. Additionally, grazing pressure in the lowlands under dry and hot conditions result in increased dust emissions that in turn reduce snowpack albedo, accelerate snowmelt, and reduce water availability.[135]

In the MRG headwater watersheds, the wildfire season (May through July) is followed by the monsoon rains (July through September). The timing of these events can lead to extreme flash flooding, debris slides, severely degraded water quality, and associated negative impacts on the natural and human systems that depend on the MRG and its tributaries.[136] Post-fire peak flows have been shown to be ten- to one hundred-fold higher than baseline conditions.[137] As an example of

124. *See* Allen, *supra* note 122, at 798.

125. *See* Jeffrey A. Hicke et al., *Effects of Bark Beetle-Caused Tree Mortality on Wildfire*, 271 FOREST ECOLOGY & MGMT. 81, 84 (2012).

126. *See* Allen, *supra* note 122, at 801.

127. *See* Max A. Moritz et al., *Climate Change and Disruptions to Global Fire Activity*, 3 ECOSPHERE 1, 18 (2012).

128. Tania Schoennagel et al., *The Interaction of Fire, Fuels, and Climate Across Rocky Mountain Forests*, 54 BIOSCIENCE 661, 666 (2004).

129. WILLIAM A. DICK-PEDDIE, NEW MEXICO VEGETATION: PAST, PRESENT, AND FUTURE 25 (1999); THOMAS W. SWETNAM, FIRE HISTORY AND CLIMATE IN THE SOUTHWESTERN UNITED STATES 6 (1990).

130. Margaret M. Moore et al., *Reference Conditions and Ecological Restoration: A Southwestern Ponderosa Pine Perspective*, 9 ECOLOGICAL APPLICATIONS 1266, 1270 (1999).

131. Craig D. Allen et al., *A Global Overview of Drought and Heat-Induced Tree Mortality Reveals Emerging Climate Change Risks for Forests*, 259 FOREST ECOLOGY & MGMT. 660, 666 (2010) [hereinafter *Overview*].

132. A.L. Westerling et al., *Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity*, 313 SCIENCE 940, 941 (2006).

133. A. Park Williams et al., *Forest Responses to Increasing Aridity and Warmth in the Southwestern United States*, 107 PROC. OF THE NAT'L ACAD. SCI. U.S. 21289, 21291 (2010).

134. David M. Theobald & William H. Romme, *Expansion of the US Wildland–Urban Interface*, 83 LANDSCAPE & URB. PLAN. 340, 347 (2007).

135. *See* Robert L. Beschta et al., *Adapting to Climate Change on Western Public Lands: Addressing the Ecological Effects of Domestic, Wild, and Feral Ungulates*, 51 ENVTL. MGMT. 474, 474 (2012) ("Removing or reducing livestock from large areas of public land would alleviate a widely recognized and long-term stressor and makes these lands susceptible to the effects of climate change.").

136. *See generally* Schoennagel, et al., *supra* note 133.

137Audio tape: Daniel G. Neary, 2nd International Wildland Fire Ecology and Fire Management Congress: Post-Wildfire Watershed Flood Responses, (Nov. 17, 2003), *available at* https://ams.confex.com/ams/FIRE2003/techprogram/paper_65982.htm.

wildfire and post-fire costs, the Cerro Grande Fire, near the City of Los Alamos, was estimated to cause approximately $1 billion in damages.[138]

3. Climate Change and Drought

As described *supra*, humans have profoundly altered the water distribution, landscape, and ecosystems of the MRG. Current hydrologic analyses project that the impact of each of these changes will be exacerbated by the impacts of global climate change on this already overstressed system.[139] These changes are expected to decrease overall water supplies, increase water demand from local agriculture and other outdoor uses due to higher temperatures, and intensify both droughts and floods.[140] Longer growing seasons will put additional moisture stress on our forests, while increasing the survival of the bark beetles that have been preying on them.[141] Impacts of droughts and floods on human communities have been increasing in recent years, and these increasing trends are expected to continue.[142]

C. Key Interactions and Thresholds.

The system elements discussed *supra* are obviously only part of the complex and dynamic SES known as the MRG. The social elements described—the establishment of dams and levees, historically based and narrowly construed water supply allocation regimes and water operations, and increasing tensions between agricultural and municipal uses—highlight some of the basic characteristics that make water governance challenging in this basin. The ecological elements discussed—impacts of channelization, stresses on upland forest systems, and climate change and drought—begin to provide a conceptual model of the ecology of the MRG. One advantage of using resilience theory to understand the MRG is that it emphasizes the dynamics *between* various elements of the SES, with particular emphasis on key interactions between the elements that comprise the watershed's system dynamics. Based on the necessarily cursory description of the social-ecological system elements above, we have identified three key interactions that have an important impact on the MRG's identity: impending transformation of the Bosque, changes to the system's hydrograph, and regime change in the upland forest system.

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138. *FIRE MANAGEMENT: Lessons Learned From the Cerro Grande (Los Alamos) Fire: Hearing Before the S. Comm. on Energy and Natural Res.*, 106th Cong. 1 (2000) (statement of Barry T. Hill, Associate Director, Energy, Resources, and Science Issues, Resources, Community, and Economic Development Division).

139*See supra* Part IV.

140. *See* Reclamation Secure Water Act Report, *supra* note 96.

141. Kenneth F. Raffa et al., *Cross-Scale Drivers of Natural Disturbances Prone to Anthropogenic Amplification: The Dynamics of Bark Beetle Eruptions*, 58 BIOSCIENCE 501, 504 (2008); Scott H. Black et al., *Do Bark Beetle Outbreaks Increase Wildfire Risks in the Central U.S. Rocky Mountains? Implications from Recent Research*, 33 NAT. AREAS J. 59, 59–61 (2013).

142. *See* Randy Showstack, *Concerns About Extreme Weather Focus on the Need for Better Resilience*, 95 EOS 69, 69–70 (2014) (noting that "[w]eather disasters with damages exceeding $1 billion each have hit the United States 151 times since 1980, and federal disaster declarations have increased from 65 in 2004 to 98 in 2012 . . . .").

1. Bosque Transformation: Cottonwood Die-off.

The interactions between channelization, decreased water availability, and climate change are pushing the Bosque to an ecological system threshold. Although the Bosque in its current condition may appear to be a natural and healthy ecosystem, this condition actually represents a highly modified environment that, while currently in a quasi-stable state, is unlikely to persist in the future. The MRG Bosque is currently composed of an extensive cottonwood gallery forest with areas of invasive woody and forb species, interspersed willow thickets and wetlands, and some open meadows.[143] The current state of the Bosque is the direct consequence of the myriad of modifications that have been made to the watershed, river and floodplain, and streamflow regime.[144] These alterations have stabilized the floodplain and channel banks and shifted the system from a braided mosaic of complex channel features and diverse vegetation towards its current quasi-stable condition.[145]

The existing structures and functions of the Bosque cannot be sustained under current conditions.[146] The current flow regime and channel/floodplain conditions do not support the hydrologic conditions (overbank flooding and gradual recession) required for widespread cottonwood recruitment.[147] Current conditions are more conducive to invasive species that are less tolerant to the native disturbance regime, which has been engineered out of the system.[148]

Alternative future conditions for the Bosque will depend on management and engineering decisions. Current ecosystem restoration strategies focus on site treatments such as construction of side channels, bank lowering, planting of willow swales, and island destabilization.[149] A decade of experimentation has shown that these approaches can be successful for restoring habitat within the restoration project.[150] However, the feasibility of implementing such projects at the landscape scale and the long-term sustainability of these efforts are still in question in the Rio Grande and other river systems.[151] The restoration of a flow regime that supports the recovery of natural processes is not currently under consideration due to constraints in water management, flood risks, and concerns about meeting terms of the Rio Grande Compact.[152] However, restoration of a more naturalized hydrograph

143*See* Taylor et al.,, *supra* note 109, at 372.

144. William L. Graf, *Downstream Hydrologic and Geomorphic Effects of Large Dams on American Rivers*, 79 GEOMORPHOLOGY 336, 340 (2006).

145. Benjamin J. Swanson et al., *Historical Channel Narrowing Along the Rio Grande Near Albuquerque, New Mexico in Response to Peak Discharge Reductions and Engineering: Magnitude and Uncertainty of Change From Air Photo Measurements*, 36 EARTH SURFACE PROCESSES & LANDFORMS 885, 894–95 (2011).

146. Molles et al., *supra* note 115, at 754.

147. *Id*. at 753.

148. *See* Stromberg, *supra* note 120, at 18.

149. *See* TETRA TECH EM, *supra* note 73, at 12.

150. Ondrea Hummel & Todd Caplan, *Evaluating Restoration Success and Applying Adaptive Management in the Middle Rio Grande Bosque*, *in*. 2009 ANNUAL MEETING OF THE ECOLOGICAL SOCIETY OF AMERICA1, 4 (2009), *available at* http://precedings.nature.com/documents/3649/version/1/files/npre20093649-1.pdf.

151. M.A. Palmer, et al., *Standards for Ecologically Successful River Restoration*, 42 J. OF APPLIED ECOLOGY 208, 211 (2005).

152. *See supra* note 47–50 and accompanying text.

holds greater promise for at least maintaining current Bosque conditions, if the above constraints can be addressed.

2. Changes in Hydrograph: Earlier Peak Runoff and System Dynamics.

Climate change is causing the peak spring runoff in the MRG to occur earlier in the calendar year, and the portion of the year in which snowpack can be maintained is decreasing. Snowmelt runoffs are occurring one to three weeks sooner in many portions of the American West, and these trends are projected to continue.[153] Many ecological events, including annual species reproduction, are tied to these spring runoff events, often in concert with other cues, such as the length of the day, or the timing of an insect hatch. For example, the timing of seed dispersal for various riparian plant species, such as cottonwoods and willows, is synchronous with the occurrence of peak river flows during the spring and early-summer seasons.[154] The establishment of riparian species in the Bosque (discussed *supra*) may be further impeded by the occurrence of peak flows before riparian seeds are available for germination.

The endangered Silvery Minnow may also be impacted by a decreasing snowpack and earlier peak runoff.[155] The Silvery Minnow has already suffered due to loss of riverine habitat and inadequate river flows. Reductions in snowpack and earlier spring peak flows will lead to even less available water to support summertime river flows.[156] In addition, because Silvery Minnow spawn during elevated flows, shifts in spring flows have the potential to disrupt spawning patterns and further threaten the species.[157]

Changes in the hydrograph are also affecting the social system. As will be discussed *infra*, built water storage operations may need to play many of the roles natural systems once played. In addition, milder winters and hotter summers are likely to result in longer growing seasons for agriculture and urban landscaping, making for more intense and prolonged demands for water.[158]

3. Regime Changes for Upland Forest Systems.

In the upland forest systems of the MRG watershed, many indicators suggest that we have already crossed a threshold and the forest ecosystems are undergoing a transformation.[159] The main driver of the current changes is wildfire, and the implications have been particularly noticeable in the Jemez Mountains of central New Mexico. When the Cerro Grande fire occurred in the Jemez Mountains in May 2000, it was the second largest fire in New Mexico's recorded history, with a total

153. *See supra* Part IV.C.2.
154. John C. Stella et al., *Synchrony of Seed Dispersal, Hydrology and Local Climate in a Semi-Arid River Reach in California*, 9 ECOSYSTEMS 1200, 1200 (2006).
155. *See* TETRA TECH EM, *supra* note 73, at 7.
156. David E. Cowley., *Strategies for Ecological Restoration of the Middle Rio Grande in New Mexico and Recovery of the Endangered Rio Grande Silvery Minnow*, 14 REVS. FISHERIES SCI. 169 (2010), *available at* http://www.tandfonline.com/doi/abs/10.1080/10641260500341619#preview.
157. *Id*.
158. *See* RECOVERY PLAN *supra* note 73, at 38.
159. *See supra* Part IV.B.2.

burn area of 47,650 acres; today, it ranks as the twentieth largest wildfire.[160] The 2011 Las Conchas Fire is now the second largest in New Mexico state history at 156,000 acres burned. It is the largest ever recorded in the Rio Grande watershed.[161] The combination of bark-beetle infestation, drought, and fire will have profound hydrological impacts.[162]

V. CONCLUSIONS AND IMPLICATIONS FOR MANAGERS.

As the issues discussed demonstrate, the current resilience of the MRG's water governance strategies is low, and the system operates close to a number of resilience thresholds, most notably the changes in the upland forest system and loss of the cottonwood Bosque. Some of the system's vulnerabilities can be ameliorated by building adaptive capacity and reconfiguring existing legal and institutional frameworks. Others will require a more radical approach involving meaningful participation in the system's transformation from one type of system to another. While there are many complex and overarching implications for managers resulting from the social and ecological processes discussed *supra*, this section presents five categories of recommendations for management changes that are needed to increase the adaptive or transformative capacity of the MRG.

A. Recommendation 1: Develop More Flexible and Adaptive Strategies for Water Storage and Delivery.

The MRG is a highly managed hydrological system. The construction and operation of its many dams, reservoirs, and levees, along with channelization activities, have lowered the overall functional diversity of the river system through channel simplification and bed degradation, with implications for both riverine and riparian habitats.[163] In light of the system changes that have been made, as well as the developing hydrologic changes resulting from climate change, much of this built infrastructure is now needed to play part of nature's role. For example, the dams can be operated to release high flows that support the life cycle of native aquatic and riparian species, including endangered species, while also providing water for agricultural and municipal users.

The earlier peak runoffs that the system is beginning to experience will require more nuanced and intensive water management, including adaptive capacity in the form of more management flexibility for Reclamation and the Corps, which operate the major reservoirs in the basin. All of the water projects managed by

160. *See Federal Fire Occurrence*, U.S. DEP'T INTERIOR, http://wildfire.cr.usgs.gov/firehistory/data.html (last visited Jan. 12, 2015).

161. *See Bandelier National Monument: The Las Conchas Fire*, NAT'L PARK SERVICE, http://www.nps.gov/band/naturescience/lasconchas.htm (last visited Jan. 12, 2015). The Las Conchas Fire was dwarfed the following year in a different watershed by the Whitewater-Baldy Fire in the Gila Wilderness, which burned 297,845 acres. *See* Cally Carswell, *New Mexico on Fire*, HIGH COUNTRY NEWS (June 4, 2013), http://www.hcn.org/blogs/goat/new-mexico-on-fire.

162. *See generally* Lindsay A. Bearup, Reed M. Maxwell, David W. Clow & John E. McCray, *Hydrological Effects of Forest Transpiration Loss in Bark Beetle-Impacted Watersheds*, 4 NATURE CLIMATE CHANGE 481 (2014), http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate2198.html#access.

163. *See supra* Part IV.B.1.

these two agencies have significant operational constraints, which are summarized in Table 1. Generally, these dams are authorized for flood control or water storage, but not both.[164] They also have limits on the amount of water that can be stored at a given time, regardless of the dam's actual physical capacity. In addition, releases are restricted due to designated safe channel capacities downstream of the dams, which are generally lower than the releases that would be required to achieve over-bank flows.[165]

Such changes are possible. Operations of Cochiti reservoir by the Corps in 2007 and 2010 included "deviations from standard protocols which allowed temporary storage of water for peak flow events to support the life cycle of the Silvery Minnow."[166] Such operations provide an example of how more management flexibility could benefit the system. Currently, this reservoir is operated almost exclusively for flood control, and "deviations" have occurred on only two occasions. If management parameters were reconfigured to allow for temporary storage on non-flood waters and associated pulse releases, reservoir operations could potentially support cottonwood regeneration and spawning by Silvery Minnow.[167]

Reclamation's dams and reservoirs also have significant operational restrictions. Heron Reservoir, which stores a portion of New Mexico's allocation under the Colorado River Compact, allocates water to its contractors annually, and unless a waiver is granted by Reclamation,[168] the water must be evacuated from the reservoir by the end of the calendar year.[169] Storage in El Vado Reservoir, which is operated jointly by Reclamation and MRGCD, is subject to restrictions under the Rio Grande Compact.[170] The institutional constraints on these federal reservoirs are historically based, reflecting the social needs of the time as well as the ecological assumptions held by water managers when the dams were constructed or the laws were written. Many of these assumptions, however, are now known to be invalid, and our current system of dams and reservoirs could be utilized more effectively if existing management constraints were made more adaptive.

There are a number of ways in which a change in the operational flexibilities of the federal reservoirs in the MRG could enhance system resilience through in-

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164. The reservoirs owned and operated by the Corps, including Abiquiu, Cochiti, Jemez, and Galisteo Dams, are authorized for flood control, but with the exception of the right to store San Juan-Chama Project water and possibly some native water if needed, are generally not authorized for water storage once flood-control operations have ended. *See* Susan Kelly, *New Mexico's Major Reservoirs: An Overview*, *in* WATER MATTERS!, *supra* note 33, at 19-4 to -10; *see also supra* note 47–50 and accompanying text regarding Rio Grande Compact.

165. *See* TETRA TECH EM, *supra* note 73.

166. JOINT BIOLOGICAL ASSESSMENT, *supra* note 72, at 133–35.

167. Susan Kelly, *Modeling Reservoir Storage Scenarios by Consensus*, 47 NAT. RESOURCES J. 653, 666 (2007).

168. Susan Kelly, *New Mexico's Major Reservoirs: An Overview*, *in* WATER MATTERS!, *supra* note 33, at 19-4 to -10.

169. Waivers are granted only when determined to be when that waiver is deemed to be beneficial to the government. *See* Flanigan & Haas, *supra* note 44, at 375 (citing U.S. DEP'T OF THE INTERIOR, BUREAU OF RECLAMATION, UPPER RIO GRANDE BASIN WATER OPERATIONS FINAL ENVIRONMENTAL IMPACT STATEMENT 11-5 (2007)).

170. These include storage restrictions or required releases at times that New Mexico is unable to meet its Compact delivery requirements, as well as (under Article VII of the Compact) prohibition of storage in times in which the available supply for the downstream Rio Grande Project is below a specified lower limit, and no relinquished Compact credits are available to New Mexico. *See* Susan Kelly, *New Mexico's Major Reservoirs: An Overview*, *in* WATER MATTERS!, *supra* note 33, at 19-4 to -10.

creased adaptive capacity. In general, the objectives of additional operational flexibility would be: (1) avoid storage of water in the more downstream Elephant Butte Reservoir, from which evaporation rates are extremely high, in favor of more upstream reservoirs, within which a higher proportion of stored water could be used for human and ecological purposes, and (2) the release of flows in a way that mimics the historical natural hydrograph for this basin, which is dominated by a pronounced spring (May or June) snowmelt runoff.

Article VII of the Rio Grande Compact prohibits upstream storage for use in the MRG at times when there is insufficient storage for use in the downstream Rio Grande Project, which begins at Elephant Butte Reservoir and extends through El Paso into Western Texas.[171] Article VII is therefore in effect during drought.[172] Additional flexibilities to Article VII restrictions could allow for storage of water upstream when New Mexico has met its Compact delivery requirements for a given year. Such changes could avoid storage in the highly evaporative Elephant Butte Reservoir, if New Mexico, Texas, and Colorado can come to an agreement on compact compliance.[173]

Additional management flexibilities could be achieved if the MRG water managers were able to rethink the concept of storage to include groundwater storage, storage within the infrastructure of the irrigation network, and temporary storage within functional riparian habitats. Some of these management constraints may be addressed through regulatory changes, while others, specifically with regard to operation of federal reservoirs, will require congressional amendment.

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171. Susan Kelly, *New Mexico's Major Reservoirs: An Overview*, *in* WATER MATTERS!, *supra* note 33, at 19-6 to -7.

172. Such an operation is being performed on a trial basis in the MRG in 2014. U.S. BUREAU OF RECLAMATION, 2014 ANNUAL OPERATING PLAN APRIL 1 RUNOFF FORECAST (2014), *available at* http://www.usbr.gov/uc/albuq/water/aop/2014AOP.pdf. In general, the prohibition on storage during these drought times allows for a more naturalized hydrograph, since the snowmelt runoff must be passed downstream, rather than be stored in reservoirs upstream. *See generally* William A. Paddock, *The Rio Grande Compact of 1938*, 5 U. DENV. WATER L. REV. 1 (2001) (providing detailed discussion of compact requirements). However, storage of water to meet the Prior and Paramount water needs of the Six Middle Rio Grande Pueblos, as well as for non-Indian irrigation if New Mexico has relinquished Compact credits to allow this storage, minimize this effect. *See id*. Because of this allowed storage, the small snowmelt runoffs that occur in times of drought may not create a significant pulse in the MRG. *See id*. Therefore, additional operational flexibilities that allow for temporary storage in Rio Chama reservoirs under Article VII conditions, so that releases can be made that are timed with the runoff on the main stem, could help restore these pulses. *See id*. In addition, changes to the operational rules of Reclamation's Heron Reservoir to allow storage of contracted water past December 31, so it can be released in the following spring, could further support spring pulses in the MRG. *See id*. Finally, authorization under the Rio Grande Compact for the storage, in Abiquiu or Cochiti Reservoirs, of water that has been stored to meet the needs of lands on the Six MRG Pueblos with Prior and Paramount water rights but was not needed during the irrigation season, could allow this water to support spring pulse flows as well. *See generally id*.

173. The restoration of a spring snowmelt runoff in the MRG cannot be achieved through changes to Rio Chama reservoirs alone, especially because of the channel capacity of only 1,800 cubic feet per second in the river reach below Abiquiu Reservoir, the downstream-most reservoir on the Rio Chama. Changes to the management parameters of the only federal MRG reservoir on the Rio Grande main stem would be required as well. If temporary storage of native and imported waters from the Rio Chama and the main stem were allowed, they could be released in a planned pulse, which could support both for native riparian regeneration and spawning by native fish, including the endangered Rio Grande Silvery Minnow.

B. Recommendation 2: Reexamine Water Allocation Strategies and Approaches.

While more modern water storage and release parameters for the MRG reservoirs could add some operational flexibility, rethinking *how* water is allocated could provide significantly larger benefit to the adaptive capacity of the system. We recommend that practical alternatives to the prior appropriation doctrine—technically the law is impractical in the MRG due to the lack of an adjudication—be developed to create a realistic system of water administration. In the MRG, the only form of priority administration that is frequently practiced is the allocation of water to the lands of the six MRG Pueblos with "prior and paramount" rights prior to the allocation to non-Indian water-rights holders.[174] The remaining surface water rights have not been quantified, nor have they been assigned priority dates though an adjudication process. Water is typically distributed according to various shortage-sharing arrangements.[175]

In addition, prior appropriation doctrine in New Mexico applies to both surface and groundwater, and in the MRG both are managed conjunctively based on a determination by the State Engineer that conjunctive management is necessary to protect senior water-rights holders.[176] However, these water rights are generally surface water rights, and as a practical matter, groundwater rights can be exercised long before the effects of the pumping are felt on surface waters. This makes it difficult for senior users to prove injury or make a "call" for water under a conjunctive, priority-based management approach. In short, priority administration is impractical and should be reexamined. Interestingly, this idea may be gaining ground in New Mexico among water experts.[177]

Next, the governance of land and water use must be more integrated to address what has been described as the "governance gap."[178] In 1995, the New Mexico Legislature amended the Subdivision Act to include a requirement that county boards of supervisors adopt regulations setting forth requirements for water conservation.[179] The New Mexico Office of the State Engineer was authorized to examine proposed subdivisions in unincorporated areas to make sure that county plans fulfill the anticipated maximum water requirements, including water demand and water

174. *See supra* notes 50–54 and accompanying text.

175. *See* Paul Bossert, *Active Water Resource Management*, *in* WATER MATTERS!, *supra* note 33, at 11-1, 11-4. In other parts of New Mexico, the State Engineer is implementing Active Water Resource Management in lieu of priority administration under an adjudication, however, such administration has yet to be initiated in the MRG. *See generally id*., at 11-1 to -6.

176. Stephanie Tsosie, *New Mexico Water Law Case Capsules*, *in* WATER MATTERS!, *supra* note 33, at 2-1, 2-3.

177. *See generally* N.M. WATER RES. RESEARCH INST., *58th Annual New Mexico Water Conference, New Water Realities: Proposals for Meaningful Change*, http://2013.wrri.nmsu.edu (last visited Jan. 17, 2015) (describing general conference information. At the most recent meeting of the New Mexico Water Resources Research Institute (WRRI) in Albuquerque in November 2013, there was considerable discussion of the inappropriateness of the Prior Appropriation Doctrine in the Middle Rio Grande's unadjudicated water distribution system. Specific presentations included "Is Prior Appropriation Dead?" by Em Hall, retired professor of Law, University of New Mexico, and "Priority Administration" by Dudley Jones from the Carlsbad Irrigation District.)

178. *See generally* Bates, *supra* note 90, at 63.

179. N.M. STAT. ANN. § 47-6-9 (West 2014); *see also* Consuelo Bokum & Katherine Yuhas, *Water Conservation*, *in* WATER MATTERS!, *supra* note 33, at 8-1, 8-2.

availability over a 40-year planning period.[180] But in 1997, the legislature undermined this process with an amendment that allows county commissions to approve a subdivision against the Office of the State Engineer's recommendation, eliminating an opportunity for some regulatory control over the demands urban growth places on the water system.[181]

The state of New Mexico has even less control over agricultural uses of water. Water rights are held and irrigation is practiced by individual farmers who select the crops that are grown on their lands and the irrigation methods. Most of the agricultural land in the MRG is growing alfalfa, a relatively water-consumptive crop, with flood irrigation techniques, a relatively inefficient water delivery strategy. Current incentives support these approaches. Because priority administration is impractical due to the lack of water-rights adjudication, all farmers (with the exception of those on the Prior-and-Paramount lands of the Pueblos) share equally in shortages, and therefore cannot be assured of a sufficient supply to bring a crop to harvest. Alfalfa, which provides yield throughout the season and goes dormant when watering ceases, is therefore the crop that offers the lowest risk. With a different form of water administration, some farmers may be incentivized to grow higher-value crops, and therefore water them with more water-efficient technologies than flood irrigation. As discussed *supra*, the prior appropriation doctrine's forfeiture provisions create a general disincentive for water efficiency and conservation strategies.[182]

Finally, New Mexico's current laws and regulations regarding environmental flows need to be strengthened. Currently, the state does not have official statutory recognition of water rights for in stream purposes.[183] In 2005, the state legislature enacted the Strategic Water Reserve, which *implicitly* recognized that water for fish and wildlife is a beneficial use under New Mexico law by authorizing the Interstate Stream Commission to use reserved water or water rights to benefit listed species and to avoid additional listings of species.[184] "That same year, the [State Engineer] amended the regulatory definition of 'beneficial use' to include 'fish and wildlife.'"[185] During the past several years, water has been leased by Reclamation from the Water Authority to keep water in stream to support the Silvery Minnow.[186] This program supported river flows at times in recent years when the river might other-

180. Bates, *supra* note 90, at 81.

181. *See* Paul Bossert & Sarah Armstrong, *Domestic Wells*, *in* WATER MATTERS!, *supra* note 33, at 12-1, 12-3.

182. *See* Consuelo Bokum & Katherine Yuhas, *Water Conservation*, *in* WATER MATTERS!, *supra* note 33, at 8-6.

183. Beth Bardwell & Adrian Oglesby, *Water for New Mexico Rivers*, *in* WATER MATTERS!, *supra* note 33, at 17-3 ("From 1955 to 1990, New Mexico State Engineer Steve Reynolds held steadfastly to the opinion that appropriation of surface water under New Mexico law was dependent upon a diversion of water. During Reynolds' tenure, grassroots efforts to obtain legislative approval for a 'non-diversionary' instream flow program failed to secure passage. In 1998, the Attorney General of New Mexico issued an opinion stating there is nothing in the New Mexico constitution, statutes or case law barring the State Engineer from approving an application to change the purpose of use of an existing water right to instream flow.").

184. *Id*. at 17-4 (citing N.M. STAT. ANN. §72-14-3.3(B)(2) (2005)).

185. *Id*. (stating "[i]n 2008, the [New Mexico Interstate Stream Commission] utilized the Strategic Water Reserve for the benefit of a listed species for the first time").

186. Brigette Buynak & Stefani Tsosie, *Strategic Water Reserve*, *in* WATER MATTERS!, *supra* note 33, at 29-1, 29-6.

wise have been dry. However, it represents a short-term solution to a long-term problem. Water available for lease to this program is becoming increasingly scarce, as Santa Fe, Albuquerque and other San Juan Chama Project contractors are now using their allocations and no longer offering them for lease.[187] We recommend that New Mexico follow the example of other western states and authorize permanent transfers of water rights for environmental flows.[188]

In sum, New Mexico's approach to water administration is in a rigidity trap: its institutions "become highly connected, self-reinforcing, and inflexible."[189] While the capacity for water transfers provides some flexibility, these actions take place in a piecemeal fashion (one transaction at a time) and are primarily driven by the economic concerns of individual actors or the temporary needs of endangered species. What is needed is more transformative—an institutional capacity to address the SES needs at the watershed scale at the pace and scale necessary to provide a meaningful response to the challenges to come. New Mexico's Active Water Resource Management rules may hold promise in this respect, but these rules are not currently being employed in the MRG.[190] One possible approach to creating more adaptive capacity is to move from a permit-based system to a license-based system for water administration. Water licenses subject to five-year renewal would allow managers to revisit water allocation decisions, reevaluate whether water is being beneficially used, and provide a mechanism for the state to require more efficiency and less waste. Prior appropriation's beneficial use requirement could be employed in ways that still honors the constitutional and statutory elements of the doctrine. A water right is a usufructuary, subject not only to regulation but also subject to the public trust.[191]

C. Recommendation 3: More Aggressively Manage Both the Bosque and Upland Forest Systems in the MRG Watershed.

Both the Bosque and the MRG's upland forest systems are at critical ecological thresholds. Effective management will need to include building sufficient adaptive capacity for managing these systems under the anticipated hydrologic conditions. In the case of the Bosque, the current, even-aged cottonwood stands are

187. *See Allred and Johnson Nominations: Hearing Before the Comm. on Energy and Natural Res.*, 109th Cong. 36 (2006), *available at* http://www.gpo.gov/fdsys/pkg/CHRG-109shrg32519/pdf/CHRG-109shrg32519.pdf. There are currently proposals in Congress to encourage an agricultural water-leasing program in the MRG to help maintain environmental flows. *See* S. REP. NO. 113–47, at 66–75 (2013) (highlighting the Energy and Water Development Appropriation Bill 2014).

188. *See* Kyle Jackson, A Survey of Western United States Instream Flow Programs and The Policies that Protect a River's Ecosystem 18–19, (2009) (undergraduate student thesis, University of Nebraska at Lincoln), *available at* http://digitalcommons.unl.edu/envstudtheses/28 (last visited Jan 15, 2015).

189. Stephen R. Carpenter & William A. Brock, *supra* note 44.

190. Paul Bossert, *Active Water Resource Management*, *in* WATER MATTERS!, *supra* note 33, at 11-3 ("The AWRM regulations broaden and formalize the Office of the State Engineer's (OSE) use of water districts and water masters to manage the state's waters. A water master is an appointed local administrator with the full authority of the State Engineer within the district. Water masters use measuring and metering and district-specific rules to administer and protect water rights.").

191. *See* Reed D. Benson, *So Much Conflict, Yet So Much in Common: Considering the Similarities Between Western Water Law and the Endangered Species Act*, 44 NAT. RESOURCES J. 29, 34 (2004). For commentary regarding elements of the prior appropriation doctrine that go unenforced, *see* Charles F. Wilkinson, *In Memoriam: Prior Appropriation 1848-1991*, 21 ENVTL. L., at v, xvi (1991).

reaching the end of their natural lifecycle.[192] For cottonwoods to continue to be a predominant element of the Bosque, management will be needed that supports cottonwood regeneration, while discouraging invasive species growth and minimizing wildfire risk. Without major reform of current practices, the cottonwoods that are in the Bosque today will die and not be replaced by younger cottonwood trees, and the Bosque will be susceptible to fire and invasive species.[193] For example, if the river could be modified such that water could safely flow in overbank areas, and water could be released from reservoirs in a way that provides overbank flows in the Bosque, cottonwoods could regenerate, and provide complexity and increased stability to the system. As the Rio Grande Vision project discussed *supra* demonstrates, the Bosque is a significant piece of the City of Albuquerque's ecological and social identity.[194] Without more meaningful consideration of the management challenges ahead, the impeding ecological threshold of cottonwood die-off will lead to a regime change in which large cottonwood trees are no longer a dominant species of the MRG's riparian system and invasive species become the most likely succession species.

The forest uplands of northern New Mexico provide an example for which building the resilience of the current system is no really longer an option. Instead, management must focus on the ecological transformation that is underway. Drought, climate change, and bark beetles are transforming the system from a pine-dominated landscape to one dominated by other types of vegetation, including scrub oak and grasses. That new dominant vegetation *can* be managed—if managers are willing and able to have transparent discussions with the public regarding the changes to come. For example, in many parts of the watershed, likely candidates for species succession include scrub oak and aspen. While most managers would agree that aspen is the more desirable species, successful aspen establishments will require stronger, more effective management of species that browse on aspen seedlings and bark. This implicates not only overpopulations of elk in many portions of the watershed, but also federally permitted cattle grazing practices. Changes to these practices might be required to allow the forest transformation we desire.[195]

The effective management of resources within the watershed, including wildlife and pests such as the bark beetle, is key to the MRG's health, water supply, and water quality. Some steps are being made toward more effective management, and are beginning to address the underlying drivers for increased fire risks in the upland forests of the MRG watershed, as large-scale fuel reduction (thinning and controlled burns) programs have been initiated,[196] including the South Jemez Moun-

192. *See supra* Part IV.C.1.

193. *See supra* Part IV.B.

194. *See* DEKKER ET AL., *supra* note 71.

195Current grazing practices are creating "dust on snow" events that speed up snowpack runoff. *See generally* Ann C. Bryant et al., *Impact of Dust Radiative Forcing in Snow on Accuracy of Operational Runoff Prediction in the Upper Colorado River Basin*, 40 GEOPHYSICAL RES. LETTERS, 3945, 3945 (2013); J. S. Deems et al., *Combined Impacts of Current and Future Dust Deposition and Regional Warming on Colorado River Basin Snow Dynamics and Hydrology*, 17 HYDROL. EARTH SYST. SCI. 4401, 4411 (2013).

196. See Courtney A. Schultz, Theresa Jedd & Ryan D. Beam, R. D., *The Collaborative Forest Landscape Restoration Program: A History and Overview of the First Projects*, 110 J. OF FORESTRY 381, 384 (2012).

tains Restoration Project.[197] Another example is the City of Santa Fe's municipal water user fee to collect funds for watershed protection that has resulted in $7 million in forest treatments.[198] In addition, federal programs authorized under the SECURE Water Act of 2009,[199] including the Landscape Conservation Cooperatives and the Basin Study Program, include participation from local and state governments and nongovernmental organizations, and are designed to combine scientific information and resource management in order to develop climate adaptation strategies within a specific landscape.[200] Similarly, Basin Studies are partnerships between Reclamation and local water management entities to develop adaptations to the projected impacts of climate change in the major river basins of the Western U.S.[201] More locally, the San Juan-Chama Watershed Partnership was recently formed to address the emerging threats to the watershed from fire and forest mortality from insects and disease.[202] These efforts represent the types of actions that will be required as MRG water managers prepare for the regime shifts that are underway, and that are still to come. However, in order for implementation of forest treatment programs to take place on a meaningful scale at the required pace, stakeholders will need to make much more of an investment, both financially and institutionally. In general, other stressors on the forest system, such as extended drought, climate change, and forest die-off, are not currently being addressed at the watershed scale. The City of Santa Fe's efforts to protect their portion of the watershed provide a potential model for the MRG. The Nature Conservancy is leading a recent effort to do just that via a program called the Rio Grande Fund.[203] This is a collaborative project that includes the various stakeholders in the MRG seeking to generate the funding necessary to conduct a large-scale forest treatment and watershed restoration program over a ten to thirty year period.[204] They estimate that $21

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197. U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, PROPOSED ACTION FOR SOUTHWEST JEMEZ MOUNTAINS RESTORATION 1 (2012), *available at* http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5379537.pdf.

198. Ellis Q. Margolis & Jeff Balmat, *Fire History and Fire–Climate Relationships Along a Fire Regime Gradient in the Santa Fe Municipal Watershed, NM*, 258 FOREST ECOLOGY AND MGMT. 2416, 2417 (2009); *see also Municipal Watershed Plan*, CITY OF SANTA FE, http://www.santafenm.gov/municipal_watershed_plan (last visited Jan. 17, 2015).

199. *See* Reclamation Secure Water Act Report, *supra* note 96.

200. The Landscape Conservation Cooperatives are collaborative, intergovernmental programs coordinated by the Fish and Wildlife Service, with assistance from other agencies, including Reclamation in the Desert and Southern Rockies landscapes covering the MRG. *See Landscape Conservation Cooperatives: Frequently Asked Questions* 1, U.S. FISH & WILDLIFE SERVICE (Feb. 2012), http://www.fws.gov/landscape-conservation/pdf/LCC_FAQs_2012.pdf (last visited Jan. 17, 2015).

201. *See Basin Studies*, U.S. BUREAU OF RECLAMATION, http://www.usbr.gov/WaterSMART/bsp/index.html (last updated June 9, 2014). The Basin Studies are conducted in locations where: (1) there are BOR projects; and (2) there are existing or projected imbalances between water supply and demand. For each grant project, the BOR partners with a local or state agency and works with it to develop a comprehensive water study and subsequent strategy for meeting future water demands. *See id*.

202. *San Juan – Chama Watershed Partnership*, CHAMA PEAK LAND ALLIANCE, http://chamapeak.org/programs/san-juan-chama/ (last visited Jan. 17, 2015) [hereinafter *Chama Watershed Partnership*].

203. *See* THE NATURE CONSERVANCY, EXECUTIVE SUMMARY OF THE RIO GRANDE FUND: COMPREHENSIVE PLAN FOR WILDFIRE AND WATER SOURCE PROTECTION (2014), *available at* http://www.nmconservation.org/RGWF/RGWF_CompPlan_Exec.pdf.

204. *Id*.

million a year—or close to $420 million over the next 20 years—will be needed.[205] This is precisely the type of transformative adaptive capacity needed because it identifies the ecological threshold (upland forest regime change) and creates the capacity for choices among the different trajectories in order to build resilience.

D. Recommendation 4: Develop a New Flood Management Paradigm.

Our final recommendation is to develop a new flood management paradigm. Conventional flood management frameworks, which are based on an expectation of hydrologic stationarity, need to be recast and made more adaptive in order to consider new challenges of shifting hydrologic conditions.[206] The most recent Intergovernmental Panel on Climate Change makes it clear that regional precipitation and flooding patterns are becoming more intense and frequent compared to previous decades.[207] This trend will likely be conspicuous in the Rio Grande, where the frequency and intensity of floods is expected to increase, impacting flood control operations, ecological resilience, and water quality.[208]

Currently, national flood protection standards recognized by the Federal Emergency Management Agency require that levees meet minimum design standards for protecting public safety.[209] Included in these standards is a requirement that levees are "certified" by a licensed engineer.[210] In regions where the Corps maintains levees or is part of an ongoing Corps-authorized project, the Corps may provide certification through its Levee System Evaluation.[211] Under this framework, the Corps issues a technical finding that demonstrates whether a levee protects a leveed area from the 100-year flooding event.[212]

Protecting the public from flooding risk using the conventional certification framework may not be adequate under new flood regimes. Flood management infrastructure in the MRG currently consists of a system of certified and uncertified levees along the Rio Grande,[213] as well as diversion canals within the city of Albu-

205. *Id*.

206. P.C.D. Milly et al., *Stationarity Is Dead: Whither Water Management?*, 319 SCIENCE 573, 573 (2008).

207. *IPCC Synthesis Result*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE. Synthesis Report 47, 47 (2014), *available at* http://www.ipcc.ch/scripts/_session_template.php?page=_40ipcc.htm.

208. Dagmar Llewellyn & Seshu Vaddey, WEST-WIDE CLIMATE RISK ASSESSMENT: UPPER RIO GRANDE IMPACT ASSESSMENT iv (2013), *available at* http://www.usbr.gov/WaterSMART/wcra/docs/urgia/URGIAMainReport.pdf (prepared for the U.S. Department of the Interior, Bureau of Reclamation as part of its west-wide risk assessment under the Secure Water Act); *see* U.S. Bureau of Reclamation, SECURE WATER ACT SECTION 9503(C)—RECLAMATION CLIMATE CHANGE AND WATER 2011, at 2-3 (April 2011). The Secure Water Act was incorporated into and passed as part of the Omnibus Public Land Management Act of 2009, 123 Stat. 991 (2009), *codified as* 16 U.S.C. §§ 9501-9510. *See* Robin Kundis Craig & Melinda Harm Benson, *Replacing Sustainability*, 46 AKRON L. REV. 841, 867–75 (2013) (discussing Reclamation's work under the Secure Water Act from a resilience-based perspective).

209. *See* 44 C.F.R. § 65.10 (2009).

210. *See id*.

211. *See* U.S. Army Corps of Engineers, Circular, USACE PROCESS FOR THE NATIONAL FLOOD INSURANCE PROGRAM (NFIP) LEVEE SYSTEM EVALUATION 2 (2010) *available at* http://damsafety.org/media/Documents/DownloadableDocuments/ProcessForNFIPleveeSystemEval.pdf.

212. *Id*. This is a key requirement of regulations implementing the Federal Emergency Management Act. *Id*.; 44 C.F.R. § 65.10. (2009).

213. *National Flood Hazard Data for New Mexico Interactive Map*, U.S. FED. EMERGENCY MGMT. AGENCY, http://nmflood.org/MAPS/NFHL (last visited Nov. 9, 2014).

querque.[214] This system of flood protection was not designed to protect against the shorter, but stronger, river flows that may occur in the future. In addition, as heavy precipitation events become more localized,[215] regional infrastructure is unable to protect against small scale, even neighborhood-centric floods.

The paradigm of flood management in the MRG needs to become more flexible and holistic in order to address shifting hydrologic conditions and incorporate other floodplain needs. More emphasis should be placed on localized flooding risk, which may require a shift away from levee certification as the de jure standard for flood protection. Within regional and localized settings, design standards should be evaluated to ensure adequate protection against shorter duration but higher discharge floods.[216]

In addition, our flood management paradigm should be more holistic; the ecological and hydrologic benefits of flooding should be properly managed in conjunction with protecting property from catastrophic events. As discussed *supra*, important ecological processes, such as riparian recruitment, depend on episodic floodplain inundation, and watersheds naturally buffer the effects of flooding if water is allowed to spill into the floodplain.[217] Flood management should take advantage of natural ecological services, such as flood buffering, within regional and localized settings. Increasing the functionality of the natural system to address flooding builds the resilience of the SES. An example of the needed shift from conventional to more holistic approaches in is the newly founded Valle de Oro Wildlife Refuge in the MRG.[218] Management of the refuge includes an interagency effort that will use storm water runoff to restore wetlands in the MRG while also providing an ecologically based approach to floodwater management.

VI. BUILDING ADAPTIVE CAPACITY AND FACILITATING TRANSFORMATION IN THE MIDDLE RIO GRANDE.

All of these implications for managers share several characteristics that highlight additional changes needed in MRG water governance. First, all require a significant commitment of resources beyond what is currently happening in the watershed. Second, they all require collaboration across all scales of governance. And finally, all these recommendations would benefit from the use of adaptive management. To date, the only aspect of water governance that has formally embraced

214. *Maintenance Responsibilities for Drainage Facilities in the Albuquerque Metropolitan Area (Map)*, ALBUQUERQUE METRO. AGENCY FOR FLOOD CONTROL, http://www.amafca.org/documents/Maintenance_Map_2014web.pdf (last visited Jan. 15, 2015).

215. Examples of extreme localized precipitation and flooding occurred between September 10 and 18, 2013, in Bernalillo County, New Mexico. *See Historic Rainfall Event Bernalillo County*, NAT'L WEATHER SERV.,, http://www.srh.noaa.gov/abq/?n=2013SeptemberFlooding-BernalilloCounty (last visited Jan. 15, 2015) (providing the hydrologic records of these events).

216. For example, the agency's levee and embankment construction manual, the U.S. Corps of Engineers' Engineering Manual 1110-2-1913, may need to be updated to provide sufficient protection against floods of shorter duration but higher magnitude. U.S. ARMY CORPS OF ENG'RS, EM 1110-2-1913, DESIGN AND CONSTRUCTION OF LEVEES (2000).

217. Christopher J. Woltemade & Kenneth W. Potter, *A Watershed Modeling Analysis of Fluvial Geomorphologic Influences on Flood Peak Attenuation*, 30 WATER RESOURCES RES. 1933, 1933 (1994).

218. *See Innovative Storm Water Management: Valle de Oro National Wildlife Refuge*, U.S. FISH & WILDLIFE SERV., *available at* http://www.fws.gov/southwest/docs/Valle_de_Oro-factsheet.pdf (last visited Jan. 18, 2015).

the idea of adaptive management is the Collaborative Program's recovery efforts for endangered species.[219] But the challenges for water governance in the MRG go far beyond protection of one or two species. The projected hydrologic conditions of the American Southwest will place stresses on water systems that make the current modes of water management unviable. New water management strategies that promote resilience or support system transformation will need to be tested, learned from and reevaluated, and iterative adjustments will need to be made as the effectiveness of new ideas is learned through experimentation.[220]

Resilience theory allows us to recognize that, when a system's current state cannot or no longer should be maintained, it is time to think about building the transformative capacity necessary to support transition to a desirable alternative state. In the case of the MRG, we conclude that water governance must accommodate regime shifts in upland forest and riparian ecologies, increased stress from climate change and drought, and decreasing water availability. The MRG is a complex SES facing major challenges. The river itself represents the lifeblood of the system, upon which all other social and ecological elements of the system depend. Meeting these challenges will require reconsideration and restructuring of both the MRG's built water systems and its institutional structures of governance.

219. *See supra* notes 73 and accompanying text.

220. Both Reclamation and U.S. Fish and Wildlife Service are in the Department of Interior, which has embraced adaptive management as a primary strategy in watershed facing uncertainty. *See* BYRON K. WILLIAMS, ROBERT C. SZARO & CARL D. SHAPIRO, ADAPTIVE MANAGEMENT: THE U.S. DEPARTMENT OF THE INTERIOR TECHNICAL GUIDE (2009); DEPARTMENT OF THE INTERIOR DEPARTMENTAL MANUAL 522 DM 1 (2008). ("The US Department of the Interior Technical Guide is the technical basis for adaptive decision making for the Department and bureaus. Bureaus should incorporate the operational components identified in the Technical Guide – including the evaluation of success –into internal programmatic guidance as needed to assure appropriate application").