Inland Wetland Habitats
19. Nontidal Wetland Restoration

DEFINITION

Nontidal wetland restoration is the rehabilitation of a degraded wetland so that its hydrology, vegetation, and ecological processes approximate, to the extent possible, the original natural condition prior to modification (USDA 2021). Nontidal wetlands include any wetlands that are not inundated by tidal waters; this summary applies to nontidal wetlands generally but includes some details specific to arid wetlands and ephemeral wetlands. There are also separate summaries for the related strategies of peatland restoration, stream restoration, floodplain reconnection, and built wetlands.

Specific activities to restore wetlands depend on the wetland type and how it has been modified. Frequently, wetland modification occurs via drainage by surface ditching or tile drains (Biebighauser 2023, Schilling 2022). These wetlands can be restored by removing those alterations—for example, by filling or blocking ditches. Strategies to restore arid wetlands include installing rock detention structures, earthen berms, log dams, soil remediation, and riparian restoration (Wilson and Norman 2018). Invasive species removal and replanting with native species are also common wetland restoration techniques.

TECHNICAL APPROACH

1. **Site preparation:** Site preparation is often needed to remove debris and invasive species from the restoration site and may also require microtopographic alterations to ensure the wetland is slightly lower than the surrounding landscape so it will hold water (Calhoun et al. 2017; Ferren et al. 1998; USDA 2023). This is particularly important for wetlands that were previously filled to create a flat surface for agriculture, forestry, or other uses.

2. **Hydrologic restoration:** Nontidal wetland restoration frequently requires hydrologic restoration to return inundation extent and frequency to a natural state. Hydrologic restoration techniques depend on the type of drainage present in the degraded wetland:

    - **Ditch filling:** For wetlands with surface ditching, hydrology can be restored by filling in the entire ditch and regrading to the natural topography. A simpler but less effective method is to use a ditch plug, which dams the ditch at its lowest point, but does not fully restore the hydrology (Gibson et al. 2020, Sargent and Carter 1999).

    - **Removing tile drains:** For wetlands with tile drains, hydrology can be restored by removing all tile drains and filling in the resulting channel. Another option is to use tile breaks, which leaves the tile drains in place, but plugs the flow through the drains in multiple places. This technique is simpler and commonly used, but does not completely restore hydrology (Gibson et al. 2020, Sargent and Carter 1999).

- **Detention structures:** For wetlands in arid regions that need assistance with water retention following intense precipitation, rock detention structures or log dams can be used to slow down water, protect soil, and reduce erosion (TRC 2023; University of Arizona 2023; EPA 2021; Norman et al. 2022; Silverman et al. 2019).
- **Levee removal:** Wetlands that have been cut off from a nearby stream or river by a levee will benefit from levee removal (Pess et al. 2005). See the floodplain reconnection summary for more information on this technique.

3. **Revegetation:** After hydrologic restoration is complete, the area can be left to revegetate naturally, or can be planted with appropriate species. When selecting a vegetation strategy, it is important to consider the possibility of invasive species colonization, especially under natural revegetation. Planting can be done using plugs (most feasible for small areas) or by seed dispersal (more successful in large areas or frequently submerged areas) (Rodrigo 2021).

OPERATIONS AND MAINTENANCE

Invasive species, duckweed, and algae should be removed from the restored wetland annually, and trash and debris cleared as needed. Repairs to rock detention structures or log dams may be required periodically. If present, ditch plugs should be mowed and repaired about once a month. After major storms, logs and branches will need to be cleared from spillways. If problems with muskrat, woodchuck, or other animal burrows are observed, holes may need to be filled.

FACTORS INFLUENCING SITE SUITABILITY

- ✓ **Existing wetlands:** Restoration within a complex of existing wetlands will have the greatest chance of success (USDA 2021). In arid regions, connection to a larger system of intermittent streams can help channel water to wetlands during rainfall, which replenishes water in the wetland and reduces erosion.
- ✓ **Low-lying agricultural areas that are frequently flooded**: Frequently flooded agricultural areas are a sign that a former wetland was drained and planted with crops. These restoration scenarios typically involve creating tile breaks and ditch plugs to restore the hydrology (Sargent and Carter 1999).
- ✓ **Degraded area with hydric soils still present:** Hydric soils are an indicator that a wetland once existed on the site. Often covered with construction fill or trash, hydric soils can form the basis of a functioning wetland once the debris has been removed (Biebighauser 2023).
- ✓ **Landscape has many depressions containing clay soil:** Clay soil is more impervious, allowing for greater water retention within the wetland. Clay soil combined with a slight depression provides a natural bowl that can hold water (Biebighauser 2023).
- ✓ **Soils containing high levels of sulfidic material:** An indicator of a potential wetland site is when sulfur has been reduced to hydrogen sulfide. This is the source of

the common “rotten eggs” smell associated with wetlands. While not all restoration sites must meet this condition to be successful, the “rotten eggs” smell is a sign of wetlands bacteria at work (Beall n.d.).

- **Near a brownfield or landfill site:** Many species that inhabit wetlands are highly sensitive to toxic chemicals. Wetland restoration results in the soil being inundated, meaning that there is the potential for chemicals in the soil to pollute the water.
- **Slopes in the area are greater than 3°:** Wetlands need to be located in a flat basin for water to pool. Even gentle slopes can cause water runoff to leave the wetland (Uuemaa et al. 2018).
- **Near existing infrastructure (roads, off-road vehicle trails, built structures, etc.):** Wetlands are sensitive to disturbances from foot traffic, and ephemeral wetlands are especially so. During dry seasons, hikers may wander off nearby trails and into the dry wetland, endangering fauna in the mud. Off-road vehicle use and roads create obstacles for amphibians attempting to migrate between vernal pools (Uuemaa et al. 2018).
- **Area that experiences heavy grazing:** Heavy grazing pressure can significantly degrade wetlands as grazers eat many of the wetland plants. Waste products from the grazing animals can also cause nutrient pollution in the wetland.
- **Has a salinity content greater than 0.5 ppt:** Nontidal wetlands are freshwater ecosystems that cannot tolerate salt water (Cowardin et al. 1979).

TOOLS, TRAINING, AND RESOURCES FOR PLANNING AND IMPLEMENTATION

Name and Link	Resource Type	Year	Authors/ Authoring Organization	Geography	Description	Resource Includes: Design/Construction Guidance?	Site Selection?	Monitoring Guidance?	Example Projects?
USDA Part 650 Engineering Field Handbook, Chapter 13: Wetland Restoration, Enhancement, or Creation	Book chapter	2021	US Department of Agriculture – Natural Resources Conservation Service	National	Guide to the planning, design, implementation, and monitoring of wetland restoration and enhancement. Also includes methods for assessing wetland function based on hydrogeomorphic principles.	✓	✓	✓	—
A User's Guide to Wetland Restoration, Creation and Enhancement	Guidebook	2003	Interagency Working Group on Wetland Restoration (National Oceanic and Atmospheric Administration, Environmental Protection Agency, Army Corps of Engineers [USACE], Fish and Wildlife Service, and Natural Resources Conservation Service)	National	Developed by the Interagency Workgroup on Wetland Restoration, this guidebook provides information on restoration project planning, implementation, and monitoring.	✓	✓	✓	—
The Wetlands Restoration Guidebook	Guidebook	Not provided	Maryland Department of the Environment	Written for Maryland but information is generally applicable	High-level reference aimed at a general audience interested in wetland restoration. Useful information on site characteristics that increase or reduce suitability for wetland restoration.	—	✓	—	—

Name and Link	Resource Type	Year	Authors/ Authoring Organization	Geography	Description	Resource Includes: Design/Construction Guidance?	Site Selection?	Monitoring Guidance?	Example Projects?
Minnesota Wetland Restoration Guide	Guidebook	2012	Minnesota Board of Water and Soil Resources	Written for Minnesota, but information is applicable to wetland restoration in the entire upper Midwest	Ecological and engineering principles for restoring wetlands, including site assessment, design and construction, vegetation establishment, and monitoring and ongoing management.	✓	✓	✓	—
Wetland Assessment, Restoration and Management	Training	Offered periodically	US Fish and Wildlife Service	National	In-person, 36-hour course focused on evaluating degraded wetlands for restoration potential and designing wetland restoration projects. Open to US Department of the Interior employees and contractors.	—	—	—	—
Riparian Restoration in the Arid and Semi-Arid Western US	Document	2003	USACE	Western United States	Produced by USACE, this resource details restoration methods for riparian and arid wetland habitat across the Western United States. Topics covered include plant species selection, planting techniques, and monitoring procedures.	✓	✓	✓	✓
Riparian Habitat Restoration for the Arid Southwest	Training	2023	Wetland Training Institute	Southwest United States	Held in San Diego, this two-day in-person training teaches participants the fundamentals of arid wetland restoration site selection, planning, and installation. The class takes field trips to successful restoration projects in the region in addition to identifying common mistakes.	✓	✓	—	✓

Name and Link	Resource Type	Year	Authors/ Authoring Organization	Geography	Description	Resource Includes: Design/Construction Guidance?	Site Selection?	Monitoring Guidance?	Example Projects?
Wetland restoration prioritizing, a tool to reduce negative effects of drought; An application of multicriteria-spatial decision support system (MC-SDSS)	Journal article	2018	Saeideh Maleki, Ali Reza Soffianian, Saeid Soltani Koupaei, Saeid Pourmanafi, and Sassan Saatchi	Global	The authors developed a model to determine which area of a wetland would provide the most ecosystem services if restored. Because water is the limiting factor in arid wetland restoration, this tool provides a framework to best allocate scarce water resources.	✓	✓	—	✓
Dryland Watershed Restoration With Rock Detention Structures: A Nature-Based Solution to Mitigate Drought, Erosion, Flooding, and Atmospheric Carbon	Journal article	2021	Jennifer Gooden and Richard Pritzlaff	Southwest United States	This resource explains how rock detention structures have been used to restore arid watersheds across the Southwest United States and the plethora of ecosystem services they provide. The authors also provide four case studies of successful restoration projects.	✓	—	—	✓
Soil Salinity and Sodicity in Drylands: A Review of Causes, Effects, Monitoring, and Restoration Measures	Journal article	2021	Ilan Savi, Niels Thevs, and Simone Priori	Global	As soil salinization is one of the greatest threats to arid wetlands, this resource guides practitioners through the restoration process of desalinating soils. Techniques covered include salt flushing and leaching, chemical remediation, organic and microbial remediation, and phytoremediation.	✓	✓	—	—

Name and Link	Resource Type	Year	Authors/ Authoring Organization	Geography	Description	Resource Includes: Design/Construction Guidance?	Site Selection?	Monitoring Guidance?	Example Projects?
Management and Conservation of Temporary Ponds (pg. 300–305)	Journal article	2009	International Conference on Mediterranean Temporary Ponds	Global	This resource focuses on controlling hydroperiods as the primary tool for ephemeral wetland management and restoration. The authors give insight on how to create artificial hydroperiods which rejuvenate ephemeral wetlands.	✓	—	—	—
A Guide for Creating Vernal Ponds	Guidebook	2002	USDA Forest Service	National	The author lays out in-depth information about the planning and construction of a vernal pond. The guide provides practical site suitability and budgeting advice to help get projects off the ground.	✓	✓	—	—

GRAY INFRASTRUCTURE ALTERNATIVES

Nontidal wetland restoration can be an alternative to several gray infrastructure approaches: stormwater drainage systems to address urban runoff and artificial aquifer recharge systems to add water to aquifers. The ability of a wetland restoration project to replace or supplement one of these gray infrastructure types depends strongly on the project's location and whether it is designed to create the necessary outcomes. Certain environmental conditions may require gray infrastructure rather than wetland restoration. See the gray infrastructure alternative tables in Section 1 for a comparison of wetland restoration to these alternatives.

LIKELY BENEFITS AND OUTCOMES

Primary objectives for each strategy are highlighted.

Climate Threat Reduction

- **Drought mitigation:** Wetlands help capture excess runoff during intense precipitation events and slowly recharge groundwater aquifers via percolation. This allows for higher aquifer levels, reducing drought severity (Biebighauser 2002, Uhlman et al. 2020).

- **Reduced flooding:** Wetlands help reduce water runoff, preventing water from entering larger waterbodies and thus reducing flooding around those waterbodies (Biebighauser 2002). While large, permanent wetlands may have the most significant impact on the hydrological cycle, smaller, ephemeral wetlands have an outsized impact on flood mitigation because of their ability to store water temporarily. Restoring ephemeral wetlands in tandem with permanent wetlands maximizes the water storage capacity of the watershed (Zedler 2003).
- **Reduced wildfire risk:** In arid regions, wildfire severity is often determined by fuel load and soil moisture. Arid wetlands help retain water in the soil that can act as fire breaks and reduce fuel load by preventing trees from succumbing to drought, thus reducing wildfire severity. Furthermore, a functioning watershed reduces erosion and uprooted trees (which adds to the fuel load), making the region better prepared to manage future wildfires (Villarreal et al. 2022).
- **Heat mitigation:** Wetlands can cause significant reductions in air temperature, especially in urban or arid areas, helping mitigate heat. Because cooling ability becomes marginally smaller as the wetland increases in size, smaller ephemeral wetlands have a greater cooling potential than larger wetlands per acre (Wu et al. 2021).
- **Carbon storage and sequestration:** Nontidal wetlands, including arid and ephemeral wetlands, have been shown to store more carbon than estuaries (Nahlik and Fennessy 2016). This is known as *teal carbon*, and wetland restoration can help enhance carbon deposition into soil (Norman et al. 2022). However, it can take between three and 23 years after restoration for a wetland to turn into a net carbon sink (Valach et al. 2021).

Social and Economic

- **Recreational opportunities:** Restored wetlands provide venues for fishing, hunting, and wildlife watching.
- **Jobs:** Workers will need to be hired to restore wetlands, providing a boost to the local economy.
- **Mental health and well-being:** Wetland restoration enhances green space, which improves residents' mental health and well-being.
- **Cultural values:** Wetlands are not well-understood by the public. Restoring wetlands can help residents connect with this unique ecosystem, in addition to learning about the rare species that they contain. Wetlands are also places of significance in many Indigenous cultures.
- **Scientific research:** Skin secretions from amphibians are vital components of pharmaceutical research seeking to create new antiviral drugs (Hocking and Babbitt 2014). Ephemeral wetlands are vital habitats for endangered amphibians.
- **Aquifer recharge:** Wetlands are effective at recharging groundwater aquifers by facilitating an exchange between surface and groundwater in the hyporheic zone (Jolly et al. 2008). Wetland restoration means that more water will be available for agricultural, industrial, and domestic uses.

- **Reduced erosion:** Many arroyos and temporary streams in the arid United States have steep gradients, making them prone to significant erosion during heavy precipitation events. Arid wetlands help slow the flow of water and stabilize riparian areas. Furthermore, many arid wetland restoration projects involve installing erosion-control structures, which further strengthen watershed resilience against erosion (Wilson and Norman 2018).

Ecological

- **Improved water quality:** wetlands improve water quality by absorbing particulates and harmful pollutants, preventing them from running off into larger waterbodies (Calhoun et al. 2017; De Steven and Lowrance 2011).
- **Supports wildlife:** Wetland habitat supports threatened species populations, especially for reptiles, amphibians, and wetland-dependent birds, bats, and fish (De Steven and Lowrance 2011). In the United States, nine species of branchiopods, 20% of reptiles, and 40% of amphibians are threatened with extinction (IUCN 2023). These species rely on ephemeral wetlands as their primary habitat, meaning that conserving this habitat is vital to their survival (Deil 2020). Many migratory species, especially birds, use arid wetlands as an intermediate resting place during their journey (Jaensch and Young 2010).
- **Increased primary productivity:** Wetlands have unusually high levels of primary productivity, which helps enhance the species richness of the region (Simovich 1998).
- **Enhanced biodiversity:** Wetlands have a large number of endemic species and niche specialists, both of which are especially vulnerable to extinction. Wetlands also provide water sources to many other species, helping to support biodiversity.

BARRIERS AND SOLUTIONS FOR PRACTITIONERS

Common Barriers

Several barriers are common across many of the nature-based solutions strategies; these are described in more detail in Section 1 of the Roadmap. Additional notes about the barriers specific to nontidal wetland restoration are included here.

- **Expense**
- **Capacity**
- **Public opinion**
- **Conflict with other land uses:** Ephemeral wetlands are frequently cleared for agricultural use because of their small size, the relative ease of draining them, and their rich hydric soils that help improve yields (Schuyt 2005). In arid regions, urban development is often centered around ephemeral wetlands as the population needs a reliable source of water. Therefore, ephemeral wetlands are disproportionately targeted for development compared to other habitats (Smallbone et al. 2011). Cattle grazing in arid regions rely on arid wetlands as a vital source of water. Unfortunately, grazing pressures are not conducive to the health of arid wetlands, with cattle eating many

wetland plants and reducing the amount of water available to the ecosystem (Heffernan 2008). Potential sites for arid wetland restoration often overlap with future lithium mining operations. Geothermal brine and salt-rich playas are ideal spots for mining because of their lithium deposits but are also key for arid wetlands because of their water sources. With the United States striving to scale up its domestic lithium mining operations to support the electric vehicle industry, it is likely many of these sites will be developed into mines (DOE 2022).

- **Regulation:** For a waterbody to be protected under the Clean Water Act, it must be connected to downgradient navigable waters, according to the Supreme Court ruling *Sackett v. Environmental Protection Agency* (Puko and Barnes 2023). Unfortunately, many wetlands do not meet this threshold because they are isolated from other waterbodies and are nonnavigable, meaning that a landfill, construction site, or heavy industry could be sited nearby.
- **Lack of effectiveness data**

Community

- **Mosquitos:** Mosquitos are an integral part of the wetland ecosystem. Mosquito larvae help control algae blooms and eutrophication in the wetland and are vital parts of frog and salamander diets (PNHP n.d.). Some communities may oppose ephemeral wetland restoration because of this nuisance (PNHP n.d.). However, mosquitoes that harbor diseases harmful to humans, especially the *Culex* genus, prefer anthropogenic habitats over ephemeral wetlands, and natural predation generally obviates the need for mosquito control.
- **Arid wetland restoration:**
    - **Water allocation concerns:** The western United States, where the vast majority of arid wetlands are located, has always struggled with providing enough water for domestic, industrial, and agricultural uses. Because of this scarcity, little water is left for arid wetlands, which need to be replenished by runoff and snowpack because of high rates of evapotranspiration. While arid wetlands can help to mitigate the water shortage in the long run by recharging aquifers, many communities are unwilling to sacrifice water withdrawals upfront (Lemly et al. 1993).
    - **Urban development:** Arid wetlands are often targeted for urban development because they can provide a reliable source of water to sustain an urban population in arid regions. Unfortunately, urban development heavily degrades arid wetlands by changing the local hydrology and draining the wetland for development (Hollis 1990). Furthermore, arid wetlands are located in flood-prone areas, meaning that developments near them may suffer significant flood damage. This can be seen in Nogales, a city straddling the US–Mexico border, which has experienced numerous lethal floods (Freimund et al. 2022).

- **Ephemeral wetland restoration:**
    - **Off-road vehicle use:** Off-road vehicle users are often attracted to ephemeral wetlands because of their relatively open nature and muddy, yet navigable, soils. However, this activity causes extreme degradation to the wetland and its ecological community (Biebighauser 2002).

Ecological

- **Time to restore function:** Restored wetlands may take years to reach functional equivalency with natural, intact wetlands (Gutrich and Hitzhusen 2004).
- **Invasive species:** Even after being removed during the restoration process, many invasive aquatic plants recolonize wetlands. Their geographic mobility is due to their seed dispersal via migratory birds, which often stopover in wetlands (Reynolds et al. 2015). Therefore, continuing invasive species removal must occur as part of the normal maintenance processes.
- **Eutrophication and algal blooms:** Ephemeral and arid wetlands often suffer from eutrophication because they have little outflow, resulting in most of the excess nutrients staying within the wetland (Kido and Kneitel 2021). Overgrowth of algae and phytoplankton reduces dissolved oxygen levels and the wetland depth (Sánchez-Carrillo and Álvarez-Cobelas 2001, de la Cruz et al. 2017).

EXAMPLE PROJECTS

Name and Link	Location	Leading Organizations	Techniques Used	Size, acres	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Dusky Marsh Restoration Project	Baskett Slough National Wildlife Refuge, OR	**US Fish and Wildlife Service (USFWS),** Oregon Department of Fish and Wildlife	Removing water control structures, dam removal, adding natural debris and ditch plugs	98	Not provided	8 weeks	To restore the hydrology of Dusky Marsh, workers removed dams and water control structures. They then built a ditch plug to keep water in the wetlands and added in natural debris.	No	All restoration activities had to be completed in an eight-week period before the wetland was inundated.
Watergate Wetlands Restoration Project	Delaware Gap Nationa Recreation Area, NJ and PA	**National Park Service (NPS)**	Dam, pond, and invasive species removal	20	Not provided	10 months	Contractors removed a dam and corresponding pond that had been filled with invasive species. They then reseeded plants native to ephemeral wetlands.	No	Biological monitors helped remove any animals from the area before the restoration work began.
Wetland Jewels Restoration Project	Carson and Santa Fe National Forests, NM	The Nature Conservancy, US Department of Agriculture Forest Service, Amigos Bravos and Western Environmental Law Center	Ditch plugs, microtopographic alterations	~1,000	Not provided	Ongoing	To restore these remote wetlands, workers are building ditch plugs, one-rock dams, and altering the topography.	Inland flooding, drought	A 10-day cap on grazing was implemented to help the wetlands recover during the restoration process.

Name and Link	Location	Leading Organizations	Techniques Used	Size, acres	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Del Sol Vernal Pool Enhancement Project	Santa Barbara, CA	University of California Santa Barbara, California Conservation Corps, State Coastal Conservancy, Isla Vista Recreation and Park District	Ditch plugs, microtopographic alteration, debris removal	12	13.2 million	1 year	Workers constructed ditch plugs to keep water from flowing out and removed soil and debris.	No	This project was part of a research study determining whether created wetlands were as biologically diverse as historic ones that were being restored.
North Dakota Prairie Pothole Restoration Project	Northwest North Dakota	**Bureau of Reclamation**	Tile breaks, removing agricultural fill	1,018	Not provided	1 year	Tile breaks were cut and agricultural fill was removed to return agricultural lands to their original state as ephemeral wetlands.	No	Studies showed that flora quickly repopulated the restoration sites after construction was finished, but not to the same extent as undisturbed wetlands.
Spring Peeper Meadow Restoration Project	Chaska, MN	University of Minnesota, Minnehaha Creek Watershed District	Tile breaks, invasive species removal	30	Not provided	3 years	Workers applied herbicides to remove invasive species, removed agricultural tile to restore the hydrology and then reseeded the wetland.	No	Invasive species declined as trees gradually shaded more of the wetland.

Name and Link	Location	Leading Organizations	Techniques Used	Size, acres	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Proctor Valley Vernal Pool Restoration Project	San Diego National Wildlife Refuge, CA	**USFWS,** City of San Diego, Chaparral Conservancy.	Invasive species removal, microtopographic alterations	38	$1.7 million	7 years	Team members removed invasive species, dug shallow depressions in the terrain, and replanted native plants.	Drought	Restricting off-road vehicle use in this area has been challenging.
Ciénega San Bernardino Wetland Restoration	San Bernardino National Wildlife Refuge, AZ	**USFWS, US Geological Survey (USGS)**	Gabion installation, invasive species removal, cattle grazing elimination	51	Not provided	12 years	Gradually, workers built 46 gabions and one check dam to help keep water in arid wetlands. The removal of invasive species and cattle grazing also helped the wetland recover.	Inland flooding	The watershed continues into Mexico, where partners also performed wetland restoration to expand the functioning portion of the ecosystem.
Chiricahua Mountains Watershed Restoration Project	Chiricahua National Monument, AZ	**USGS, NPS,** private landowners	Check dam, gabion, and leaky weir installation	~300	Not provided	20 years	More than 20,000 rock detention structures were installed, including small check dams, leaky weirs, and gabions.	Inland flooding, drought	This watershed has 28% more flow than nearby watersheds that haven't been restored.

Name and Link	Location	Leading Organizations	Techniques Used	Size, acres	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Babocomari Watershed Project	Southeast Arizona	**USGS,** The Walton Family Foundation	Gabion and leaky weir installation	20	Not provided	2 years	Gabions and leaky weirs were installed as a part of a managed aquifer recharge project to help retain water after large rainfalls.	Drought	The gabions resulted in downstream scouring. This limited water ponding above the gabion to help sustain a wetland. Installing additional gabions upstream helped mitigate this problem.
Glorieta Creek Wetland Restoration Project	Pecos National Historic Park, NM	**NPS**	Levee removal and native plant installation	7	98,9996	2 years	Workers removed a levee that was blocking water flow in between Glorieta Creek and the arid wetland. The site was regraded, and native plants were installed.	Inland flooding	A portion of the levee was left in place until the site was established and was then later removed.
Resaca Wetland Restoration Project	Palo Alto Battlefield National Historic Park, TX	**NPS,** University of Arizona	Levee and ditch removal, native plant installation	34	Not provided	2 years	To convert this agricultural field back to its natural state, workers removed levees and ditches and planted more than 50,000 plugs of gulf cordgrass.	No	Because the wetland was an important battle site in the Mexican-American War, managers had to take into account historic as well as ecological considerations.

Name and Link	Location	Leading Organizations	Techniques Used	Size, acres	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Arroyo Seco Restoration Project	Pasadena, CA	City of Pasadena, USACE	Invasive species removal, stream reconfiguration	34	2.56 million	2 years	Much of the Arroyo Seco and surrounding wetlands had been degraded by impacts of urban development. Workers reconfigured the stream to avoid developed areas and removed invasive species.	Inland flooding	Restoring water quality has been challenged because the areas directly upstream and downstream of the restoration site are heavily modified.
Cienega Creek Restoration Project	Las Cienegas National Conservation Area, AZ	**Bureau of Land Management (BLM),** Cienega Watershed Partnership	Invasive species removal, erosion remediation, native plant installation	339	Not provided	4 years	To mitigate erosion, volunteers removed invasive species, restored soils, and installed native plants.	Drought	The stakeholder engagement was critical, because the project spans private and BLM lands.
Blue Hole Cienega Restoration Project	Santa Rosa, NM	**USFWS,** New Mexico Department of Game and Fish	Rock dams, grazing management, and prescribed burns	116	Not provided	3 years	Rocks were installed and cattle grazing was limited to protect this arid wetland fed by alkaline spring water. Prescribed burns are occasionally used to remove invasive species and promote the growth of native species.	Drought	There has been significant debate about whether cattle grazing should be allowed at this site. While cattle remove invasive species, they also damage wetland soil.

Bolding indicates DOI affiliates.

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