A WETLANDS ACTION PLAN
FOR THE LOWER RIO EMBUDO WATERSHED

December 20, 2024




Compiled and Edited by

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Justification and Credits

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Acknowledgements

This first Wetlands Action Plan (WAP) for the Lower Rio Embudo Watershed carries the voices and informational contributions of many people. It is the product of many years of work between residents of the Lower Rio Embudo Watershed, members of Picuris Pueblo, team members of Ecotone Landscape Planning, and natural resource managers and researchers with state and federal agencies and institutions. The Ecotone team particularly wants to recognize Emily Toczek, Shinya Burke, Jared Wood, Maryann McGraw, and Abraham Franklin of the New Mexico Environment Department; Mark Meyers and Bianca Gonzalez of the New Mexico State Land Office; Talon Newton, Dan Koning, and Stacy Timmons of the New Mexico Bureau of Geology and Mineral Resources; Sage Dunn and Shannon Smith of the Taos Field Office of the Bureau of Land Management; the late Richard Mermejo, Cecilia Shields, and Cynthia Naha representing Picuris Pueblo; and Dr. Severin Fowles of Barnard University. We are also very grateful for the many local residents in the Dixon area who contributed to this WAP, and especially Joseph Ciddio, Rosalia Ciddio, José Luis Ortiz y Muñiz, Robert Templeton, Rachel Exposito, Annette Maestas, Cathy Underwood, Thomas "Tommy" Valdez, the late Horacio Martinez, and Scott Aby. The project's team of field contractors also contributed to our understanding of the wetlands and how we can restore them, and therefore, we want to thank Jamie Tedesco and his team at Wood Sharks, LLC and Jeremiah Kidd and his team of San Isidro Permaculture, Inc. The Ecotone team included Adrienne Rosenberg, Erin McElroy, and Jan-Willem Jansens.

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Abbreviation/Acronym	Description
ac	Acre
ATV	All-terrain vehicle
BLM	US Bureau of Land Management
CBC	Christmas Bird Count
cfs	Cubic feet per second
CWA	Clean Water Act (of 1972, as amended)
CWDG	Community Wildfire Defense Grant
ECR	Ecological Condition Ranking
EPA	US Environmental Protection Agency
EVRAA	Embudo Valley Regional Acequia Association
EVL	Embudo Valley Library and Community Center
FAR	Functional-at risk
FEMA	Federal Emergency Management Agency
ft	Feet
ft2	Square feet
FWS	US Fish & Wildlife Service
HUC	Hydrologic Unit Code
IPaC	Information for Planning and Consultation
ISP	Invasive Species Present
km2	Kilometers squared
NMBGMR	NM Bureau of Geology and Mineral Resources
NMAA	New Mexico Acequia Association
NMDOT	New Mexico Department of Transportation
NMED	New Mexico Environment Department
NMDGF	New Mexico Department of Game and Fish
NM RAM	New Mexico Rapid Assessment Method

Abbreviation/Acronym	**Description**
NMSLO	New Mexico State Land Office
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint source
NRCS	Natural Resource Conservation Service
NWI	National Wetlands Inventory
ORDs	One-rock-dams
ORV	Off road vehicle
PCN	Pre-Construction Notification
PFC	Proper Functioning Condition
PJ	Piñon-Juniper
QAPP	Quality Assurance Project Plan
RA	Rio Arriba
SA	Sampling area
SCOTUS	Supreme Court of the United States (of America)
SGCN	Species of Greatest Conservation Need
Sp.	Spring
SSC	Suspended sediment concentration, mg / L (or ppm)
SSI	Spring Stewardship Institute
STL	State Trust Lands
SWQB	Surface Water Quality Bureau, of the New Mexico Environment Department
TBD	To Be Determined
T&E	Threatened and Endangered (species)
US or U.S.	United States of America
USDA	United States Department of Agriculture
USFS	USDA Forest Service
USGS	United States Geological Survey

Abbreviation/Acronym	Description
WAP	Wetlands Action Plan
WBP	Watershed-Based Plan
WUI	Wildland Urban of Interface

EXECUTIVE SUMMARY

The Wetlands Action Plan (WAP) for the Lower Rio Embudo Watershed aims to describe past and current conditions, explain stressors, outline priorities, and recommend specific actions for the conservation and restoration of the springs and wetlands. The plan also furthers the goals and objectives laid out by the 2019 Watershed-Based Plan (WBP) for the Lower Rio Embudo Watershed. Overall, the WAP's goals are to help community members protect and restore the proper functioning conditions (PFC) of the area's wetlands and springs and to support the integrity of the surrounding landscape and the wellbeing of downstream communities. To do this, the WAP suggests tackling the indirect effects of wetland degradation rather than geophysical or human induced causes. As a note, the Lower Rio Embudo Watershed is within what is known by some as the Embudo Valley area.

The WAP planning area comprises approximately 40 sub-watersheds that flow into the Rio Embudo from the south across an area of 8,141 acres in the far western part of the Lower Rio Embudo Watershed between the confluence of the Cañada de Ojo Sarco (a.k.a. Cañada del Oso) with the Rio Embudo and the confluence of the Rio Embudo with the Rio Grande. These springs and wetlands are spread out between State Trust Lands, BLM lands, and private properties south of the Rio Embudo.

The WAP planning area includes many different types of wetlands, yet the total acreage of all these wetlands is unknown because many have not yet been assessed. In recent field inventories, the BLM surveyed, named, and described at least 37 of these springs and wetlands, which together encompass at least 26 acres. There remains a great shortage of information about the springs and wetlands in the WAP planning area and about the associated human stressors.

For centuries, original Native American and subsequent communities have valued the springs and wetlands in the Lower Rio Embudo Watershed as sources of drinking and irrigation water. The springs and wetlands have also held great spiritual and cultural value for activities such as wildcrafting of plants and wildlife hunting. Presently, the springs and wetlands are of critical importance for regulating functions and societal values, including (a) stabilizing soils and geological formations; (b) promoting ecological habitat functions for the area's wildlife; (c) providing flood control and aquifer recharge; (d) filtering of sediment and other forms of water pollution; and (e) offering economic, cultural, ceremonial, recreational, and agricultural opportunities in the watershed's communities.

Chemical analysis of spring samples revealed that the water is most likely several thousands of years old and originates from the mountainous regions above the Embudo Valley. However, the portion of water that comes from recent rainfall may decrease when the climate becomes drier and hotter, and despite a stable base flow, the total discharge volume from the springs will probably decline over time. Furthermore, the BLM identified that the largest wetland complexes in the area are "functional-at risk" (FAR), which means that they still support the ecosystem and provide the main ecosystem benefits but possess a downward trend in their ability to function.

The wetlands are especially suffering from sudden and prolonged natural impacts, such as drought, flash floods, cumulative channel erosion, and the gradual depletion of habitat quality. Extreme weather impacts compounded by historical and ongoing land-use impacts are major wetland stressors in this landscape and lead to wetland degradation and to flooding in residential areas in the watershed. Erosion of the sandstone canyons contributes to serious, and sometimes extreme, sediment pollution of the Rio Embudo and the Rio Grande waters. Overall, the most important factors that degrade the wetlands are (a) geophysical processes, such as severe drought and flash flooding, which cause abrasion, bank erosion, and sedimentation; (b) human impacts, such as disturbance of plants and soil, free-range livestock grazing, ORVs, and foot traffic; and (c) indirect and cumulative effects, such as invasive plant encroachment, evaporation due to bare soil, or headcutting in channels.

Specific objectives to curb wetland and spring deterioration should mostly address indirect effects, and select human impacts, as they are within an achievable scale. Such objectives include: (a) reducing sediment loads and erosion from drainages and slopes; (b) halting head cuts and channel degradation and successfully raising channel elevations to improve wetland functions; (c) restoring native streamside and wetland vegetation and its associated aquatic and wildlife habitats; (d) removing invasive species where possible; and (e) protecting riparian areas, seeps, springs, and wetlands from off road vehicle impacts and heavy impacts from ungulates.

To achieve the goal of aiding community members to conserve and revitalize the wetlands, the WAP recommends four strategies: (1) conducting assessments and research; (2) implementing physical protection and restoration activities; (3) conducting educational outreach activities; and (4) developing capacity building activities. The document does not recommend prohibiting any grazing, ORV's, and foot traffic from the WAP area as more research is needed to clarify the proportional role and impact of each of these factors.

1. INTRODUCTION

Purpose and Need

The southwestern portion of the Lower Rio Embudo Watershed features a remarkable number of springs and wetlands. They are mostly hidden in the deep canyons of the sandstone landscape. The bright green of cottonwoods leafing out in spring and their bright yellow and gold colors in fall seasonally reveal the presence of the water to Lower Embudo valley residents and visitors. For centuries, the springs and wetlands have profoundly contributed to water quality, water quantity, and community wellbeing. However, the springs and wetlands and the community values they embody have remained mostly undocumented until the last few decades and are being threatened by several stressors within the landscape.

The purpose of this WAP is to further the goals and objectives of the 2019 Watershed-Based Plan for the Lower Rio Embudo Watershed (Jansens, 2019) and document and qualify the wetland stressors which endanger the ecosystem's health and water quality. Overall, the WAP's goals are to support community members in stabilizing, protecting, and restoring the Lower Rio Embudo Watershed wetlands and springs to proper functioning condition. In addition, the WAP seeks to minimize risk and impacts of wetland degradation on the integrity of the surrounding landscape and on the wellbeing of downstream communities. This document creates an actionable plan outlining priorities and specific activities that support its goals.

The 2007 Rio Embudo Watershed Management Plan (Environmental Health Consultants and NMED, 2010) and the 2019 Watershed-Based Plan (Jansens, 2019) are some of the first documents that identified the springs and wetlands as valued features in the Lower Rio Embudo landscape. In recent years, additional studies by the BLM have revealed many details about the springs and the wetlands they feed. While the WBP described the presence of the wetlands and their potential functions in service of reducing sediment pollution and turbidity of the Rio Embudo, more information was needed to implement the WBP recommendations.

The Lower Rio Embudo Watershed WAP was developed as part of the project "Restoring Springs and Wetlands on State Trust Lands in the Lower Embudo Valley" with funding from the US Environmental Protection Agency (EPA) through the NMED SWQB. It builds on the growing awareness about the numerous poorly studied springs and the potential role of these wetlands in sediment retention and nonpoint source pollution reduction. The WAP responds to the 2019 WBP knowledge gaps by providing additional information and a more concrete plan; therefore, this WAP can be considered an amendment to the 2019 WBP.

Additionally, the WAP provides an overview of the location and known status of the seeps, springs, slope wetlands, *ciénegas* (marsh, stable spring fed wet meadow), and riverine wetlands on public and private properties south of the Rio Embudo between the confluence of the Cañada del Ojo Sarco (a.k.a. Cañada del Oso) with the Rio Embudo and the confluence of the Rio Embudo with the Rio Grande. Figure 1 illustrates the location of the Lower Rio Embudo Watershed. As a note, the Lower Rio Embudo Watershed is within what is known by some as the Embudo Valley area.

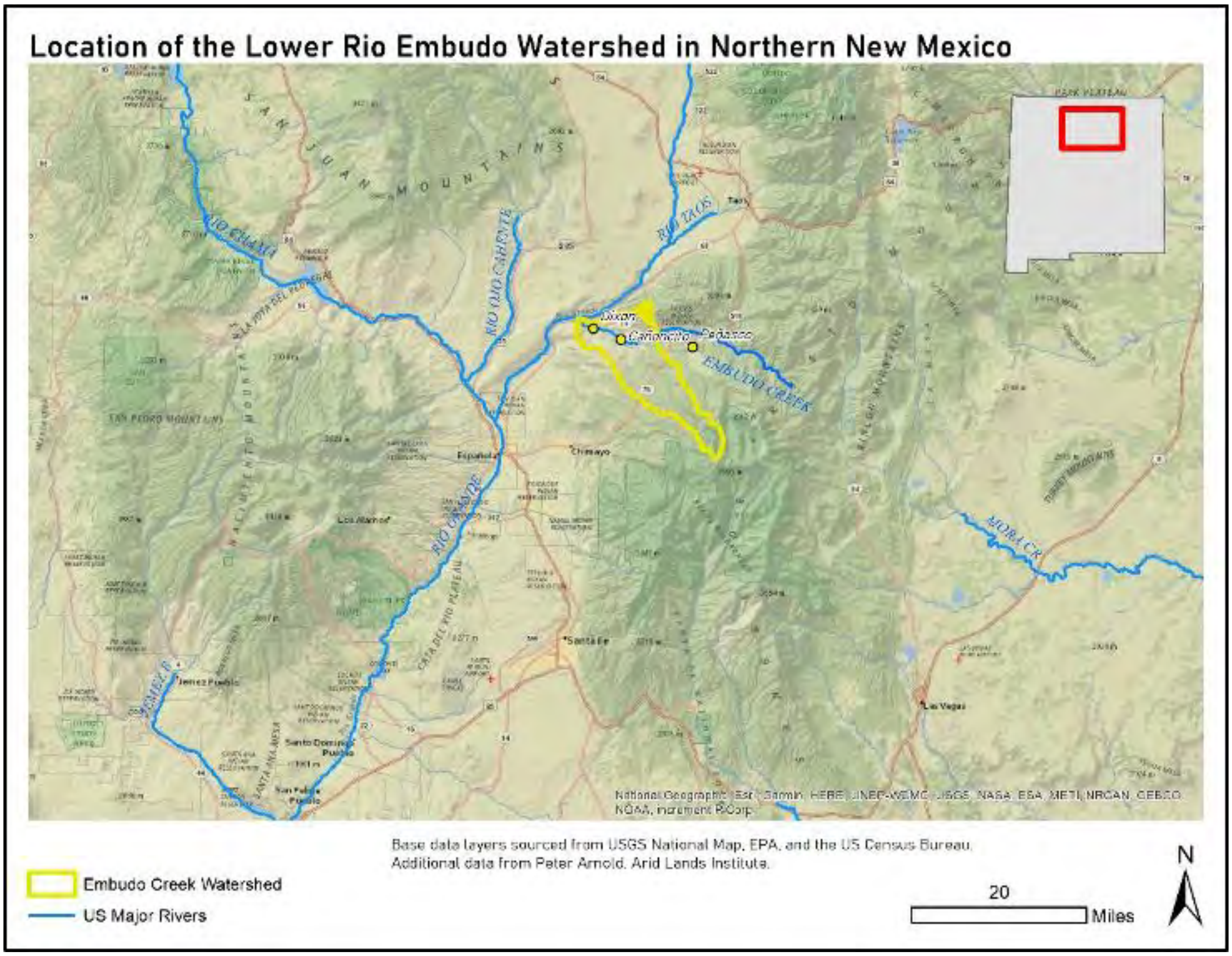

Figure 1. Map of the Lower Rio Embudo Watershed in relation to surrounding towns and roads.

Extreme weather impacts compounded by historical and ongoing land-use impacts are major wetland stressors in this landscape and lead to wetland degradation. Erosion of the sandstone canyons contributes to serious, and sometimes extreme, nonpoint source pollution of the Rio Embudo and the Rio Grande. Yet, the springs and wetlands are of critical importance for (a) stabilizing soils and geological formations; (b) promoting ecological habitat functions for the area's wildlife; (c) providing flood control and aquifer recharge; (d) filtering of sediment and other forms of water pollution; and (e) offering economic, cultural, ceremonial, recreational, and agricultural values in the watershed's communities (Figure 2). This WAP offers objectives and strategies to protect and restore the wetlands and springs and encourage their proper functioning conditions.

Additionally, the development of this plan included a notable amount of community input. Ecotone's WAP development team met with and surveyed residents to understand what community members value about the springs and wetlands. These community interactions revealed many perspectives of people's historical connections to the land, and community members confirmed and specified the values identified in the past documents. The surveys also indicated that the ecosystem role of the springs and wetlands in soil stabilization, habitat qualities, and local water security is poorly understood within the community.

By reversing the trends of channelization, loss of floodplain connection with stream channels, spread of invasive species, and diminishment of native species, it is hoped that restoring the spring-fed wetlands will promote the realization of natural benefits or ecosystem services for the community.

Figure 2. View of the Cañada Corral, the middle fork of the Arroyo la Mina sub-watershed, in which springs and wetlands are made visible by the yellow fall colors of cottonwood trees amid the badlands of the eroding sandstone landscape.

Planning Process and Partners

The planning process for this WAP began in the fourth quarter of 2021 immediately after the start of the project "Restoring Springs and Wetlands on State Trust Lands in the Lower Embudo Valley." In accordance with EPA Section-319 funding arrangements, the WAP planning process adhered to a Quality Assurance Project Plan (QAPP). Figure 3 provides an overview of the planning process for the WAP.

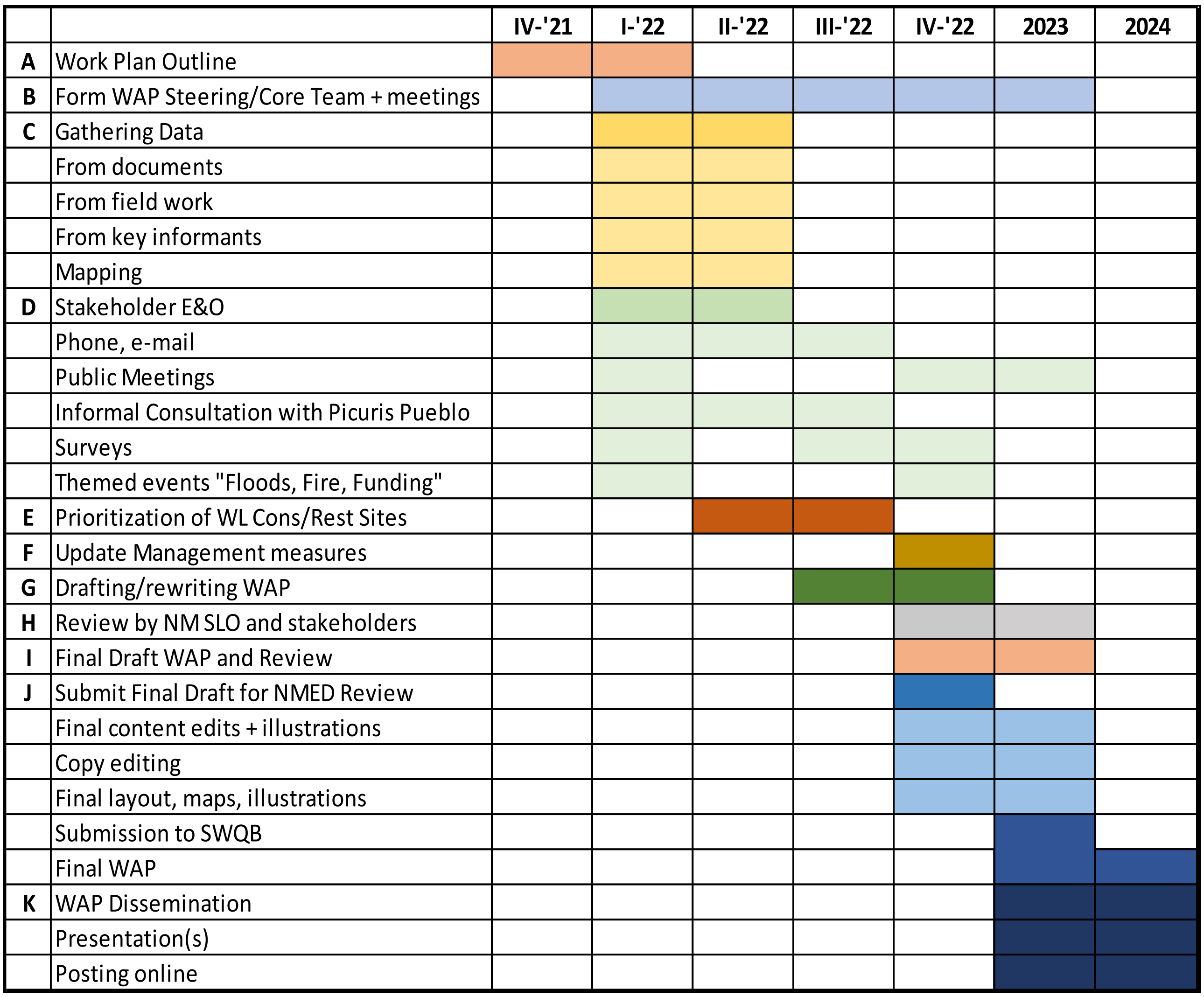

Figure 3. Gantt Chart with a list of WAP planning tasks and time schedule.

The Core Team members who directed the compilation of this WAP included:

- Jan-Willem Jansens, Ecotone Landscape Planning (Project Manager; Data Management Coordinator)
- Adrienne Rosenberg, Ecotone Landscape Planning (Local Project Coordinator)
- Emily Toczek and Jared Wood, New Mexico Environment Department Surface Water Quality Bureau (former Program Managers, former Quality Assurance Officers)
- Alan Klatt, New Mexico Environment Department Surface Water Quality Bureau (Program Manager)
- Mark Meyers and Bianca Gonzalez, New Mexico State Land Office (Project Coordinator, former Project Coordinator)
- Cynthia Naha and Cecilia Shields, Picuris Pueblo (former Pueblo representatives)
- Dr. Severin Fowles, Picuris Pueblo (Pueblo representative)
- Joe Ciddio, Embudo Valley Regional Acequia Association
- Sage Dunn, BLM Taos Field Office
- Rosalia Ciddio, Community member and Embudo Valley Library (former librarian)
- Jose Luis Ortiz y Muniz, Community member
- Robert Templeton, Community member and Rio Grande Birds

Other partners included:

- New Mexico Bureau of Geology & Mineral Resources (Field Contractor)
- San Isidro Permaculture, Inc. (Field Contractor)
- Wood Sharks, LLC (Field Contractor)
- EPA-Region 6 (Funding Agency through Section 319(h))
- Embudo Valley community members and landowners

The Core Team aimed to use the WAP development and planning process to educate community members and build local capacity for wetland protection and restoration. Besides building local capacity, the WAP planning process also included an informal consultation between NMED and Picuris Pueblo to seek optimal involvement of the tribe in the project and the WAP planning process. Furthermore, the WAP planning process encouraged local control of the wetlands and its protection as well as stimulated local community collaboration and broad stakeholder participation.

Ecotone also conducted a series of consultations on the WAP draft with local organizations and community members, some of whom are part of the WAP Core Team, including: prior Embudo Valley Library (EVL) staff members Rachel Exposito, Rosalia Ciddio, and Annette Maestas; Embudo Valley Regional Acequia Association (EVRAA) representatives Cathy Underwood and Joe

Ciddio; local historians Thomas “Tommy” Valdes and the late Horacio Martinez; Rio Grande Birds founder Robert Templeton; archaeologist Severin Fowles; geologists Scott Aby and Dan Koning; the late Picuris Pueblo representative Richard Mermejo; numerous residents who spoke with us in confidence; and others.

Overview of the WAP Area of Interest

The WAP area of interest (Figure 4) encompasses 8,141 acres (12.72 square miles) and covers the far western part of the Lower Rio Embudo Watershed. The WAP area comprises forty sub-watersheds (tributaries) that flow into the Rio Embudo from the south; these are all the tributaries located to the west of the Cañada del Ojo Sarco and down to the confluence of the Rio Embudo with the Rio Grande. The WAP focus area is entirely located in the Cañada del Agua (Arroyo la Mina/Embudo Creek) hydrological unit (HUC 130201010909). The documented stream reaches in this WAP area are the Arroyo la Mina (with Assessment Unit ID NM-98.A_003) and Rio Embudo (from the confluence with the Rio Grande to the confluence with the Ojo Sarco, Assessment Unit ID NM-2111_41).

The WAP area of interest comprises mostly public land managed by the BLM, State Trust Lands (STL) overseen by the New Mexico State Land Office (NMSLO), Carson National Forest, and Rio Arriba County. A small portion, mostly along the Rio Embudo and at the downstream ends of some of the larger tributaries, is privately owned. The majority of the WAP area is wildland with occasional, low intensity grazing and some low impact recreational uses, such as hiking and nature observation. Other land uses include cultural activities and non-commercial forest product harvesting in the wildland area and water diversion for irrigation, irrigated agriculture, and residential and commercial uses in the urban fringe along the Rio Embudo.

The WAP area includes more than 40 springs and associated wetlands which encompass at least 26 acres and an unknown number and acreage of riverine wetlands. Of the 40 or more springs and wetlands, at least 37 have been named and inventoried by the BLM to some extent (Figure 4). More details about the inventory and classification of springs and wetlands are described in Section 6 (Springs and Wetland Inventory). Spring and wetland type descriptions and illustrations can be found in Appendix A.2.

The springs and wetland in the WAP area include at least the following types:

a. Hypocrene, rheocrene, hanging garden, hillslope, and helocrene springs
b. Riparian areas and riverine wetlands along the Rio Embudo, Cañada de Ojo Sarco (a.k.a. Cañada del Oso), and Cañada Agua (a.k.a. Arroyo la Mina)
c. Slope wetlands, such as those on the slopes of the canyons and ciénegas in canyon bottoms

d. Riparian areas along the drainage channels

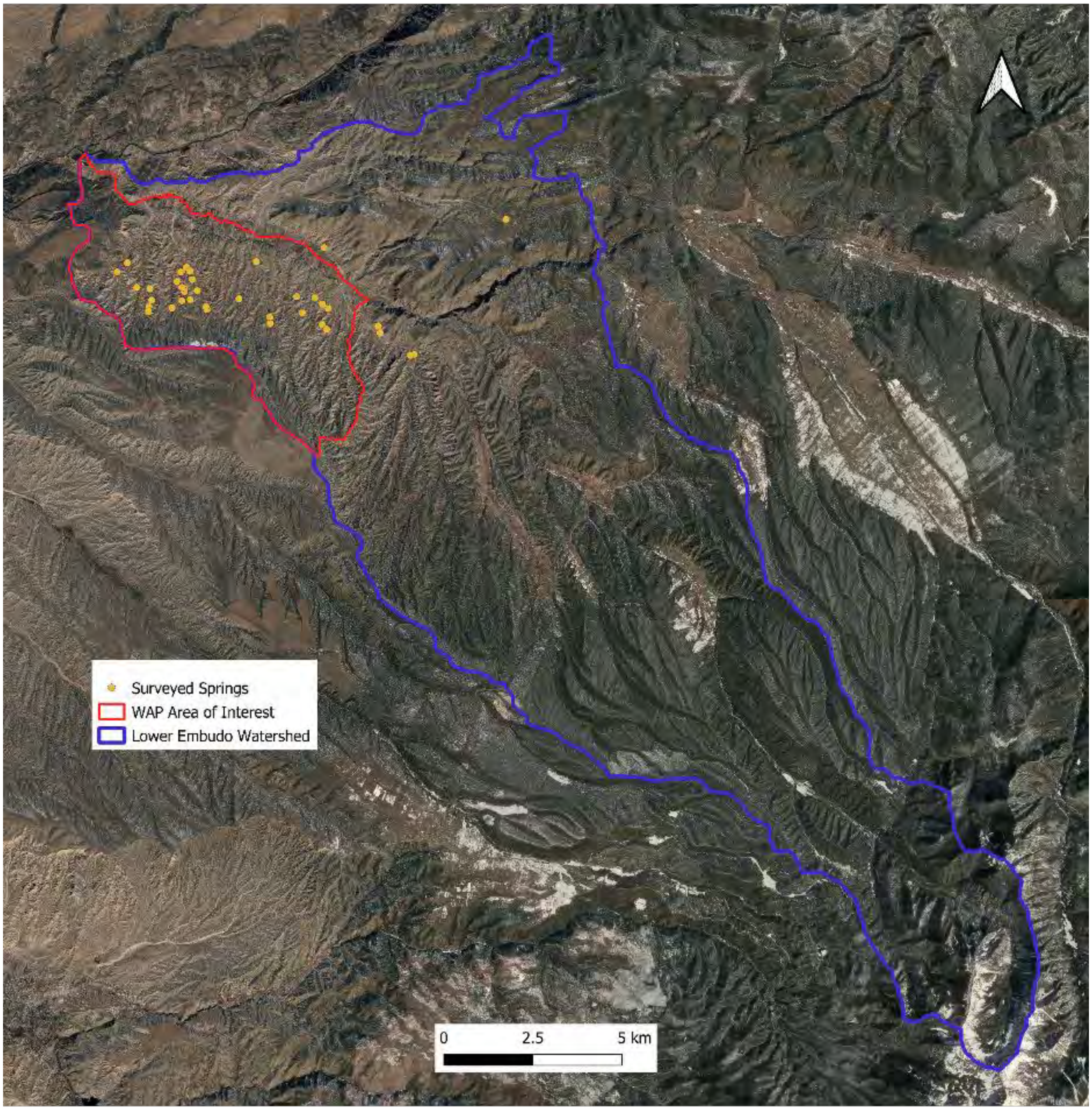

Figure 4. Map of the Wetlands Action Plan area of interest in relation to the 2020 Watershed-Based Plan for the Lower Rio Embudo Watershed study area and springs surveyed by the BLM (McElroy, 2022c).

The BLM used the Spring Stewardship Institute's Level-1 and Level-2 sampling protocols (Stevens et al., 2016) and the BLM's Proper Functioning Condition methodology for the assessments (Gonzalez and Smith, 2020) on the 37 springs and wetlands. Seven of these springs and wetlands fall outside of the area of interest for this WAP as they are in the sub-watershed to the east, HUC-12 130201010907 of Cañada de Ojo Sarco.

The riverine wetlands and riparian areas of the Rio Embudo are located at the far northern boundary of the WAP area. The ciénegas in the canyon bottoms are located on both BLM land and State Trust Lands. Slope wetlands are usually related to springs and seeps but have been poorly studied and were not described in relation to the spring inventories. Riparian areas in the many sub-watersheds are also poorly documented, unless they were inventoried in association with specific restoration projects. This WAP is the first documentation of these ecosystems in a comprehensive way across the lower watershed.

Between 2021 and 2024, Ecotone focused on two State Trust Land Sections, 2 and 32, for the implementation of ecological restoration work (Figure 5). Within Section 32, Ecotone and its partners concentrated efforts in four ciénegas wetland reaches. Ecotone also inventoried and documented three of the four wetland reaches using the New Mexico Rapid Assessment Method (NM RAM) for Montane Riverine Wetlands, as explained and depicted in the NM Wetlands Rapid Assessment Method section. Within STL Section 2, Ecotone worked with Wood Sharks, LLC under a US Forest Service Collaborative Forest Restoration Program project utilizing restoration techniques across approximately 120 acres of woodland and riparian areas, including a few small, degraded seeps.

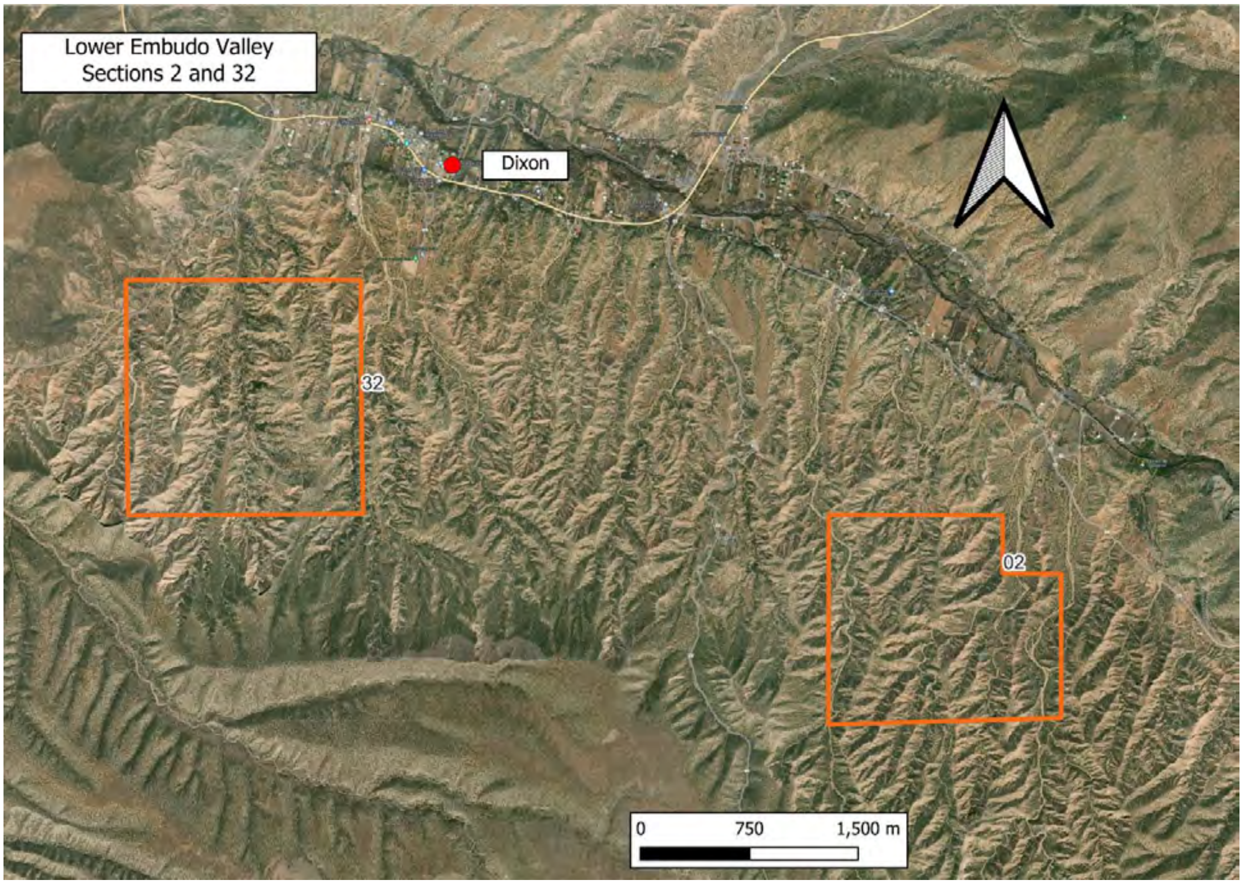

Figure 5. State Trust Land Sections 2 and 32.

The wetlands and springs have been known for many centuries to the Picuris Pueblo community and probably to other Native American populations in northern New Mexico. The Hispanic, or sometimes self-referred to as Indo-Hispano, community and some people in the contemporary communities also have been aware of the springs and wetlands. However, recent surveys show that many people have been unaware of the presence of the springs and wetlands along with their ecological functions and community values. Furthermore, the 2007 Watershed Management Plan for the Lower Rio Embudo Watershed is the first document that described the springs and wetlands in this WAP in relation to water quality protection needs (Environmental Health Consultants and NMED, 2010). People in both the Native and newer communities who have been aware of the springs and wetlands highly value them for the many natural benefits (*i.e.,* "ecosystem services") that they provide. Section 2 further describes these wetland values as well as their functions.

Sackett et al. v. US Environmental Protection Agency et al. Decision

On May 25, 2023, in Sackett vs. EPA, the Supreme Court of the United States of America (SCOTUS) changed the legal wording and nature of wetland protections under the Clean Water Act nationwide by reducing the protection of wetlands, stating that a wetland must have a "significant nexus" and "continuous surface connection" with a US navigable body of water (*Sackett et al. v. U.S. Environmental Protection Agency et al*., 2023). The ruling's impact on the protection and restoration opportunities for the local wetlands and springs will have to be assessed on a case-by-case basis in the future.

2. WETLAND FUNCTIONS AND WETLAND VALUES

It is useful to distinguish between wetland ecosystem functions and the values such ecosystem functions represent for people. Ecosystem functions pertain to ecological relationships and processes. In fact, wetland functions are defined as processes that take place in a wetland (Novitzki et al., 1993) and that are necessary for the self-maintenance of a wetland ecosystem.

Values relate to the benefits that the ecosystem functions provide to people. According to their needs and preferences, different people will value ecosystem functions differently. Wetland values are often expressed in terms of "ecosystem benefits" (or the benefits of nature) which wetlands provide for people.

Wetland Functions

Like springs and wetlands elsewhere, and as described in general scientific investigations about wetland functions (Mitsch and Gosselink, 2007; Johnson, 2005), the springs and wetlands in the Lower Rio Embudo Watershed perform many different ecological functions. The 2019 Watershed-Based Plan (Jansens, 2019) identifies the springs and wetlands in the WAP area of interest as important ecosystems that maintain watershed health and stability and help regulate water quality in the Rio Embudo and the Rio Grande. As rare and unique water bodies and areas in the semi-desert of the Lower Embudo valley, the many small wetland ecosystems enhance the regional biodiversity and are of great importance to wildlife, birds, and many plant species. They play a role, for example, in the concentration and dispersal of ungulates, such as mule deer, in the landscape.

The ecosystem functions of the wetlands in the WAP area of interest also influence the adjacent piñon-juniper ecosystems and river ecosystems. For example, the slope wetlands and ciénegas in the sandstone canyons provide stability to the slopes and soils of the surrounding woodlands. The wetlands also provide a dense vegetation cover with living roots that contribute to soil stability while the vegetation and lesser grade of the wetland slopes accumulate sediments from runoff events. In these ways, the wetlands regulate sediment and flood flows and can, to a certain extent, protect downstream wetlands, riparian areas, and agricultural lands against flooding. These regulating functions highlight the importance of the wetlands in holding in place the highly erosive sandy soils and sandstone formations of the tributaries to the Rio Embudo.

The riverine wetlands along the Rio Embudo can modify flooding and sediment dispersal along the river's course. The wetlands also exhibit variability because of geologic and landform variations, difference in historical and current access and land-use pressure, plant species composition, soil type, biogeochemistry, and other factors. As a result, wetland functions also vary across the WAP area depending on the wetland type and location.

Wetland Values

For centuries local communities have valued the springs and wetlands in the Lower Rio Embudo Watershed as sources of drinking water and irrigation water. The springs and wetlands have also been of great spiritual and cultural value and have values associated with wildcrafting of plants and hunting of wildlife. More recently, the wetlands are valued for many important regulating functions within the watershed, such as streambank stabilization, flood control, aquifer recharge, wildlife habitat, and filtering of sediment and other forms of water pollution. There appears to be a growing awareness among people in the community that these functions are essential to provide a habitable environment for plants, animals, and people in the watershed.

In general, wetlands are valued because specific wetland functions have proved to be useful to humans (Mitsch and Gosselink, 2000b). While perceived values arise out of the functional ecological processes, such as the value of water supply to the community, research has shown that values are also determined by human perceptions, the location of a particular wetland, the human population pressures on it, and the extent of the resource (Mitsch and Gosselink, 1993, 2000a).

The values attributed to the springs and wetlands in the WAP area of interest are a case in point. Depending on landownership, access, proximity to residential areas, and the amount of water discharged, some springs and wetlands are known to be used for human water supply or have been modified and used as livestock watering places, while other springs and wetlands have not. Similar differences appear to apply to people's values of the wetlands for recreational, social, or cultural purposes. Field observations have revealed that in some cases wetland areas are impacted by recreational, transportation, or gas utility management uses to the detriment of other values.

The "2005 Millennium Ecosystem Assessment" (Watson et al., 2005), a four-year United Nations assessment of the condition and trends of the world's ecosystems, identifies four categories of ecosystem services, or benefits of nature, which also apply in the context of wetland values. They include:

- **Provisioning Services** *or the provision of food, fresh water, fuel, fiber, and other goods;*
- **Regulating Services** *such as climate, water, and disease regulation as well as pollination;*
- **Supporting Services** *such as soil formation and nutrient cycling; and*
- **Cultural Services** *such as educational, aesthetic, and cultural heritage values as well as recreation and tourism.*

Formal surveys and informal conversations in the community of Dixon and its immediate surroundings indicate that community members value the wetlands for specific ecosystem services. However, it became apparent that different population segments value the springs and wetlands differently. Table 1 provides an overview of the values that people mentioned during meetings, in surveys, and in informal conversations, with a reference to any of the four ecosystem services categories. The information about people's perceptions of the wetland values presented in Table 1 is not based on statistically representative data. Therefore, the listing is in no particular order. However, there seems to be some agreement that the most critical natural benefits of the wetlands for large segments of the population in the Lower Rio Embudo Watershed are water supply, sediment and flood control, cultural heritage values, wildlife habitat and wildlife viewing, and scenic values.

Table 1. Listing of Ecosystem Services of Wetlands as Perceived by Residents in the Lower Rio Embudo Watershed

Value	Ecosystem Service Category
Water supply and water quality in relation to local agriculture (irrigation, *acequias*, livestock)	Provisioning
Spiritual affinity, cultural heritage, and community or personal history	Cultural
Maintaining cultural traditions, cultural knowledge, etc.	Cultural
Wildlife and bird habitat; including water provision for wildlife	Supporting
Flood control and reduction or regulation of sediment flows	Regulating
Hiking and water supply for dogs	Cultural
Bird watching	Cultural
Low intensity recreation and relaxation	Cultural
Scenic and sensory landscape experience	Cultural
Wildfire risk reduction	Regulating
Climate control	Regulating
Wildcrafting	Provisioning
Star gazing	Cultural
Information; esp. indication or early warning about changes in land health and climate	Cultural
Biodiversity	Supporting
Aridification and desertification reduction/control	Regulating

Water supply. Historically, water supply for drinking water and irrigation purposes has been of great importance. Anecdotal information reveals that until the middle of the 20th century water from some of the area's springs and associated wetlands supported several agricultural communities in the Lower Rio Embudo Watershed. The water from the springs was used to feed *acequias* (communal irrigation systems), water livestock, and provide drinking water for residents (J.E. Arellano, personal communication, 2013). At present, the wetlands and springs no longer provide water supplies of any significance to the acequias, although some *parciantes* (*i.e.,* members of acequia associations) have a sense that the water flowing from wetlands still makes a difference between no water and a little water in their ditches during dry times. A rough estimation of the total annual spring flow based on extrapolated data from a study of five of the largest springs conducted in 2022 by the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) (Newton and Koning, 2022) found that all the springs together discharge at least 8 acre-feet of water a year. Furthermore, the wetland areas annually provide drinking water for livestock and support native, herbaceous plants that serve as forage for one livestock permittee. It is likely that the aquifers associated with the springs also support local domestic wells.

Sediment and flood control. The settings of the springs included in this WAP offer a unique opportunity for additional ecosystem benefits in view of the surrounding landscape's highly erosive character. The 2019 WBP confirmed that sediment-laden runoff causes water quality impairments associated with turbidity in the Rio Embudo, which eventually contributes to turbidity and sediment impairments in the Rio Grande. Springs and wetlands upstream of the Rio Embudo therefore have direct impacts on water quality. When degraded, these areas can contribute to nonpoint source pollution as they shed eroded sediments during precipitation events (Jansens, 2019).

Conversely, when functioning properly, the spring-fed wetlands can store greater amounts of water for longer periods of time, enabling wetland plants to grow and stabilize sediment. In addition, after summer storms the wetlands filter runoff that flows down to the irrigated parts of the valley, stabilizing erodible slopes and buffering sediment movement (Figure 6). Therefore, the wetlands are of value in reducing maintenance and operational costs of the acequia-dependent agricultural operations in the valley.

Although there is not yet any in depth comparative research on sediment movement between various drainages in the WAP area, it is reasonable to assume that the drainages without wetlands deposit relatively more sediment into acequias; onto roads, fields, and farmyards; and into the Rio Embudo than the drainages with wetlands. More research will be needed to confirm this hypothesis over time. The wetlands also play a critical role in flood control as they can absorb moisture and slow stormwater runoff flows and, in so doing, reduce the peak of the flood flows and spread the outflow time. This is of particular importance in small sub-watersheds because they are generally more prone to flash flooding.

Figure 6. The Labyrinth Spring area absorbed large amounts of sediment in its ciénega wetlands during the summer of 2022 (Photo taken by Jan-Willem Jansens in November 2022).

Cultural heritage values. Many of the springs and wetland areas in the Lower Rio Embudo Watershed are of great cultural and historical importance to Pueblo Indian communities, and in particular to Picuris Pueblo. According to the late Richard Mermejo, Picuris Pueblo elder,

> …The springs that appear in the WAP draft report are still being used in our traditional ceremony, and they have native names, like Black Water Springs is referred to as *tuy noy paxwii*. This spring was a resting place for travelers going to and from Tewa Pueblo along the Rio Grande, also used as a shortcut from Dixon to Velarde. Another spring that has some cultural significance is a spring that is located on private land in the village of Apodaca. The name of the spring in Tiwa is *weh p'eh p'eh paxwii*… (R. Mermejo, personal communication, 2023; lightly edited for readability).

Several areas around springs and wetlands on and around Section 32 are the object of ongoing field research and conservation efforts in a collaborative initiative between Picuris Pueblo, Barnard University, and cultural resource experts from other institutions. Prior to restoration activities, hired contractors for the NMSLO conducted cultural resource surveys according to the agency's protocols. Archaeological findings outside of the NMSLO surveys include burned soil strata combined with lithic artifacts from a wide geographic region that date from a period of several hundreds of years to thousands of years (Severin Fowles, personal communication, June 14, 2022). These signs of human habitation indicate that the springs and wetlands may have supported human settlements or camps over a period of several thousands of years. Hence, the springs provided water to the downstream wetlands during these historical times as well.

The Hispanic community also has a deep relationship with the wetlands and springs of the area, which were utilized as watering areas for livestock, places of respite and replenishment, and at times sources of water for fields. Like the *arroyos* webbed across the Lower Rio Embudo Watershed, each spring and wetland supposedly has a Spanish name assigned to it.

Wildlife habitat and wildlife viewing. The springs and wetlands in the WAP area of interest constitute important habitat areas for many different life forms and wildlife species. According to a wildlife habitat assessment done with the online Information for Planning and Consultation (IPaC) tool of the US Fish & Wildlife Service, the wetlands are potential habitat to seven federally listed endangered, threatened, or candidate species. For specific T&E species and SGCN, see Appendix B.2. The remote location of the wetlands likely provides relative protection to the animals. While there have been observations of the presence of many species of mammals and birds, more research is needed to confirm the presence of any specific macroinvertebrates, insects, and amphibians. In addition, some residents enjoy formally monitoring bird species while others enjoy informal wildlife viewing.

Scenic values. Surveys and informal conversations have indicated some residents hike to the spring and wetlands. Although many residents may not know about the presence of springs and wetlands or have never visited these wetland areas in the WAP area of interest, surveys have indicated that many appreciate the visual quality of the landscape in which the springs and wetlands occur and the water, wildlife, and vibrant fall colors that they associate with these areas (Figure 7).

Figure 7. Ciénega wetlands in the canyon of the Blackwater Spring with scenic rock formations and fall colors (Photo taken by Jan-Willem Jansens).

3. GOALS AND DESIRED CONDITIONS

Goals, Strategies, and Timeline

Goals. Protect and restore wetlands and springs to achieve and maintain proper functioning conditions and to minimize the risk and the impacts of wetland degradation on the integrity of the surrounding landscape and on the wellbeing of downstream communities.

Strategies. Key strategies to achieve this goal include:

1. Conducting research and assessments
2. Implementing site-specific wetland and spring protection and restoration projects as well as comprehensive landscape restoration and conservation projects to address landscape-wide stressors
3. Conducting educational outreach to raise awareness and understanding of the importance of wetlands and springs in the area
4. Developing local organizational, technical, and financial capacity

Timeline. This WAP has been developed simultaneously with the planning of several of the key strategies listed above. The WAP development informed the deployment of these strategies, while the implementation of the strategies served as pilot studies for the WAP. Therefore, the timeline for the implementation of the WAP effectively started in early 2022. It is envisioned that the WAP's lifetime is at least ten years (2022-2031) with a possible continuation for another five to ten years. However, by 2031, the WAP must be reviewed and updated to meet the needs and outlook of that time. The strategies listed above and the priority actions flowing from them, listed below, will be phased according to a ten-year time schedule.

Desired Conditions

The desired conditions of the springs can be defined as spring-fed wetlands that meet "proper functioning conditions" according to the methodology for Proper Functioning Condition Assessment for Lentic Areas developed by the BLM (Gonzalez and Smith, 2020). Key elements of proper functioning conditions include 20 indicator categories (Appendix A.3., Table 17).

The PFC method has been chosen for this WAP because most springs and wetlands in the WAP area of interest are on BLM land. BLM also samples springs and wetlands on State Trust Lands, and there is a baseline of existing BLM data using the PFC method. However, the NMED SWQB uses the NM RAM to assess wetland integrity. An NM RAM method is being developed based on the Spring Stewardship Institute (SSI) method for spring assessment. Yet, the NM RAM for Montane Riverine Wetlands was used to monitor three wetlands in relation to the NMED wetland restoration project associated with this WAP (NMED, 2022). This type of NM RAM was chosen because it was the most appropriate NM RAM method at the time of the assessment.

In terms of the PFC method, the desired future conditions of wetland sites, areas, or complexes can be defined as each wetland meeting proper functioning conditions. In terms of the NM RAM, the desired future conditions of wetland sites, areas, or complexes can be defined as each wetland Sampling Area (SA) meeting the highest Ecological Condition Ranking (ECR) in NM RAM wetland assessments for Montane Riverine Wetlands. This assumes that wetland SAs must be representative for the larger wetland areas and that all abiotic, biotic, and landscape context conditions are performing optimally toward reaching wetland health and integrity (Muldavin et al., 2022).

Success Definition and Benchmarks

This WAP recommends the following measurable objectives and associated indicators (a.k.a. benchmarks) for use in defining the success of actions proposed in this WAP. The indicators conform to those in the 2019 WBP and are referenced as such, in so far applicable (Table 2).

Table 2. Listing of Objectives, Indicators/Benchmarks, Methods, and WBP References

Objectives	**Indicators / Benchmarks**	**Measuring Method**	**WBP Reference**
Reduce sediment loads and erosion from drainages and slopes	Measurable soil cover increases or reduction of bare soil percentage	Vegetation cover transects	WBP Ch-6, p8
	Volume of sediment retained behind structures and in the landscape	Cross sections, sediment area estimates; and modeling results using STEPL 4.4b or other methods	WBP Ch-6, p8 and Ch-6, p6
	Successful installation of bio-technical slope stabilization structures; streambank, gully, and head cut restoration structures; and implementation of vegetation treatments	Visual inspection and photo documentation	Ch-6 p7
Objectives	**Indicators / Benchmarks**	**Measuring Method**	**WBP Reference**

Halt headcuts and channel degradation, and successfully raise the channel elevation to improve wetland functions such as sediment retention	Measurable rise in channel bottom elevation to the design level for sites with degraded channels	Elevation cross sections	Ch-6, p8
Restore native riparian and wetland vegetation and its associated aquatic and wildlife habitat	Measurable protection of native plants	Vegetation cover transects, such as the modified "Greenline method" (Winward, 2000)	Not in WBP
	Measurable area increases of native riparian and wetland vegetation	NM RAM assessment data and/or the modified "Greenline method"	Not in WBP
	Qualitative improvement of wetland health	NM RAM scoring system: increase in wetland NMRAM Ecological Condition Ranking level	Not in WBP
Remove invasive plant species where possible	Invasive plants removed and regeneration suppressed	Comparing pre- and post-treatment estimates of invasive plant cover	Not in WBP
Protect riparian areas, seeps, springs, wetlands and alluvial fan wetland areas from off road vehicle (ORV) impacts and identified cattle grazing impacts	Identification of the absence of ORV impacts	Visual and photographic monitoring	Not in WBP
	Identification of the absence of livestock impacts and human access impacts on the riparian and wetland areas	Tallying occurrences and estimating area affected (targets are 0 occurrences and 0 sq. ft. affected)	Not in WBP

Monitoring

Projects aimed at working toward the goals and benchmarks for specific priority areas described in this WAP would need to track progress toward goal achievement (*i.e.,* monitor implemented work and outcomes) to ascertain success. The indicators and measuring methods described above in relation to the success definition and benchmarks for this WAP serve to guide specific project monitoring activities. Each project team would need to develop a study design and establish a monitoring plan that describes the indicators that apply to the project area and how these indicators would be measured as well as the timeline, the means, and the staff resources needed to measure and track the activities. A monitoring plan could also include indications about data integrity, replicability of measurements, data storage, and information transfer in the form of reporting or adaptive management activities. Monitoring requirements are sometimes specified by individual funding agencies. This WAP has been developed under a project specific QAPP for the project "Restoring Springs and Wetlands on State Trust Lands in the Lower Embudo Valley" (SWQB, 2022).

In addition to project-level monitoring it will be important to establish watershed-level tracking mechanisms for sediment loads and water flows. Ideally such tracking mechanisms could be combined with weather stations. One option is to reactivate the two stream sampling stations (at the end of State Road 580 in Cañoncito and at Vivác near State Road 75), which were established in 2013 for the WBP data gathering process. Both stations included staff gages and a lock box with a data logger, which was connected to optical turbidity sensors, pressure transducers, and water thermometers. Both stations were also equipped with weather stations and telemetry for remote data collection. The station at Vivác was built to include an ISCO sediment sampler (see 2019 WBP for details).

Data gathered from these stations, combined with soil loss estimates collected through field monitoring would provide useful estimates of correlations between erosion (soil loss) levels around the wetlands and sediment loading in the rivers. Comparison of the automatically gathered data at the stations could be compared with USGS data for the Rio Grande to obtain information on the relative contribution of sediment by the Rio Embudo (USGS, n.d.). Over time, if a critical area has been treated with soil and sediment stabilization practices, conclusions could possibly be drawn regarding the effectiveness of WBP and WAP implementation on sediment impairment levels in the rivers based on a comparison between erosion data and the extent of management practices for the protection and restoration of the wetlands.

4. WATERSHED CONDITIONS

Bio-physical Environment

Geology, hydrology, and wetlands. The valleys of the Lower Rio Embudo Watershed are cut into rocks formed from both volcanic and sedimentary deposits dating back approximately 1.8 billion and 3 million years (Environmental Health Consultants and NMED, 2010). Over time, ancestral versions of the watershed's streams and rivers carved the valleys and other landforms that are present today (Jansens, 2019). In the Dixon valley, these rocks belong to the Santa Fe group, composed of basalts, ash, and sediment from the late Miocene to early Pliocene (7.2M – 3.6M years ago) (Environmental Health Consultants and NMED, 2010).

The dominant geologic formation of Sections 2 and 32 is the Tesuque Formation which extends south to the Santa Fe area and between Abiquiu and the Sangre de Cristo Mountains (Figure 8).

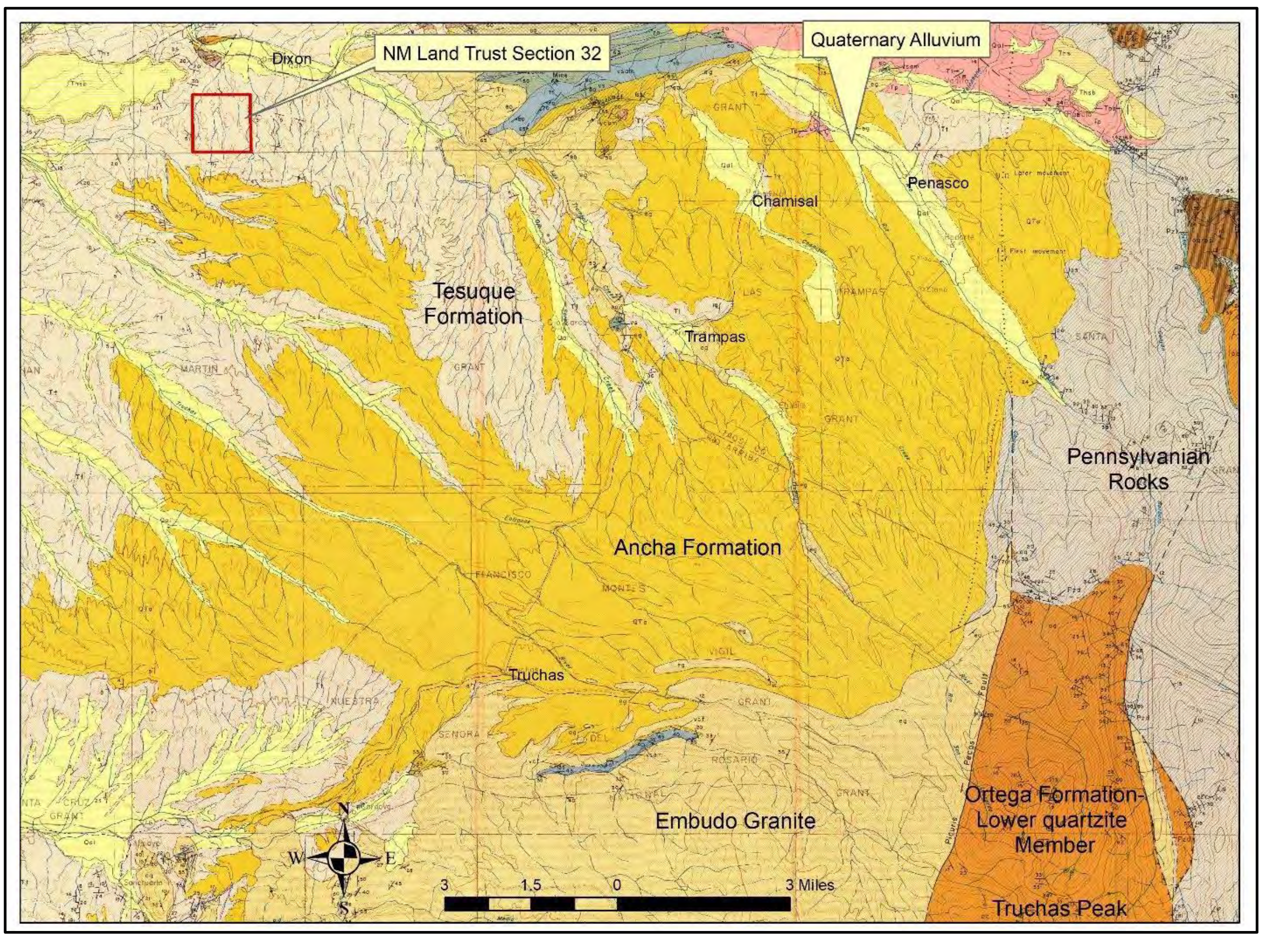

Figure 8. Regional geologic map, modified by Newton and Koning (2002) from Miller et al. (1963). Only geologic units of interest for this report are labeled.

This formation was laid by ephemeral paleo-streams (or possibly small perennial rivers) and wind processes between 17 to 10 million years ago. The present sedimentary rocks erode relatively easily due to their moderate consolidation and weak to moderate cementation. The Tesuque Formation can be further divided into four members: the Chama-El Rito Member, the Dixon Member, the Ojo Caliente Sandstone, and the Cejita Member (Figure 9). (Newton and Koning, 2022).

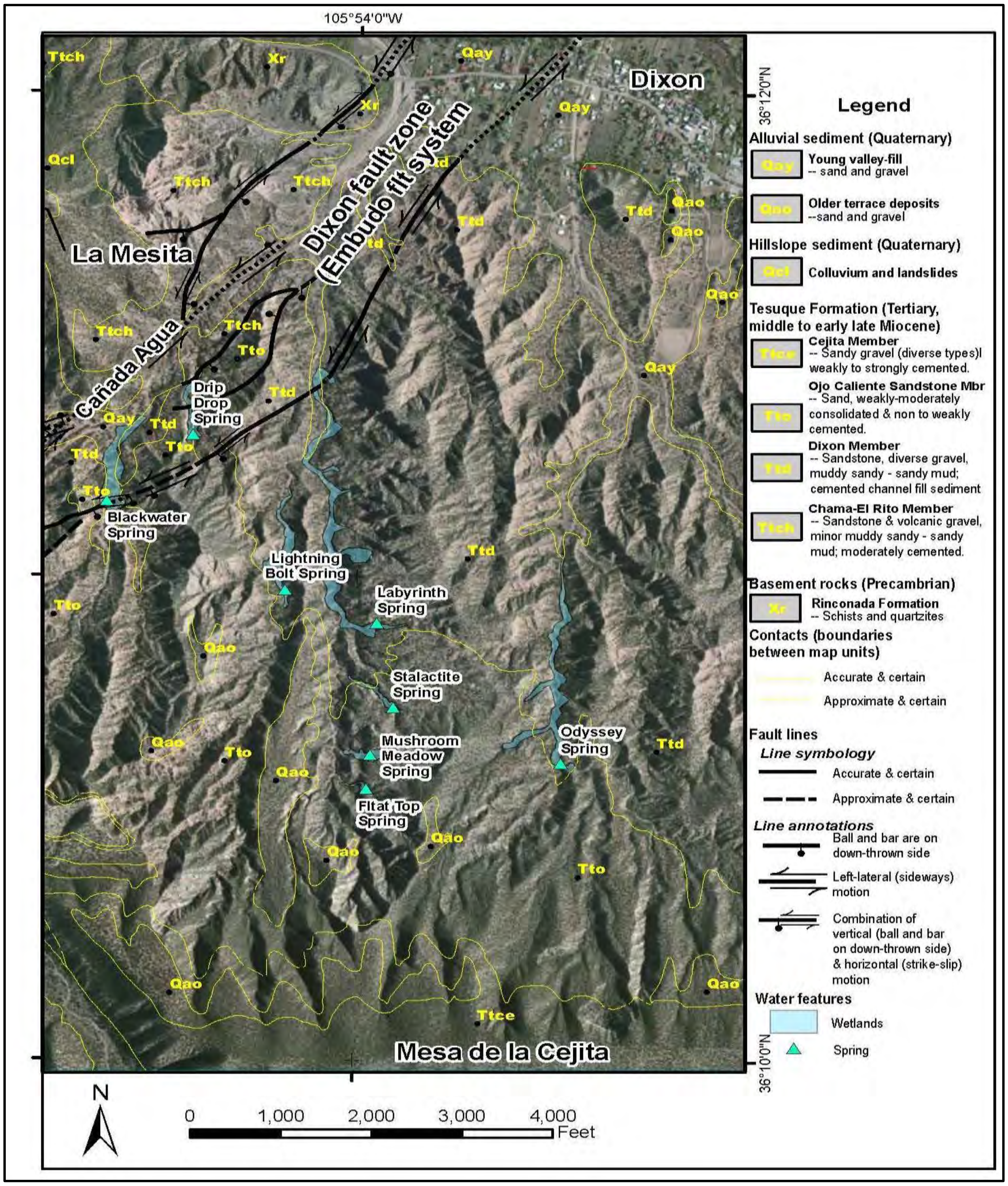

Figure 9. Simplified geologic map of study area (Newton and Koning, 2022).

A GIS-based delineation of stream networks and sub-watersheds within the HUC-12 boundaries aided the identification of 118 sub-watersheds with first and second order drainages within the WBP study area. Figure 10 displays the HUC-12 watershed, the three sub-watershed units, and the individual streams within each unit. The Lower Rio Embudo Watershed is within the 130201010909 HUC unit.

The largest acreage of spring-fed wetlands is located on and around USGS Topographic Map Section 32, just south of the Dixon village, in small canyons and drain northwards into the Embudo Creek. The Embudo Creek in turn discharges northwestward into the Rio Grande. The arroyos in this section drain the north flank of Mesa De La Cejita. In addition, the Embudo River and Rio de las Trampas ultimately drain water from the Sangre de Christo Mountains toward the northwest (Newton and Koning, 2022).

The Arroyo la Mina sub-watershed has the greatest density and cumulative area of springs and wetlands in the WAP area. The ten largest sub-watersheds within the WAP area are, in descending order, Arroyo la Mina, Arroyo Lorenzo, Arroyo Pino, Arroyo Montecito, the east fork of the Arroyo de los Pinos Reales, the west fork of the Arroyo de los Pinos Reales, Arroyo 102, Arroyo 106, Arroyo 30, and Arroyo 28. These arroyos comprise more than 83% of the WAP area. Twenty-seven smaller drainages comprise the remaining 17% of the area.

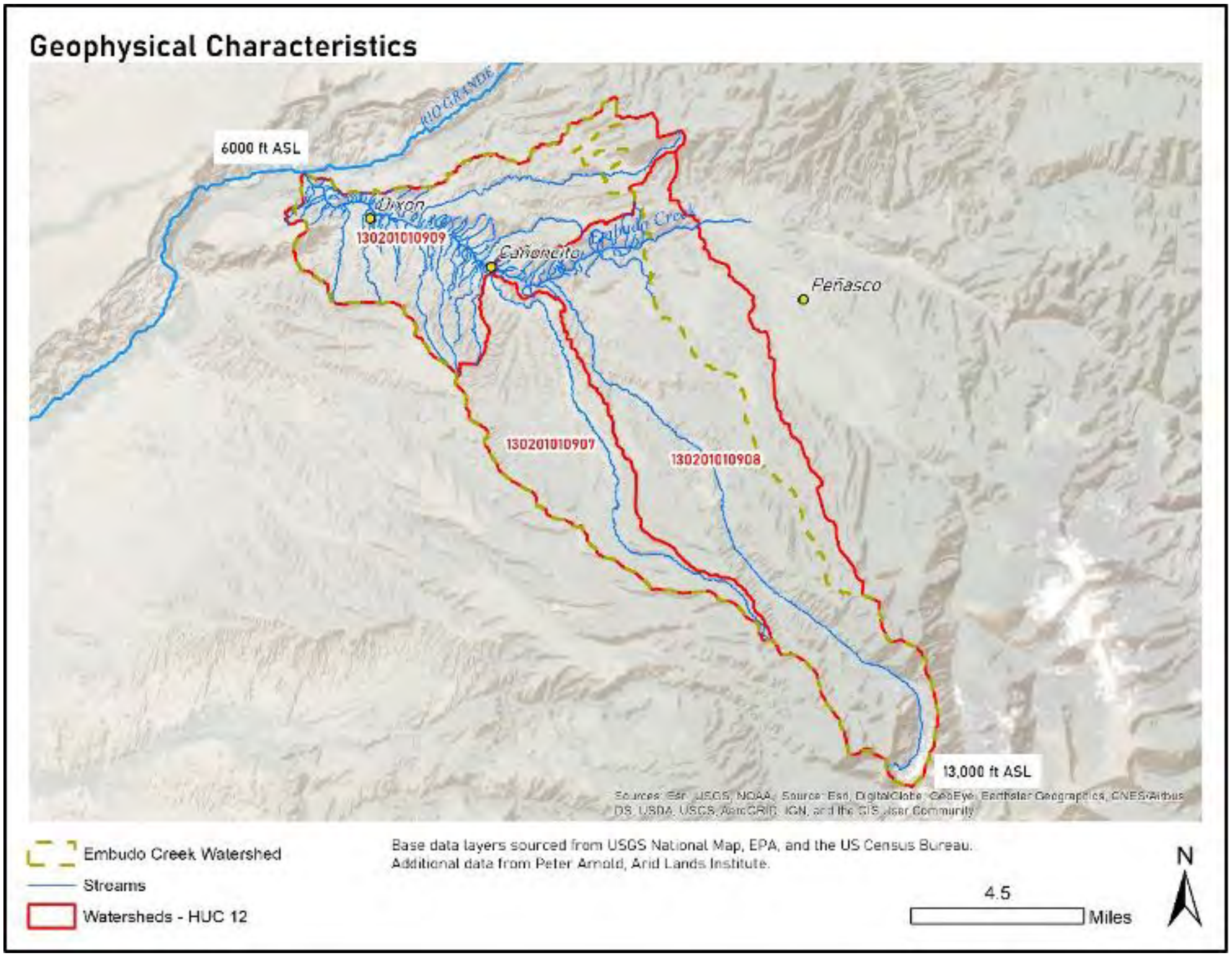

Figure 10. The Lower Rio Embudo Watershed (green dashed lines) and HUC 12 sub-watersheds.

Many of these small (<1.0 km^2) sub-watersheds are likely to exhibit "flashy" hydrologic responses during precipitation events—runoff volumes increasing rapidly within a short duration of time—and are located within the steep walls of the Embudo Canyon as well as the hillslope areas within Montecito, Dixon, and Embudo. Research conducted for the WBP revealed that small drainage areas have a greater incidence of flash flooding and sediment transport proportional to their size. Hence, in terms of ecosystem functioning, wetlands in small tributaries are critical for retaining sediment, and their destruction may lead to relatively large volumes of sediment transport per acre. The reason for this phenomenon is that in this landscape small drainages have relatively limited sediment retention surface in the form of alluvial fans, terraces, and arroyo bottoms. Smaller watersheds have relatively large surface areas of steeper slopes. Together these factors lead to a greater proportional soil loss and sediment flux per acre.

The relative absence of wetlands in small drainages likely exacerbates the risk of sediment fluxes from these small drainages. Of the more than 31 drainages that are smaller than 500 acres, only four drainages include small wetland sites, seven total, that cover about 1.55 acres. Of the three drainages that are between 500 and 1,000 acres in size, only one drainage includes two very small wetland sites of less than 0.02 acres. However, the three largest drainage areas in the range between 1,000 and 2,000 acres include more than 24 wetland sites that cover nearly 25 acres.

Despite the consistent geological mapping within the study area, very few hydrogeological studies have been conducted, likely due to the lack of domestic wells. Based a study conducted by Borton in 1974 and the known surface water drainages, Newton and Koning (2022) assume that the recharge to the groundwater system associated with the Dixon Springs Complex may include regional input from the Sangre de Cristo Mountains to the southeast and potentially local input from the Mesa De La Cejita.

Soils. Many areas in the WAP planning area have rocky and highly erodible soils leading to rapid runoff. Sedimentary soils have variable soil erodibility conditions and are in places susceptible to severe wind erosion as well as to water erosion, especially where soil cover has been compromised. The soil loss tolerance, also known as the natural soil recovery potential, varies across the landscape as well. However, the soil loss tolerance for the WAP area soil types was established many years ago when terrain conditions were less impacted by recent degrading forces and climate change. Due to the recent and ongoing impacts, the soil loss tolerance for the soils in the planning area has most likely declined and may need to be reevaluated by the Natural Resource Conservation Service (NRCS).

An NRCS Web Soil Survey compilation for the Lower Rio Embudo Watershed shows great variability in soil types, terrain steepness, and sparse vegetation types across the Lower Rio Embudo Watershed area. When running a custom soil survey for the springs within Sections 2 and 32, the database shows the soil as Florita Outcrop complex, 15-45% slope (NRCS, n.d.). According to the USDA, the Florita series consists of very deep, well drained soils that are formed in coarse-textured alluvium derived from sandstone and shale.

The Web Soil Survey reports an average annual precipitation of about 12 inches and an average annual air temperature of about 50°F. The soil taxonomic class is coarse-loamy, mixed, superactive, nonacid, mesic Ustic Torriorthents (NRCS, n.d.). The soils at each spring may be influenced by deeper organic matter deposits from localized vegetative cover, which would presumably reduce the K-factor and the C-factor. As a result, soil loss at the springs and in the surrounding wetlands is probably lower than in the surrounding drier Florita soils.

Water quality. Most of the drainages leading into the Rio Embudo within the project boundary are ephemeral, meaning they are only seasonally active with relatively short flow periods. The EPA has acknowledged that in the arid and semi-arid Southwest ephemeral streams make up a larger portion of all streams (approximately 81% compared to 59% nationally) and play a vital role in contributing to the hydrological, biogeochemical, and ecological health of a watershed

(Levick et al., 2008). Within the WAP area of interest, only the Arroyo la Mina, and particularly the Cañada Corral drainage, have permanent flow characteristics—although certain segments of this drainage network are intermittent.

Water quality within the Lower Rio Embudo Watershed is impaired. The EPA-approved 2022-2024 State of New Mexico Clean Water Act (CWA) §303(d)/§305(b) Integrated Report Appendix A1 states that the probable causes for non-attainment of the designated use of water (*i.e.,* water quality impairment) in the Rio Embudo are turbidity, sedimentation/siltation, and temperature (NMED, 2022a). Geospatial modeling and field research conducted in 2014 (see WBP for more information) revealed that the water quality impairment of the Rio Embudo is driven by short, intensive, seasonal precipitation events that generate runoff principally originating from sparsely vegetated, steep hillslopes. This runoff is collected by a network of ephemeral stream channels discharging into the Rio Embudo.

Soil loss due to erosion of natural surface roads and trails, exposed rocky outcrops, alluvial sediment deposits, and other bare areas are caused by a combination of natural processes and past and ongoing land use. Although the entire Rio Embudo-Rio Pueblo Watershed area (305 square miles of drainage area) constitutes about 4% of the Rio Grande basin area at the confluence of both rivers (7,560 square miles of drainage area), the Rio Embudo contributes a proportionally much larger volume of sediment to the Rio Grande (USGS, 2019) (see side bar on next page). The background research for the 2019 WBP identified the area of the sandstone canyons and ridges in the Lower Rio Embudo Watershed as the predominant source of the Rio Embudo sediment load.

The sediment loads constitute considerable water quality limitations and purification costs for water users and water management agencies downstream. Additionally, watershed residents and the Ecotone team have observed that annual sediment removal from acequias, fields, roads, and culverts comes at a high cost to the community, Rio Arriba County, and the State of New Mexico.

In recent memory, the catastrophic 2022 floods damaged at least four ditches in the Embudo Valley with three of the lower ditches silting up and thus becoming inoperable within one day. The destruction was significant as Acequia del Bosque, for example, received more than 1,000 cubic feet of silt, and a culvert blew out on a parciante's property (R. Templeton, personal communication, October 20, 2022).

The New Mexico Acequia Association (NMAA) shared a cost estimate to clean, repair, and reinforce the Plaza Ditch de Dixon totaling $177,412.50 (NMAA, personal communication, October 11, 2022). These scenarios were a result of localized, microburst storms in the uplands that fed into the arroyos and downstream acequias. With the forecast of more severe and localized storms, these events are likely to be repeated creating ecological and social consequences.

Proportional Sediment Contribution of the Rio Embudo to the Rio Grande

Comparisons of 43 USGS data sets for sediment loads in the Rio Grande (1/15/1997 through 10/7/2002) and 11 for the Rio Embudo (5/27/1981 through 6/13/1995) – while not related in time – provide an order of magnitude indication of the Rio Embudo's proportional sediment contribution to the Rio Grande (USGS, n.d.). When years with extreme outliers in sediment loads are excluded, the Rio Embudo contributes approximately 7% of the sediment load to the Rio Grande. When including the sediment load extremes in both rivers the Rio Embudo could be a contributor of up to 78% of the sediment load in the Rio Grande. WBP research revealed that in 2014 the Rio Embudo contributed nearly 19,000 tons of sediment to the Rio Grande (a mean of 52 tons a day) (Jansens, 2019). Compared with the total five year mean of daily sediment samples (n=43) in the Rio Grande data set (1997-2002) measured at the Embudo Station (a few miles downstream from the confluence), the 2014 sediment load discharged by the Rio Embudo is 29% of the five-year mean of the sediment loads in the Rio Grande. Despite poor comparability of the data because of different years of data sets, these data point at the order of magnitude by which the Rio Embudo contributes sediment to the Rio Grande in relation to its watershed.

Climate. Climate change is expected to lead to an increasing occurrence of extreme weather events and increasing temperatures. New Mexico is the sixth-fastest-warming state in the nation and is about 3°F warmer since the 1970s. By 2100, average annual temperatures are projected to rise another 3.5 to 8.5°F (UCS, 2016). Although droughts have been endemic to the Southwest for the past 1,000 years, the impacts of drought will be more severe due to temperature increases (NMPBS, 2022).

Within the Lower Rio Embudo Watershed project area, total precipitation due to climate change is uncertain but are not expected to change dramatically (NMBGMR, 2022). However, winter precipitation in the form of snowfall will decline and will instead fall increasingly in the form of rain, which will result in less snowpack in the watershed. An earlier onset of the spring season could cause earlier snowmelt in the headwaters of rivers, such as the Rio Embudo, which will contribute to lower stream flows during critical portions of the season (UCS, 2016). Ephemeral springs are particularly at high risk from the effects of human-related climate change and habitat disturbance as elevated temperatures will lead to increased evapotranspiration rates resulting in water loss and decreased availability of surface water (NMDGF, 2016).

In riparian habitats, flow dynamics impact the vegetative community composition, and the climate induced reduction of streamflow is expected to decrease the abundance of shallow rooted cottonwoods and willows. This reduction could favor certain invasive herbaceous and late successional species as well as drought-tolerant woody species that are more deeply rooted, which could establish and out compete the native vegetation, thus shifting the community composition (NMDGF, 2016). Limited observations of encroaching invasive woody species, such as *Elaeagnus angustifolia* and *Tamarix chinesis,* and the limited regeneration of native woody species, such as *Salix spp.* and *Populus spp.*, matches the predicted community composition shifts in STL Sections 2 and 32.

Under the predicted climate trends, the future conditions of the Rio Embudo and surrounding springs and wetlands will become increasingly uncertain if left unmanaged. The trend toward ecosystem degradation and collapse, combined with increased unpredictability and intensity of rainstorms, amplifies the probability of years with accelerated erosion rates and greater sediment flux. The findings of the WBP are a useful indicator for the magnitude of possible sediment emissions resulting from currently predicted climate trends. Besides the natural causes of these projected extreme events, other causes continue to include the current state of forest health and management, woodland ecosystem conditions, off road vehicle use, and legacy stressors along with numerous miles of arroyos and streambanks. The impacts associated with climate change are not stand-alone events; rather they are added stressors on systems that are already strained and create larger and more intense impacts.

Wildfire. Dry and hot weather conditions are known to increase the risk and intensity of catastrophic wildfires. Earlier snowmelt causes forests to be drier for a longer spring season, which increases the exposure of forest lands to wildfire. In New Mexico, the fire season has lengthened over the past 40 years from five months to seven months. In addition, fires of more than 1,000 acres occur twice as often (UCS, 2016; NMDGF, 2016). Wildfires often cause massive erosion as the destruction of vegetation removes the critical mechanism to retain water and sediment.

Due to the predominant cover by forest lands of the upper watershed area, the most important sources of such fire induced suspended sediment load (SSL) peak volumes could be the Cañada de Ojo Sarco and Rio Trampas HUCs as well as the Santa Barbara and Rio Pueblo sub-watershed portion. A 2017 Environmental Assessment for the Trampas watershed states that climate change impacts leading to catastrophic wildfire could lead to 99% tree mortality and highly increased runoff and erosion that would affect water quality and downstream flooding in such places as the Rio Embudo (USFS, 2017; Rio Arriba County, 2009).

Such disastrous and converging catastrophic events are expected to have sudden and long-lasting economic and social effects on the local communities in the area and for downstream beneficiaries. A case in point is the 2022 Hermit's Peak-Calf Canyon Fire that burned possibly as many as 12,400 acres (NMHU, 2023) in the Rito Angostura drainage in the Rio Embudo upper watershed. The exposed soil in the Rito Angostura basin burn area caused accelerated stormwater runoff, which deposited ash and soil into the Rio Pueblo and caused flooding and debris deposition in the Lower Rio Embudo Watershed. Compounding the fire's destruction, intense summer precipitation in and around the upland canyons and small arroyos caused catastrophic floods and sediment deposits that damaged homes, drinking water supplies, fields, roads, and acequias around Dixon.

Ground cover and vegetation for riparian areas. In general, the Lower Rio Embudo Watershed contains wetlands and uplands with a diversity of species both native and non-native. Each spring has its own composition of trees/shrubs species, forbs, and graminoids (Appendix B.1., Table 18).

Wildlife habitat and ecosystems. The Lower Rio Embudo Watershed area is highly diverse and complex; it includes many ecosystem sequences with different soil types and plant communities. Springs and their surrounding wetlands are a center of biodiversity and habitat. Although no detailed bird and wildlife studies are known to exist for the WAP area of interest, anecdotal observations of wildlife tracks and signs show a rich presence of mule deer, coyotes, and many bird species. It is expected that the area is also habitat to black bear, mountain lions, various species of fox, raccoon, porcupine, badger, elk, and small rodent species.

A local expert bird watcher has closely monitored birdlife in the Lower Rio Embudo Watershed for 25 years. From 1997-2021, the Dixon Audubon Christmas Bird Count (CBC) detected on average 60 species and 3,100 individuals. A total of 120 species have been recorded in the area (Rio Embudo Birds, n.d.). Additionally, the bird watcher has posted more than 345 eBird Checklists for the area.

Threatened and Endangered Species and Species of Greatest Conservation Need. An online assessment of the US Fish and Wildlife IPaC database revealed that seven Threatened and Endangered (T&E) species are potentially present in the areas of interest. Critical habitat, or habitat areas that are essential to the conservation of listed species, exists for one species within the study area—the southwestern willow flycatcher. The critical habitat consists primarily of stream segments and the surrounding riparian and wetland areas. The vast area and diversity of springs and wetlands are likely of critical importance to the survival of these species in the Lower Rio Embudo Watershed. IPaC also describes nine migratory bird species protected under The

Migratory Bird Treaty Act of 1918 that are likely present in the area for certain periods of the year. In addition, 63 Species of Greatest Conservation Need (SGCN) occur in the Southern Rocky Mountains ecoregion; over half are birds (NMDGF, 2016). For specific T&E species and SGCN, see Appendix B.2.

Cultural Environment

Land use and ownership. The New Mexican people possess a unique, dynamic heritage that is a rich composite of many peoples and histories. The Lower Rio Embudo Watershed is no exception, with its sweeping mosaic of inhabitants and land usage. Although there isn't much written on the relationship between the different peoples with the springs and wetlands, one can make inferences through the trajectory of history and the small amount of information that is available.

Picuris Pueblo, whose reservation stands about 10 miles east from the Lower Rio Embudo Watershed, regards the valley as a part of its ancestral lands and recognizes 40 springs in the watershed. In addition, the area may be considered ancestral lands by other Pueblos (C. Naha, personal communication, 2022). Although anthropogenic charcoal around the watershed has radiocarbon that dates back 9,000 years, it is quite likely that humans spent time in the area many millennia prior (S. Fowles, personal communication, 2023). An archaeological team also conducted an initial round of radiocarbon dating around some springs in Arroyo la Mina. The burned layers present at the springs produced several dates between 250 BCE-900 CE (S. Fowles, personal communication, 2023). During the 10th century CE, the Embudo Valley likely experienced plenty of use but little permanent settlement as the upper portions of the watershed began to be agriculturally developed (EVL and The Gorge Project, 2022).

During the mid-13th century, large multistory villages were established throughout the Ancestral Northern Tiwa region. Two large villages were present in the Picuris watershed—Old Picuris itself and a second large multistory village established in the late 13th century up north of Dixon (known as *El Bosque* to locals and *punn t'ah* in Tiwa). Presumably, the inhabitants were farming in the floodplain. By the mid-14th century, the Ancestral Tiwa had all moved into two very large villages: Picuris and Taos Pueblos. Archaeologists have mapped agricultural terraces from Picuris down the watershed to nearby Dixon. It is suspected that the floodplain near Dixon was under cultivation throughout the late pre-colonial period. Archaeologists have unearthed a couple of 14th or 15th century dates from the Dixon midden, suggesting at least limited camps in the vicinity of the plaza prior to the arrival of the Spanish (EVL and The Gorge Project, 2022).

Much of the Indigenous agricultural use of the watershed probably ended, first, with the loss of Picuris population due to 16th and 17th century epidemics and, second, with the departure of most of the tribe following Vargas's reconquest of New Mexico at the end of the 17th century (S. Fowles, personal communication, 2022).

Although the Picuris people no longer inhabit the Embudo Valley, they still have an important connection to the landscape and the wetlands. As the late Richard Mermejo, tribal elder, recalls the Embudo Valley's use and significance to Picuris Pueblo,

> The Pueblo of Picuris had grazed their horses and cultivated some fields until 1725 when the Spanish Kingdom adjudicated the Embudo de Picuris to the Embudo land grant. The valley still has a Cultural significance to the natives of Picuris. The springs that appear in the WAP draft report are still being used in our traditional ceremony…
>
> We have other areas that we periodically pay Spiritual pilgrimage which might not be in the study area but have Cultural Resources and is called in Tiwa *puun nah* where we gather resources for ceremonies. Other places that are mentioned in our fairytales are around the Embudo Station. The cliffs behind the old restaurants are referred to in the stories are the cliffs bench *pa t'ahn men łah*. The El Bosque *punn t'ah* was once a farming Pueblo which my Ancestor used as a summer place to plant beans, corn, and short season cotton among other edible plants due to its isolation from Picuris. With raids from nomadic tribes such as the Comanche, Utes, and other tribes it was abandoned around the late 1400, but the Picurisons still used it to farm and also to gather its rich natural resources for spiritual usage. Around the Dixon, *Tuy Noy*, area the Rio Embudo merge with the Rio Grande is called *p'a ocho na*.
>
> The Pueblo of Picuris is looking forward to the protection of all cultural places, as well as all springs and land within the Embudo area. These sites are held in high regard to the history and cultural significance it holds within the Picuris People (R. Mermejo, personal communication, 2023; lightly edited for readability).

In 1725, the Spanish Crown declared today's Embudo Valley as *La Merced de San Antonio del Embudo* a.k.a. the Embudo Land Grant (Figure 11). Picuris Pueblo protested that they used the valley's land for planting corn and raising horses, as recounted by Richard Mermejo. However, their outcries were ignored as the Spanish settlers concluded that there was no evidence of cultivation (EVL and The Gorge Project, 2022). Like many other land grants across the state, the valley's grantees resided on private property apportioned among the original settlers in equal amounts. The surrounding uplands and canyons were *ejidos*, or commons, with no marketable title. These lands were used for 300 years for activities like livestock grazing and wood harvesting. Many of the wetlands and springs in the Lower Rio Embudo Watershed are in these former ejidos.

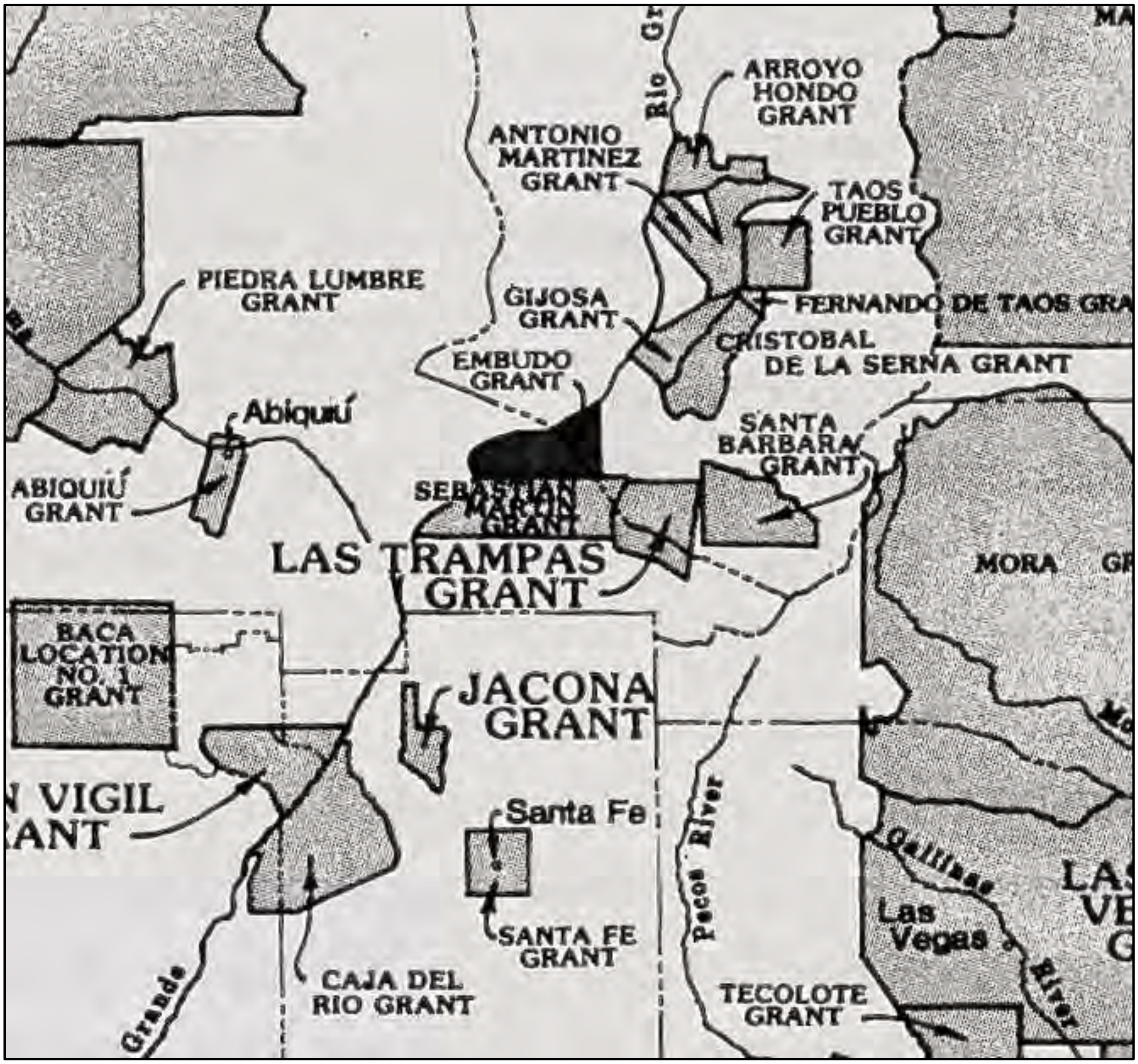

Figure 11. Map of La Merced de San Antonio del Embudo boundaries (black) (Ebright, 1994).

In 1846, after a short period of Mexican independence and occupation of New Mexico, the United States declared war on Mexico. The Taos Revolt of 1847 came to a clash in the Battle of the Embudo Pass where resisters awaited to attack the American troops, eventually surrendering to the invading troops. Boulders marked by bullet scars and crucifixes pecked into the rock faces, perhaps to commemorate fallen defenders (EVL and The Gorge Project, 2022), are still evident along the Cañada del Agua (western fork of the Arroyo la Mina), immediately to the west of the Section 32 wetlands and springs. In 1848, Mexico surrendered to the United States and signed the 1848 Treaty of Guadalupe Hidalgo, which promised to honor all previously held Mexican and Spanish land grants. However, in time this agreement was not upheld as U.S. and Spanish legal interpretations of land ownership, and in particular the ejidos, vastly differed. In 1898, La Merced de San Antonio del Embudo was rejected by the American government on a technicality proving that U.S. government was unwilling to recognize Spanish and Mexican custom. As U.S. law did not recognize the communal integrity of these commons, Anglo speculators, wealthy cattle barons, local politicians, and investors took advantage of this discrepancy by buying large tracts of ejidos out from under the grantees (Ebright, 1994).

For many years during the Spanish and Mexican occupations, livestock was kept at a local level with families moving their herds into the uplands and down into the valleys depending on the season. The Homestead Act created the Forest Reserve System of 1897, which prohibited any villager grazing on national public lands (DeBuys, 2015). Thus, grazing became concentrated in the nearby valley bottoms. This likely caused an overgrazing effect of areas with more palatable vegetation, such as the wetlands and springs.

By the end of the 19th century, the fragile landscape had begun to show signs of overuse, caused by economic need and the surrounding political factors. Eventually the nascent U.S. government agencies bought large swaths of the fragmented former ejidos, by this time fairly removed from the grantees, and placed them into public management (DeBuys, 2015). In 1912, New Mexico gained full statehood. Under later NMSLO and BLM policies, grazing permits relegated ranchers to certain pieces of land, such as Section 32, but not the full former commons, which may have further contributed to overuse and ecological degradation. Community members continue to recall their cash-poor family members having to buy back their land from the government. Many of the land-based, traditional residents continue to feel dispossessed by the historical losses, resulting in poor relationships with federal and state agencies.

The springs and wetlands in the WAP area of interest are located on these former commons, which leads to frequent, local, informal uses and a high cultural and historic value of the area. The late, local historian Juan Estevan Arellano recounted in “Enduring Acequias: Wisdom of the Land, Knowledge of the Water” how he would travel to Ojo Sarco (southeast of Dixon) to see his aunt, Merced. Arellano wrote,

> On our way to Ojo and on our way back, or when we would go for wood, we would always stop for a drink from *Ojo del Oso*, Bear Spring. There would be tracks of deer, coyotes, and an occasional bear. The spring had the most crystalline and pure water I have ever tasted. One could count the grains of sand on the bottom of the *chupadero* [a small, handmade cup used to gather and drink water]… We always knew where to find water. My father would always tell me, if there’s sand, there’s water; the same if you see cottonwoods—there’s water, because they have shallow roots and they grow only where there’s water close to the surface (Arellano, 2014).

Horacio Martinez, late Embudo Valley resident and community historian, recalls that when the river was too dirty he would go with his father to Apodaca, a small village on the outskirts of Dixon, to gather clean water from an *ojito* (spring) that he says his *tío* owned. The spring ran down to the road, but today it stops about 300 feet shy of its previous destination. In another story, Horacio recounts the cow who sank in quicksand in the nearby arroyo. He and other children were often warned not to go near the bubbling mud. Unfortunately, the cow could not be saved by ropes and met its death in the shifting sand (H. Martinez, personal communication, October 20, 2022).

Since the 1960s, many people of Anglo descent have been moving into the valley, bringing along wealth discrepancies and other land uses and values, such as a distaste for grazing or ATV usage, which have led to management conflicts and a renewed sense of displacement among the long-time Hispanic residents. As discussed in the “Local and Public Involvement Strategy and Education and Outreach” section, tensions have mounted between “newcomers” and the Hispanic population over how to use and preserve the landscape within the area of interest.

Presently, the majority of the springs and wetlands are located within the public land woodlands. The woodlands are used for recreation, such as hiking, nature observation, ORV use, and for occasional grazing by one permittee. The private lands are used for irrigated agriculture, dryland grazing, infrastructure, and residential and business uses. The riverine zone includes small public land parcels under management by BLM.

5. SPRINGS AND WETLAND INVENTORY

Spring and Wetland Mapping and Classification

The WAP area of interest includes springs and seeps, wetlands associated with springs and seeps, riverine wetlands along the Rio Embudo and the Cañada del Ojo Sarco, and riparian areas. Most of the springs, seeps, and wetlands occur as relatively isolated ecosystems spread across approximately 40 drainages, *i.e.,* arroyos, in the WAP area of interest. Table 3 provides an overview of the drainages with their known names, acreages, and indications of the presence of springs and wetlands.

Between 2012 and 2022, the BLM Taos Field Office identified at least 39 springs and seeps and their associated wetlands on BLM land and State Trust Land in the Lower Rio Embudo Watershed. Seven springs are outside of the area of interest for this WAP and are either to the north of the Rio Embudo or in the sub-watershed to the east (HUC-12 130201010907; Cañada del Ojo Sarco).

In 2022, Ecotone Landscape Planning compiled a wetland delineation based on the U.S. Fish & Wildlife Service's National Wetland Inventory (NWI) for a Pre-Construction Notification (PCN) of a Nationwide Permit-27 in anticipation of restoration work in several wetlands on Section 32 (Appendix A.1.). In addition, Ecotone in collaboration with the NMED Surface Water Quality Bureau conducted wetland assessments of three large spring-fed wetlands located on State Trust Land in the Arroyo la Mina sub-watershed using the NM RAM. Also in 2022, NMBGMR conducted a hydro-geochemical and water source analysis of five springs on State Trust Land (Newton and Koning, 2022).

Between 2018 and 2021, a team of BLM biologists sampled 37 of the springs, and two additional ones on State Trust Land that were afterwards determined not to be springs, using the Level-1 or Level-2 spring sampling method developed by the Springs Stewardship Institute. The BLM Level-1 and Level-2 SSI spring assessments indicated that basic chemical and physical water quality conditions are largely similar across the major spring areas on State Trust Land (Besser et al., 2021b). The NMBGMR water sampling and age dating assessment also found that sampled springs have basically the same water chemistry signature (Newton and Koning, 2022).

Table 3. Listing of Drainages, Acreages, and Associated Springs and Wetlands in the WAP Area

Arroyo Code	Arroyo Name(s)	Acreage	Area in Km2	Known Springs (name)	Known Wetland Acreage	Ownership
7		30.4	0.123			private, BLM
17	La Mesita Road Arroyo	22.5	0.091			private, BLM
20		8.9	0.036			BLM
22		18.3	0.074			private
25		33.9	0.137			private, BLM
28		157.4	0.637			private
29		23.5	0.095			private
30		162.8	0.659			private, BLM
31		87.0	0.352			BLM, private
35		16.3	0.066			private
40		16.3	0.066			private
41	Ballpark arroyo	50.2	0.203			RA County
46		7.4	0.030			BLM, private
47		16.6	0.067			BLM, private
49		63.8	0.258			BLM, private
51		12.4	0.050			BLM, private
55		10.9	0.044			BLM, private
56		59.1	0.239			BLM, private
63		138.9	0.562			BLM, private
66		53.1	0.215			BLM, private
67		17.1	0.069			BLM, private
71		36.1	0.146			BLM, private
74		16.1	0.065			BLM, private
77		125.8	0.509			BLM, private
79		16.8	0.068			private
84		117.1	0.474			BLM, private
94		60.3	0.244	Dixon S.#6 spring with Mud Bowl spring	<0.02	BLM, private
102		287.4	1.163			BLM, private
105	Cañadita del Agua	76.4	0.309	Spillway spring; Dixon S. #5 spring	>0.233	BLM, NMSLO
106		203.4	0.823	Dixon S.#7 spring; Spring #5	<0.01	BLM, NMSLO
110	Arroyo de los Arellanos	125.0	0.506	Wellcap spring	1.3	BLM, NMSLO
112	Arroyo Pino	1047.2	4.238	Dixon S.#1-#2-#3-#4-#8-#9-#10-#11 springs; Red Top spring; Slip & Slide spring; Cotton-wood Arroyo spring; Mesa Vista spring; Baseball View spring; Odyssey spring	total: 4.508	BLM, NMSLO
113	Cañada del Agua/ Arroyo la Mina/ Cañada Corral	1741.8	7.049	Labyrinth sp.; Stalactite sp.; Mushroom meadow sp.; Flat Top sp. Lightning Bolt sp.; Drip-drop sp.; Blackwater sp. (+ several unnamed springs)	total: 17.67	NMSLO, private, BLM
114	Arroyo de los Pinos Reales W	552.3	2.235	Spring#1-#2 spring	<0.02	BLM, NMSLO
115	Arroyo de los Pinos Reales E	669.7	2.710			BLM, NMSLO
116	Arroyo Lorenzo	1231.3	4.983	Serpentine spring; Orchard spring; Juniper thicket spring	total: approx. 2.5	BLM, USFS
117	Arroyo del Montecito	729.0	2.950			BLM, NMSLO
SUB_TOTAL		8042.0	32.545			
other	est. area of small arroyos	98.8	0.400			private, BLM
TOTAL		**8,140.9**	**32.945**		**>26.25**	

BLM staff informally estimated the acreages of springs that were not measured. More information is needed to generate a complete overview of spring and wetland conditions in the WAP area of interest.

The 37 springs first identified, named, and assessed by BLM represent five major spring types: helocrene, rheocrene, hypocrene, hanging garden, and hillslope springs (Appendix A.2.). About half of the assessed springs are hypocrene, a type of buried spring where flow does not reach the surface. Rheocrene springs, where flow emerges into a defined channel, comprise a quarter of the springs (Figure 12).

The primary rock type of all the springs surveyed by the BLM is sedimentary in geologic strata dominated by colluvium, which is loose, unconsolidated sediment deposited at the base of hill slopes. Most of the springs support downstream wetlands, which typically exist on slopes around the springs and in the arroyo bottoms. The wetlands often comprise several microhabitats, including a channel and surrounding terrace with varying degrees of wetness and at times distinct seeps. The dominant aspects of springs surveyed were northeast to northwest with no south facing springs.

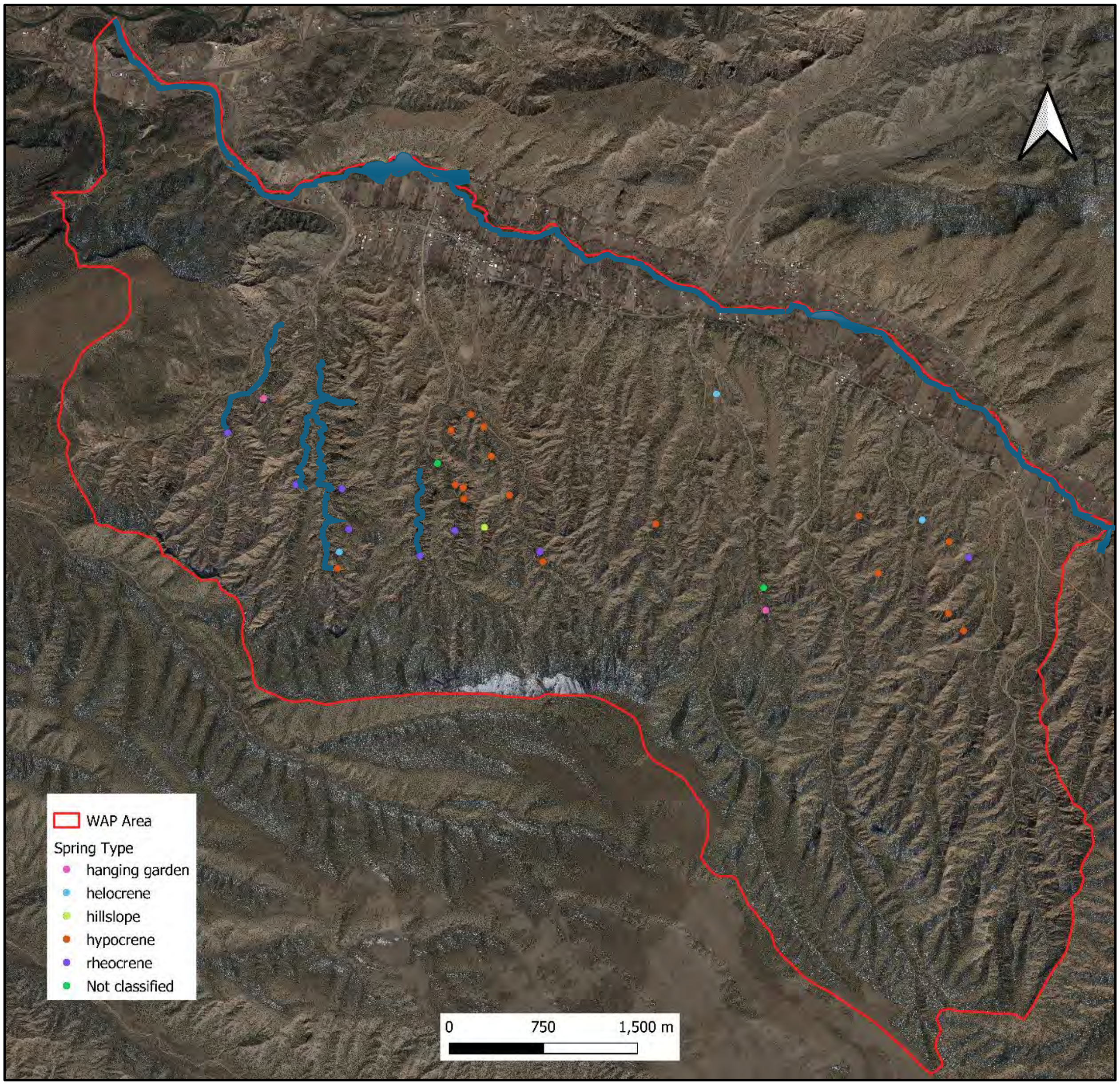

Figure 12. WAP study area with identified springs classified by primary spring type. The assessed and presumed areas for riverine wetlands along the Rio Embudo and the tributaries of the Arroyo la Mina are indicated with a blue line.

All surveyed springs emerged subaerially in a seepage/filtration environment with a gravity flow force mechanism. Many of the springs had no flow at the time of being surveyed while eight of the springs had active flow. Flow rates range between 0.0729 and 0.49 liters per second with a mean value of 0.33 liters per second (Besser et al., 2021b). This equates to 5.23 gallons per minute or 8.43 acre-feet per year. The NMBGMR research identified that water flowing from the springs is largely originating from sandstones in the Miocene Tesuque Formation which is part of the Santa Fe Group (Newton and Koning, 2022). Typically, the water in this aquifer is at least 50 to 60 years old and younger than 10,000 years. The aquifer is thought to recharge mainly from snowmelt infiltrating in the form of mountain block recharge into deep fractures of Precambrian crystalline rock and mountain front recharge in alluvial fans from mountain streams and summer storms (Newton and Koning, 2022). The flow path is probably at least 1 km deep and at least several kilometers long (Figure 13).

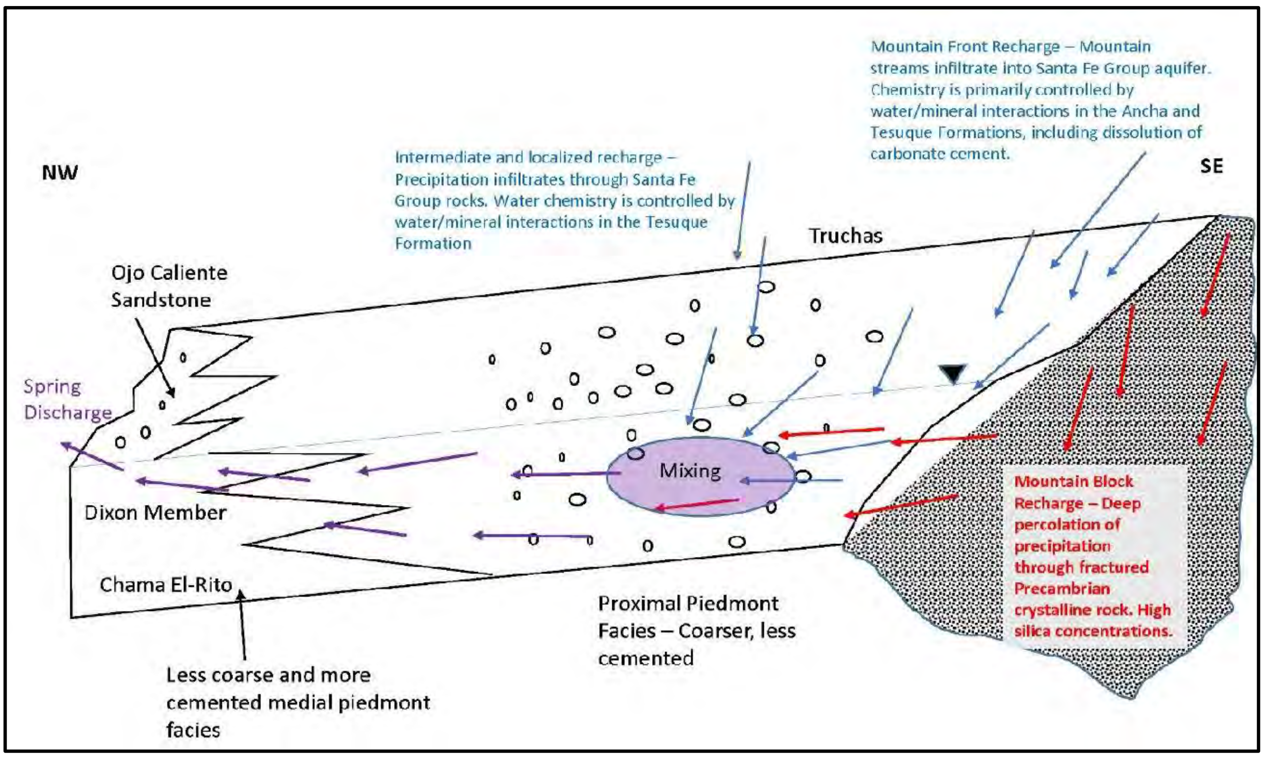

Figure 13. Conceptual model of flow paths for groundwater that discharges at springs within the Dixon Spring Complex, south of Dixon, NM. Not to scale (Newton and Koning, 2022).

The aquifer that feeds the springs originates from the Tesuque Peak area in the Sangre de Cristo Mountains to the southeast of the Lower Rio Embudo Watershed. NMBGMR's findings indicate that mountain block water gets possibly mixed with some local infiltration on mountain front alluvial fans and in the Ancha and Tesuque Formations on Mesa de la Cejita. The authors caution that more sampling is required to solidify the assertions made in their report (Newton and Koning, 2022).

As a result of the findings in 2022, it can be stated with near certainty that the base flow of the springs is stable with variable discharges of less than 1 cfs for each spring. The discharge is expected to be “fairly resilient to changes in the water cycle as a result of climate change” (Newton and Koning, 2022). This is evidenced by the existence of the wetlands downstream from the springs that rely on a persistent, relatively shallow water table. The suspected age of the spring water indicates that the wetlands have been continuously fed by the springs over millennia.

Newton and Koning (2022) observe that many spring deposits at higher position on the local hill slopes indicate that during relatively wet periods spring discharge increases. As a result, fluctuations in annual and seasonal precipitation likely cause fluctuating recharge in mesas upstream of the WAP area as well as localized recharge in the piñon-juniper ecosystems in the landscape above the springs and wetlands. This leads to fluctuations in flow rates from the springs. Infiltration in the wider landscape is thus expected to boost spring flow during years with ample precipitation while during periods of drought the springs will rely on the baseflow provided by the deep aquifer. Additionally, the chemical signature of the water of the spring sample for Lightning Bolt Spring shows indications of evaporative water loss (Newton and Koning, 2022).

The NMBGMR describes that the springs are arranged along a southeast to northwest trend, becoming lower in elevation toward the northwest and discharging from lower stratigraphic layers to the northwest (Newton and Koning, 2022). This trend aligns with the northwesterly direction of the groundwater flow in the area.

BLM assessments indicated that the springs have variable ecological conditions. Twelve springs were meeting PFCs and five were “functional-at risk” but within management control. The at-risk sites were impacted by a progressing invasion of exotic plant species such as Russian olive, saltcedar, cheatgrass, and redtop which could lead to dewatering and loss of wetland characteristics. Table 4 describes the FAR conditions for the large spring-fed wetlands on State Trust Land in Section 32.

Table 4. Description of Functional-at Risk Springs in Study Area

Spring Name	**Stressor Description**
Blackwater Spring	Livestock presence, 4x4 use in the lower section of the channel, light recreation (hiking, dogs), and a dirt road nearby the lower end of the spring, at risk due to invasion by Russian olive
Labyrinth Spring	Invasion by Russian olive and tamarisk; variable incision
Lightning Bolt Spring	Invasion by exotic species, especially tamarisk; channel incision
Redtop	Presence of tamarisk. Since this is already a low-flow site in a very dry area, the presence of tamarisk has the potential to dewater the spring.
Spillway	Significant human activity (firewood collection, path clearing)

Note: Descriptions from BLM Taos Field Office Spring Reports (Besser et al., 2021b).

NM Wetlands Rapid Assessment Method

Ecotone and NMED-SWQB used the NM RAM Montane Riverine Wetlands v. 2.5 (Muldavin et al, 2022) to evaluate the ecological conditions of Blackwater Spring, Lightning Bolt Spring, and Labyrinth Spring, all of which are located within State Trust Land in Section 32 south of Dixon (Figure 14). The NM RAM for Montane Riverine Wetlands uses fourteen wetland ecological metrics including GIS-based and field measurements. These metrics fall within three attribute categories: (a) the evaluation of the landscape context using GIS and maps to evaluate conditions surrounding the Sampling Area (landscape context), (b) field-based evaluation of abiotic metrics (abiotic context), and (c) field-based evaluation of biotic metrics (biotic context).

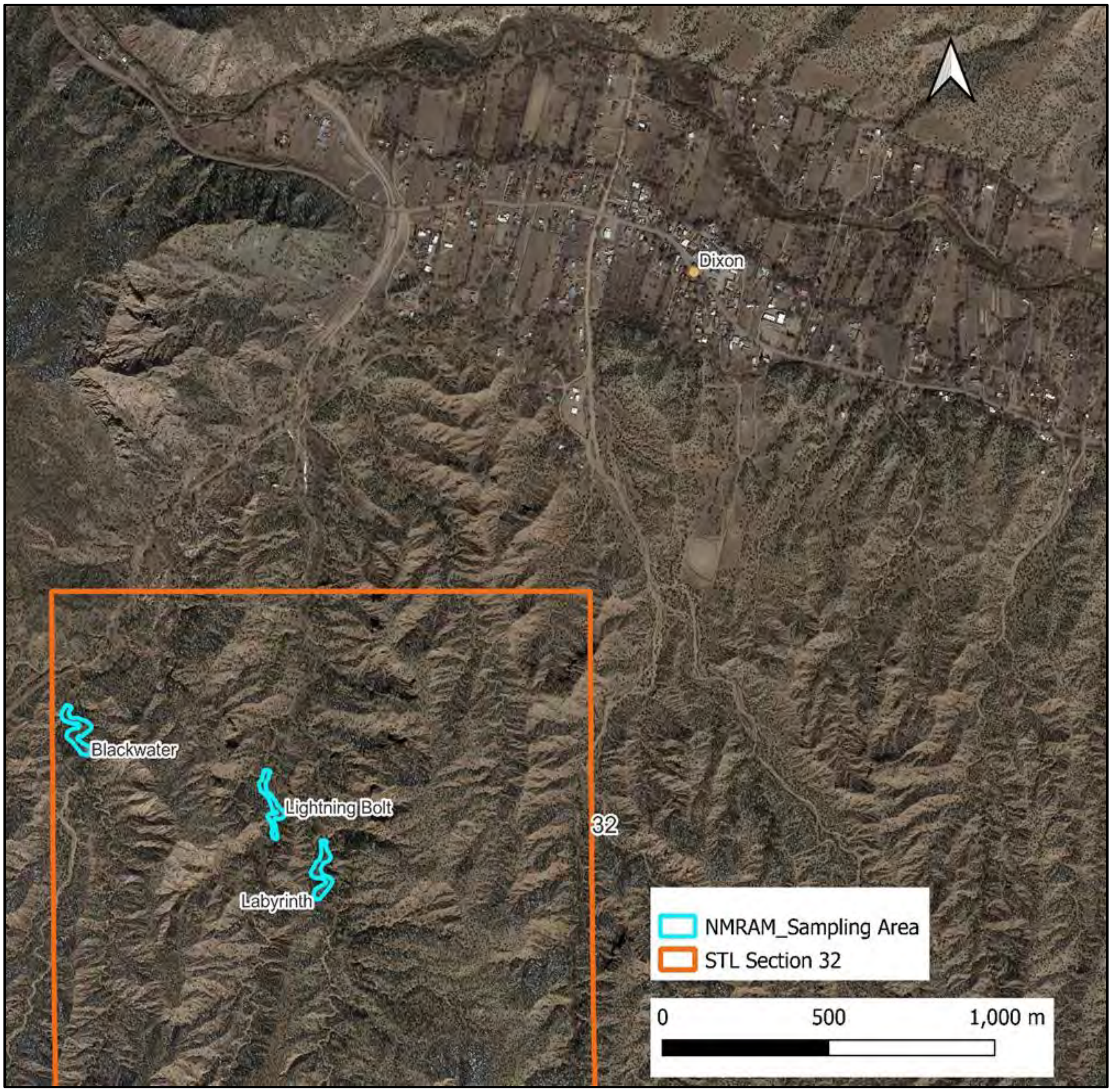

Figure 14. Three Sampling Areas used for NM RAM.

Surveys were conducted in 2022, before restoration implementation, and again in 2024, after implementation. Several techniques were utilized between 2023 and 2024 to treat the springs and wetlands, such as building low-tech, process-based structures (Zuni bowls, one rock dams, etc.); strategically placing lop and scatter on bare soil; spot thinning; seeding native grasses; and laying back banks. The similarity of the geophysical conditions of other wetlands in the WAP area suggests that the wetland evaluation findings can serve as proxies for the varying conditions of spring-fed wetlands across the WAP area of interest. Conclusions drawn from post implementation comparisons to the baseline data also serve as insight into expected improvements within springs and wetlands when restoration actions are taken. A description of the Sampling Area for each spring is detailed in Table 5.

Table 5. NM RAM Sampling Area Descriptions for Assessed Wetlands

Spring Name	**Approx. SA Acreage**	**Approx. SA Length (ft)**	**Approx. SA Valley Width (ft)**
Blackwater Spring	1.28	830	50-110
Lightning Bolt Spring	0.96	890	25-80
Labyrinth Spring	1.09	760	35-100

Although conditions were somewhat variable between the three springs, the three areas experienced similar stressors in both monitoring instances. These stressors included drought impacts followed by intense flash floods which result in varying degrees of channel erosion, which appears to be exacerbated by observed trailing (ruts caused by trodden vegetation and compacted soil), and streambank collapse due to seasonal treading by cattle and human foot traffic. The springs showed stressed conditions among many older cottonwoods and invasion of Russian olives, tamarisk, and redtop, likely due to dry conditions resulting from channel incision which leads to a hydrologically disconnected floodplain and decreasing water availability for wetland plants. Encroachment of junipers further points to a general drying of these wetlands. Although efforts were taken to rehydrate the floodplains during the implementation phase, longer term data collection is needed to understand if the restoration actions positively affect the vegetation.

The 2024 NM RAM scores indicated that two wetlands were in “Good Condition” and one was in “Excellent Condition,” all having improved since the 2022 NM RAM. Each spring had an “Excellent Condition” score for the landscape context category, with two springs improving and one remaining the same. Abiotic metrics were variable between springs resulting in “Good Condition” to “Excellent Condition” scores. Labyrinth Spring abiotic metrics notably improved from a “B” to an “A”, while Blackwater Spring dropped slightly in score. Conversely, the biotic metrics scored the lowest with “Fair Conditions” score, which is the same as 2022. This is due in all instances to a high degree of invasion of non-native plant species, specifically by Russian olives, low native tree regeneration, and limited patch and vertical plant diversity. Despite the overall “Good” to “Excellent” conditions assessed for each spring, the low scores in biotic metrics seem to point at a decline of these ecosystems. However, scores did improve or stay the same since 2022, which potentially indicates that the restoration techniques may have contributed to the reduction of the underlying stressors and led to incremental biotic shifts.

Table 6 and Table 7 present the findings for Blackwater Spring, Lightning Bolt Spring, and Labyrinth Spring. The Wetland Rank Descriptions are: A = Excellent Condition; B = Good Condition; C = Fair Condition; D = Poor Condition

Table 6. 2022 NM RAM Findings for Each Spring/Wetland (Baseline Survey)

Spring Name	**NM RAM**		**Abiotic Condition** *(Measured at three transect locations)*	**Biotic Condition**	**Landscape Context**
	Score (1-4)	**Rank (D-A)**			
Blackwater Spring	2.945	B	Abiotic metrics were highly variable. Hydrologic connectivity as measured by entrenchment ratio scored high as did physical patch complexity. However, there was also many signs of surface disturbance and disequilibrium as indicated by signs of erosion and sediment deposition. **Score: 3.2 (B)**	The biotic condition was the most degraded compared to other metric categories. There was a high presence of invasive species (esp. Russian Olive and poison ivy) and limited signs of regeneration of native cottonwoods. Together with evidence of juniper encroachment this indicated general drying of the wetland. **Score: 2.0 (C)**	Highest score in all metrics except relative wetland size. The area is well insulated from outside perturbances related to land use and development; however, the wetland size has shrunk due to channel incision. **Score: 3.75 (A)**
Lightning Bolt Spring	2.875	B	Good hydrologic connectivity measured by entrenchment. Medium scores for physical patch diversity and stream bank stability and cover. Low scores for channel equilibrium and soil disturbance for similar reasons as Blackwater. Evidence of channelization was worse than other springs in many places. **Score: 3.0 (B)**	The biotic conditions were also very degraded. There was limited patch diversity and complexity and the area was heavily invaded by Russian olives (estimated 20% cover of the SA). There was limited regeneration, evidence of herbivory, and many stressed cottonwoods. Herbaceous wetland plants were not evident of the floodplain but were restricted to the channel, again indicating drying of the wetland. **Score: 2.0 (C)**	Highest score in all metrics except relative wetland size. Same context and landscape stressors as the nearby Blackwater Spring. **Score: 3.75 (A)**
Labyrinth Spring	2.875	B	High stream bank stability and cover and good floodplain hydrologic connectivity according to entrenchment ratio. Little physical patch diversity and evidence of disturbed soil surface. Deep incision and parallel channels in some locations. **Score: 3.2 (B)**	All biotic metrics for Labyrinth scored a C or below despite better cover of herbaceous species than Lightning Bolt. High degree of invasion (~15% cover) especially of Russian olive that is readily regenerating. Low regeneration of native cottonwood and willows and evidence of herbivory. **Score: 1.8 (C)**	Like other wetlands, high score in all metrics except relative wetland size. **Score: 3.75 (A)**

Table 7. 2024 NM RAM Findings for Each Spring/Wetland (Final Survey)

Spring Name	NMRAM Score (1-4)	NMRAM Rank (D-A)	**Abiotic Condition** *(Measured at three transect locations)*	**Biotic Condition**	**Landscape Context**
Blackwater Spring	2.98	B	Abiotic measurements are variable. Hydrologic connectivity scored high. Stream bank stability and cover scored low due to bank soil stability and stream bank erosion potential. Cattle and drought are the largest stressors with possible flash flood impacts. All likely created incision of spring area. Vegetation holding banks is variable. **Score: 3.1 (B)**	Biotic metric is the lowest for BWS as "fair condition." Invasives had a considerable amount of coverage (>10%), mostly composed of Russian olives in different size classes). There was limited riparian tree regeneration. There is a limited degree of patch diversity and complexity. Cattle impact evident on native spp. saplings. Observationally, areas are drying since many cottonwoods are dying, and there is an encroachment of Juniper and Russian olives. **Score:2.2 (C)**	Landscape context has a high score. Relative wetland size is equal to or more than 60% of its natural size. **Score: 3.75 (A)**
Lightning Bolt Spring	2.94	B	Abiotic measurements were highly variable. The lowest score was attributed to soil disturbance from ungulate activity. Observationally, there was less floodplain and incision present. **Score: 3.2 (B)**	Biotic conditions were "fair" with low relative native plant community compositions, a low degree of patch diversity and complexity, and low representation of native riparian tree regeneration. In addition, there is a high percentage of invasive exotic plant species cover (mostly Russian olive in various size classes). **Score: 2.2 (C)**	Landscape context rated high. The relative wetland size was the only negative as it has been reduced by more than 40% to its natural size. This is likely due to cattle, drought, and flash floods, which have likely caused present incision. **Score: 3.5 (A)**
Labyrinth Spring	3.33	A	Abiotic conditions scored high. Soil surface conditions had some disturbance from cattle but limited. Observationally, there is not a lot of overbank flow indicators. Bankfull height was very convoluted, and a couple inches of water was in the water channel. **Score: 3.9 (A)**	Biotic conditions are "fair" with a low relative native plant community composition (20-50% non-native, mostly Russian olive and alfalfa). Observationally, there were lots of wetland obligate and facultative species. In addition, horsetail and rushes stretch up the bank into the hillside to another spring in one area. **Score: 2.4 (C)**	Landscape conditions are "excellent." Relative wetland size remains equal to or more than 60% of its natural size. Visually, biotic and hydrological wetland expansion at the valley edges (upslope) and in various side valleys and at lower end of the restored wetland reach. **Score: 3.75 (A)**

Riverine Wetlands and Riparian Areas

The larger rivers and their tributaries in the Lower Rio Embudo Watershed support riverine wetlands and riparian areas. However, none of these have been delineated, identified, named, or inventoried. As a result, no quantitative information exists on their acreage, ecological conditions, stressors, functions, values, and risks for the larger landscape. These wetlands and riparian areas are particularly present along the Rio Embudo, the Arroyo la Mina, including Cañada Agua, Cañada Corral, and the lower reach of the Cañada de Ojo Sarco near the confluence with the Rio Embudo.

However, from observations and anecdotal information in the community, it is known that the riverine wetlands along the Rio Embudo are flooded during high-runoff years. Flooding often causes stress on wetland conditions due to scour and deposition of cobble, gravel and coarse sand. Overbank flows often occur both in the spring season due to snowmelt runoff in the upper watershed and in the summer and fall due to severe thunderstorms. Peak flows in the Rio Embudo are highly variable with occasional daily peak flows of 1,000 cfs or more and seasonal peak flows between 175 and 340 cfs in the spring runoff season (USGS, n.d.). Occasional peak flows cause severe bank erosion as well as debris and coarse (cobble) sediment deposition onto the floodplains and banks of the Rio Embudo that impact flow paths of the river channel and damage riverine wetland ecosystems (Figures 15, 16). Cumulative flood impacts have had a degrading effect on many riparian areas. At various locations the riverbanks and old floodplains have been disconnected from the river channel.

The riverine wetland habitat of the Rio Embudo supports streamside vegetation of cottonwood and willow in wetland *bosques*. However, many bosque patches are dry, dead, and dense, constituting a wildfire hazard, and large portions of floodplain wetlands and riparian areas include invasive plants, such as Russian olives and saltcedar. The last riparian wildfire occurred in the summer of 2011 near the bridge of County Road 65 across the Rio Embudo. The streamside vegetation also constitutes beaver habitat. Annually, beaver have been building dams and ponding the river water in several locations.

The tributaries with riverine wetlands, notably the Cañada de Ojo Sarco and Arroyo la Mina, have highly variable flow regimes with a flashy character as well. In the past twenty years flows in these tributaries have been very erosive to channel bottoms and banks. The erosion has caused certain reaches to be badly degraded, sometimes down to bedrock, and unable to support wetland vegetation. Locally, riparian restoration work has taken place or has been planned. For example, at the confluence of the Cañada de Ojo Sarco and the Rio Embudo, the NM State Land Office, a private landowner, and the NRCS are preparing to create check dams and stabilize the banks of about 15 contributing drainages and provide habitat improvement in the bosque.

Figure 15. View upstream of bank erosion of riverine wetlands on the right bank of the Rio Embudo at the upper end of CR 240.

Figure 16. View upstream along CR240 and Rio Embudo toward locations where bank stabilization work on river right was implemented in 2022. Note riverine wetland vegetation on both sides of the river.

6. WETLAND DEGRADATION CAUSES, THREATS, AND STRESSORS

Wetland degradation is a complex process that involves several different stressors and overarching causes. Planning the stabilization of ongoing and future wetland degradation requires assessments of cumulative effects of past, ongoing, and anticipated new stressors and causes. Understanding whether and how certain causes and stressors can be alleviated is critical in ensuring that the most effective management measures for wetland restoration are employed in the near and longer-term future.

Causes and symptoms of degradation must be clearly distinguished. Causes are the underlying, fundamental reasons behind degradation while symptoms are the visible indications of the issues. For example, while drought or fire are typically causes of degradation, associated symptoms may include soil loss (erosion), turbidity in the Rio Embudo, sedimentation of acequias, flooding on private lands, decline of bird populations, invasion of exotic trees, or die back of cottonwood trees or herbaceous wetland plants. In turn, sometimes certain symptoms are causes in themselves of further wetland degradation.

The springs, wetlands, and riparian areas in the WAP area of interest have been affected by seven major causes of wetland degradation. These causes and their subordinate stressors threaten to continue if no action is taken. The seven causes include:

a. Climate change, expressed in the cumulative effects of extreme weather events, such as periods of extreme drought, events of high intensity rainfall, and increased exposure to high temperatures leading to increased evaporation from the soil and open water in springs and wetlands
b. Catastrophic ecological events, such as periods with extremely high temperatures, an absence of precipitation, and subsequent soil moisture deficits, or events, such as mass wasting, destructive flooding, channel and bank erosion, and wildfire
c. Removal or destruction of vegetation and soil structure due to grazing, fire, off road vehicle use, foot traffic, or deliberate vegetation removal
d. Reduced groundwater flow potentials due to groundwater diversion in the region by domestic wells
e. Reduced surface water inflow due to land degradation and climate impacts
f. Cumulative separation of the channel and its water from the floodplain and terraces, represented by channel degradation, bank failure, and sediment transport, due to the combined impacts of the stressors listed above

g. Encroachment by and proliferation of invasive plants and the gradual depletion of habitat qualities, ecological resilience, and biodiversity

While these causes pertain to ongoing and future stressors on the wetlands, an initial rapid appraisal of wetland conditions in 2021 and 2022 of the four large wetlands in the project "Restoring Springs and Wetlands on State Trust Lands in the Lower Embudo Valley" indicated that present stressors that impact the ecological integrity of the springs and wetlands can be summarized in three categories for the purpose of planning corrective actions:

A. **Geophysical processes**, such as (a) abrasion caused by flash floods and bank erosion, (b) smothering caused by sediment movement, and (c) dewatering caused by channel degradation, bank erosion, and high temperatures leading to evaporation losses and drought
B. **Human impacts**, at specific locations, associated with periodic, free-range livestock grazing, off road vehicle use, and foot traffic, which lead to compaction, perforation and drying of wetland soils, formation of channelized cutoff channels, bank erosion, and gradual decline of species richness and conversion of plant communities
C. **Indirect and cumulative effects** from the disconnect between channels and floodplains, headcutting processes in channels and tributaries, evaporation due to bare soil, and ecological competition from non-native, invasive plant species, (*e.g.,* Russian olive and saltcedar) and native, upland species, (*e.g.,* one-seed juniper), leading to gradual decline of species richness and conversion of plant communities and wildlife communities.

Category A of geophysical processes exceeds the scale of the landscape and time within which this WAP can be effective. Some management measures and practices that have a regulating or mitigating function may be possible and effective, but solutions to the root causes of the threats in this category will require a long-term approach beyond the geographical area of this WAP. Category B of human impacts is a tangible but socially challenging category for which this WAP provides some recommendations with the understanding that change will take time. Finally, Category C of indirect and cumulative effects offers several opportunities for mitigation through the application of practices that stabilize soils, restore natural channel morphology and overbank flows of wetland stream channels, and induce the conversion of invasive plant communities to native ones.

This listing of stressors observed at the individual wetland level mirrors the listing of area-wide threats and trends documented in the WBP and through community surveys. These types of stressors as well as specific human activities (such as river channelization, road and utility infrastructure, construction, and water diversion structures) are also impacting the riverine wetlands and riparian areas along the Rio Embudo and Cañada del Ojo Sarco. The combined impacts from these practices have resulted in stream bank erosion and collapse, changes to natural vegetative structures, increased fire hazard, and changes to overall natural functioning of the landscape (Environmental Health Consultants and NMED, 2010).

Causes of wetland degradation as well as degradation symptoms can occur at different intensities. They may occur gradually over many years, rapidly, or suddenly; they may occur in one location or all over the landscape. An example of slowly progressing degradation is the dying of wetland ecosystems due to drought. Rapid degradation is possible as a result of annual overgrazing or widespread pollution incidents. Sudden degradation may be caused, for example, by a flash flood event that causes severe erosion in an old cattle trail. Sudden, large-scale degradation could, for example, be caused by high intensity wildfire.

Wetland degradation can have damaging effects on the surrounding ecosystem and on downstream human communities. Similar to the Scott et al. (2013) risk definition of wildfire, the risk of wetland degradation is a combination of the likelihood of ecosystem degradation, its intensity, and the vulnerability of landscape values that may be impacted, as expressed in Figure 17. The risk of wetland degradation can, therefore, be described as the likelihood and intensity of wetland ecosystem decline and the vulnerability to degrading impacts of the surrounding landscape, including human communities. Identifying the risk of wetland degradation for downstream communities and specific risk levels (low to very high) helps with identifying priorities for intervention and the benefits of the interventions for downstream communities.

RISK LEVELS OF WETLAND DEGRADATION		Wetland degradation hazard		
		LOW	MEDIUM	HIGH
Vulnerability of landscape values to wetland degradation	LOW	Low	Medium-low	Medium
	MEDIUM	Medium-low	Medium	High
	HIGH	Medium	High	Very High

Figure 17. Graphic explanation of wetland degradation risk level. Graphic created by J.W. Jansens is based on Scott et al. (2013) and unpublished graphics by Forest Stewards Guild.

Wetland degradation in the Lower Rio Embudo Watershed bears the risks of causing:

a. Increased flash flooding, inundation, and debris and sediment deposition on and around valuable infrastructure, land, and buildings
b. Severe erosion of valuable infrastructure and productive land
c. Increased costs associated with flood damage mitigation
d. Nonpoint source pollution in the Rio Embudo and Rio Grande and associated siltation of downstream water storage and conveyance infrastructure
e. Reduction of additional water supplies provided by springs and wetlands
f. Degradation of soil health, water retention capacity in soil, native plant cover, wildlife habitat, and scenic qualities.

Risk of Impacts on Landscape and Community Values

Observations and community feedback during severe thunderstorms in 2022 confirm the general geophysical principle that cloud bursts over small drainage areas tend to cause sudden and intense flash floods. Such flash floods hold the risk of serious downstream effects. Figure 18 shows the critical impact locations of flash flooding in the Lower Rio Embudo Watershed based on flashfloods in 2022 and additional community input from past experiences. Besides flood damage and debris flows affecting homes, fields, and the Rio Embudo and Rio Grande, wetland degradation also risks potentially significant loss of marginal baseflow to local acequias due to evaporative water loss, which is particularly problematic during times of extreme drought.

Wetland degradation furthermore risks the loss of many ecosystem functions that are valued in the community, as explained elsewhere in this WAP.

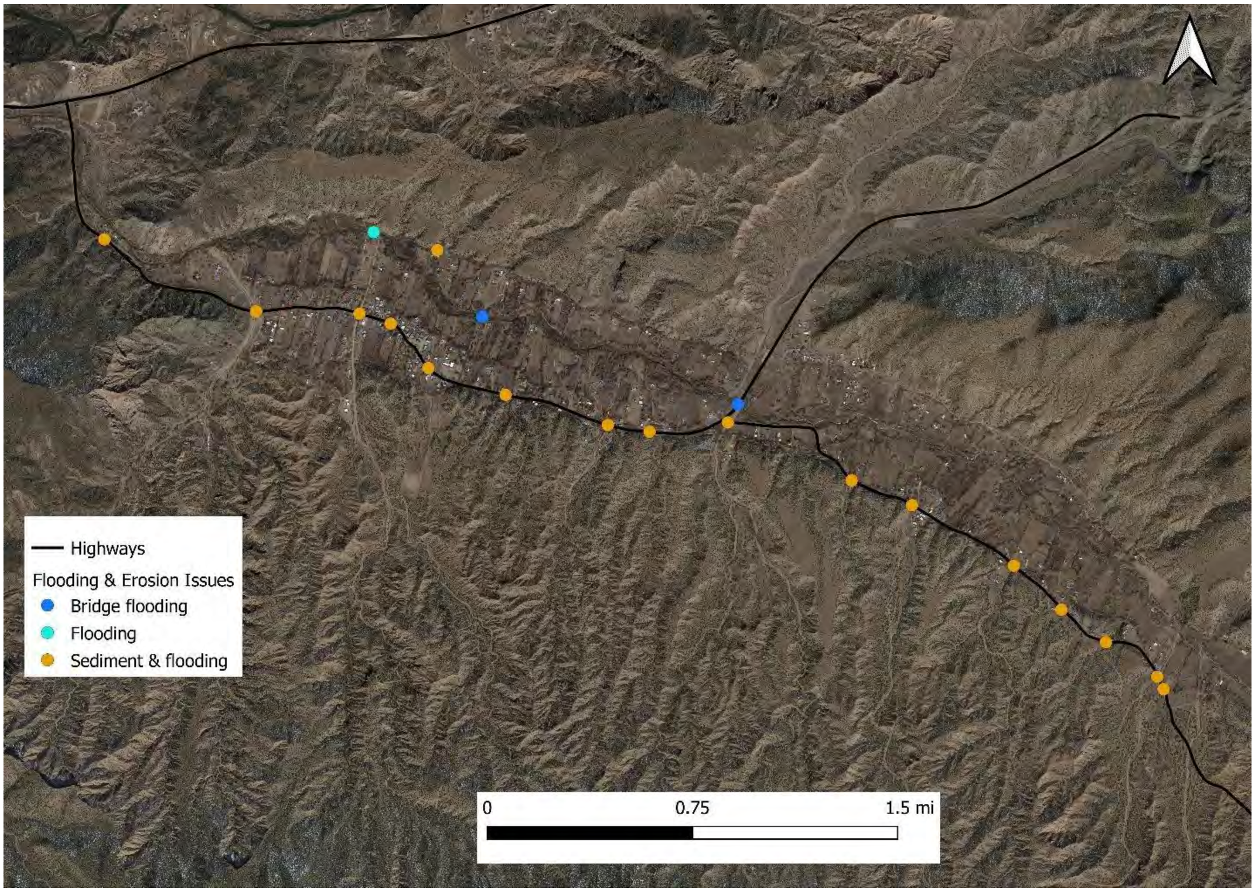

Figure 18. Map of locations in the WAP area of interest where there is a risk of flooding of bridges, flooding of property, or sediment deposition combined with flooding of property (McElroy, 2022a).

On a regional scale, the risk of ongoing degradation and the collapse of the springs and wetlands have serious consequences for water quality in the Rio Grande and for the cost of water purification and infrastructure management downstream. Starting with the landscape of the Sangre de Cristo Mountains, wildfire and other forest and soil degradation processes could lead to a reduction of snowmelt and stormwater infiltration which presently boost the aquifer-fed baseflow of the springs. Furthermore, accelerated erosion, debris flows, and mass wasting in a post-fire landscape would likely cover or undermine springs and scour or cover the wetlands.

When the functioning conditions of wetlands are further impaired, it is conceivable that the soils in the wetland areas will begin to erode, as has been observed at several of the degrading springs and wetlands in the eastern and far western parts of the WAP area. Such wetland channel erosion likely leads to head cutting, gullying, and accelerated erosion from side slopes and from the upper areas of each tributary above the wetlands due to gravity forces caused by increased slope steepness and reduced aggregate stability related to a loss of plant and root mass, combined with increased runoff (and flash flood) energy. These cascading processes will inevitably lead to increased sediment transport down the drainages to the Rio Embudo. This may cause increased sediment loads in the Rio Embudo and the Rio Grande.

7. ACTIONS TO PROTECT AND RESTORE WETLANDS

Proposed actions to protect and restore wetlands can be subdivided into (a) assessments and research, (b) physical protection and restoration activities, (c) educational outreach activities, and (d) capacity building activities. This WAP suggests a prioritization of actions based on terrain conditions and practical feasibility.

a. Assessments and Research

Several significant information gaps exist in this WAP as well as the documents published by the BLM, Ecotone, and NMBGMR. By conducting further assessments and research, a more accurate understanding of the restoration work needed in the springs and wetlands can be obtained. Table 8 presents the prioritization of the needed assessments and research for the springs and wetlands. Priorities were suggested by the Core Team for this WAP.

Table 8. Actions Ranked by Priority Regarding Assessments and Research (1=High, 2=Medium/Lower)

Needed Assessments	Priority	Area	Key Partners
Any springs and wetlands not yet identified or assessed, including riverine wetlands and riparian areas along Rio Embudo and other streams in the WAP area	1	WAP area, along Rio Embudo, Canada de Ojo Sarco, and Rio de las Trampas	BLM, USFS, private
More complete assessments, including Level-2 assessments for all springs	1	WAP area	BLM, NMSLO
PFC assessments and/or NM RAM assessments for key wetlands	1	WAP area	BLM, NMSLO
Details on the severity of impacts of wild ungulate and cattle grazing on spring and wetland functions and viability in the WAP area	2	Grazed areas on State Trust Land and BLM	NMSLO, BLM, permittee(s)
Details on the impacts of past and ongoing ORV impacts on their ecological functions and viability of arroyos and wetlands	2	Upland slopes and arroyo bottoms and banks used by ORVs	NMSLO, BLM, community members
Details on the impacts of pedestrian visitation on the ecological functions and viability of springs and wetlands	2	Upland slopes and arroyo bottoms and banks used by hikers	NMSLO, BLM, community members
Aquatic life conditions, especially regarding macroinvertebrates, of the most important springs: Level-3 SSI spring assessment	2	Selected areas (TBD)	NMSLO, BLM

Needed Research	Priority	Area	Key Partners
Benefits, feasibility, appropriate methods, and consequences of the removal of Russian olives from wetlands and springs	1	Wetland areas with Russian olives	BLM, NMSLO
The role and relative importance of springs and wetlands in reducing the magnitude of flows and deposition of sediment on farms and infrastructure downstream	1	WAP area	NMSLO, BLM, community members
Information on the flow volumes, age, flow paths, and source of origin of the water of many springs (see Appendix C for details and NMBGMR tasks 1-5 below)	1	WAP area	BLM, NMSLO, NMBGMR
Relationships between mountain front recharge and water discharge in springs (Appendix C)	2	Watershed	BLM, NMSLO, NMBGMR
Relationships between groundwater diversion in wells and water discharge in springs (Appendix C)	2	Watershed	BLM, NMSLO, NMBGMR
Ongoing sampling and tracking of sediment loads in the Rio Embudo	1	Watershed and Rio Grande	NMED, NOAA, and USGS

The ongoing identification and assessment of the springs and wetlands in the WAP area is of high importance for understanding the ecological health of the resource base and to plan needed actions. PFC or NM RAM methods can be utilized to assess the springs and wetlands, although we recommend using the PFC as stated previously in this document. Completing the Level-2 SSI assessment for all springs and Level-3 SSI spring assessments of the most important springs with flowing water would give a more holistic understanding of the spring health and assist with future prioritization of spring and wetland restoration actions.

In 2022, the NMBGMR collected and analyzed five water samples from four different springs. Geochemical analysis of the sampling data and existing geologic and hydrogeologic data provided important information about potential recharge sources and flow paths for the springs. However, due to the small dataset (5 samples), conclusions from the study contain several uncertainties. The NMBGMR study proposed a hypothetical hydrogeologic conceptual model that has helped to identify more specific questions about the region and local hydrogeologic systems. Additional research is needed to better evaluate these systems, determine flow volumes, age, and source of spring water origin (Appendix C).

This WAP does not suggest the banning of current uses of the wetlands. Instead, the WAP recommends that further investigations be launched to better understand the underlying causes and conditions of land-use stress. Fairness to residents and land users and effectiveness of propositions for changes in land-use practices require an understanding of the precise impacts of land-use practices (*e.g.,* grazing, ORV use, hiking, water extraction) in the watershed before taking any actions. It is important to understand the impacts of land use practices in terms of their timing, intensity, duration, and specific locations.

Furthermore, researching the role of wetlands and springs in reducing the magnitude of flows and deposition of sediment on farms and infrastructure downstream is important to determine future risks for residents and local agencies, such as NM DOT. This research requires different methods than the PFC or NM RAM and a social data gathering component. Concurrently, it is of great importance to reactivate the existing sampling stations in the Rio Embudo in order to compare and track the relative contribution of sediment from the Rio Embudo into the Rio Grande. Their activation would provide an extensive and long-term data set on sediment loads that would help track the overall goals of the WBP and WAP and allow for an early warning system about excessive sediment discharges in the Rio Grande or indications for improvements in the impairment levels of the Rio Embudo.

b. Physical Protection and Restoration Activities

In this WAP, the selection of actions for the physical protection and restoration of springs and wetlands is based on identifying past and ongoing activities that could be improved or expanded, identifying the protective functions and associated risk of wetland degradation, and practical feasibility criteria. Past and ongoing initiatives may provide lessons learned for new initiatives and serve as anchor points for new initiatives. Figure 19 shows a map of the past and ongoing project locations, and Table 9 provides a listing of past projects.

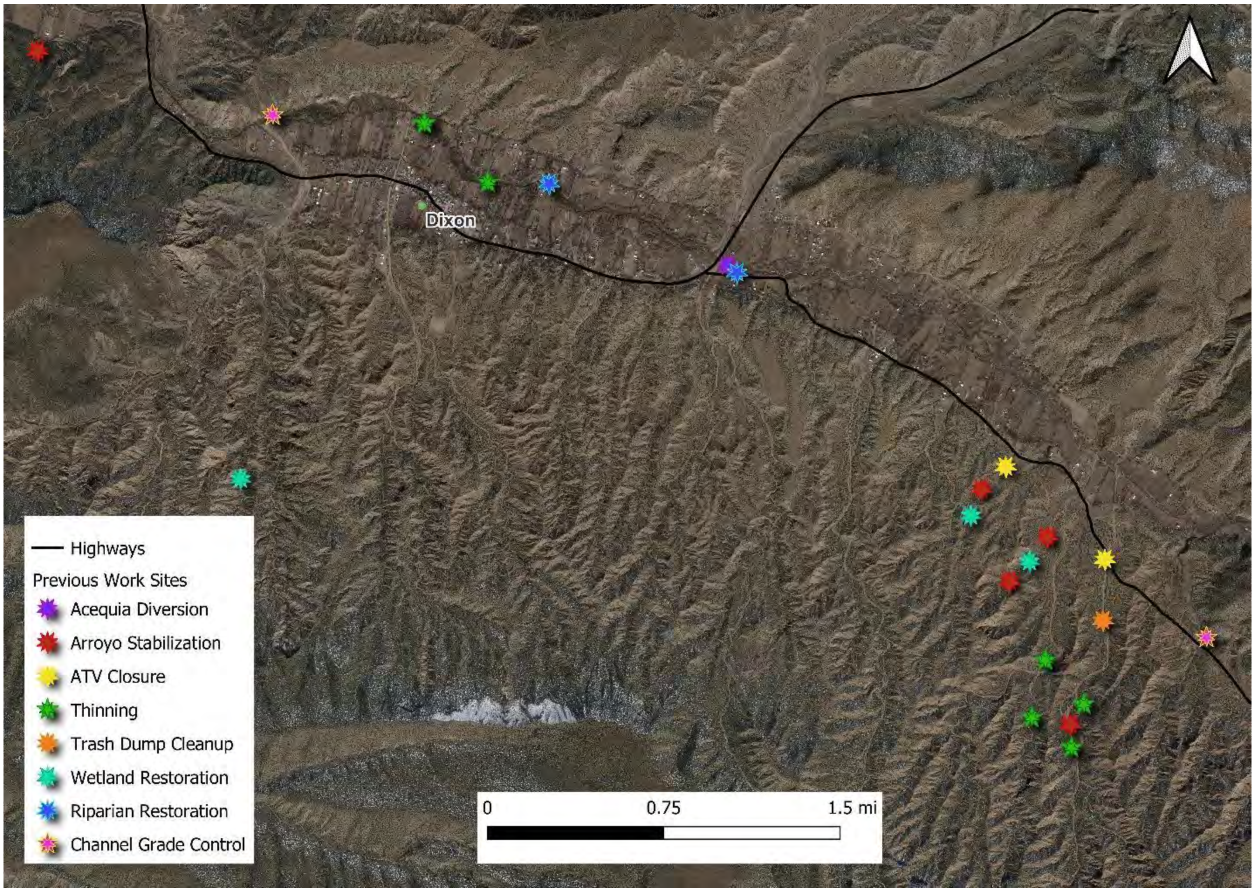

Figure 19. Map of past and ongoing Lower Rio Embudo Watershed project locations (McElroy, 2022a).

Table 9. Listing of Known Past Wetland and Stream Restoration Projects

Years	Wetland Location	Work Accomplished	Parties Involved
<2010	Riverine wetland creation and bank protection along CR240 (1.3 ac)	Planting of willows and Rio Embudo rechannelization	NMED
2010-2013	Cañadita del Agua - Cañoncito (1.25 ac)	Large rock rundown, series of wicker weirs, one-rock dams, Zuni bowls, plug and spread structures, and willow planting; removal of Russian olive and tamarisk trees	BLM, Earth Works Institute, SF Watershed Association, Ecotone, and Keystone Restoration Ecology

Years	Wetland Location	Work Accomplished	Parties Involved
2010-2013	Arroyo de los Arellanos - Montecito (3.3 ac)	Series of wicker weirs, one-rock dams, Zuni bowls, plug and spread structures, and willow planting; removal of Russian olive and tamarisk trees	BLM, Earth Works Institute, SF Watershed Association, Ecotone, and Keystone Restoration Ecology
2010-2013	Riverine wetlands upstream of presa of Acequia de la Plaza (0.35 ac)	Removal of invasive trees; bank excavation to allow overbank flows; construction of boulder cross-vane grade control and headgate; planting of willows	BLM, Earth Works Institute, SF Watershed Association, Ecotone, and Rangeland Hands
2012-2013	Thinning of riverine wetland bosque west of bridge of CR65 (1.5 ac)	Removal of invasive trees and approx. 50% of canopy cover for wildfire prevention, plant regeneration, and wildlife habitat restoration	Private landowner, Ecotone, and Chimayo Conservation Corps
2012-2013	Thinning of riverine wetland bosque east of end of CR548 (Arroyo Pino road) (2.5 ac)	Removal of invasive trees and approx. 50% of canopy cover for wildfire prevention, plant regeneration, and wildlife habitat restoration	Private landowner, Ecotone, and Chimayo Conservation Corps
2013-2014	Grade control of Cañada de Ojo Sarco along CR69 east of Cañoncito (3.6 ac)	Construction of grade control structures, rock rundowns and overflow channels to restore stream morphology and protect wetland conditions downstream	BLM and Riverbend Engineering
2021	Streambank stabilization in Rio Embudo meander along CR240 (1 ac)	Streambank stabilization with gabions and willow plantings along Rio Embudo	Rio Arriba County
2022	Woodland thinning and ecological restoration of spring sites in 3 canyons along Cañadita del Agua (9 acres of wetlands and >65 acres of woodland)	Removal of approx. 50% of woodland canopy for wildfire prevention; construction of dozens of small wood and rock structures for erosion control and water retention	Ecotone and Wood Sharks, NMSLO, and USFS

Table 10 below provides a listing of ongoing, planned, and proposed projects. In order to prioritize protective and restoration actions for wetlands at risk of degradation, consideration was given (and should be given for the future) to the PFC or NM RAM health rating as well as the size of the spring and wetland area, observed erosion features (*e.g.,* as part of baseline monitoring), terrain conditions that bear inherent erosion risk (*e.g.,* slope length, steepness, and amount of soil cover), wetlands upstream of residential areas or other values at stake, observed or known streambank stability, vegetation type and vigor, and risks to the wetland from outside stressors (*e.g.,* the size of the upstream catchment area, observed signs of flash flooding, proximity to a road or trail, observed livestock impacts, observed impacts of human presence, and observed presence of restoration or protection practices).

Table 10. Listing of Ongoing, Planned, and Proposed Projects

Years	Wetland Location	Work Accomplished	Parties Involved
2022-2024	Woodland thinning and ecological restoration of spring sites	Removal of approx. 50% of woodland canopy for wildfire prevention; construction of small wood and rock structures for erosion control and sediment and water retention	Ecotone, Wood Sharks, NMSLO, and USFS
2022-2024	Restoration of Blackwater Spring and wetlands (4 ac)	Removal of Russian olive and tamarisk; construction of in-stream wood and rock structures for erosion control and sediment and water retention	Ecotone, Wood Sharks, San Isidro Permaculture, NMSLO, and NMED
2022-2024	Restoration of Lightning Bolt Spring and wetlands (2.3 ac)	Removal of Russian olive and tamarisk; construction of in-stream wood and rock structures for erosion control and sediment and water retention	Ecotone, Wood Sharks, NMSLO, and NMED
2022-2024	Restoration of Labyrinth Spring and wetlands (8.3 ac)	Removal of Russian olive and tamarisk; construction of in-stream wood and rock structures for erosion control and sediment and water retention	Ecotone, Wood Sharks, NMSLO, and NMED
2022-2024	Restoration of Odyssey Spring and wetlands (0.7 ac)	Removal of Russian olive and tamarisk; construction of in-stream wood and rock structures for erosion control and sediment and water retention	Ecotone, Wood Sharks, San Isidro Permaculture, NMSLO, and NMED

Years	Wetland Location	Work Accomplished	Parties Involved
2023-2025	Cañada del Agua (Arroyo la Mina) (2.9 ac)	Removal of Russian olive and tamarisk; construction of in-stream wood and rock structures for erosion control and sediment and water retention	Ecotone, San Isidro Permaculture, NMSLO, and NMED
2023	Cañada del Ojo Sarco (pending) (20 ac)	Removal of Russian olive and tamarisk; construction of bank stabilization structures and check dams for erosion control and sediment and water retention	Private landowner, NRCS, and NMSLO

Practical Considerations

The WAP planning team reviewed possible treatment sites from the perspective of feasibility and social desirability. Developing a key feasibility criterion is important to determine whether a proposed action can be expected to achieve the desired results at a scale and duration that is cost effective. Once it's been determined that prospective work is meaningful and effective in reaching overall goals, it is essential to gauge the support of landowners or the ease by which landowner support can be obtained. Absentee private landowners require more lead time and may have less interest in participating in proposed activities because of their physical and experiential distance from the land. For projects and sites that are widely appreciated by the community, it is very important to obtain community and stakeholder support. It may also be important to obtain signs of support from elected officials and seek political and institutional support. A key feasibility criterion is the likelihood that financing can be secured for a proposed project in a timely manner.

Other practical considerations include the accessibility of a site in relation to the presence of roads or tracks for vehicles (to bring supplies, equipment, and people) or in relation to topography and other terrain conditions, distance to main roads, and jurisdictional and other legal barriers. Furthermore, one must evaluate site specific sensitivities of a project location, such as cultural resources at risk, biological resources at risk, erosion risks, and post-treatment rehabilitation needs (and associated costs). The practical feasibility of proposed actions must also be considered in relation to the technical capacity of the community, agency, or partnership undertaking the restoration work. This technical capacity is related to the entity's available know-how; the practical solutions, techniques, or methods they can deploy; and the human capacity they bring. Some practical considerations may not be easily included in the prioritization of proposed activities until a project idea is worked out in more detail. Table 11 provides a set of criteria that can be applied to determine the feasibility of future protection and restoration projects.

Table 11. Summary of Prioritization Criteria for Physical Protection and Restoration

Criteria	Data Component	Experiential Component
a) Information & Initiatives		
Relevant and recent assessment data available	Data gap inventories in this WAP	Feedback from core team partners and community
Connection or leverage of past and ongoing activities	Listing of past projects in this WAP	Feedback from core team partners and community
Connection or leverage of planned or proposed activities	Listing of planned projects in this WAP	Feedback from core team partners and community
Potential educational (demo) value of a restoration site	Distance and accessibility for educational purposes	Feedback from core team partners and community
Impact of Sackett vs. USEPA SCOTUS decision	Agency interpretation of the ruling	Coordination with relevant agencies
b) Landscape Context & Risk Assessment		
Individual spring or wetland assessments, type, and level	Data from PFC, NM RAM, and baseline monitoring	Feedback from core team partners and community
Landscape context assessment of stressors and causes	Data from WBP, aerial analysis, NM RAM, and baseline monitoring	Feedback from core team partners and community
c) Practical Considerations		
Effectiveness of solution (meets goals and objectives)	WBP indication and rational relation between solutions and goals	Core team partners' opinion
Cost effectiveness (efficient)	Case-by-case benefit-cost analysis	Core team partners' opinion
Urgency (timeline to meet (cost) effectiveness)	Stakeholder and expert opinions (and reports)	Core team partners' opinion
Landowner support	Agreements in place or ongoing dialog	Core team partners' familiarity with landowners
Community, stakeholder, and institutional support	Information from public meetings and surveys	Core team partners' familiarity with stakeholders
Financing feasibility	Funding in place, applied for, or funders identified	Core team partners' info on funding sources

Criteria	Data Component	Experiential Component
Access	Data from aerial analysis, NM RAM, and baseline monitoring	Core team partners' familiarity with terrain conditions
Landscape Sensitivities	Data about cultural resources and permit requirements	Core team partners' familiarity with sensitivities and regulatory requirements
Size, complexity, technical feasibility in relation to available technical capacity	Analysis & data about size and complexities and technical capacity	Core team partners' familiarity with complexities and technical capacity

Action Lists and Recommended Key Goals for Projects

Based on a review of the criteria and available information about the springs and wetlands, a list of current actions needed for landscape wide projects and specific wetlands has been made below (Table 12 and Figure 20). Recommended key goals for projects that protect and restore wetlands and springs are:

- Mitigate drought effects by ensuring minimal water diversion and other water losses from the hydrogeological system in the wider landscape
- Optimize soil and water conservation and water infiltration in uphill forest, woodland, riparian, and wetland ecosystems; preserving optimal ecological functioning conditions of these ecosystems
- Stabilize slopes and drainages that directly flow down into the springs and wetlands, and especially those drainages that exhibit sediment flows and flash floods
- Stabilize degrading slopes and channels that are part of springs and wetlands to maintain their geophysical integrity and sediment balance
- Stabilize incised and degrading channels downstream from springs and wetlands to prevent head cutting and the undermining of upstream parts of these springs and wetlands
- Protect and restore streambanks and slopes that have been impacted or destabilized
- Manage access to sensitive wetlands and springs
- Remove invasive plant species in places where the removal has net positive consequences
- Reduce the vehicle and ORV/ATV impacts on riparian and wetland channels and streambanks

- Reduce the impacts of utilities and their maintenance on riparian and wetland channels and streambanks

The Core Team for the WAP allocated suggested priorities to the list of proposed actions in this WAP based on the prioritization criteria. The wetlands that have been assessed as having PFC are rated as having the lowest urgency for intervention. However, when in proximity to human activities, they may need to be protected with fencing, signage, or social interactions that garner user support for spring and wetland protection and conservation. Wetlands that are listed as "Functional–at risk" score high because their protection and restoration is still feasible and will have immediate benefits. Wetlands that are indicated with "No PFC" are either not inventoried, have no flow, are degraded, or no longer have any wetland functions. Those that are not inventoried have a high priority for assessment; the remainder has either been scored as Medium High or Lower Priority depending on their need for restoration in relation to the protection of other functions (*e.g.,* erosion of a larger area, flood and sediment control) or as a Low Priority if they don't have considerable ecosystem functions and are beyond repair as a wetland or for erosion control and sediment retention.

Table 12. Priority Action List for Wetland Protection, Restoration, and Monitoring Work

LANDSCAPE WIDE					
Priority	**Project**	**Supporting Documentation**		**Locations**	**Proposed Action**
3	Landscape restoration of the mountain front landscape that feed the springs	WBP; Regional Water Plan; inference from NMBGMR spring water research		Mnt. streams, alluvial fans, Cejita Mesa	Wildfire protection and selective forest thinning and soil stabilization
1	PJ ecosystem restoration and soil stablization	NMSLO forest plan (2016); WBP and CFRP proposal; BLM management plan (2012)		PJ woodlands in WAP area	Selective (spot) thinning and con-struction of soil stabilization structures
1	Community educational outreach and organizational capacity building for future restoration support	Community meetings and meetings with local entities		Lower Embudo Valley; Rio Arriba County	Development of a local watershed group, recruitment and training of staff and volunteers; hands-on field training workshops; inclusion of special interest groups; youth involvement
1	Regenerative agriculture initiatives in support of local environmental restoration	TBD		Northern Rio Grande region	Landscape wide assessment and collaborative community/rural development actions
3	Identify endangered aquatic life forms	TBD		All springs with pools; all wetland channels	Conduct systematic, prioritized SSI Level III assessments or NMRAM for Springs
WETLAND SPECIFIC					
Priority	**Spring/Wetland Name**	**PFC Rating**	**NMRAM Rating**	**Location (Arroyo Name)**	**Proposed Action**
3	Pocket Spring	No PFC	N/A	Can. De la Orilla off Can. De Ojo Sarco	Site inventory and PFC rating
3	Orchard Spring	No PFC	N/A	Arr. Lorenzo	Assessment and PFC or NMRAM rating
3	Tres Spring	No PFC	N/A	Can. De Ojo Sarco	Site inventory
1	Wellcap Spring (Arr. De los Arellanos)	No PFC	N/A	Arr. #110	Site inventory and continued restoration work

Priority	Spring/Wetland Name	PFC Rating	NMRAM Rating	Location (Arroyo Name)	Proposed Action
3	Coopers Hawk Spring	No PFC	N/A	Can. De Ojo Sarco	Site inventory and PFC rating
2	Big Guy Spring	No PFC	N/A	Confluence Can. De la Orilla & Can. De Ojo Sarco	Assessment and PFC or NMRAM rating; restoration needed after major flash flood damage + in relation to parking area
3	Serpentine Spring	PFC	N/A	Arr. Lorenzo trib	site inventory; 5-yearly monitoring; hydrogeological sampling
2	Dixon South #1	No PFC	N/A	Arr. Pino	Site inventory and PFC rating
2	Dixon South #2	No PFC	N/A	Arr. Pino	Site inventory and PFC rating
2	Dixon South #3	No PFC	N/A	Arr. Pino	Site inventory + PFC rating; difficult access
3	Dixon South #4	No PFC	N/A	Arr. Pino	Site inventory + PFC rating; very remote
3	Dixon South #5	No PFC	N/A	Arr. #105 (Area #6)-NMSLO	PFC rating, monitoring and adaptive management (repairs) on NMSLO
2	Dixon South #6	No PFC	N/A	Arr. #94	Site inventory + PFC rating; restoration may help retain sediment and water in a flashy arroyo; complements work nearby
2	Dixon South #7	No PFC	N/A	Arr. #106	Site inventory + PFC rating; restoration may help retain sediment and water in a flashy arroyo; complements work nearby
3	Dixon South #8	No PFC	N/A	Arr. Pino	Site inventory and PFC rating
2	Dixon South #9	No PFC	N/A	Arr. Pino	Site inventory + PFC rating; may have restoration potential
2	Dixon South #10	No PFC	N/A	Arr. Pino	Site inventory + PFC rating; may have restoration potential
2	Dixon South #11	No PFC	N/A	Arr. Pino	Site inventory + PFC rating; may have restoration potential
2	Baseball View Spring	PFC	N/A	Arr. Pino	Site inventory; 5-yearly monitoring; hydrogeological sampling

Priority	Spring/Wetland Name	PFC Rating	NMRAM Rating	Location (Arroyo Name)	Proposed Action
3	Cottonwood Arroyo Spring	PFC	N/A	Arr. Pino	Site inventory; 5-yearly monitoring; hydrogeological sampling
3	Juniper Thicket Spring	PFC	N/A	Arr. Lorenzo	Site inventory; 5-yearly monitoring; hydrogeological sampling
2	Mesa Vista Spring	PFC	N/A	Arr. Pino	Site inventory; 5-yearly monitoring; hydrogeological sampling
2	Redtop Spring	FAR-no Trend	N/A	Arr. Pino	Site inventory; may have restoration potential; geohydrological sampling (large watershed area; poor access)
3	Rock Wren Spring	PFC	N/A	Arr. Pino	Site inventory; 5-yearly monitoring; hydrogeological sampling; may have reference conditions for Dixon South #9, 10, and 11
3	Slip and Slide Spring	PFC	N/A	Arr. Pino	Site inventory; 5-yearly monitoring; hydrogeological sampling
1	Spillway Spring	FAR-no Trend	N/A	Arr. #105 (Area #6)- BLM	Site inventory; and continued restoration work on BLM land; monitoring on NMSLO
1	Labyrinth Spring	FAR- Downward Trend-ISP	Good Condition-Decline-ISP	Arr. La Mina	Work completed; more work needed in future years (large watershed; sediment retention potential; poorly accessible)
1	Blackwater Spring	FAR- Downward Trend-ISP	Good Condition-Decline-ISP	Arr. La Mina	Work completed
2	Odyssey Spring	PFC-ISP	N/A	Arr. Pino	Work completed but not certain; may need work in future years; ongoing review and planning on RO removal (limited access)
1	Lightning Bolt Spring	FAR- Downward Trend-ISP	Good Condition-Decline-ISP	Arr. La Mina	Work completed; more work needed in future years (poorly accessible; small watershed; high potential)
3	Drip Drop Spring	PFC	N/A	Arr. La Mina	Site inventory; NMRAM; Cultural resource constraints; grazing pressure
3	Stalactite Spring	PFC	N/A	Arr. La Mina (trib to Labyrinth Spring)	Site inventory; NMRAM; remote

Priority	Spring/Wetland Name	PFC Rating	NMRAM Rating	Location (Arroyo Name)	Proposed Action
3	Mushroom Meadow Spring	PFC	N/A	Arr. La Mina (trib to Labyrinth Spring)	Site inventory; NMRAM; very remote
3	Flat Top Spring	PFC	N/A	Arr. La Mina (trib to Labyrinth Spring)	Site inventory; NMRAM; very remote
3	Section 2 Spring #1	No PFC	N/A	Arr. #114 (Area #5)	PFC rating; Monitoring (during project & 5-yearly); area stabilized in CFRP project
3	Section 2 Spring #2	No PFC	N/A	Arr. #114 (Area #4)	PFC rating; Monitoring (during project & 5-yearly); area stabilized in CFRP project
3	Section 2 Spring #3	No PFC-no spring	N/A	Arr, #110	Site inventory; probably not a spring; area stabilized in CFRP project
3	Section 2 Spring #4	No PFC-no spring	N/A	Arr. #106	Site inventory; probably not a spring; area stabilized in CFRP project
3	Section 2 Spring #5	No PFC	N/A	Arr. #106	PFC rating; Monitoring (during project & 5-yearly); area stabilized in CFRP project; (very poor access)
2	Spring with Mud Bowl	No PFC	N/A	Arr. #94	Assessment and PFC or NMRAM rating; restoration may help retain sediment and water in a flashy arroyo; complements work
3	Spring: 120933314	No PFC	N/A	Rio Embudo-East	(just outside WAP area) Assessment and PFC rating
1	Riverine wetlands of Rio Embudo	No PFC	N/A	Rio Embudo	Assessment and PFC or NMRAM rating; design of restoration for selected areas; (good access; sediment filtering potential)
2	Riverine wetlands of Can. De Ojo Sarco	No PFC	N/A	Can. De Ojo Sarco	Assessment and PFC or NMRAM rating; design of restoration for selected areas
1	Riverine wetlands of Can. Del Agua	No PFC	N/A	Arr. La Mina/ Can. Del Agua	Awaiting funding; assessment and plan needed for BLM reach; stressors include grazing, ORVs, traffic, and invasive trees
2	Riverine wetlands of Arr. La Mina	No PFC	N/A	Arr. La Mina	Assessment; potential road planning; stressors include traffic and sediment
2	Riverine wetlands of Can. Corral	No PFC	N/A	Arr. La Mina/ Can. Corral	Assessment; potential road planning; stressors include grazing, traffic , channel incision, invasive trees, and sediment
3	Riparian areas of Arroyo de los Pinos Reales	No PFC-no springs and wet wetlands	N/A	Arr. #114, 115	Being stabilized under CFRP project with Wood Sharks (2021-2024); (some access; education and training potential)

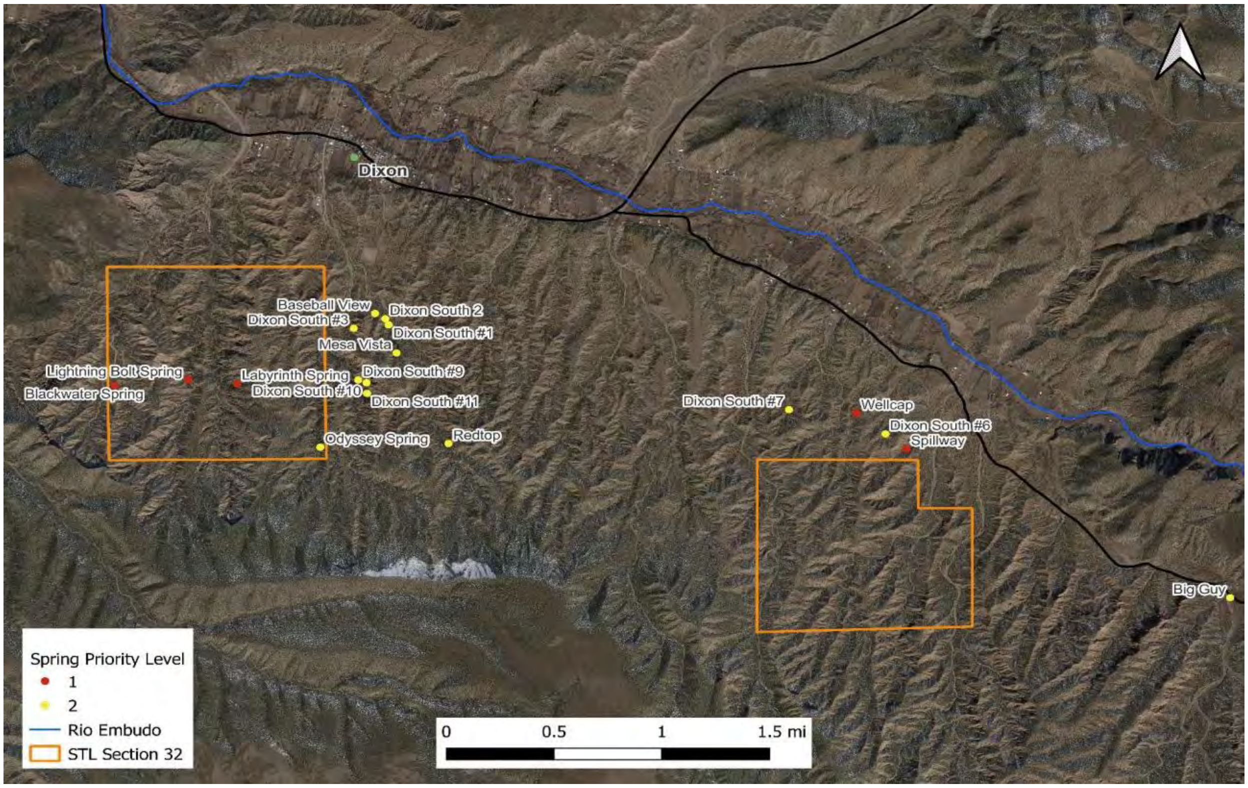

Figure 20. Map of priority wetlands and springs that need to be restored (McElroy, 2022b).

Table 13 provides an overview of general management measures and their purposes, which can be useful when encountering situations or locations not listed in Table 12 above.

Table 13. Management Measures for Spring and Wetland Protection and Restoration for the WAP Area

Location	Considerations	Recommended Management Measures	Reference List
Dry (hypocrene) springs	Do the springs have cultural significance or a cultural resource designation?	No action, unless spring function is undermined by headcut or other erosion, treading, or evaporation; stabilize or starve head cut by instream structures; cover site with slash (not in channel) to reduce soil loss and evaporation.	A
Flowing springs	Is the stressor at the spring?	No action; or very careful, site specific work.	A
Head cuts	What is the sediment balance in the channel? Will there be enough sediment to fill head cut?	If enough sediment flux, build grade controls downstream to fill head cut; otherwise starve head cut with plug & pond / spread.	A and B

Location	Considerations	Recommended Management Measures	Reference List
Degraded upland channels - small	How large is the uphill watershed? How much water energy is unleashed?	Consider brush mattresses, one-rock dams, and small wicker weirs. Spread water on side slope where possible.	A and C
Degraded wetland channels - small	Same as degraded upland channels-small. How much sediment is moving?	Consider One Rock Dams (ORDs), wicker weir, sod plugs, and small Zuni bowls to stabilize grade; try to combine as plug & pool.	A and D
Degraded upland channels - main	Is water spreading useful? How much water energy is unleashed? How much sediment can be captured?	Consider wicker weirs, ORDs, Zuni bowls, log racks, and plug & spread structures	C and D
Degraded wetland channels - main	Same as upland channels	Consider rock baffles, log step dams, log racks, plug & pond structures, Zuni bowls, wicker weirs, and ORDs	A and D
PJ woodland	What woodland type is it (fire risk)? How much bare ground and grass cover? Will wood / slash be used for soil stabilization?	Consider no action, unless necessary for wildfire management (WUI area) or for harvesting slash for soil stabilization.	E, F, and G
Ciénega woodland	Would any treatment increase wetland functionality, native riparian plant cover and diversity?	Consider no action, unless necessary for wetland function improvement and removal of invasive trees that provides a durable solution.	H
Bare areas	Is bare area from sedimentation or soil loss?	Only treat soil loss areas: mulch or slash cover, logs on contour, native grass seed.	A, C, and G
Areas with wild ungulate and cattle impacts	What are the grazing rights? Where will cattle do least harm? What impacts should be reduced?	Keep dense invasive trees; create stable paths to water (rock structures to hold grade in pathways); spread (jackfall) branches over areas that must be protected; negotiate managed grazing, fencing, piped drinkers.	WBP (Table 4.3) and A
Areas with vehicle impacts	What are the access rights? Where will vehicle access do the least damage?	Use boulders and wicker weirs to close tracks; use techniques from	WBP (Table 4.3) and D

Location	Considerations	Recommended Management Measures	Reference List
		dry channels to close ruts and spread water.	
Areas with trailing and hoof stress	What are the access rights? Where will people or animal access do the least damage?	Create stable paths to water (rock structures to hold grade in pathways); use techniques from dry channels to close ruts and spread water.	WBP (Table 4.3) and A
Upland forests	What is the fire risk? What is the downstream impacts on wetlands?	Consider action if impacts are expected after forest degradation or wildfire.	WBP (Table 4.3)
Riverine wetlands	What is the risk of fire, flooding, sediment accumulation, and bank erosion?	Consider action only after due diligence and if solution has lasting, comprehensive impact.	H

Reference List with Table 13

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c. Educational Outreach Activities

This section describes past and ongoing activities regarding public involvement, educational outreach, and local capacity building as well as proposed activities in this realm in support of wetland protection and restoration. The proposed activities for the life of the WAP are based on experiences from the public involvement and education activities used during the WAP development phase.

Throughout the public involvement process, we learned that the springs and wetlands in the Lower Rio Embudo Watershed represent a treasured land history for different watershed residents, which to some extent defines people's current identity and relationship with the area. For an important number of people, stewardship conversations about the springs and wetlands rekindled feelings of dispossession and colonial and post-colonial landownership transitions that they and their ancestors experienced in the last few centuries, as discussed in Current Conditions section.

During the formulation of this WAP it has become clear that reflection and appropriate engagement of northern New Mexico's rich and complex history and peoples are critical in managing the wetlands in the WAP area. Public involvement in sharing information about the wetlands, their natural values, land-use practices, and proposed management measures requires a careful, inclusive approach. In each subsection, we have included lessons learned and some principles and solutions we recommend for future projects.

Community Meetings and Tribal Consultations

In 2022, Ecotone held several community meetings about wetland planning. The meetings offered a hybrid of in person and virtual participation and were held at the Embudo Valley Library and the Dixon Volunteer Fire Department. Attendees were presented with an overview of the project, asked to respond to an informal survey, shown the likely treatments, introduced to the WAP document, and given the opportunity to ask questions.

In October 2022, Embudo Valley Library and Ecotone teamed up to present a series of community events dubbed, "Floods, Fire, and Funding." This information and discussion program followed a series of extreme flooding events in Dixon during the summer of 2022 which were caused by concentrated bursts of precipitation in the uplands south of Dixon. Residents' concerns about flooding extended to the potential impacts of the catastrophic Hermit's Peak-Calf Canyon wildfire, which affected approximately 12,400 acres in the headwaters of the Rio del Pueblo/Rio Embudo watershed (NMFWRI, n.d.). These events supported WAP relevant topics including the causes and potential responses to recent flooding events and a strategic plan to guide the protection and restoration of wetlands in the Lower Rio Embudo Watershed.

Presentations and community meetings had fair attendance and feedback. Through continuous conversations with key individuals in the community, it came to Ecotone's attention that the physical space of meetings and workshops can influence who feels comfortable attending and speaking at community meetings. Equitable and welcoming space is important for community wide trust and participation, especially for Hispanic people. Therefore, it is recommended that for future wetland related educational outreach activities appropriate meeting spaces are selected where community members feel at ease to present their thoughts and several small events, such as wetlands walks and hands-on workshops, are organized to create an inclusive approach for diverse engagement.

Separately, Ecotone and the New Mexico Environment Department exchanged information about the planned wetland restoration project and the goals of the WAP with Picuris Pueblo officials. Governor Craig Quanchello expressed his support of the project along with an interest in the restoration techniques and the wish that Pueblo youth be engaged in site walks and discussions. In the course of 2022, Dr. Severin Fowles, Associate Professor of Anthropology at Barnard College-Columbia University, was assigned by Picuris Pueblo to represent the Pueblo's interests regarding the preservation of archaeological sites associated with the wetlands. Dr. Fowles walked some of the most western wetlands in Section 32 with Ecotone staff to determine how to best mitigate the impacts of erosion in the springs and wetlands while maintaining the archaeological and cultural history of the area. In a follow up meeting in early 2023, Ecotone staff met again with Pueblo officials to update them about the WAP and other project activities.

Surveys and Interpersonal Conversations

Due to only a small portion of the grant being marked for outreach activities, Ecotone conducted a community survey to swiftly communicate the project and WAP information and collect information about local perceptions and priorities regarding the wetlands and their restoration needs. Two versions of the surveys were distributed along with a translation in Spanish of the second version (v.2) in an effort to be more inclusive. Ecotone advertised the surveys through various mediums within the community, such as bulletin boards, online newsletters, and church newsletters. The surveys were physically posted or handed out at various meetings, and a digital survey was available online. Ecotone received thirteen English v.1 and ten English v.2 online surveys in addition to five v.1 physical surveys, totaling 28 surveys—a small sample (3%) from a population of about 900 people.

The surveys reported that the wetlands are used mainly for hiking, birding, and spiritual reasons. The wetlands are also considered important for the following values: a place for respite in the desert, a legacy for future generations, and as a historical asset, such as the gathering of *chimaja* (an herb that is the member of the parsley family). Respondents referred to wetland functions when listing the sites as an important area for wildlife and native vegetation, a function of holding back water to prevent flooding and erosion control, a sign of ecosystem health, a large part of the water cycle, and an opportunity to reduce desertification. The surveys also helped gather unexpected, tangential information about gaps in public wetland knowledge. One person expressed a need for careful dissemination of any wetland locations, so they do not become another visitors' attraction. Some of the answers demonstrated that the connections between the wetlands and the watershed are not always clear. Thus, there must be a concerted future effort to clarify how the springs and wetlands relate to the landscape and the community. Survey results were considered for the formulation of restoration actions suggested in this WAP and will be of value in future planning.

Evaluating the semi-formal survey technique, in hindsight, the Ecotone team concluded that surveys are a poor tool for gathering community input on wetland planning in the Lower Rio Embudo Watershed based on the number of survey responses received for this WAP and for the WBP in 2014. Conclusions about more appropriate methods for data gathering among residents are suggested below. Ecotone found that the survey responses did not represent an accurate sample of the population. The survey responses also did not provide a complete picture of the community concerns and desires concerning the wetlands as residents who had poor access to internet, lack of free time, and residual historic trauma around land ownership and stewardship were unlikely to respond. The Ecotone team also learned that many people from the traditional Hispanic community feel more at ease having conversations with community members, especially those who represent their heritage, rather than filling out a survey. Often, their sense of community input is based upon reciprocity and relationship with people.

During a few informal conversations concerning the WAP survey with individuals from the Hispanic community, we received responses that differed greatly from those found in the surveys. People commented on issues that are of bigger concern to them, such as climate change, colonialism, traditional knowledge erasure, and gentrification and how these issues tie into the subject of land stewardship. Key words such as "ATV/ORV" and "cattle" can cause friction because when presented by outsiders these words are perceived as holding a racial bias and judgement toward the local populations about how they engage in their ancestral landscape. The informal conversations also revealed a locally held need that the project team and land managers show an understanding of the historical continuum of occupation that has led to land management decisions such as grazing cattle in the wetlands.

The survey responses did not represent community members of Picuris Pueblo due to the need to work through tribal government mechanisms and representatives rather than individual members. Picuris' concerns and ideas have largely been expressed through these conversations with the Pueblo officials and representatives. In the future, there must be a concerted effort to gather Picuris' input on their ancestral lands when designing and planning any projects.

Although Ecotone was able to extract individual and group determined wetland values and functions to inform this WAP, all these observations point to a need for a gradual approach in outreach toward collaboration with the community and a mutual understanding of the best strategies for protecting and restoring the wetlands. Community leaders, EVL, and Ecotone are working to further the communication process within all demographics of the community for the future. Specific recommendations for education, outreach, and information gathering from the community include:

- Conducting meetings and educational events in culturally neutral space
- Clarifying to the community the importance and functions of springs and wetlands
- Hiring local community members to conduct outreach
- Holding small meetings and one-on-one conversations in addition to surveys
- Compensating community members for time and knowledge when contributing to outreach, planning, and capacity building
- Providing Spanish translated outreach materials
- Conducting better information gathering with Picuris Pueblo

d. Capacity Building Activities

The development of this WAP faced the conundrum of declining community capacity to organize and implement local land stewardship while the need for stewardship activities seems to increase to avert the loss of valuable ecosystem services and increase of damaging environmental events. Several social, economic, and demographic changes in the watershed—and throughout New Mexico in general—have led to a decline in land stewardship activities. These caretaking activities are necessary to reduce stressors on the landscape and on wetlands and mitigate symptoms of landscape and wetland degradation. An aging rural population in the Embudo Valley leads to a reduced local workforce for land stewardship activities and losses in traditional land stewardship know-how, such as historical maintenance of the arroyo pathways. To compensate for these losses, acequia associations and the Ecotone project increasingly rely on hired labor from a wider area. Rapid residential development has led to increased densities of buildings and infrastructure on alluvial fans and next to wetland areas. In this process pathways for stormwater flows have been obstructed. Many properties are in harm's way of flash floods while increases in the number of domestic wells likely divert more groundwater and create possible impacts on springs and wetlands. Motorized transportation and recreational uses have increased the area of bare and compacted hillsides and stream bottoms.

Due to these listed issues, caring for the land and water has become more important and at the same time more challenging. Therefore, effective capacity building, planning, and land management at the community level is crucial for successful projects and improvements in the landscape. To some extent, outside entities, such as government agencies, NGOs, and consultants can help with organizing and providing stewardship services. However, community-based initiative, organizing, and decision making is essential to provide equitable support to such activities and ensure continuity.

The Ecotone team discussed several community organizing and capacity building options with interested residents and community organizations in the Embudo Valley. However, no conclusive results were achieved. Therefore, the following recommendations remain a brainstorm of possible capacity building activities to bridge the conundrum discussed above. Table 14 provides the suggested elements for better capacity building related to wetlands and springs.

Table 14. Summary of Suggested Priority Actions for Community Capacity Building (1=High, 2=Medium/Lower)

PRIORITY	ACTIVITY
Growing local awareness	
1	Holding meetings & interpersonal conversations, sharing information
2	Encouraging people to participate in conservation networks
1	Building mutual understanding between all stakeholders and especially of land use practices of long-term land users and permittees
Getting organized	
1	Creating a local action group
Networking	
2	Networking and joining regional support networks
Obtaining funding and technical support	
2	Preparing for obtaining funding and technical support
Participating in community-based projects	
2	Visiting projects by landowners or local groups and nearby projects in the region
1	Learning land stewardship skills in workshops and demonstration projects
Planning for youth activities	
2	Creating multi-generational activities
1	Providing activities specifically for youth
1	Creating outdoor education and involvement in local stewardship
Creating one or more information repositories	
1	Creating information repository in Embudo Valley Library or other local organizations

Growing local awareness*.* Awareness is the first step for people toward increasing their understanding and willingness to engage in action for change. EVL and the Dixon Volunteer Fire Department along with other civic groups have already stepped up to raise awareness about issues of flooding, fire, and other environmental concerns. If the awareness raising process can be conducted through a shared experience, people will also have a chance to connect with others and build community around the land stewardship activities. People often feel less helpless or overwhelmed and have a more joyful learning experience and grow a sense of shared responsibility when they can participate in shared stewardship experiences.

Awareness also includes sharing information and building mutual understanding between all stakeholders, especially the land use practices of long-term land users such as grazing permittees. It is important that all parties working on land (and wetland) stewardship in the Lower Rio

Embudo Watershed become aware of the history and practices of key land users in the area in order to respect their traditions and needs.

Getting organized. In Ecotone's experience, one community member or company cannot sustainably carry forward the actions listed above and have a larger impact. A local action group or collaboration is necessary to continue the ongoing stewardship work of streams, springs, and wetlands. The Core Team of this WAP could be a valuable starting point for the local action group. The action group may grow out into a regional watershed stewardship group. Such a group could serve as the keeper and distributor of information, a sparkplug for local engagement activities, a point of contact for government entities and outside organizations, the local entity to receive and oversee the use of outside funding, and the coordinator of government support services.

Networking. Community members and local groups would benefit from networking that can support the community in its goals for the WAP. For example, the NMED Surface Water Quality Bureau Wetlands Program organizes half-yearly Wetland Roundtables, which offer excellent learning and networking opportunities with governmental and non-governmental entities with expertise in the restoration of springs, wetlands, arroyos, and flood zones. The New Mexico Soil Health Network provides information about soil and landscape health and organizes local enthusiasts and experts into a national network of Soil Health Champions. The East Rio Arriba Soil and Water Conservation District (SWCD) provides services for landowners in the SWCD district and could serve as a fiscal agent and source of funding and information on land health and restoration activities. The North Central New Mexico Economic Development District (NCNMEDD) is a public-private Council of Government entity that supports rural economic development initiatives and can also serve as a fiscal agent, assist with grant writing, and connect the community with sources of funding and information on community development matters.

Obtaining funding and technical support. Stewardship activities will eventually require funding and outside support. The community will need to explore their eligibility for funding, technical support, or labor resources. This may mean that one or more local entities will need to register with funding agencies and/or register with the federal government.

Participating in community-based wetland and spring restoration projects. Ecotone has found that conducting workshops, community tours, and workdays proliferates knowledge and skills across a community. As the Lower Rio Embudo Watershed restored wetlands have begun to revegetate and aggrade recently, many community members have become interested in the restoration work, perhaps creating a positive feedback loop between project implementation, demonstration, and community participation.

Future project teams and community-based action groups are encouraged to continue organizing hands-on training workshops and demonstration tours to stakeholders to broaden people's understanding of and skills in practical land stewardship. Field trips to other landscape restoration projects in the wider area and presentations of work done elsewhere (*e.g.,* via online media, videos, or in live talks and PowerPoint presentations) could also help increase awareness, knowledge, and initiative toward ongoing stewardship and restoration work in support of springs and wetlands.

Planning for Youth Activities. Educational outreach and public involvement must include the area youth. This could happen through multi-generation activities, activities aimed at specific age groups, and local school involvement. There are several youth programs in Dixon, and area schools include the Dixon Elementary School, Velarde Elementary, Peñasco High School, various schools in Española, and Northern New Mexico College in Española.

Creating centralized location(s) for information repository. EVL has expressed the intention to become a repository of environmental information about the Lower Rio Embudo Watershed. This might include the placement of printed information in the library and the posting of digital information sources on the EVL website. Ecotone has also posted a selection of relevant digital documents and an area map on its website.

8. FUNDING AND TECHNICAL ASSISTANCE

There are many financing opportunities for the proposed actions described in this WAP. Table 15 provides an overview of funding sources that match actions listed in this WAP.

Table 15. Overview of Potential Funding Sources and Their Applicability

Funding Source	Education, outreach, and community capacity building	Research, assessments, monitoring	Private land	Rio Arriba County land	State Trust Land	BLM land
Charitable foundation and corporate grant programs	Y	Y	Y	TBD		
Crowd funding (social media-based)	Y	Y	Y	TBD		
NM Counties – Community Wildfire Defense Grant (CWDG)			Y	Y	Y	Y
New Mexico Legislature – Special Appropriations	TBD	TBD	TBD	Y	Y	
NM Finance Authority/Water Trust Board – Water Fund			TBD	Y	TBD	
NM Dept. of Game & Fish – various grant programs	Y	Y	Y	Y	Y	TBD
NM State Forestry Division – various programs		TBD	Y	Y	Y	
NMED-SWQB – River Stewards Program			Y	Y	Y	TBD
Private sources (Landowners, donors, businesses)	Y	Y	Y	Y	Y	Y
Rio Grande Water Fund			Y	Y	Y	Y
Soil and Water Conservation Districts			Y	Y	TBD	
USDA NRCS – various programs		TBD	Y	Y		
US EPA – Section 319(h) funds (through NMED-SWQB)	Some	Some	Y	Y	Y	Y
US FEMA			Some	Y		
US Fish & Wildlife Service – various grants & cooperative agreements	Some	Some	Y	Y	TBD	

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APPENDIX A: BACKGROUND DETAILS ON SPRINGS AND WETLAND INVENTORY

A.1. Wetland Delineation Conducted for a Pre-Construction Notification for a Nationwide Permit-27.

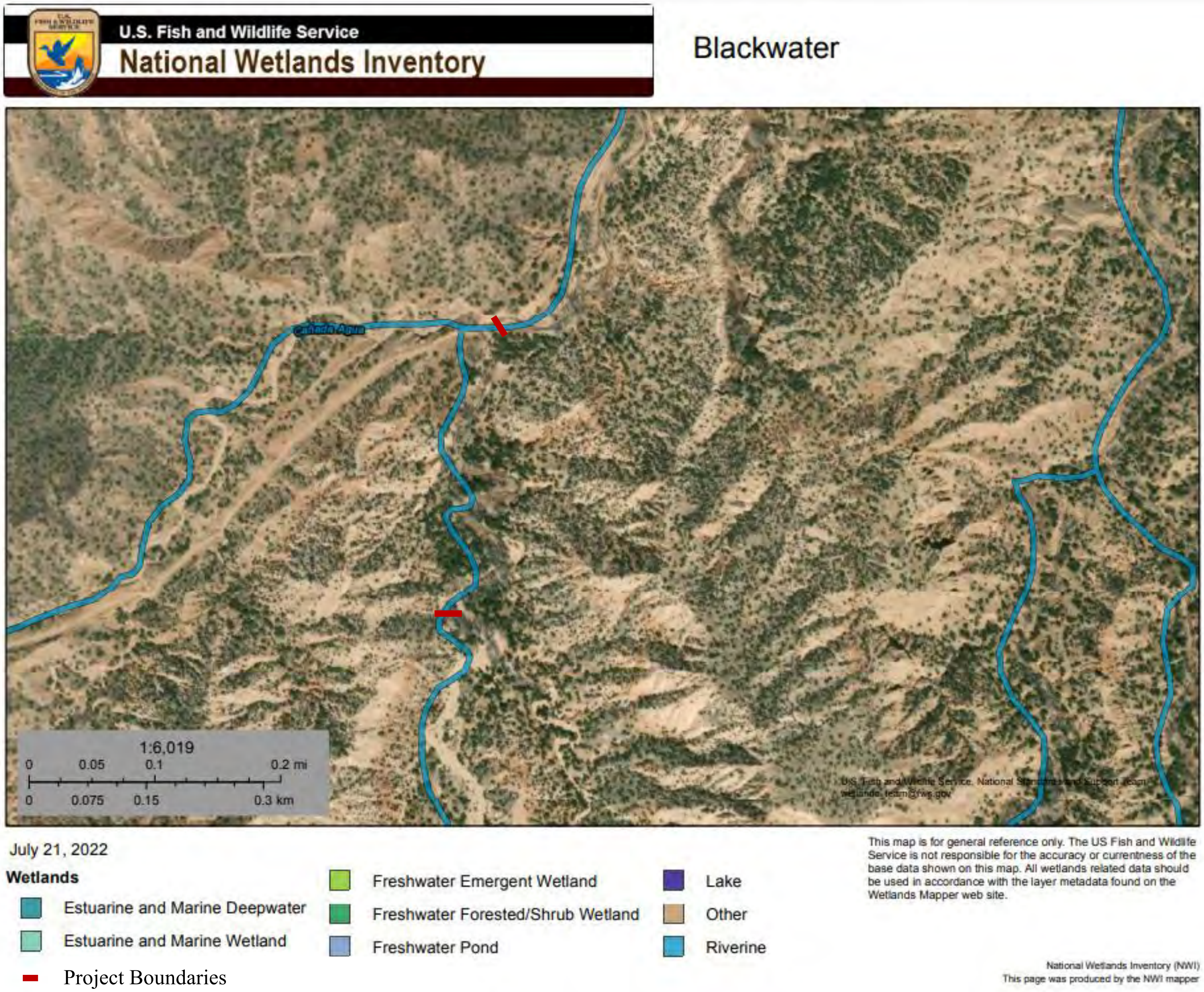
Information obtained from the National Wetland Inventory.

As part of the regulatory requirements for the planned implementation of wetland restoration work, Ecotone compiled a wetland delineation based on NWI interactive map data. The project team created wetland maps and associated descriptions for four distinct riparian habitat and spring-fed wetland areas located within state trust land on Section 32. Two of the four spring-fed wetlands, Labyrinth and Lightning Bolt, are within the same habitat in the NWI map and were therefore mapped together.

According to the NWI, all four spring-fed wetlands are classified as R4SBC. The Riverine System (R) includes all wetlands and deep-water habitats contained within a channel. A channel is an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water. The Intermittent Subsystem (4) includes channels that contain flowing water only part of the year. When the water is not flowing, it may remain in isolated pools or surface water may be absent. The Streambed Class (SB) includes all wetlands contained within the Intermittent Subsystem of the Riverine System and all channels of the Estuarine System or of the Tidal Subsystem of the Riverine System that are completely dewatered at low tide. The Seasonally Flooded Water Regime (C) describes that surface water is present for extended periods especially early in the growing season but is absent by the end of the growing season in most years. The water table after flooding ceases is variable, extending from saturated at the surface to a water table well below the ground surface.

Blackwater Spring (tributary to the Cañada Agua)

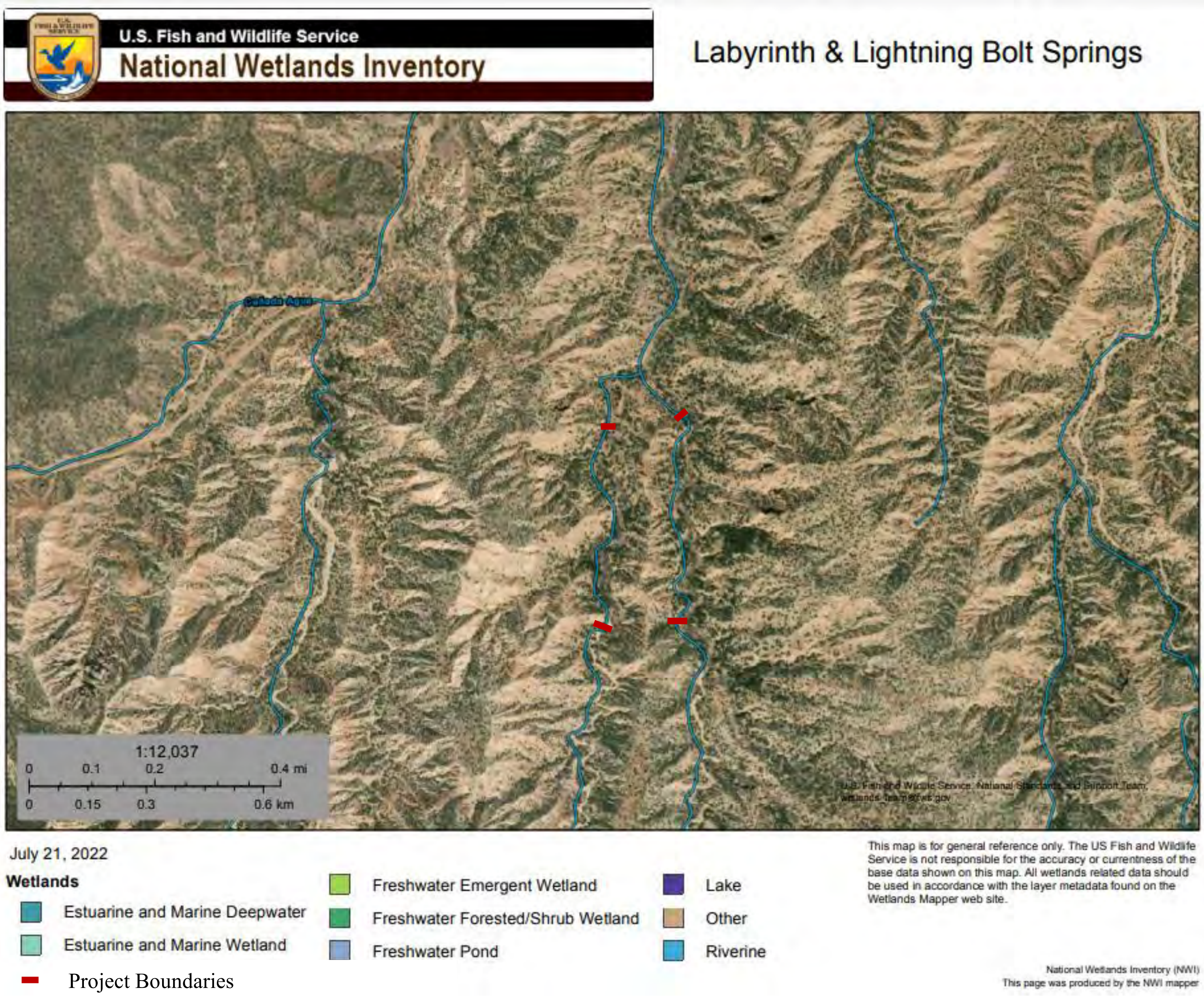
The project area within Blackwater Spring is comprised of approximately 1,056 linear feet of stream reach and 2.04 acres within the larger riverine habitat. The upstream drainage is approximately 171.3 acres in size.



Lightning Bolt and Labyrinth Springs (Cañada Corral)

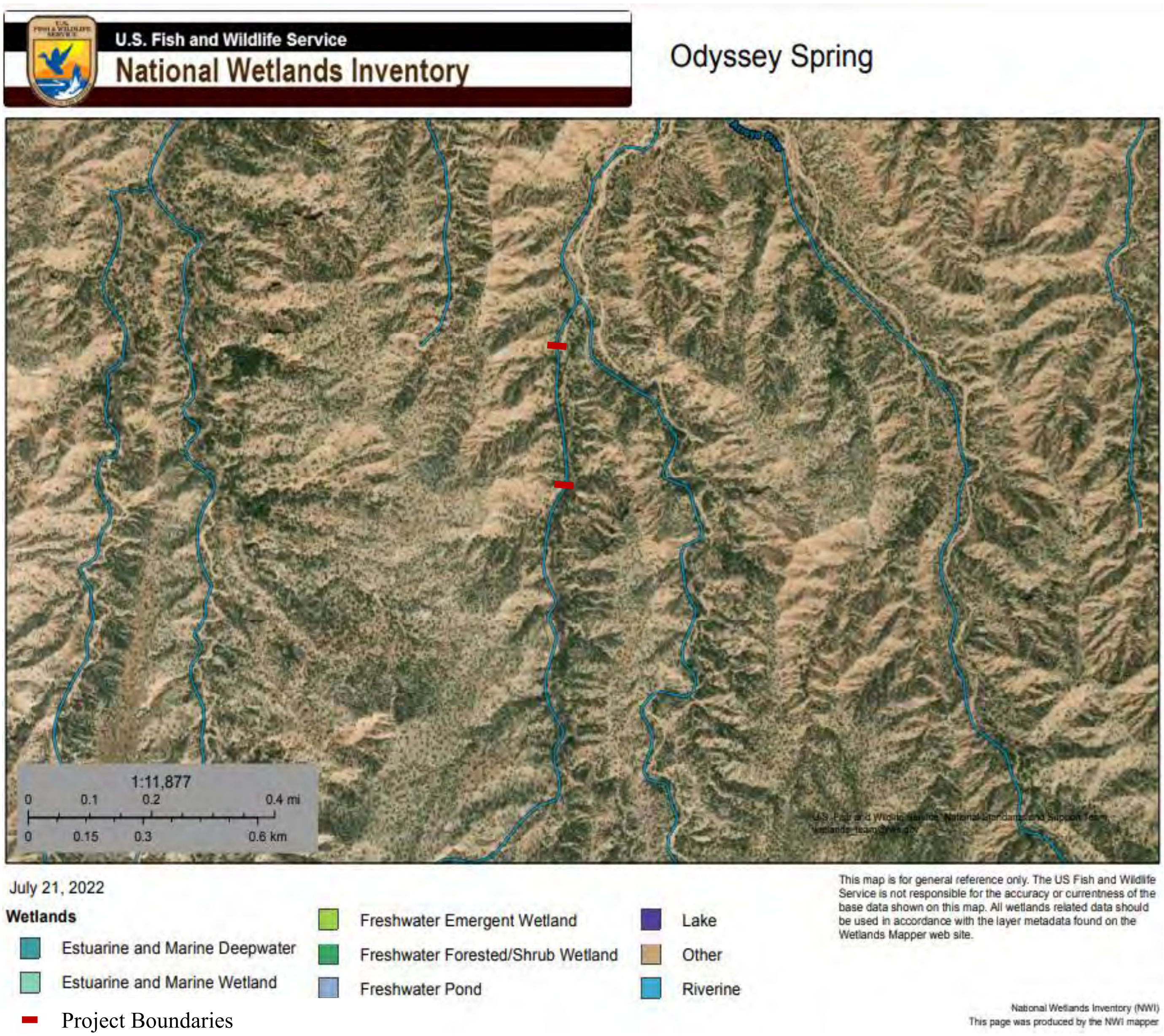
The project area within Lightning Bolt Spring (left in map) is comprised of approximately 1,664 linear feet of stream reach and 1.62 acres within the larger riverine habitat. The upstream drainage is approximately 193.7 acres in size.

The project area within Labyrinth Spring (right in map) is comprised of approximately 1,730 linear feet of stream reach and 1.92 acres within the larger habitat. The upstream drainage is approximately 188.6 acres in size.



Odyssey Spring (West Fork of Arroyo Pino)

The project area within Odyssey Spring is comprised of approximately 554 linear feet of stream reach and 0.28 acres within the larger riverine habitat. The upstream drainage is approximately 206.4 acres in size.



A.2. Wetland and Spring Types in the Wetland Area of Interest

The State of New Mexico defines wetlands as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (NMAC 20.6.4). In other words, wetlands are found in the presence of surface water or water within the root zone for at least a portion of the year, and this water creates anaerobic soils during the growing season. Wetlands contain plants that can handle these wet conditions and do not contain any plants that are intolerant to flooding. Wetlands can be variable in size, biology, chemistry, and physical characteristics; they include swamps, marshes, fens, bogs, riparian floodplains and forests, springs, seeps, playas, ciénegas, and other wet ecosystems. The differences in geomorphology, hydrodynamics, and sources of water provide the basis for typical wetland classifications (SSI, n.d.).

Riparian areas are connected to and interdependent with the same water sources and hydrologic regimes that support wetlands. They consist of entire floodplains. These floodplains support vegetation that is dependent on runoff, sedimentation, overbank flow, infiltration, and shallow ground water. Riparian areas also depend on perennial, intermittent, or ephemeral surface water and/or local shallow water tables. Overall, they are considered part of a wetland's ecosystem (SSI, n.d.).

NMED SWQB has classified New Mexico's wetland types into the following categories: depressional, riverine, lacustrine fringe, slope, mineral soil flats, and organic soil flats. In the Lower Rio Embudo Watershed WAP area of interest, riverine and slope wetlands dominate the landscape.

Riverine wetlands occur in riparian corridors and floodplains in association with stream channels. Flows may be perennial or ephemeral. These wetlands lose surface water from the return of floodwater to the channel and through saturation surface flow to the channel during rainfall events. Subsurface water is lost through discharge to the channel, evapotranspiration, and movement to deeper groundwater. Riverine wetlands are the most common and the most threatened wetlands in New Mexico. Bosque floodplains are an example of riverine wetlands (SSI, n.d.).

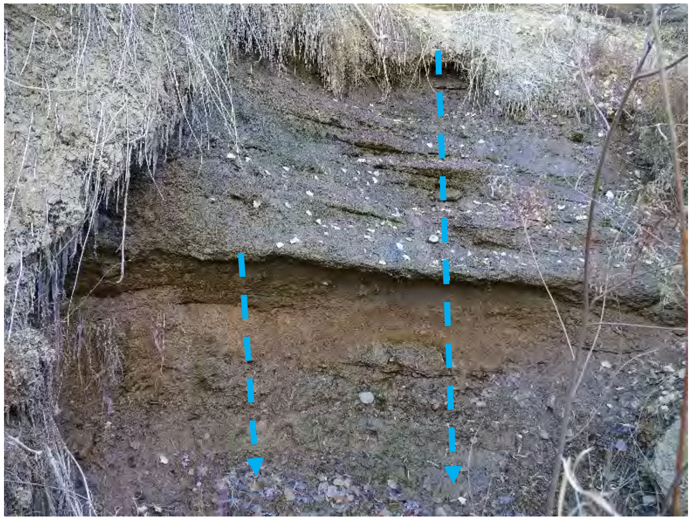
Slope wetlands are located where groundwater discharges to the land surface. As the name suggests, these wetlands usually occur on sloping land—gradients range from steep hillsides to slight slopes. Principal water sources are usually groundwater flow and interflow from surrounding uplands. Precipitation can also contribute to the wetland. Slope wetlands lose water by surface flows and subsurface saturation as well as evapotranspiration. They may develop channels that carry the water away from the wetland. Seepage can occur along hillsides and can support wet tolerant ferns, some herbaceous plants, and shrubs. Common examples of slope wetlands are seeps, springs, fens, and ciénegas (SSI, n.d.).

Springs are where groundwater meets the surface, often called ojitos by the Hispanic population. A spring's source is from underground aquifers or water tables and can travel long distances over small to large amounts of time. They can be perennial or ephemeral. If the flow is immeasurably small, springs are considered seeps. Springs ecosystems support more than 20 percent of the endangered species in the United States. They are considered important indicators of global climate change and hold deep cultural significance for many southwestern Indigenous and Hispanic cultures. *Ciénega* in Spanish means a "hundred waters." These are isolated, spring fed wetlands that have salty soil conditions which impacts the type of vegetation that can inhabit the area. The adapted plants can aid in slowing flood waters and preventing erosion (SSI, n.d.).

Springs have not been consistently classified with a common lexicon until recently when Springer and Stevens (2008) defined the twelve types of springs according to hydrogeology of occurrence and the microhabitats and ecosystems they support. The mapping and classification of springs enable scientists and land managers to protect the spring's ecosystem and the related species. Visit the Spring Stewardship Institute website for spring type definitions and illustrations developed by the SSI. Table 16 describes the relevant spring type classifications for the WAP area of interest.

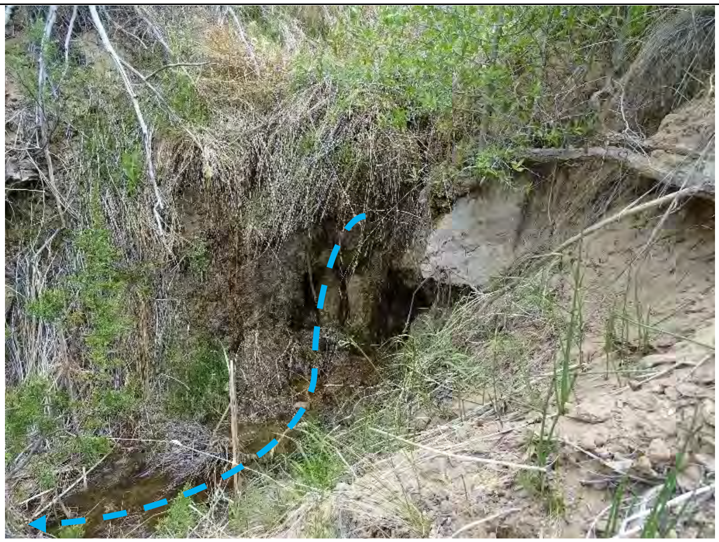
Table 16. Spring Type, Description, and Illustration of Springs and Wetlands Found in Section 2 and 32

Spring Type	Description	Illustration
Rheocrene	Flowing spring, emerges into one or more defined stream channels. Flow emerges from a surface flow-dominated channel bed. Upstream of the spring source, the channel may be a perennial stream or it may be dry. Lotic flow conditions generally prevail. These springs are subject to channel flood scour. Examples: Blackwater Spring, Lighting Bolt Spring, Odyssey Spring Blue arrows: Low flow channels within defined channel that shows signs of flood scour.	

Spring Type	Description	Illustration
Hanging Garden	Emerges from low gradient wetlands; often indistinct or multiple sources seeping from shallow, unconfined aquifers. In the SW, these complex springs usually emerge from perched, unconfined aquifers in aeolian sandstone formations. Both lotic and lentic flow conditions can occur. Example: Drip Drop Spring Blue arrows: Flow emerges along a horizontal geologic contact, typically dripping along a seepage front and often creating a wet backwall.	

Spring Type	Description	Illustration
Helocrene	Emerges from low gradient wetlands; often not distinct or multiple sources seeping from shallow, unconfined aquifers. A wet meadow with seepage emerging outside and away from an active surface flow-dominated channel or floodplain, and not subject to regular flood scour by a stream. Example: Mushroom Meadow Spring Blue Polygon: Wetted meadow fed by seeps.	

Hypocrene	A buried spring where flow does not reach the surface, typically due to very low discharge and high evaporation or transpiration. Groundwater levels are close to the surface, but do not emerge. Of all spring types, hypocrenes typically have the lowest discharge and the lowest inputs of atmospheric water. Groundwater is expressed solely through wetland or obligate riparian vegetation. Examples: Odyssey Spring (see images), Flat Top Spring, Section 2-Spring 1 & Section 2-Spring 2 Blue Arrows: Sub surface water flow but no sun lighting to the surface.	 

Spring Type	Description	Illustration
Hillslope	Emerges from confined or unconfined aquifers on a hillslope (30 to 60-degree slope); often indistinct or multiple sources and not associated with a floodplain or channel that is subject to regular surface flow stream flood scouring. Support a diverse array of microhabitats. The slope gradient is usually negatively related to floral diversity. Aspect also strongly influences diversity, although those relationships have yet to be rigorously quantified. Example: Stalactite Spring Blue Arrow: Emergence and flow of spring from the hillslope.	

Note: Text from Spring Stewardship Institute website on Spring Types Index (SSI, n.d.). (Photographs taken by Ecotone Landscape Planning, LLC.)

A.3. Spring Functional Assessment

Between 2018 and 2021, a team of BLM biologists sampled 37 of the springs and two additional ones on State Trust Land that were afterwards determined not to be springs using the Level-1 or Level-2 spring sampling method developed by the Springs Stewardship Institute. Springs that were determined to have insufficient size, quantity of water, and associated habitat were surveyed in less depth at Level-1 based on the *Springs Ecosystem Inventory Protocol* (Stevens et al., 2016). Of the 37 sampled springs, 14 were surveyed as Level-1, eight springs, all on State Trust Land, were surveyed at Level-1.5, representing an incomplete Level-2 survey. Fifteen springs, all on BLM land, were surveyed at Level-2.

The BLM team walked the perimeter of the spring-fed wetlands that were sampled at Level-2 with GPS devices to record the acreage of each wetland. Spring and associated wetland acreages of Level-2 springs range from 0.01 to 2.06 acres. The springs and their downstream wetlands surveyed at Level-1.5 on State Trust Lands range between 0.24 and 8.3 acres and are among the largest springs in the WAP area. Their total acreage is 18.35 acres, while the total acreage of all known springs and wetlands is estimated to be at least 23.67 acres. The largest of all surveyed spring-fed wetlands is Labyrinth Spring with 8.3 acres of wetlands (Besser et al., 2021b). Various side canyons with springs and wetlands add approximately two additional acres to the total acreage of this wetland complex.

BLM conducted Proper Functioning Condition assessments on 17 spring-fed wetland sites (Besser et al., 2021a, 2021b). The BLM "Proper Functioning Condition" assessment was performed on nine of the Level-2 spring-fed wetlands on BLM land and on eight of the Level-1.5 spring-fed wetlands on State Trust Land. This assessment evaluates how well physical processes of spring-fed wetlands are functioning. The method uses 20 metrics that fall within three attribute categories: (a) Assessing Hydrology Attributes and Processes; (b) Assessing Vegetation Attributes and Processes; and (c) Assessing Soil and Geomorphic Attributes and Processes. Table 17 lists key metrics for the BLM's Proper Functioning Condition indicator categories.

Findings indicated that twelve springs were meeting proper functioning conditions (rated PFC; 7 on BLM and 5 on State land) and five were "functional-at risk" (rated FAR) but within management control (2 on BLM and 3 on State land). The at-risk sites were impacted by a progressing invasion of exotic plant species such as Russian olive, saltcedar, cheatgrass, and redtop which could lead to dewatering and loss of wetland characteristics.

Table 17. A Listing of BLM's Proper Functioning Condition Indicator Categories

Assessing Hydrology Attributes and Processes
Item 1: Riparian-wetland area is saturated at or near the surface or inundated in "relatively frequent" events
Item 2: Fluctuation of water levels is within a range that maintains hydrologic functions and riparian-wetland vegetation
Item 3: Riparian-wetland area is enlarging or has achieved potential extent
Item 4: Riparian-wetland impairment from the contributing area is absent
Item 5: Water quality is sufficient to support riparian-wetland plants
Item 6: Disturbances or features that negatively affect surface- and subsurface-flow patterns are absent
Item 7: Impoundment structure accommodates safe passage of flows (*e.g.,* no head cut affecting dam and spillway)

Assessing Vegetation Attributes and Processes
Item 8: There is adequate diversity of stabilizing riparian-wetland vegetation for recovery/maintenance
Item 9: There are adequate age classes of stabilizing riparian-wetland vegetation for recovery/maintenance
Item 10: Species present indicate maintenance of riparian-wetland soil-moisture characteristics
Item 11: Stabilizing plant communities are present that are capable of withstanding overland flows (*e.g.,* storm events, snowmelt), and wind and wave actions, and can resist physical alteration
Item 12: Riparian-wetland plants exhibit high vigor
Item 13: An adequate amount of stabilizing riparian-wetland vegetation is present to protect soil surfaces and shorelines, to dissipate energy from overland flows and wind and wave actions, and to resist physical alteration
Item 14: Abnormal frost or hydrologic heaving is absent
Item 15: Favorable microsite condition (*e.g.,* woody material, water temperature) is maintained by adjacent site characteristics

Assessing Soil and Geomorphic Attributes and Processes
Item 16: Accumulation of chemicals affecting plant productivity/composition is absent
Item 17: Saturation of soils (*i.e.,* ponding, flooding frequency, and duration) is sufficient to compose and maintain hydric soils
Item 18: Underlying geologic material/soil material/permafrost is capable of restricting water percolation
Item 19: Riparian-wetland area is in balance with the water and sediment being supplied by the watershed (*i.e.,* no excessive erosion or deposition)
Item 20: Island and shoreline characteristics (*i.e.,* rocks, coarse and/or large woody material) are adequate to dissipate wind- and wave-event energies

APPENDIX B: BACKGROUND DETAILS ON CURRENT CONDITIONS OF THE LOWER RIO EMBUDO WATERSHED

B.1. Ground Cover and Vegetation for Riparian Area

Ground cover and vegetation within each of the BLM documented springs in Section 2 and 32 consisted of both native and non-native species as well as wildlife and livestock palatable plants (Table 18). Many springs have overlapping species while plants such as Wood's rose, American licorice, velvety golden rod, fowl manna grass, and others are only found in a single wetland, making native plant inhabitance all the more localized and susceptible to invasive species encroachment.

The listing of palatable species in Table 18 is not exhaustive. One asterisk (*) indicates "livestock palatable"; two asterisks (**) indicate "wildlife palatable" (Dr. James Biggs, personal communication, September 30, 2022).

Table 18. Vegetative Species in BLM Taos Field Office Recorded Wetlands

			Name of Spring									
Woody/Forbs/Graminoids	**Common Names**	**Scientific Name**	Labyrinth Spring	Blackwater Spring	Odyssey Spring	Lightning Bolt Spring	Drip Drop Spring	Stalactite Spring	Mushroom Meadow Spring	Flat Top Spring	Springs #1-5 (Section 2)	Note
Woody	Rio Grande Cottonwood	*Populus deltoides*	x	x	x	x	x	x	x	x	1	
	Narrowleaf Cottonwood	*Populus angustifolia*	x			x	x	x		x		
	Black Cottonwood	*Populus balsamifera ssp.*					x		x	x		
	Cottonwood (unknown sp.)	*Populus* sp.									2, 5	
	Russian Olive **	*Elaeagnus angustifolia*	x	x	x	x	x	x	x			Birds and small mammals eat fruit
	Three Leaf Summac*/**	*Rhus trilobata*	x		x			x		x		Good for wildlife ungulates and birds
	Rocky Mountain Juniper**	*Juniperus scopulorum*	x		x	x	x	x	x			Seeds good for birds and small mammals
	Oneseed Juniper**	*Juniperus monosperma*									3	
	Juniper (unknown sp.)	*Juniperus* sp.									2	
	Coyote Willow**	*Salix exigua*	x	x	x	x	x	x		x	1	
	Shining Willow, Red willow,	*Salix lucida*	x			x						
	Goodding's Black Willow	*Salix gooddingii*			x	x						
	Blue-stem Willow, Sandbar	*Salix irrorata*			x	x						
	Chinese tamarisk, Tamarisk, Salt Cedar	*Tamarix chinensis*		x		x						
	Mountain Mahogany*/**	*Cercocarpus montanus*		x	x						3	Good for ungulates, have high value for
	Piñon Pine**	*Pinus edulis*			x						3	
	Wood's Rose	*Rosa woodsii*			x		x					
	Gambel Oak*/**	*Quercus gambelii*			x							Fed on by large ungulates frequently
Forbs	Scouring Rush, Rough	*Equisetum hyemale*	x	x	x	x	x			x		
	Smooth Horsetail	*Equisetum laevigatum*					x	x				
	Yellow Sweet Clover**	*Melilotus officinalis*	x	x	x	x	x	x	x	x		
	Butterfly Orchids, Fringed	*Platanthera* sp.	x					x	x			
	Penstemon	*Penstemon* sp.		x	x							
	Fringed willowherb	*Epilobium ciliatum*		x	x							
	American Licorice	*Glycyrrhiza lepidota*			x							
	Canada Thistle*/**	*Cirsium arvense*			x							
	Spearmint**	*Mentha spicata*			x							
	Old-man's Beard	*Clematis ligusticifolia*			x							
	Velvety Goldenrod	*Solidago velutina*			x			x				
	Spiny sowthistle**	*Sonchus asper*			x							
	White Prairie Aster, Western	*Symphyotrichum falcatum*			x			x	x			
	Western Poison Ivy	*Toxicodendron rydbergii*			x			x				
	American Brooklime	*Veronica americana*					x	x				
	Water Horehound	*Lycopus* sp.						x				
	Wild Mint	*Mentha arvensis*						x				
Graminoids	Three-square Bulrush	*Schoenoplectus pungens*	x	x		x	x	x				
	Redtop*/**	*Agrostis gigantea*	x	x	x	x	x	x	x	x		
	Spikerushes	*Eleocharis* sp.	x	x		x	x	x				
	Rocky Mountain Rush	*Juncus saximontanus*	x	x		x		x				
	Cat Grass**	*Dactylis glomerata*	x									
	Tall Fescue*/**	*Schedonorus arundinaceus*	x									
	Mexican Rush	*Juncus mexicanus*		x	x					x	1, 5	
	Broadleaf Cattail	*Typha latifolia*		x	x	x	x	x	x			
	Scratchgrass	*Muhlenbergia asperifolia*		x	x		x	x	x			
	Nebraska Sedge*/**	*Carex nebrascensis*			x			x	x			
	Canada Wild Rye	*Elymus canadensis*			x			x				
	Fowl Manna Grass	*Glyceria striata*			x							
	California Brome Grass	*Bromus carinatus*			x							

B.2. Wildlife Habitat and Ecosystems

If the climate scenarios for the Southwest play out as predicted, biodiversity of the Lower Rio Embudo Watershed's ecosystems will decline sharply during the 21st century. Additionally, increased incidents of wildfire and bark beetle outbreaks may further degrade the watershed ecology while natural regeneration opportunities from the outside may decline. Other trends will likely include changes in the timing of species events, such as nesting and pollination (Robles and Enquist, 2010). The downward trends in surface water availability and the decrease of plant species dependent on animal pollinators could eventually have dramatic consequences for insects in the area, cascading in the further collapse of the plant communities, and contributing to further desertification of great parts of the lower elevation watershed. In addition, ephemeral water bodies, a large portion of streams in New Mexico, will experience increased water temperatures and evaporation rates, which will cause a reduction in their availability and value as habitat (NM Department of Game and Fish, 2016).

Furthermore, an online assessment of the US Fish and Wildlife Service's Information for Planning and Consulting database revealed that several T&E species are potentially present in the areas of interest. Endangered species in the Lower Rio Embudo Watershed area include the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*), the Jemez Mountains salamander (*Plethodon neomexicanus*), and the southwestern willow flycatcher (*Empidonax traillii extimus*). Threatened species within the area could include the Canada lynx (*Lynx canadensis)* and the Mexican spotted owl *(Strix occidentalis lucida*). The endangered, yellow-billed cuckoo (*Coccyzus americanus*) has also been identified in the Lower Rio Embudo Watershed. Species that are candidates for listing include the Rio Grande cutthroat trout (*Oncorhynchus clarkii virginalis*) and Monarch butterfly (*Danaus plexippus*). Critical habitat exists for the southwestern willow flycatcher. The critical habitat is primarily stream segments and the surrounding riparian and wetland areas.

IPaC also describes nine migratory bird species protected under The Migratory Bird Treaty Act of 1918 that are likely present in the area for certain periods of the year (* indicates species listed in Table 19). These include the bald eagle (*Haliaeetus leucocephalus*)*, Cassin's Finch (*Carpodacus cassinii*)*, Clark's Nutcracker (*Nucifraga columbiana*), Evening Grosbeak (*Coccothraustes vespertinus*)*, Grace's Warbler (*Dendroica graciae*), Lewis's Woodpecker (*Melanerpes lewis*)*, Olive-sided Flycatcher (*Contopus cooperi*)*, Pinyon Jay (*Gymnorhinus cyanocephalus*)*, and Virginia's Warbler (*Leiothlypis virginiae*)*.

In addition, 63 Species of Greatest Conservation Need (SGCN) occur in the Southern Rocky Mountains ecoregion; over half are birds (NMDGF, 2016). Species counted in the Lower Rio Embudo Watershed include 19 species that were identified in the 2016 State Wildlife Action Plan for New Mexico as SGCN for the Southern Rocky Mountains and Arizona-New Mexico Mountains

(NMDGF, 2016). Based on the previously mentioned work, the status of those 19 species is summarized in Table 19.

Table 19. Species of Greatest Conservation Need

SGCN Species observed in the Lower Embudo Creek watershed				
Common Name	**Species**	**Breeding Regularly Observed**	**Season**	**Abundance**
Yellow-billed Cuckoo	Coccyzus americanus		Migrant	Rare
Mexican Whip-poor-will	Antrostomus arizonae		Migrant	Uncommon
Bald Eagle	Haliaeetus leucocephalus		Winter Visitor	Uncommon
Lewis's Woodpecker	Melanerpes lewis	Yes	Year-round	Common
Williamson's Sapsucker	Sphyrapicus thyroideus		Transient	Uncommon
Peregrine Falcon	Falco peregrinus		Year-round	Uncommon
Olive-sided Flycatcher	Contopus cooperi		Spring/Fall Transient	Uncommon
Willow Flycatcher	Empidonax traillii		Spring/Fall Transient	Uncommon
Unidentified Empidonax Flycatcher	Empidonax (sp)		Spring/Fall Transient	Common
Loggerhead Shrike	Lanius ludovicianus		Year-round	Uncommon
Pinyon Jay	Gymnorhinus cyanocephalus	Yes	Year-round	Common
Woodhouse's Scrub-Jay	Aphelocoma woodhouseii	Yes	Year-round	Common
Juniper Titmouse	Baeolophus ridgwayi	Yes	Year-round	Common
Western Bluebird	Sialia mexicana	Yes	Year-round	Common
Mountain Bluebird	Sialia currucoides		Winter Visitor	Uncommon
Evening Grosbeak	Coccothraustes vespertinus		Year-round	Common
Cassin's Finch	Haemorhous cassinii		Transient/Winter Visitor	Uncommon
Vesper Sparrow	Pooecetes gramineus		Spring/Fall Transient	Rare
Virginia's Warbler	Leiothlypis virginiae	Yes	Migrant Summer Breeder	Common
Black-throated Gray Warbler	Setophaga nigrescens		Migrant Summer Breeder	Uncommon
Source: Robert Templeton (rt@rioembudobirds.org).				

Note: Table courtesy of Robert Templeton.

APPENDIX C. EVALUATION OF RECHARGE SOURCES AND FLOW PATHS ASSOCIATED WITH SPRINGS SOUTH OF DIXON, NM – RECOMMENDED FUTURE WORK

By B. Talon Newton, Hydrogeologist, NM Bureau of Geology and Mineral Resources (2023)

[For more information, please contact Talon Newton (talon.newton@nmt.edu; 575-835-6668)]

In 2022 the New Mexico Bureau of Geology and Mineral Resources (NMBGMR), as part of a cost-match collaboration with Ecotone Landscape Planning and state agencies, conducted a small study focused on several springs located south of Dixon on NM Land Trust Section 32. This study focused on estimating the age of the water discharging at the springs and identifying water sources that contribute to the springs and the associated flowpaths. This information would be used to assess different restoration scenarios in an effort to protect the springs and reduce sediment transport in nearby arroyos. We collected and analyzed 5 water samples from 4 different springs for several constituents, including general water chemistry, Carbon-14, tritium, and stable isotopes of water, for the purpose of characterizing the local and regional hydrogeologic systems associated with these springs. Geochemical analysis of these data and existing geologic and hydrogeologic data provided important information about potential recharge sources and flowpaths for the springs. However, due to the small dataset (5 samples), conclusions from the study contain several uncertainties. We were able to construct a hypothetical hydrogeologic conceptual model that has helped to identify more specific questions about the region and local hydrogeologic systems. These questions help to determine the direction of future research needed to better evaluate these systems. This document provides a general description of a recommended study plan for future work. The questions driving this study are:

1. What is the temporal variability for spring discharge on different time scales?
2. What is the spatial and temporal variability of regional precipitation in the Sangre de Cristo Mountains to the southeast of the springs?
3. What is the spatial and temporal variability of water chemistry for the springs, nearby streams and up-gradient wells in the area?
4. How many water sources (*e.g.* mountain front recharge, mountain block recharge, local recharge, etc.) contribute to spring discharge?
5. How does the relative contributions of these different sources to spring discharge vary with time?

The following tasks help answer the above questions:

1. Continuous hydrograph analysis - Install weirs on at least two springs (Section 32 or Section 2) instrumented with data loggers that will collect continuous data for at least 2 years. The resulting hydrographs will characterize diurnal and seasonal variability of spring discharge.
2. Isotopic characterization of regional precipitation - Install three precipitation collectors at different elevations and collect samples for at least 2 years.
3. Additional water sampling (at least twice during different hydrologic regimes to be determined (*e.g.,* seasonal, wet period, dry period, etc.) – Collect water samples from springs in Section 32 and Section 2, and wells and streams in the vicinity and upstream of springs. Ideally, the sampling would identify at least 3 wells at different positions along an apparent groundwater flowpath (20 to 30 samples total, general chemistry, trace metals, stable isotopes, tritium, ^{14}C for wells only).
4. Hydrograph separation - Collection of several spring samples for chemical analysis during a high flow event at one of the spring discharge measurement areas. The constituents to be analyzed for and used to identify the different potential end members will be decided based on the water sampling results (Task 3). The combination of the spring hydrograph and chemical analyses will allow us to mixing ratios during the event (% old base flow, % young local recharge, % other endmember?). Predicting the occurrence of a high-flow event so that we can collect samples during the event will be difficult. Discharge data collected for Task 1 may help us to identify storm events that will likely produce a high-flow hydrograph.
5. Construct an improved cross-sectional hydrogeologic conceptual model based on increased understanding from additional data efforts described above.

Continuous spring discharge measurements

Continuous measurement of spring discharge will help to understand temporal fluctuations associated with seasonal precipitation patterns and how spring discharge responds to large precipitation or snowmelt events. Analysis of the resulting spring hydrographs (spring flow rate as a function of time) will provide useful information about the flowpath(s) associated with the springs in Sections 32 and 2. The low discharge rates of these springs makes discharge measurements difficult. We propose to use a temporary weir of some type, such as the one shown in Figure 21, which contains a water level data logger in the stilling well.

Figure 21. A v-notch weir installed in a small spring in Southern New Mexico. A data logger in the stilling well to the left collects continuous water level data which is used to calculate spring discharge.

Isotopic characterization of regional precipitation

To characterize the isotopic composition of local and regional, precipitation samples need to be sampled at different elevations and times for stable isotopic analysis. The installation of 3 precipitation collectors (Figure 22) at different locations, and different elevations (to be determined) is recommended for this project. In addition, a tipping bucket rain gauge and data logger should also be installed at each site.

Figure 22. Precipitation collector for collection of rain and snow for isotopic analysis.

Water sampling and analysis

Additional water sampling (at least twice during different hydrologic regimes to be determined, *e.g.* seasonal, wet period, dry period, etc.) – Springs on Section 32 and section 2, wells (Figure 23) and streams in the vicinity and upstream of springs. It would be nice to identify at least 3 wells at different positions along an apparent groundwater flowpath (20 to 30 samples total, general chemistry, trace metals, stable isotopes, tritium, ^{14}C for wells only).

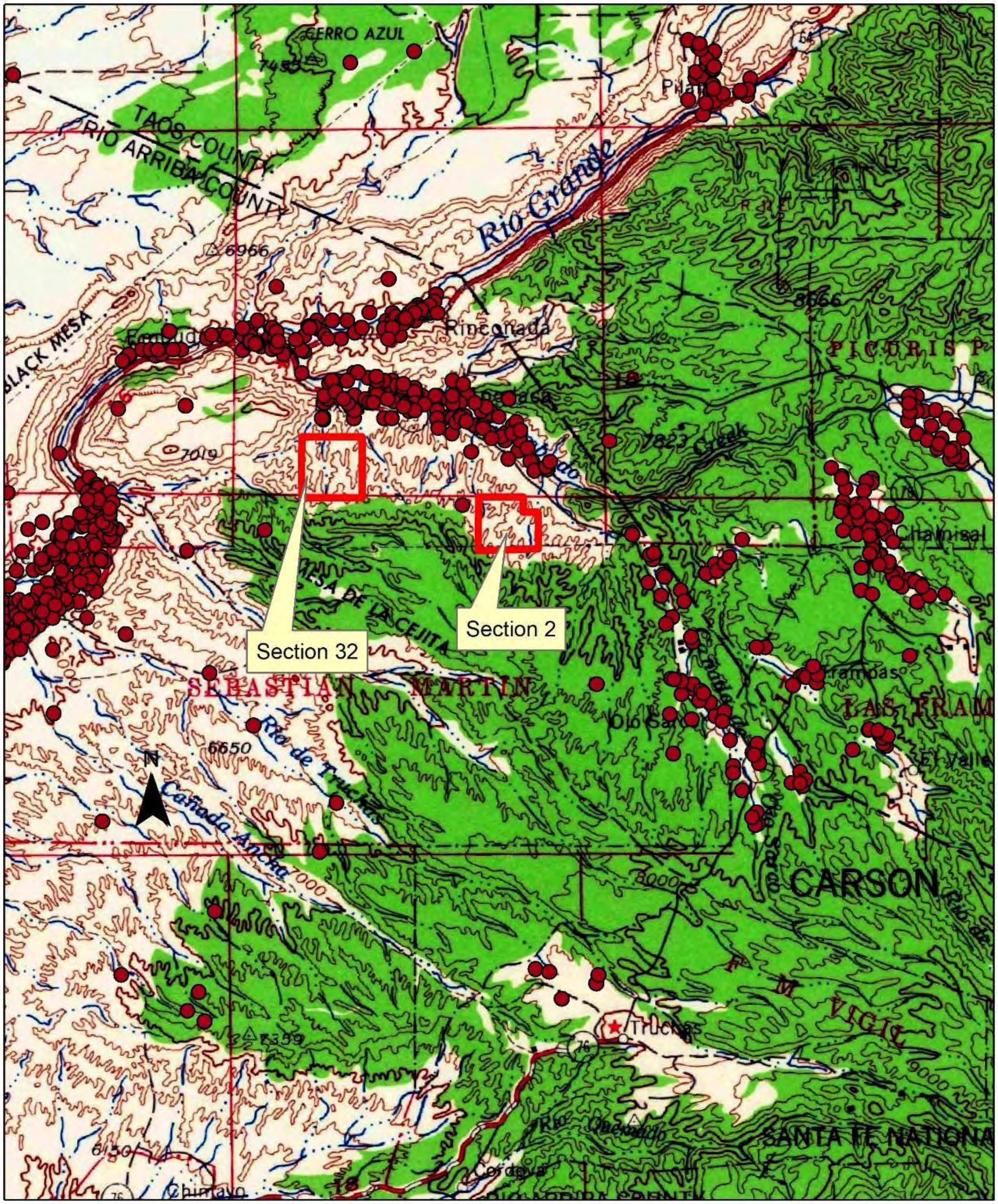


Figure 23. Locations of State Land Grant sections 32 and 2, where springs of interest are located. Red points are existing well locations in the area.

Hydrograph separation

Information from tasks 1 - 3 will help to predict an event when spring discharge is expected to increase significantly for some amount of time and to identify the different mixing endmembers that contribute to spring discharge during such an event. By collecting many samples during an event, and analyzing samples for different chemical constituents (to be determined), we should be able to use a hydrograph separation technique to determine the relative contributions of the different end members to spring discharge. We can use the storm hydrograph along with chemical analyses to identify the different endmembers, such as regional groundwater, local groundwater, and local runoff, and their relative concentrations at different times during the event.

Construct an improved cross-sectional hydrogeologic conceptual model

Figure 24 shows the hypothetical hydrogeologic conceptual model presented in the Technical Report submitted to Ecotone Landscape Planning in December 2022. Information gained from the previous tasks will allow the construction of an improved cross-sectional hydrogeologic conceptual model (to scale).

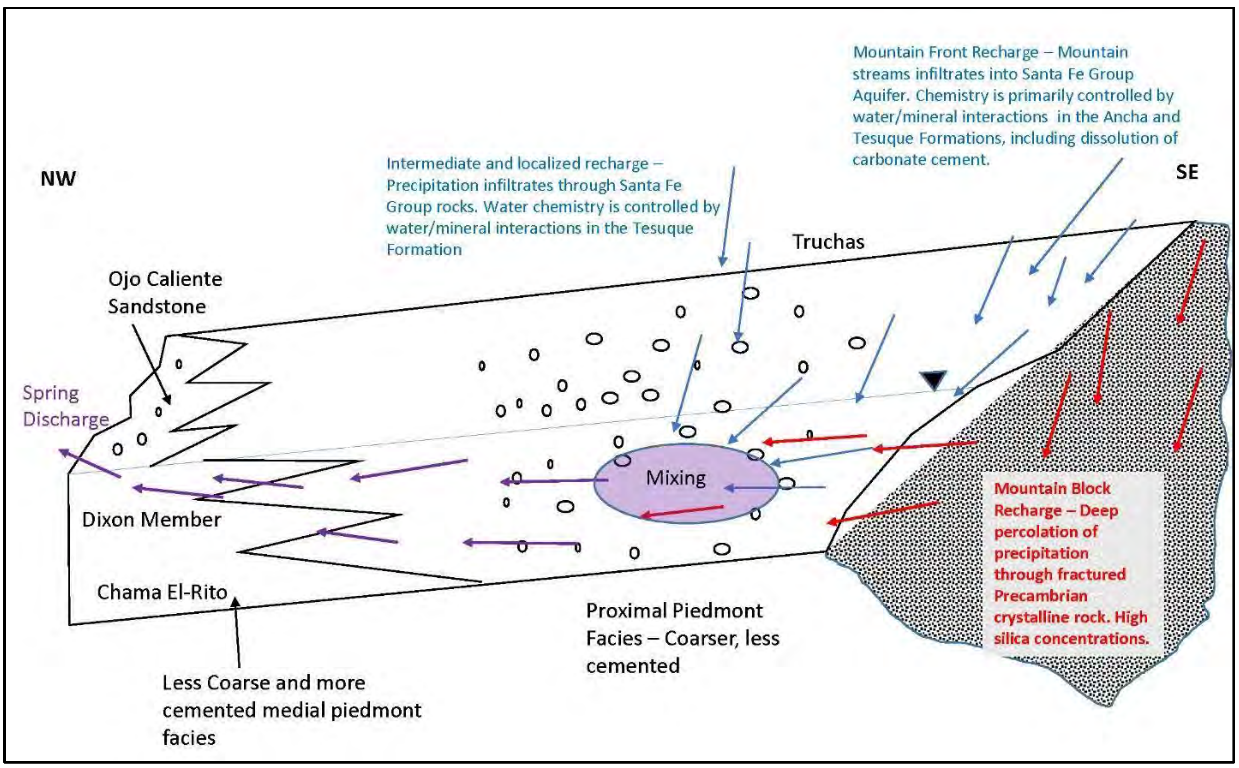


Figure 24. Hypothesized conceptual model of flowpaths for groundwater that that discharges at springs south of Dixon, NM. Not to scale.

The table presented below (Table 20) lists the different tasks described above along with a very rough cost estimate. The cost estimates are for the different tasks as standalone projects. Costs will differ if more than one task is included in a single funded project. Ideally, this full study (all tasks) should be conducted over at least 2 years, with tasks 1 and 2 being implemented at the same time and prior to tasks 3-5, as each task builds on the information from the previous task.

Table 20. Tasks, Descriptions, Estimated Cost, and Comments for Recommended Future Work

Task #	Task	Description	Estimated cost	Comments
1	Continuous spring discharge measurements	Inventory springs in Sections 2 and 32; Install weir, stilling well, data logger at 2 different sites; Collect and download water level data for two years; Data analysis	$50,000	This task should be started at least a year before tasks 3 - 5. Estimated cost includes the purchase of weir materials and data loggers, salaries, and travel.
2	Stable isotopic characterization of regional precipitation	Install precipitation collectors and tipping bucket rain gauge at three different locations and elevations; Collect and download data for two years; Data analysis	$45,000	This task should be started at least a year before tasks 3 - 5. Estimated cost includes the purchase of materials used to build the precipitation collector and tipping bucket rain gauges.
3	Water chemistry analysis for springs, streams, and wells	Collect 20 spring samples, 10 stream samples, 10 well samples; Chemical analyses; Data Analysis	$100,000	Sample locations and timing will be determined based on partial analysis of data from tasks 1 and 2.
4	Hydrograph separation	Collect up to 20 spring samples at one of the Weirs sites during an event that causes a significant increase in spring discharge; Data analysis	$36,000	The identification of sampling events and mixing end members to be used will be based on information gained from tasks 1, 2, and 3.
5	Construction of cross-sectional hydrogeologic conceptual model (to scale)	A geologic cross-section along the apparent flow path associated with the springs will be constructed based on existing geologic data. Hydrologic context to the geologic cross-section will be based on information gained from previous tasks and existing data.	$30,000	This task should be done after Tasks 1-4 are mostly done, as we will use all data from previous tasks, along with existing geologic and hydrologic data to construct the cross-sectional conceptual model.