

PAKOON WASH AND PAKOON SPRINGS
RESTORATION AND ENHANCEMENT PROJECT
FINAL REPORT

AWPF GRANT CONTRACT #11-180WPF

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Arizona Department of Water Resources
Phoenix, AZ

August 31, 2016

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EXECUTIVE SUMMARY

The Pakoon Wash and Pakoon Springs Restoration and Enhancement Project (AWPF Grant Contract #11-180WPF), a five year project conducted by Grand Canyon-Parashant National Monument, successfully moved the Pakoon Springs complex toward a more natural state. The complex now resembles other minimally modified large spring complexes in the Mojave Desert.

Twelve tasks were defined for this project in 2011. These included:

- Attainment of permits, authorizations, clearances and agreements*
- Assessment of Pakoon Springs riparian area*
- Develop and submit project work plans*
- Implementation of earthwork and structures*
- Implement invasive species removal plan**
- Implement invasive weed eradication and native plant revegetation**
- Implement identification and prioritization of local rare species translocation*
- Implement riparian habitat monitoring plan***
- Implement translocation of local rare species
- Implement visitor education and outreach
- Implement construction of visitor footpaths and boardwalks
- Final report*

Overall this project completed six out of twelve tasks (indicated by *), completed another two tasks that will continue (indicated by **) and partially completed a ninth (indicated by ***). The three tasks not started and the continuing tasks will be accomplished over the coming years as the site develops and as part of the Monument's commitment to the rehabilitation of Pakoon Springs.

Under this grant, the agricultural fields contiguous with the springs complex have been recontoured, over 2200 invasive bullfrogs have been removed, and baseline data for vascular plants, aquatic insects and small mammals has been collected. Detailed plans for rare species introductions (Grand Wash springsnail, speckled dace and relict leopard frog), visitor infrastructure and educational materials have been generated.

This project provided an opportunity to work closely with the Nongame Branch of Arizona Game and Fish Department and US Fish and Wildlife Service.

INTRODUCTION

Pakoon Springs, one of the largest spring complexes in northern Mohave County, has been the site of active restoration to a more natural state since 2004. The highly altered and modified condition of Pakoon Springs resulted in many uncertainties regarding the appropriate target conditions for rehabilitation. The current AWPf grant is a continuation of work initiated under AWPf Grant 06-137 (2006-2010). The current grant aimed to expand upon the restoration activities conducted since 2006 as well as include longer term monitoring of the site, species introductions, and visitor outreach and infrastructure.

SITE DESCRIPTION AND HISTORY

The Pakoon Springs system has undergone extensive modification since it was acquired by the Bureau of Land Management (BLM) in 2004. Removal of all aboveground ranching structures, recontouring of impoundments and agricultural fields, planting of native vegetation, all have contributed to the rehabilitation of a site that no longer resembled a natural large spring system in the Mojave Desert. (Figure 1).

A combination of geomorphic analyses and aerial photography suggest that Pakoon Springs primarily discharged water to the east and south prior to ranching efforts in the area. The various spring heads (at least 15) have a variable flow due to changes in groundwater level and shifts in the several adjacent fault planes. Aerial photography indicates at least until the 1950s, the northern springs discharged almost directly to the east. Springs associated with what became known as Pakoon Tank flowed in a more southeasterly route until the water was diverted for agricultural use sometime in the mid-20th century.

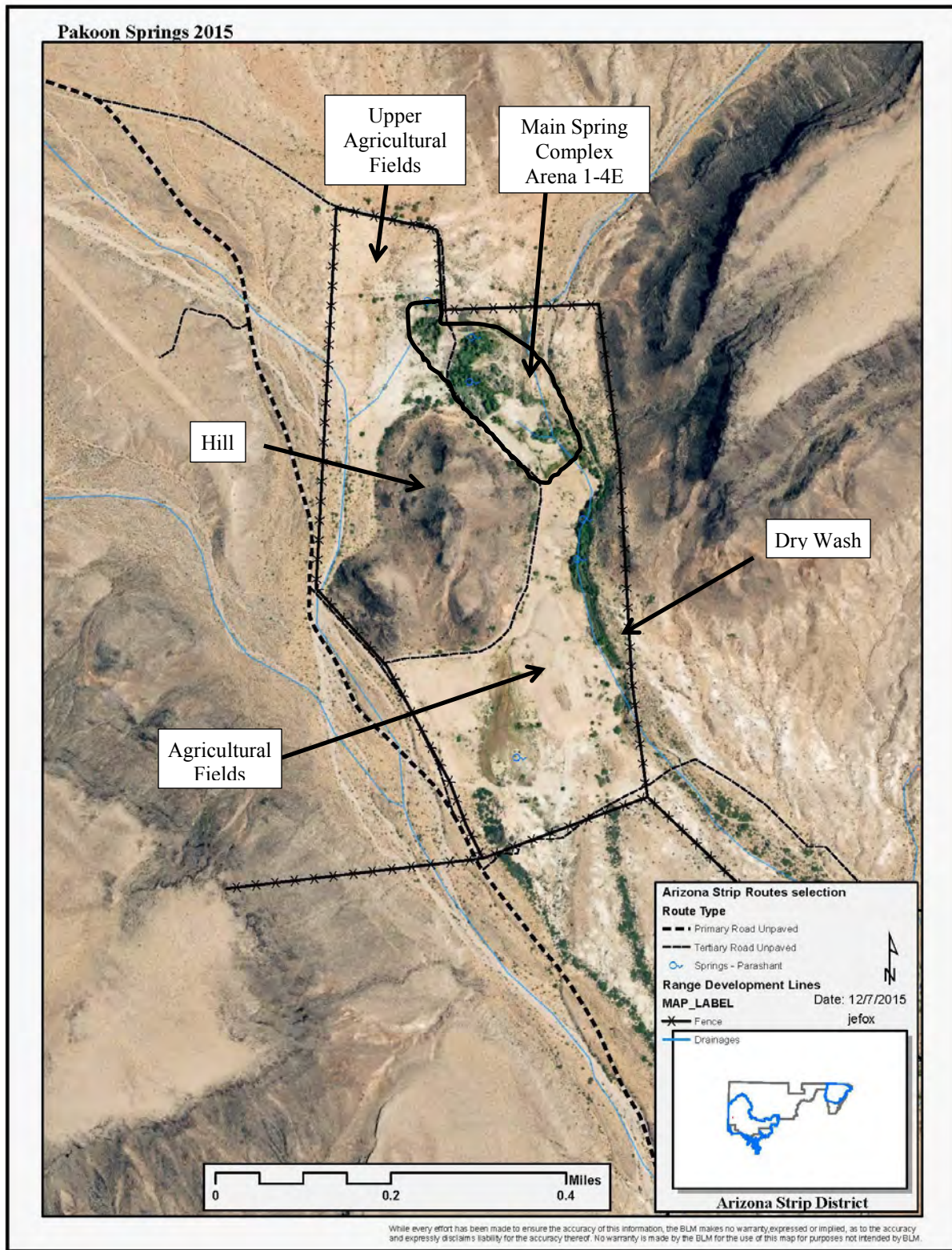


Figure 1. Overview map.

Based on a vegetation map developed under AWP Contract #06-137, six arenas were developed to guide revegetation and rehabilitation work (Figure 4). Arena 1 is a rectangular springs catchment basin on the northwest side of the site, which has been filled in and the springs flow allowed to pursue a gravity-driven course. At this time, Arena 1 has no visible surface water. Arena 2 is a circular springs catchment basin on the northeast side of the site that has been filled in and the springs flow allowed to pursue a course to the east. Arena 3 is a central channelized springs capture system. Flow on the northern end now moves to the south, and flow from the center and southern portions of the arena now moves to the east and southeast. Arena 4, also known as Pakoon Tank, has been largely filled in. Initially Arena 4 was a large, excavated pool that captured flow from a springs complex on the northwest side of the arena and internally within the pool, and from which a large proportion of the flow was directed through piping to the south into agricultural fields. This was modified in 2015 (Figure 2) to a more linear step springbrook in which several springs within the old bottom of the pond are forming travertine “steps” around them. The springbrook flows to the southeast through a portion of the old agricultural fields before flowing into the dry wash designated as “Pakoon Creek” in previous reports. Arena 4E (another springs catchment basin to the east of Arena 4 that has been filled) now has several springheads seeping water from the eastern side of the mounds, forming a second springbrook into the wash. Arena 5 was a paleospring site on the northeast corner of the large hill near the springs inside the boundary fence.

Arenas 1-4 were planted with native plant species under AWP 06-137 WPF and weeded of establishing tamarisk. The wash was revegetated following gabion construction using a variety of techniques. A series of high water events, most notably in 2013, have realigned major portions of the wash and northern agricultural fields. This has resulted in the need to relocate the permanent flume for water quality measurements, a consideration of active revegetation efforts vs natural events and the removal of several of the heavily damaged gabions.

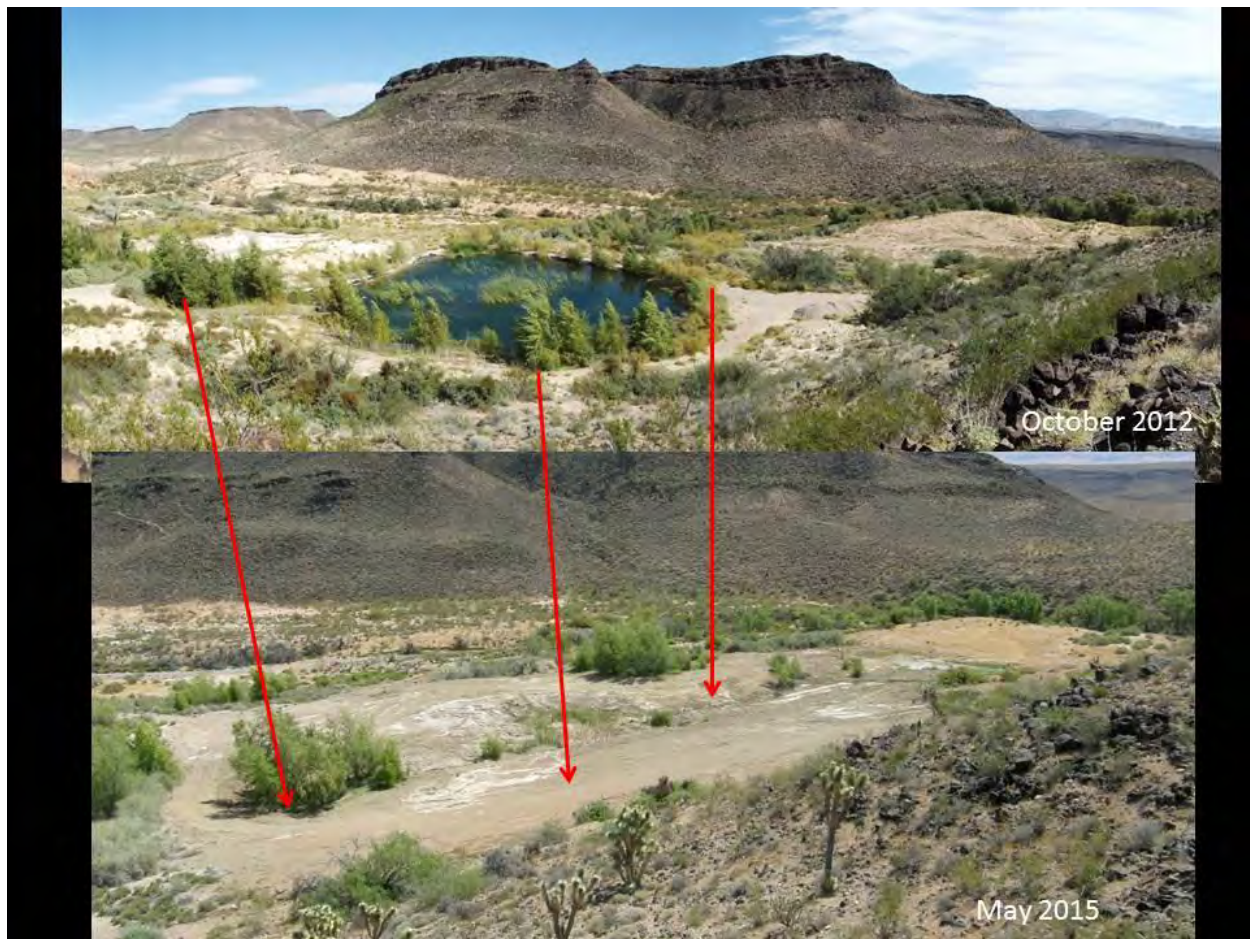


Figure 2. Changes to Arena 4. Red arrows indicate the same points in 2012 and 2015 for comparison purposes.

STATEMENT OF THE PROBLEM

Pakoon Springs, a large springs complex in the Mojave Desert, has been partially restored since 2004 to a less altered desert spring complex. However, further restoration was necessary to promote a stable Mojave Desert spring ecosystem that would be self-sustaining as well as provide a site for visitor use.

PROJECT GOALS AND OBJECTIVES

This project further restored, enhanced, and maintained a spring, riparian, wetland, and upland habitat complex at Pakoon Springs. Twelve tasks or objectives were created to provide a detailed framework to guide the project goals. Tasks 1-3 and 7 were essentially planning tasks. Tasks 4-6 and 8-11 were project implementation tasks.

Task 1: Permits, Authorizations, Clearances and Agreements

Task Description: Conduct and document an interdisciplinary Pakoon Springs Rehabilitation Environmental Analysis (EA), Finding of No Significant Impact

(FONSI), and Decision Record (DR). Develop and receive approval for the Pesticide Use Proposal (PUP). The Grantee shall obtain all permits, authorizations, environmental clearances and agreements necessary to complete the tasks listed in this Scope of Work. These include but are not limited to:

- Assistance Agreement between Grand Canyon Wildlands Council (GCWC) and BLM: Agreement dissolved March 2014; new agreement with Dixie State University (DSU) September 11, 2015;
- Pesticide Use Proposal: Not Applicable;
- National Environmental Policy Act (NEPA) compliance: EA DOI-BLM-AZ-A030-2010-0004-EA
- Quitclaim Water Right Deed: Obtained June 25, 2002;
- Donation Land Deed: Obtained June 25, 2002;
- Clean Water Act (CWA) 404 permit: Army Corps of Engineers (ACOE) Letter of Concurrence, February 27, 2008;
- State Historic Preservation Office (SHPO) clearance: SHPO Letter, January 19, 2007;
- Access Agreement: Not Applicable;
- Notice of Intention to Drill: Not Applicable;
- Data Collection Permits: Issued to DSU November 23, 2015.

Task 2: Assessment of Pakoon Springs Riparian Area

Task Description: Review and compile the contents of the EA and previous studies of the biological, hydrological, and geomorphological characteristics of the area to guide in the creation of plans.

Task 3: Develop and Submit Project Work Plans

Task Description: Using the contents of the Pakoon Springs Assessment Report, develop plans for all subsequent tasks:

Riparian Habitat Improvement Plan (Task 4, 6)

Design channel and stream-bed stabilization. Design the re-contouring of the old agriculture fields to create flood plains, including soil cut and fill, removal and/or transfer. Design re-vegetation, detailing what species shall be planted in what zones.

Invasive Aquatic Species Removal Plan (Task 5)

Create removal plan for bullfrogs (mature, immature, and tadpole), as well as mosquito-fish.

Identification and Translocation of Local Rare Species Plan (Task 7, 9)

Create plan for the identification of locally rare species, and for the translocation process and goals.

Riparian Habitat Monitoring Plan (Task 8)

Create plan for monitoring vegetation, birds, and insects bi-annually. Design plan for a one-time small mammal inventory, to establish a baseline of present species.

Visitor Education and Outreach Plan(Task 10, 11)

Create plan for visitor outreach and educational materials. Design plan for visitor access to Pakoon Springs to minimize visitor impact on springs and riparian habitats while enhancing educational opportunities.

Task 4: Implementation of Earthwork and Structures

Task Description: Using the Riparian Habitat Improvement Plan, complete all soil re-contouring activities on Pakoon Creek and adjacent areas. Re-contour the floodplain topography to match, as closely as possible, the undisturbed upstream geomorphologic condition. Stabilize spring flows from upper terraces and re-contour channels into Pakoon Wash above the travertine ledge. Reconstruct the flood plain the entire length of perennial flow in Pakoon Wash. Fill in the pools in the wash that formed due to head cutting. Place large rocks and boulders in erosion-reducing gabion structures, as well as locally sourced logs, and use the materials to create braided flow in Pakoon Wash. Fill in with smaller skeletal material and gravels.

Task 5: Implement Invasive Species Removal Plan

Task Description: Using the Invasive Aquatic Species Removal Plan, remove mature bullfrogs through hunting trips with Arizona Game and Fish Department (AGFD). Use alternatives identified in the plan in consultation with partners to remove mosquito fish.

Task 6: Implement Invasive Weed Eradication and Native Plant Revegetation

Task Description: Using the Riparian Habitat Improvement Plan, remove exotic plant species: tamarisk, Russian thistle, and yellow-star thistle through combination of hand-tools and approved herbicides. Transplant riparian vegetation to Pakoon Creek. Pole plant Goodding's willow, seepwillow, and Fremont cottonwood along flood plain in zones that are from 2 to 3 feet above the water table.

Task 7: Implement Identification and Prioritization of Local Rare Species Translocation

Task Description: Using the Identification and Translocation of Local Rare Species Plan perform habitat assessments, species priority ranking, and identification of local rare species populations for potential translocation into Pakoon Springs. Potential

species include the Arizona toad, Pacific treefrog, relict leopard frog, and muskrat. Stakeholders from various agencies will be engaged in this process. Site visits to habitat for at least the two highest priority species, will be conducted as part of the process to fill in gaps in the published record regarding habitat requirements.

Task 8: Implement Riparian Habitat Monitoring Plan

Task Description: Using Implement Riparian Habitat Monitoring Plan, riparian habitat of Pakoon Springs and Pakoon Wash will be monitored for vegetation, birds, and insects. A one-time small mammal inventory will be conducted to establish a baseline of what species are present.

Task 9: Implement Translocation of Local Rare Species

Task Description: Using the Identification and Translocation of Local Rare Species Plan and the identification and prioritization of local rare species report (Task 7), translocate two highest priority species as determined by the assessment. Translocation will involve: capture, treatment (if necessary), release, and short term monitoring of up to two locally rare species.

Task 10: Implement Visitor Education and Outreach

Task Description: Using the Visitor Education and Outreach Plan, create visitor educational materials, design and install informational kiosk, and implement educational outreach.

Task 11: Implement Construction of Visitor Footpaths and Boardwalks

Task Description: Using the Visitor Education and Outreach Plan, construct visitor footpath through desert landscape and around riparian areas to guide visitor traffic in order to protect riparian vegetation, native Mojave Desert vegetation and biological soil crusts. Construct boardwalks as needed over flowing water and wetted soils. Construct new pass-through gate near parking area.

Task 12: Final Report

Task Description: We will prepare and submit a comprehensive final report consistent with the Final Report Guidelines in AWPf Policies and Application Guidelines Manual, including a summary of all methodologies used, outcome of all tasks, analysis of all project data, suggestions for any further changes needed in the project, and an evaluation of the project's success measured against the objectives.

IMPLEMENTATION

This section will focus on Tasks 4-8. Methods for Task 1 were a compilation of previously acquired documentation and following established permitting processes. Task 2 was a survey of the current state of knowledge of the historic, biological and physical aspects of Pakoon Springs. Based on a variety of sources, including the work done under the previous AWPf grant, this review drew conclusions about what the springs complex would have looked like prior to modern modification. The report also highlighted changes to the system since 2010 that should be addressed during the new grant. Under Task 3, detailed work plans were created by Monument staff and cooperators. These plans specifically described Tasks 4-11. To avoid repetition, those methods will be described with their respective task. Task 12 was accomplished by following the “Arizona Water Protection Fund Guidelines for Final Report Development”.

TASK 4: IMPLEMENTATION OF EARTHWORK AND STRUCTURES

Gabion Design and Construction (See Appendix A for plans and images)

The longitudinal profile of Pakoon Wash revealed the degree and locations of active headcutting and was used to select optimum locations for gabion installation. The bank to bank stream channel width above the furthest most upstream headcut was approximately 25 feet and the channel slope was approximately 2%. The most incised section of stream channel was typically 8 to 15 feet wide and steeper (approximately 4-5%). Finally, the furthest downstream, aggrading and actively widening section was approximately 25 feet wide with a slope of approximately 2-3%.

During stream channel surveys it became evident that the wash channel was undergoing rapid changes in the form of headcutting. Since 2006, at least two of the primary headcuts have migrated upstream approximately 1 meter. Five locations within the wash were selected to halt this headcutting (Table 1).

Table 1. Primary locations selected for stabilization structure installation (UTM Zone 12S).

Site ID Initial/Final	Easting	Northing
1/1	235064	4033605
2/2	235091	4033566
2A/3	235096	4033563
2B/4	Approximately 100 feet downstream from 2A	
3/5	235103	4033459

Several stabilization structure types were considered, including:

- Rock and Fence Weir
- Rock, Fence and Willow Wattle Weir
- Willow Wattle Weir
- Layered Brush Pile Check Dam – Zuni Type Structure
- Gabion Basket Weir

Consideration was given to the desire for lower impact structures and the necessity for the structures to stabilize the stream channel incision while withstanding high magnitude flood events. For example, the layered brush pile check dam is the most natural-appearing structure but may not withstand the same quantity and magnitude of flood events. Conversely, the gabion basket weir, which has the most rigid and engineered appearance, is most likely to withstand higher magnitude flood events when installed correctly. The final design decision made by project stakeholders was to install the most durable structure possible while adding a softer or live component to the more rigid core structure. Therefore, the gabion basket weir was selected as the primary structure. Gabion basket weir design drawings were based on standard gabion installation protocol (see Appendix A) (Freeman and Fischenich, 2000; USDA-NRCS, 2011) and prepared by R. Andress, restoration design consultant for the Pakoon rehabilitation project. No major design or installation changes were necessary during implementation and the gabions were installed as shown in Appendix A.

The following steps outline the general installation sequence of each gabion weir stabilization structure:

- Pre-construction meeting with crew and all stakeholders held in order to ensure a clear understanding by all stakeholders of the implementation and construction requirements
- Final site specific selection of stabilization structure placement, elevations, size, and materials by construction crew and stakeholders
- Site preparation including clearing and grubbing (if necessary), excavation (if necessary), and bank sloping
- Installation of each gabion basket weir and associated filling with rock following guidelines in ACOE technical notes and specifications as shown in design drawings
- Placement of 12-36 inch rock at margin and base of structure to protect against lateral erosion and undercutting

Due to the remote nature of Pakoon Springs, rock materials and willow cuttings used in the stabilization structures were collected locally. The width of each gabion basket weir was 20-30 feet and each weir was keyed in to the stream bank for resistance to high magnitude flood events and to reduce the likelihood of lateral incision or flanking.

The following specifications were followed in order to ensure that the gabion structures were installed to ensure the greatest level of quality and potential for stream channel stabilization.

- The placement and construction of each gabion weir was completed in a manner to achieve the primary goal; halt upstream migration of nick points.
- Each gabion weir was installed in a manner to prevent the constriction of flow, while focusing on two primary goals:
 - Halting upstream migration of nick points
 - Promoting high flow events to spread on to floodplain
- The base mattress of each gabion weir was placed on level gravel bedding in order to ensure a level structure.
- The base mattress of each gabion weir was partially embedded in the stream channel to control scour at base of each structure.
- Manufacturer guidelines for gabion installation including internal bracing, installation of rock in lifts in combination with internal bracing to prevent the baskets from bulging/sagging and sufficient securing of individual baskets to adjacent baskets were followed to ensure the construction of a single, massive structure.
- Individual gabion baskets were filled with a range of rock sizes from 6-10 inches with a minor amount of smaller material for filling interstitial space.
- Material larger than 10 inches was avoided when filling the gabion baskets in order to allow for even filling and prevent settling of the individual baskets.
- Large boulders, cobbles, and/or willow wattles around edges and downstream plunge areas were placed and secured to protect bases and edges of gabion structures from lateral erosion and undercutting.
- 12-36 inch diameter rocks were placed along the margin of each gabion weir to reduce risk of flanking.
- 12-36 inch diameter boulders were placed over each base mattress at spillway and downstream to control scour downstream from the structure.

The following materials were used during project implementation.

- Maccaferri, Inc. galvanized and PVC coated, 8 X 10 mesh, mattresses and gabion baskets
- Permeable geotextile fabric for installation between stream banks and baskets (15' x 300')
- Stainless steel rings for closing and securing baskets
- Wire for tying internal bracing on individual baskets

The following gabion basket and rock quantities were used during project implementation (Table 2).

Table 2. Gabion basket quantities, dimensions and rock volume by site.

Site ID Initial/Final	Quantity	Dimensions	Rock Volume (cubic yds)
Site 1/1	5	12'x6'x12"	13
	10	6'x3'x1.5'	10
	7	6'x3'x3'	14
Site 2/2	5	12'x6'x12"	13
	5	6'x3'x1.5'	5
	7	6'x3'x3'	14
Site 2A/3	5	12'x6'x12"	13
	5	6'x3'x1.5'	5
	7	6'x3'x3'	14
Site 2B/4	5	12'x6'x12"	13
	5	6'x3'x1.5'	5
	7	6'x3'x3'	14
Site 3/5	5	12'x6'x12"	13
	5	6'x3'x1.5'	5
	7	6'x3'x3'	14
		TOTAL	167

Wash Floodplain Widening and Agricultural Field Recontouring Design and Implementation

Earthen material excavated from the floodplain area was hauled on to the former fields by dump truck and placed in a manner to recreate a more natural and undulating topography similar to nearby alluvial and erosional terraces and hill slopes. The earthen material was shaped into the design topography using a bulldozer and tracked excavator. Following final topography shaping efforts, all surfaces were ripped to a depth of 1 foot to lessen compaction and encourage the entrainment of native seeds and collection of precipitation in shallow grooves and depressions.

TASK 5. IMPLEMENT INVASIVE SPECIES REMOVAL PLAN

Bullfrog Removal

Cattail (*Typha domingensis*), while not an invasive species, created a complication for removal of bullfrogs. A protocol was developed to control the distribution of cattails. Cattail removal efforts were completed during most seasons with a focus during the fall and winter months when cattails were dormant. Cattails were cut using both manual and mechanical removal methods. In addition, water level manipulation was used to hinder regrowth. Reducing oxygen to rhizomes is an effective way to control cattails. Water level in Arena 4, the only remaining open pond, was

lowered and cattails were cut to the base. Following cutting, the water level was raised a minimum of 12 inches above the cut stalks.

Bullfrog eradication efforts included a variety of methods and approaches including targeting all life stages. Population surveys and targeted removal surveys were conducted during daylight and nighttime hours and relied on a combination of aural reconnaissance for bullfrog calls and visual sightings. Bullfrogs were removed through hunting trips led by the AGFD throughout the year. Bullfrog eradication efforts included the following techniques:

- Hand-capture
 - This method was used to target metamorphosed frogs at night.
- Giggling/Hawaiian sling
 - This method was used to target metamorphosed frogs at night.
- Shooting
 - This method was used to remove large breeding individuals.
 - Only non-lead ammunition was used.
 - Non-AGFD shooters demonstrated experience, were approved by AGFD, and were covered under a scientific collecting permit.
- Trapping to Target Tadpoles
 - Minnow traps baited with dog food in conjunction with hand capturing and giggling were used to capture and remove tadpoles.
- Fencing
 - Areas known to contain bullfrogs (Arenas 4 and 4E) were fenced in order to facilitate eradication by preventing dispersing individuals from moving into or out of the Arena 4 and 4E.
- Egg Mass Surveys and Monitoring
 - Locations of calling males were marked to increase the chances of finding and removing egg masses during breeding season (April - September).
- Installation of Black Plastic Covering in Arenas 4 and 4E
 - Black plastic was used to cover the banks and bottom of the pond and outlet in order to minimize cattail growth, reduce vegetation cover, and facilitate bullfrog eradication. (Removed in 2013-2015).

Mosquitofish Removal

Mosquitofish remain at Pakoon Springs. Due to a temporary moratorium on the use of rotenone in the State of Arizona, eradication efforts have been limited. With the new guidance on rotenone use, fish may be eradicated using the piscicide if it is determined to be necessary by AGFD. Until that time, mosquitofish reduction is occurring by natural predation since their habitat is now a shallow spring system more easily accessible to wildlife, including piscivorous wading birds.

TASK 6. IMPLEMENT INVASIVE WEED ERADICATION AND NATIVE PLANT REVEGETATION

The revegetation plan focused on two target areas that dictated two complimentary sets of methods, invasive removal and active and passive revegetation.

Invasive Removal¹

Non-chemical methods of invasive plant removal such as hand-pulling were the primary methods during this project. Herbicides were applied using spot treatment, backpack sprayer application to control non-native invasive Malta star thistle, Russian thistle, and other exotic weeds. Herbicides included glyphosate and imazapyr (both terrestrial and aquatic formulations); and metsulfuron and clopyralid (terrestrial formulations only). Native vegetation was avoided during herbicide application.

Herbicides were applied as follows:

1. By ground based equipment such as backpack or tank sprayers
2. At the minimum recommended label rates to be effective (which depends on the target species)
3. According to label directions
4. Under supervision of a BLM certified applicator, according to BLM policies (H-9011-1)

Only aquatic approved herbicides (formulations of glyphosate and imazapyr) were applied within 10 feet of surface water (open water, saturated soils and/or damp to wet soils, during hand application). A 25 foot “no application” buffer was delineated around open water, saturated soils and/or damp to wet soils if applying non-aquatic approved herbicides from a vehicle.

Workers applying the herbicides took all necessary safety precautions, including following label directions, the use of proper handling procedures, and use of personal protective equipment, protective clothing (coveralls, gloves), and eye protection (splash goggles or face shields). During and following the application of herbicides, the project site was closed to the public for 24 hours. All gates were locked, and warning signs were placed on the gates. The labels and risk assessments for all the chemicals proposed include precautionary measures, which were implemented to reduce both human and ecological risks.

The herbicide treatments were monitored during and after treatment application, and periodically thereafter.

Revegetation

A generalized vegetation model based on previous vegetation mapping and monitoring as well as previous experience enhancing or rehabilitating wet cienega wetlands, limnocrane, and

¹ Herbicides were used 3/2010-4/30/2011, prior to the initiation of this grant. As such these methods and the accompanying results are for informational purposes only.

peripheral riparian habitats at Pakoon Springs were used to develop this revegetation design. In addition, results and knowledge gained from previous revegetation efforts at Pakoon Springs (2006-2010) guided the development of this revegetation plan. Therefore revegetation efforts to date have been completed in a manner similar to previous efforts undertaken at the site.

Revegetation of the floodplain and stream channel was undertaken by collecting and installing pole cuttings of woody phreatophyte species, translocating local native plant stock, and installing native plant cores.

Priority areas for pole cuttings included stream channel margins adjacent to the gabion basket weirs and moist soil areas throughout the floodplain. Pole plantings were installed in areas where the water table was within 2 feet below ground surface. Cut poles were debranched and all exposed cuts were sealed with latex paint to prevent moisture loss. Poles were soaked and stored in water. Poles were installed by digging a hole with a planting bar to the depth necessary to reach saturated soil. Poles were installed with approximately 1 foot of the pole exposed above ground surface. Smaller cuttings obtained from trimming branches off of the poles were also planted where soils were saturated at the ground surface, such as along the stream channel margins. These cuttings were planted by burying the cuttings in moist soil with a shallow covering (2-6 inches) of soil.

Priority areas for native plant plugs included stream channel margins adjacent to the gabion basket weirs and moist soil areas throughout the dry wash floodplain. Native plant plugs were installed where sufficient soil moisture was present to support the plugs without supplemental irrigation. The plugs were collected by excavating 6-12 inch diameter clumps of the selected species with a shovel. The plugs were transplanted to the desired location into holes similar in depth to plug size.

TASK 7. IMPLEMENT IDENTIFICATION AND PRIORITIZATION OF LOCAL RARE SPECIES TRANSLOCATION

In 2015, eight representatives of 4 agencies (AGFD, US Fish and Wildlife Service (USFWS), National Park Service (NPS), and BLM) met to select a group of species suitable for introduction to Pakoon Springs. Species were considered based on an initial list of candidates identified in the 2012 implementation plan (Grand Wash springsnail, Tassi speckled dace, Arizona toad, Baja California treefrog, lowland leopard frog, Agassiz's desert tortoise and muskrat) as well as Arizona-identified special status species. Prioritization was developed based on the following hierarchy:

1. Appropriateness of introduction to Pakoon Springs
2. Special species status
3. Likelihood of successful introduction
4. Preliminary steps necessary for introduction still to be considered or done

Appropriateness was determined in relation to preexisting native species habitat and lifecycle requirements and whether the proposed species would be within their native range (historic or present). If a species was determined to be inappropriate, it was no longer considered for introduction, regardless of special status considerations. The species selected are: Grand Wash springsnail (Hydrobiidae: *Pyrgulopsis bacchus*), speckled dace (Cyprinidae: *Rhinichthys osculus*) and relict leopard frog (Ranidae: *Lithobates (Rana) onca*).

To focus the habitat assessment, two main factors were considered, physical parameters and biotic interactions. Water quality and quantity (including flow rates, temperature and chemical parameters) play an important role in determining the likelihood of successful reintroduction of 2 of the species, speckled dace and Grand Wash springsnail. While speckled dace are widespread, a variety of parameters (including physical) have led to several speciation events; it is important to verify similarity of the source population's home habitat to Pakoon Springs to determine the likelihood of dace quickly adapting to their new habitat. Springsnails are known to inhabit extremely limited ranges, even within a single spring, based on water quality and other environmental parameters. It is necessary to determine the exact location for the combination of these parameters at Pakoon Springs to ensure maximum success for introduction. Water quality was compared between Pakoon Springs and all locations on the Monument where *P. bacchus* was known or suspected to occur since the springsnail is likely to be the most restrictive of the species to be introduced in its needs for specific water quality parameters. In addition, substrate for spawning and feeding habitat was considered. Biotic interactions considered include the presence of two invasive animal species at Pakoon Springs, American bullfrog and mosquitofish, the newly identified snail, *Physa acuta*, and the general riparian and aquatic vegetation.

An overview workplan was developed for each species.

Grand Wash Springsnail (*P. bacchus*)

1. Verify water quality is within parameters known to support *P. bacchus*.
2. Determine level of substrate manipulation necessary to bring about appropriate surface habitat.
3. Determine areas of spring system where introduction is most likely to succeed.
4. Determine if other springsnail exists in system.
5. Determine if *Physa acuta* will decrease effectiveness of *P. bacchus* introduction.
6. Determine if *Gambusia* is at acceptable levels for #3.
7. Introduce *P. bacchus* to main flowing springs.
8. Monitor for *P. bacchus* distribution and density in spring system.
9. If necessary, introduce second or third population until *P. bacchus* is determined to be successfully recruiting in the system.

Speckled Dace (*R. osculus*)

1. Verify water quality is within parameters known to support *R. osculus*.
2. Determine level of substrate manipulation necessary to bring about appropriate surface habitat.
3. Determine areas of spring system where introduction is most likely to succeed.
4. Determine if *Gambusia* is at acceptable levels for #3.
5. Introduce *R. osculus* to wash below main springs.
6. Monitor for *R. osculus* distribution and density in wash.
7. If necessary, introduce second or third population until *R. osculus* is determined to be successfully recruiting in the system.

Relict Leopard Frog (*R. onca*)

1. Verify water quality is within parameters known to support *R. onca*.
2. Determine level of substrate manipulation necessary to bring about appropriate surface habitat.
3. Determine areas of spring system where introduction is most likely to succeed.
4. Determine if American bullfrog is extirpated.
5. Determine if *Gambusia* is at acceptable levels for #3.
6. Introduce late-stage tadpoles or juvenile frogs from about April into early June in varying numbers to main springs each year for 5 years.
7. Monitor for *R. onca* distribution and density in springs and wash.

TASK 8. IMPLEMENT RIPARIAN HABITAT MONITORING PLAN

Site Visits

Pakoon Springs was visited 31 distinct times for the purposes of monitoring and site protection. Table 3 provides the dates and main purposes of each visit. In addition, Monument personnel periodically monitored or visited the site in the course of other duties such as monitoring station placement/maintenance or law enforcement patrols. These additional visits, when reported to the project lead, often provided anecdotal riparian monitoring information or species observations.

The following entities participated in the site visits: Parashant National Monument staff (GCPNM), Arizona Game and Fish Department (AGFD), Dixie State University (DSU), Grand Canyon Wildlands Council (GCWC) and Mojave Desert Inventory and Monitoring Network (MOJN).

Table 3. Site visits to Pakoon Springs 2012-2016.

Date	Purpose
November 20, 2012	GCWC vegetation monitoring, species inventory and gabion assessment
February 13, 2013	GCPNM site assessment and photopoints
February 20, 2013	GCPNM gabion status
April 8, 2013	MOJN water quality and gabion status
May 1, 2013	GCPNM, AGFD, GCWC site visit and overview
July 18, 2013	AGFD bullfrog removal and fencing status
September 19, 2013	GCPNM site assessment post high water event
September 22, 2013	AGFD bullfrog removal and site status monitoring
September 28, 2013	National Public Lands Day – post high water site cleanup
December 17, 2013	GCWC vegetation, faunal and water quality monitoring
January 16, 2014	GCPNM and MOJN site assessment of hydrologic monitoring station damage post high water event
February 6, 2014	GCPNM and AGFD post water event fence and gabion damage assessment
July 14, 2014	GCPNM review of pond status re: plastic lining
March 11-16, 2015	GCPNM oversight of pond removal, recontouring, gabion removal
March 25-April 1, 2015	Outer fence repair by ACE under guidance of GCPNM
April 1, 2015	MOJN aquatic invertebrate sampling and water quality. GCPNM site repeat photography Arena 4
May 3, 2015	AGFD bullfrog removal and site monitoring
June 9, 2015	GCPNM-funded bat survey
July 21, 2015	AFGD springsnail survey and water quality. GCPNM site repeat photography Arena 4
September 19, 2015	DSU vegetation survey
October 4, 2015	DSU vegetation survey
December 9, 2015	GCPNM site repeat photography Arena 4
January 14, 2016	UNLV (on behalf of AGFD) bullfrog/amphibian survey

Date	Purpose
March 11, 2016	GCPNM site repeat photography Arena 4 & AWPf photopoints
March 12, 2016	DSU ornithology survey
March 24, 2016	MOJN aquatic invertebrate sampling and water quality
April 23, 2016	DSU vegetation survey
May 9-10, 2016	DSU small mammal survey
May 16-20, 2016	AGFD bullfrog removal
June 1, 2016	GCPNM site repeat photography Arena 4 & MOJN/GCPNM collection of snails for DNA identification
July 21, 2016	GCPNM SETP site assessment and monitoring of Arena 4

Site Repeat Photography

In accord with the protocols described in AWPf Photodocumentation Protocols, GCPNM and GCWC re-photographed the site over the course of the project from approximately the previously established permanent photo points used to develop long-term data on site responses to treatment (Figure 3). These long-term photo points are situated on the adjacent hillside, affording top down and oblique views of the site over time. An additional photopoint (Point 5) was established in 2015 to record ground-level visible changes to Arena 4 since the pond was removed.

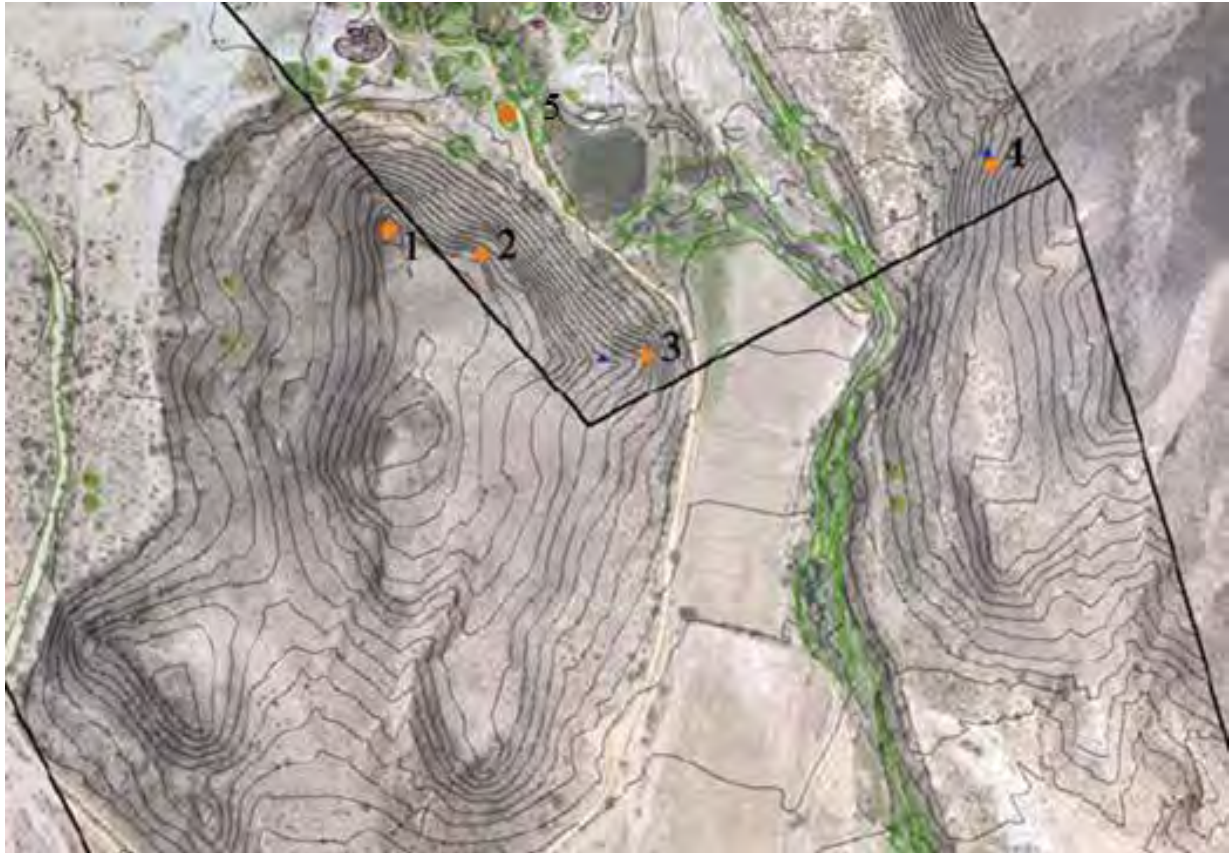


Figure 3. Approximate photopoint locations.

Vegetation Survey

2012-2014

Vegetation surveys in 2012-2014 focused on the riparian areas (Arenas 1-5, Figure 4), the lower agricultural fields and the dry wash designated as Pakoon Creek. All plant species were identified in all vegetation patches within the site, and vegetation was categorized in polygons roughly corresponding to the pre-established arena boundaries, the recontoured agricultural area to the south and the dry wash to the east. Vegetation cover in each polygon was visually estimated in four strata: ground cover – herbaceous or graminoid, 0-ca. 3 m; shrub cover – woody perennial 0-4 m tall; mid-canopy cover – woody, 4-10 m tall; and tall canopy cover – woody, >10 m tall.

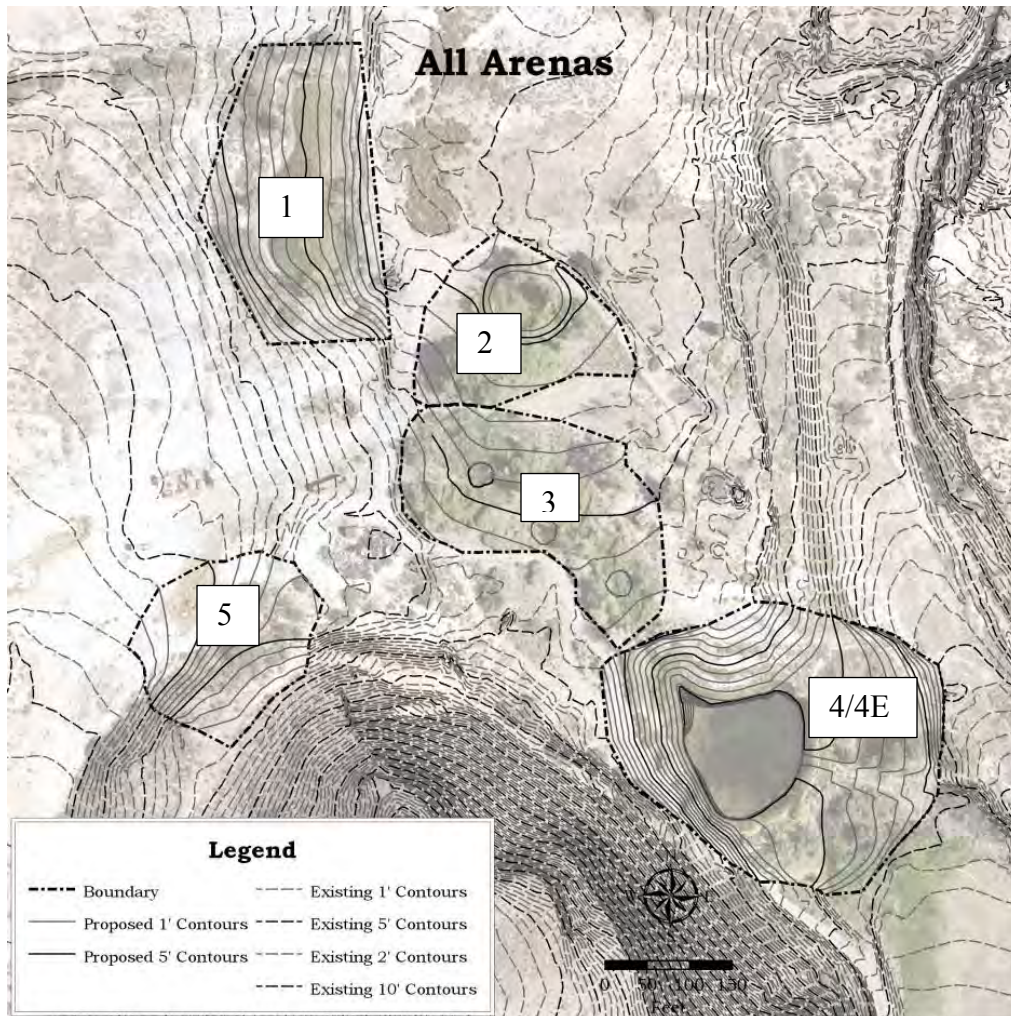


Figure 4. Approximate polygons for vegetation surveys conducted near Arenas 1-5, indicated by the “boundary” lines.

2015-2016

To provide a more stable baseline to compare changes in riparian and upland vegetation, formal transects were run in three zones in 2015 and 2016: disturbed which corresponded to Arena 5 and the west side of the hill, riparian which included Arenas 1-4, and undisturbed which include the wash and hillside outside the main area of ranching activities (Figure 5). The riparian zone also includes the areas previously surveyed for Task 8. Comparisons of these three are hoped to illuminate the changes in the systems as a result of active human manipulation as compared to natural changes caused by events such as flooding.



Figure 5. The three regions of the site included in the initial vegetation structure study.

Ten transects were run in each zone. Transects in the riparian area were run approximately parallel to the flow of the creek fed by the natural spring spaced so that the end of one was approximately 1 m away from neighboring transects (Figure 6A). Transects in the disturbed and undisturbed areas were run east to west and were 50 m long and 20 m apart (Figure 6B and 6C). Vegetation cover was characterized as in 2012-2014 with an additional category, aquatic (standing water), to better represent the changing surface circumstances at the springs, the emergence of true aquatic obligate vegetation. At each meter along a transect the presence/absence of standing water was recorded along with information about the plants rooted at the spot and any plants whose canopies covered the spot at any height. This was done because the riparian habitat had large gaps between very short ground cover and tree canopies. An additional 3 transects were run on the large hill at Pakoon Springs (Figure 6D). While the vegetation on the hill may not entirely reflect the potential vegetation of Arenas 1-5 or the agricultural fields because some of the vegetation is better adapted to rocky hillslopes than to silty floodplains, the hill does act as a seed source for the modified project area.

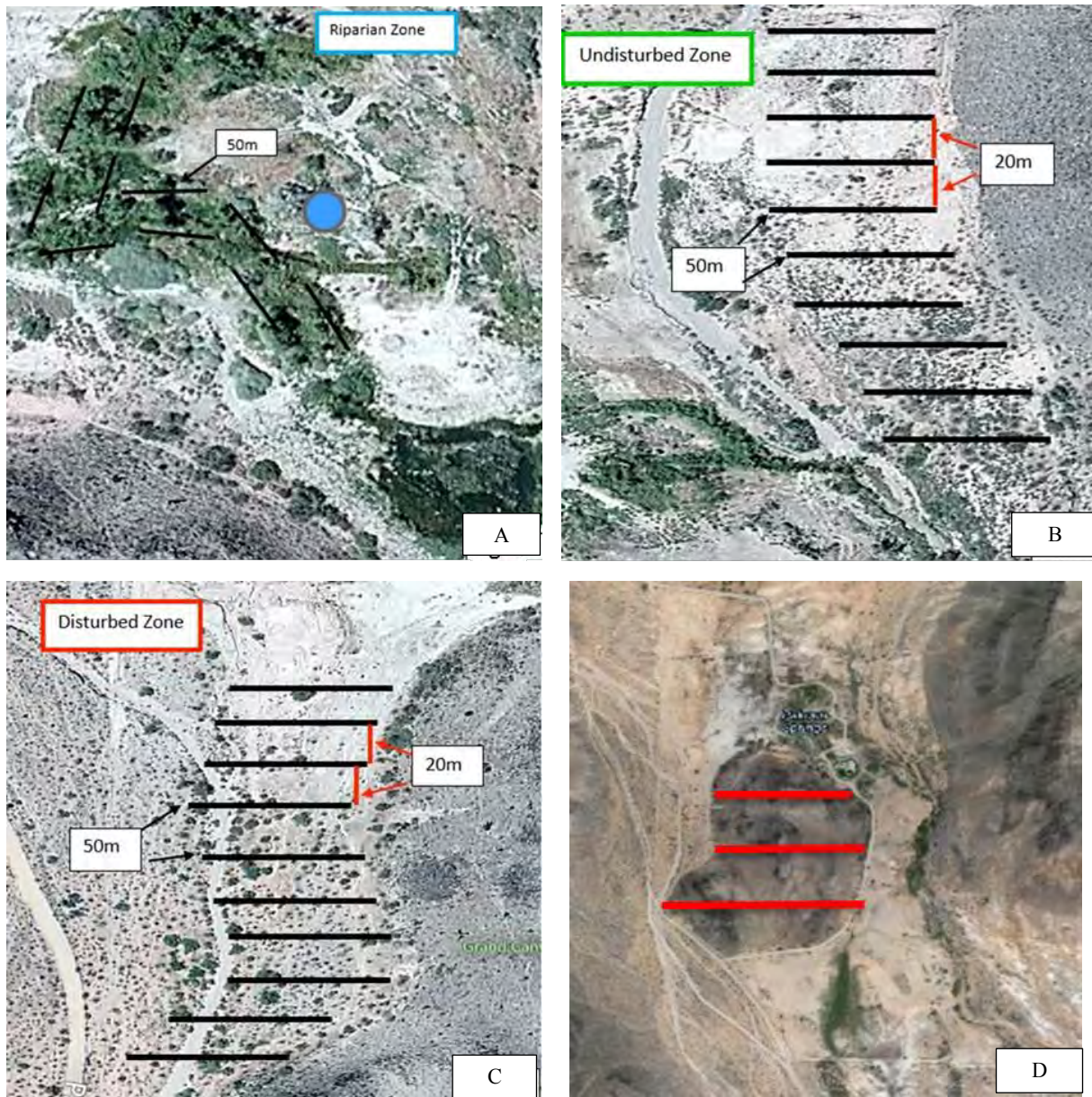


Figure 6. General locations of transects in the three areas studied to assess the vegetation structure. Each site had ten transects that were 50 m long with the plant structure measured at 1 m intervals. In the undisturbed and disturbed zones, transects ran east to west and were space 20 m apart. Lines are not to scale. A. The transect map of the riparian zone. Transects were run parallel to spring-fed creek responsible for the habitat along both sides of the creek. B. The transect map of the undisturbed zone. The plant community in this part of the property is consistent with Mojave Desert. C. The transect map of the disturbed zone. D. The transect map of the hill at Pakoon Springs.

In addition to vegetation structure transects, an intensive plant survey of Arenas 1-5 and the wash was conducted. Identification of the plants was primarily conducted in the field; however

specimens of perennial and annuals that could not be identified were collected for identification at DSU. Dr. Larry Higgins, a botanist who has collected extensively in northern Arizona, provided identifications for those that students and other specialists cannot identify.

Vertebrate Surveys

Prior to 2015, bird, amphibian, reptile, aquatic and terrestrial invertebrate, and small mammal surveys were performed during completion of vegetation monitoring activities and were strictly observational with the exception of invasive bullfrog surveys conducted by AGFD. For the observational surveys, all species visually observed or audibly detected were identified and noted. AGFD focused on bullfrog presence/absence and removal and incidentally noted other species of interest. Survey methods for bullfrogs are incorporated in Task 5 methods.

Amphibian surveys were conducted January 14, 2016. The entire watercourse was surveyed during the afternoon and again after dark using a combination of visual searches, spotlighting and listening for auditory signatures.

In March 2016, a DSU Ornithology class surveyed bird species using both visual (4x binoculars) and audible survey techniques. The survey started at 7:50 am and ended at 9:50 am.

As part of a larger bat survey project, Arena 4, as the only source of open water at Pakoon Springs was surveyed for bats in summer 2015. Bats were mist-netted and identified by a bat biologist.

In May 2016, all small mammal survey was conducted. 5 trap lines of 20 traps each (100 Sherman live traps total) were placed and monitored near the springs and in the agricultural fields. Trapping was carried out the nights of May 9 and 10, between new moon and first quarter phases, within the time period generally shown to have the highest nocturnal rodent activity in the Mojave Desert.

Invertebrate Survey

Aquatic invertebrates were sampled within 2 weeks of the removal of the pond in Arena 4 to obtain a baseline to determine spring-related faunal changes. MOJN followed the Selected Large Springs Protocol (see Appendix C of Task Report #7 (Final) for more details). Samples were taken in the channel previously in the bottom of the pond, in the new springbrook immediately below the old pond agricultural outfall, and in the springbrook prior to its entry into the nearby wash. The invertebrates were again sampled in March of 2016. Aquatic invertebrates were identified to the family or genus level.

Aquatic snails were specifically surveyed for on July 20, 2015. Several small snails noted at Pakoon triggered the question if Grand Wash springsnail had reached Pakoon since the Sada survey in 2007. Snail surveys were conducted at 4 locations using a 20 min patterned search technique by an AGFD snail expert and his intern.

In June 2016, snails were collected in 3 locations for species identification via DNA analysis.

Hydrological Monitoring and Geomorphology

Discharge measurements and field water quality measurements were taken using the following procedures.

Field water quality measurements were taken each time an aquatic survey was conducted. Water quality parameters were collected using a sonde at various locations throughout the watercourse in Arenas 4 and 4E. Discharge measurements were more sporadic. The loss of the permanent weir and nearly all data in Arena 4E due to the high water of 2013 necessitated the use of temporary weirs and other devices to measure flow. While the pond outflow was directed to the fields through a pipe that discharged approximately 1 foot above ground level, discharge was measured repeatedly by GCPNM staff using a bucket/timer technique. Once the pond was removed, discharge was measured at the new springbrook outfall to the wash.

In April 2016, a weir plate was installed downstream from Pakoon Springs where a steep embankment on one side of the stream provided an anchor. A small dam was constructed to impound the water behind the Weir Plate, which has a 45° Notch that the water flows through. The height of the water above the bottom of the v-notch gives a discharge measurement. The height above the notch is checked every 15 minutes by an Onset Hobo MX Water Level Meter which is installed a couple of feet upstream from the weir plate. The water level meter also records temperature as it records water level. Dissolved oxygen, pH and conductivity were measured in the field and water samples were collected to take back to the lab. Soluble reactive phosphorus and dissolved inorganic nitrogen concentrations were determined using a Hach Colorimeter.

Substrata was categorized by grain size using a log-scale (1 – clay, 2 – silt, 3 – sand, 4 – pea gravel, 5 – coarse gravel (1-10 cm), 6 – small boulder (0.1-1.0 m), 7 – large boulder (>1.0 m), and 8 – bedrock. Leaf litter percent cover and average depth across the arena were visually estimated in 2012.

TASK 9.² IMPLEMENT TRANSLOCATION OF LOCAL RARE SPECIES

Once the habitat has been verified as ready for introductions by AGFD and USFWS, environmental compliance documents will be generated by BLM. It is expected at this time that the USFWS National Environmental Policy Act authority will be used or tiered from for the Pakoon Spring species introductions. Introduction of these species may overlap or may be temporally spaced widely depending on the considerations of acceptable timing for introduction, availability of appropriate lifestages and staff safety. Specifically, Grand Wash springsnail can be introduced at any time once the pesticide treatment has occurred or is determined to be unnecessary. Speckled dace will depend on physical parameters as well as any noted lifecycle events in the source population such as spawning time. Once AGFD is satisfied with American

² Task 9-11 have not been completed as of this reporting, however their anticipated methods are included.

bullfrog removal, the relict leopard frog's introduction will depend on appropriate timing as determined by the Relict Leopard Frog Conservation Team (RLFCT) and the availability of Overton Arm stock. Additional considerations for timing depend on RLFCT staff availability as this is the only proposed species that cannot be relatively easily transported from a nearby (approximately 3 hour) source by Monument and AGFD staff.

To determine the success of the introductions, monitoring would occur. This monitoring varies by species. Monitoring for *R. onca* would be carried out by the RLFCT as part of their directive to establish refuge populations of RLF. Monitoring is expected to be at least twice yearly, in the spring (March - May) and again in the fall (Sept - Oct). At least one of the surveys would be a nocturnal survey, which for these frogs provides a better count of adults and juveniles. They use a visual encounter survey approach (Crump and Scott 1994), with at least two observers. Surveys at night are conducted with the use of high-powered flood lights. Animals are generally not handled, but on occasion may be captured by hand for closer inspection, usually to confirm species identification (tadpoles) or to measure growth (to assist with determining juveniles). Mid-year and annual summary reports of all monitoring and management actions are produced, as stipulated by the RLFCT.

Speckled dace monitoring would be carried out either in a directed fashion yearly or on an ad hoc basis more frequently depending on the stock chosen for introduction. Monitoring will be comprised of visual surveys, and, if the source stock is genetically mixed, may include periodic genetic sampling to determine race percentages.

Springsnail and water quality/quantity monitoring would be carried out by the NPS Mojave Desert Inventory and Monitoring Network on a yearly to every three year basis as part of their Selected Large Springs protocol (long-term monitoring).

TASK 10. IMPLEMENT VISITOR EDUCATION AND OUTREACH

This Task is guided by the Grand Canyon-Parashant Long Range Interpretive Plan (2012). The site is routinely monitored for indications of increased visitation and any associated impacts. A traffic counter and register will be installed to help determine visitation patterns and reason for visit. A visitor satisfaction survey may also be considered for the site in the future to determine more specific information and interest levels.

TASK 11. IMPLEMENT CONSTRUCTION OF VISITOR FOOTPATHS AND BOARDWALKS

Visitor trail infrastructure has been determined to be a combination of gates, fences, trail signs, boardwalks and small bridges. Once the gate nearest the parking area is added, intensive monitoring of visitor use is expected to begin. This will identify the paths taken most often by

visitors and help determine if and where actual trail infrastructure needs to be placed. To respond to vegetation shifts as well as an unknown level of visitor use, the trail to the spring complex will undergo modification if visitor use indicates damage to the complex caused by social trails, improper use (e.g. trash dumping or vegetation harvest), or proper use that changes the character of the spring complex (e.g. picnicking that results in rings of logs and rocks for sitting), or if the natural processes indicate the trail is incorrectly placed or needs to be modified (e.g. trail is now through an area of intense cottonwood regeneration or a spring now flows through the middle of the trail). Modification may include further signage, increased visitor education, trail realignment or conversion of sections of trail to boardwalks.

The design of the Pakoon Springs Interpretive Trail and parking area must take into consideration:

- Shifting soil and substrate conditions due to the proximity to two active washes
- Potential for camping
- Ease of access for large vehicles or vehicles pulling trailers
- No camping within one-fourth mile of a wildlife watering tank/hole (Arizona Revised Statutes § 17-308: "It is unlawful for a person to camp within one-fourth mile of a natural water hole containing water or a man-made watering facility containing water in such a place that wildlife or domestic stock will be denied access to the only reasonably available water.")
- Shifting patterns in visitor use
- The unique and changing nature of the Pakoon spring complex

At this time, the only element that has been well defined are Two types of gates. Both types of gates will have a spring loaded closing mechanism. Gates will be mounted so the gate will self-close to keep feral animals out of each fenced area. The first type is a utility tube gate. This will be used on the inner pipe rail fence around the springs core in two locations once environmental compliance is complete. This was chosen to match the expected pipe rail fencing materials and will better withstand high salinity and seasonally wet soils than a wooden fence and gate. The second type will be used at the main trail pass-through for the outer fence. This will be a split rail gate constructed primarily of wood. It will match the surround for the gate. To draw the eye to the intersection of the trail and the barbed wire fence, it was decided to make the gate more visible to the visitor. Until approximately 20 ft. from the fence, the trail follows a road. Signage and the more visible split rail fence and gate will help indicate that visitors should no longer follow the road, but turn slightly to the right and enter the fenced area at that point.

The trail to the springs complex has been roughly described below. The trail will follow the road bed until it is at least within 20 ft. of the fence around the springs. This section of road is also relatively stable and is an already disturbed area. The nearby topography suggests that a more direct line approach to the spring complex from the parking area would cut across several washes and an area of native Mojave Desert vegetation that, being outside the modified ranch area,

retains the natural character of the desert, including several large patches of fragile biological soil crust which should not be stepped on. The trail approach will be via a pass-through gate in the boundary fence to discourage cattle and burros from damaging the site. The trail will follow contour lines to provide an easy approach to the spring complex while highlighting aspects and examples of desert, wetland and riparian ecosystems. In the upper areas of the trail, the trail will be marked with stones, carsonites or other small markers to provide direction without detracting from the character and naturalness of the site. Once the trail reaches the wetland area, it will skirt along the inside of the fence until it intersects with the old road. This road will also be reclaimed, but instead of full return to Mojave Desert spring complex state, a portion of the road will be modified for a trail (narrowing, edge makers, and potential interpretive signage). At this time it is difficult to determine how much of the road will be converted to trail.

RESULTS

TASK 4. IMPLEMENTATION OF EARTHWORK AND STRUCTURES

The reconstructed total width of the stream channel and floodplain is approximately 50 to 75 feet. The design width was based on stream channel and floodplain dimensions upstream and downstream of the formerly constricted section of stream channel. Excavated material was used to create a more natural and topographically complex landscape in the former agricultural fields. In addition to creating a more natural appearance, recontouring of the fields created variations in topography, elevation, and aspect resulting in variations in microclimate and microhabitat necessary for the recovery of native plant and animal assemblages throughout the Pakoon Springs site. Stream channel stabilization efforts, including gabion weir installation, was focused within a 1 acre area. Floodplain widening resulted in the placement of earthen materials over an area of approximately 6 acres within the former fields.

Gabion Status

Gabion structural integrity was impacted by the normal monsoon flows and newly continuous flows from the pond in Arena 4 in 2012. Two February 2013 site visits recorded flow circumventing the Gabion 2, 3 and 4 structures and causing downcutting behind Gabion 5.

In mid-September 2013, rains across the region impacted Parashant National Monument. The first post high water site visit was within 2 weeks of the event (See Appendix A for images detailing the progression). Four of the five gabions were severely damaged. All gabions were damaged during the high water event. Damage ranged from minor bank cuts (Gabion 1) to complete destruction (Gabion 5). Further serious damage occurred during the normal monsoon season in 2014. The gabions did not fulfill their designed purpose to widen the “floodplain” of the creek, instead they constricted flow, narrowing the flow path of the high water event and decreasing the natural floodplain widening opportunity. The 2013 high flows flushed much of the fine sediments out of the wash bottom where headcutting was occurring, leaving a much more armored surface similar to the unaltered wash upstream of the Pakoon Springs Ranch.

Gabions were surveyed for structural status in February, April, May, September and December 2013, and January and February 2014. Assessments were carried out by a variety of specialties including engineering, construction leads, hydrologists and resource specialists. It was also discovered the design and placement of the damaged gabions inadvertently increased habitat for the invasive American bullfrog (*Lithobates catesbeianus*).

In 2015, the damaged gabions (Gabion 2-5) were removed from the dry wash. Rocks from the gabions were left in the wash bottom in piles to stabilize the system, but the “baskets” were removed to provide the beginning of natural armoring of the channel while the wire and cloth were disposed of.

In 2016, USGS StreamStat was used to determine if gabions of the size and type originally designed for the site would be adequate if rebuilt. The results indicate a much more robust set of gabions would be necessary. However, since the 2013 high flow event, headcutting has not been in evidence in the wash. At this time, since Gabion 1 continues to function as designed, it has been determined that Gabion 1 will remain while the other gabions will not be replaced.

TASK 5. IMPLEMENT INVASIVE SPECIES REMOVAL PLAN

Bullfrog removal

Nineteen site visits for bullfrog removal occurred between May 2011 and 2016. Over 2200 bullfrogs have been removed from the spring complex (Figure 7). Spearheaded by AGFD, this effort has significantly reduced the number of bullfrogs at the springs. A summary of each visit is provided below and in Table 4.

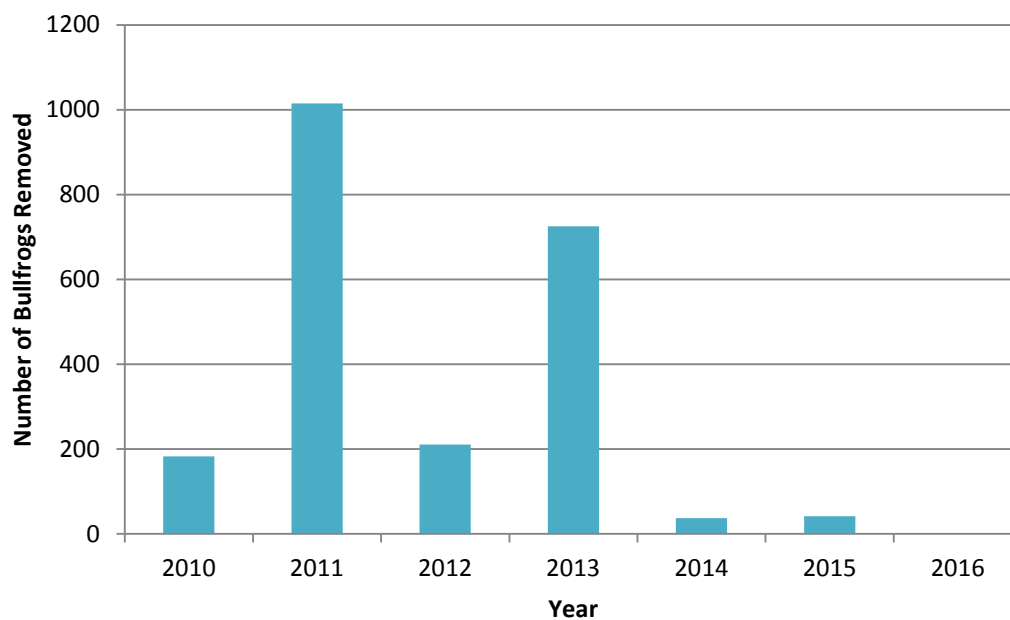


Figure 7. Number of bullfrogs removed by year from Pakoon Springs.

Three bullfrog removal trips were made in 2011 after May (after initiation of 11-180WPF).

- June 15-17: 100 bullfrogs removed.
- July 19-22: 750 frogs removed from the pond and adjacent drainage, 27 of which were adults.
- November 15-17: 50 bullfrogs removed.

Six bullfrog eradication trips were made in 2012. Bullfrog eradication efforts were also conducted during a Pakoon Wash revegetation site visit April 30, 2012 through May 1, 2012. A total of 211 bullfrogs were removed. In addition, breaches in the frog exclusion fencing were repaired.

- March 30- April 1, 2012: 1 large male removed from Arena 2, 36 from the pond, and 5 larger sub-adults were removed from Arena 4E. No egg masses were observed.
- July 31-August 1, 2012: 41 bullfrogs removed. 14 bullfrogs, including several large individuals of breeding age, observed along the northern perimeter of Arena 4 pond. 4 large bullfrog tadpoles were observed in the SW corner of the Arena 4 pond. Approximately 3-4 males heard calling in the Arena 4 pond. A single, large frog was shot in the Arena 4E fenced enclosure. The largest male removed was approximately 250 mm SVL. 2 male frogs heard in Arenas 2 and 3. 2 bullfrogs removed from wash in the vicinity of the gabion basket weirs.
- November-December 2012: 37 bullfrogs removed, primarily recent metamorphs or juveniles.

AGFD traveled to Pakoon 4 times in 2013 to remove bullfrogs. A total of 725 bullfrogs were eradicated.

- June 5-7: removed approximately 170 bullfrogs from the pond, 3 adults (1 gravid female) from the wash near the lower gabions, and 16 from Arena 4E. Also detected late-stage bullfrog tadpoles in the pond.
- August 12-14: removed approximately 125 bullfrogs. Of 46 bullfrogs measured, most (67%) were recently metamorphosed juveniles and about 28% were subadults. Fewer than 10 tadpoles, all of which appeared to be approaching metamorphosis, were observed. Only a couple frogs (both males) were sexually mature. Two adult males were heard calling, one of which was removed. At least one frog that escaped capture might have been an adult female. Most of the remaining population appears to be comprised of juveniles and subadults.
- October: five days of intensive bullfrog removal (>400 out of pond), until AGFD could not see any more. Having it drained made a huge difference. No bullfrogs were found, none in drainage or pond drain outflow.
- November 29-December 1: Eleven immature bullfrogs found in the pond, all were removed. No individuals were seen on the last night and day of the visit.

AGFD has traveled twice to Pakoon Springs in 2014 and removed a total of 37 bullfrogs.

- February 5-7: inclement weather limited bullfrog control efforts to one nighttime and one daytime survey. A total of 4 immature bullfrogs were found in the pond, all removed.
- March 23-29: removed 33 juveniles from the pond

In 2015, AGFD traveled to Pakoon Springs for bullfrog removal twice. A total of 42 bullfrogs were removed.

- February 3-5: removed approximately 32 immature bullfrogs from the pond, a few were large and bordering on reproductive size. No adult bullfrogs were seen or heard, no tadpoles either. No bullfrogs were found in the drainage or other standing water area
- June 4-5: 10 bullfrogs removed. 1 juvenile noted in pool in wash.

In 2016, AGFD and a cooperator visited Pakoon Springs twice to remove or survey for bullfrogs.

- January 14: no bullfrogs found
- May 16-19: 2 bullfrogs removed. No juveniles observed.

Table 4. Number of bullfrogs eradicated at Pakoon Springs 2010-2016.

Year	Date	Number of Bullfrogs Removed
2010	March 8-12	76
	April 26-29	94
	September 7-9	13
	Total	183
2011	April 11-14	115
	June 15-17	100
	July 19-22	750
	November 15-17	50
	Total	1015
2012	March 30- April 1	42
	April 30-May 1	30
	May 22	6
	June 13-15	55
	July 31-August 1	41
	November-December	37
	Total	211
2013	June 5-7	189
	August 12-14	125
	October	400
	November 29-December 1	11
	Total	725
2014	February 5-7	4
	March 23-29	33
	Total	37

Year	Date	Number of Bullfrogs Removed
2015	February 3-5	32
	June 4-5	10
	Total	42
2016	January 14	0
	May 16-19	2
	Total	2

Cattails were periodically removed as needed from Arena 4 and 4E throughout the project (Figure 8). In May 2013, during a site visit with AGFD, Parashant and GCWC personnel, it was decided that the most useful modification to Pakoon Springs would be to keep the pond drawn down as much as possible. This would decrease the newly available habitat in the wash/creek, retard the growth of cattails in Arenas 4 and 4E and decrease the available deep water habitat necessary for successful bullfrog recruitment. In addition, habitat restoration including the transformation of standing water areas formerly dominated by cattail to alkali meadow and spring/seep habitat has resulted in a decrease in habitat suitable for bullfrogs.

Following the high water event in mid-September 2013, the efficacy of the plastic coating the pond sides and Arena 4E and the bullfrog fence was severely damaged. It has been determined that neither structure would continue to serve a useful purpose in invasive species control and was removed in 2013-2015.



Figure 8. Arena 4E before (left) and after (right) cattail removal, early summer 2013. Pictured: IIC Intern Cory Litson.

Finally, the removal of the pond in Arena 4 severely decreased the amount of deep water habitat required by bullfrogs to successfully reproduce while at the same time increased the ability of piscivorous (and tadpole-eating) animals to access the remaining bullfrog habitat.

Mosquitofish Removal

Mosquitofish remain at Pakoon Springs. Since no census was taken prior to any rehabilitation activities at the springs, it is difficult to determine if any significant decrease in mosquitofish has occurred.

TASK 6. IMPLEMENT INVASIVE WEED ERADICATION AND NATIVE PLANT REVEGETATION

Invasive removal

Weed treatment and eradication efforts occurred throughout the entire project area with a focus on the previously restored spring/seep source areas (Arenas 1 through 4), the former agricultural fields, and the dry wash.

The primary invasive weed eradication efforts in 2010 through 2016 included 1) foliar treatment and 2) manual removal of invasive plants including tamarisk, Russian thistle, Malta star thistle, African mustard, and horehound.

Efforts to eliminate or reduce invasive non-native plant species are on-going at Pakoon Springs. The Lake Mead Exotic Plant Management Team provided the primary invasive plant eradication efforts in 2010-2011 (Appendix B).

The most predominant invasive species at Pakoon in 2014-2016 is Russian thistle (*Salsola tragus*, tumbleweed). Russian thistle was seen in Arenas 1-4E and the uplands near the creek. It was not seen growing in areas where ground disturbance has been minimal since 2004. With the topsoil of Pakoon Springs severely disturbed, it will take at least 10 years to convert the area to one of Russian thistle-resistant mycorrhizal associations.

The primary invasive weed eradication efforts in 2013-2016 have been opportunistic manual removal of invasive plants including tamarisk, fan palm and date palm trees. Tamarisk has repeatedly been sighted in Arena 4. Occasional tamarisk are found in the wash, however the removal of the pond and gabions seems to have limited their ability to establish. All observed tamarisk were either pulled out by hand or dug out.

Palm trees continue to be found near Arenas 2 and 3. All palm trees, when encountered, were immediately removed by hand pulling.

Revegetation

The primary revegetation efforts completed include the installation of pole plantings and native plant plugs in the wash in April 2012 (Table 5) following the installation of gabion basket weirs for the purpose of stream stabilization and floodplain expansion. To hasten revegetation within newly constructed areas, native plant cores (e.g., from rhizomatous species, such as yerba mansa, bulrush, etc.), and pole plantings of woody phreatophytes (e.g., Goodding's willow, seepwillow) were installed.

Table 5. Riparian/Wetland Revegetation Zone planting prescription and implementation status (includes Stream Channel Stabilization Zone). OC=on center.

Common Name	Species	Approximate Quantity	Minimum Spacing	Implementation Schedule	Implementation Quantity and Status
Woody Phreatophyte Pole Cuttings					
Goodding's willow	<i>Salix gooddingii</i>	100-200	10-20 feet OC	Spring 2012, Spring 2013	100 installed April 2012
Seepwillow	<i>Baccharis salicifolia</i>	100-200	5-10 feet OC	Spring 2012, Spring 2013	100 installed April 2012
Native Plant Plugs					
Yerba Mansa	<i>Anemopsis californica</i>	50-100	5 feet OC	Spring 2012	75 installed April 2012
Spikerush	<i>Eleocharis</i> sp.	50-100	5 feet OC	Spring 2012	50 installed April 2012
Bullrush	<i>Schoenoplectus americanus</i>	50-100	5 feet OC	Spring 2012	50 installed April 2012
Saltgrass	<i>Distichlis spicata</i>	50-100	5 feet OC	Spring 2012	50 installed April 2012

Active revegetation of the Pakoon Springs riparian area and wash was halted following the May 2013 meeting with AGFD and GCWC. During that meeting AGFD requested the pond remain drawn down to facilitate bullfrog eradication. This dewatered the wash to the extent that pole planting and plant plugs would not survive the transplantation process. Following the high water event in Fall 2013, nearly all the transplanted stock died or was scoured from the wash. It was quickly replaced by cattail and new willow starts through natural regeneration. After a second large flow event in 2014, it was decided that active revegetation would not aide the system in establishing any new vegetation areas in the wash.

Passive revegetation in areas not contoured under this or the previous grant continues. The western side of the lower agricultural fields are revegetating with natives (no invasive species were noticeable, either alive or dead, in February 2014) from the local seedbank (Figure 9).



Figure 9. Lower agricultural fields facing north.

The upper agricultural field area (north and west of Arenas 1-3) that has not been modified except for initial site cleanup following property acquisition by the BLM in 2004 show a mix of native shrub species (Figure 10). Passive revegetation has also successfully colonized the new linear springbrook of Arena 4.



Figure 10. Area west of Arenas 1-3 after September high water event. Note, even with scouring flood, native shrubs are a diverse cross-section of Mojave Desert species.

TASK 7. IMPLEMENT IDENTIFICATION AND PRIORITIZATION OF LOCAL RARE SPECIES TRANSLOCATION

The workshop participants (Appendix C) determined which species may be relocated to Pakoon Springs. This group used the prioritization hierarchy to screen the potential pool of introductions (Table 6). The final species selected are Grand Wash springsnail (Hydrobiidae: *Pyrgulopsis bacchus*), speckled dace (Cyprinidae: *Rhinichthys osculus*) and relict leopard frog (Ranidae: *Lithobates (Rana) onca*).

Table 6. Species considered for introduction

Species	Scientific Name	Appropriate (Y/N)	Special Status (Y/N)	Success (Y/N)	Steps still to be done (Y/N)	Comments
Grand Wash springsnail	<i>Pyrgulopsis bacchus</i>	Y	Y	Y	Y	See accounts in Task 7 final report
Speckled dace (Tassi population)	<i>Rhinichthys osculus</i>	Y	Y	Y	Y	See accounts in Task 7 final report
Arizona toad	<i>Anaxyrus (Bufo) microscaphus</i>	N	Y			Hybridizes with local Woodhouse's toad
Baja California treefrog	<i>Pseudacris hypochondriaca</i>	N	N			Local populations are suspected to be introduced outside native range, widespread in California
Lowland leopard frog	<i>Lithobates (Rana) yavapaiensis</i>	N	Y			Outside native range
Agassiz's desert tortoise	<i>Gopherus agassizii</i>	N	Y			Unknown native population size, potential for overcrowding
Muskrat	<i>Ondatra zibethicus</i>	N	N			Limited food source, no local populations, not ideal habitat
Relict leopard frog	<i>Lithobates (Rana) onca</i>	Y	Y	Y	Y	See accounts in Task 7 final report
Virgin spinedace	<i>Lepidomeda mollispinis mollispinis</i>	N	Y			Conservation agreement does not support introductions outside Virgin River drainage

The habitat assessment used data from surveys conducted in 2000/2001, 2006, 2014 and 2015 are included in Appendix D. Springsnails were last verified to occur at Tassi and Whiskey Springs in 2015, and Grapevine Spring in 1980. While water temperatures near the Pakoon spring vents are higher than ideal, the water temperature quickly cools to a more habitable range for *P. bacchus*. The presence of the thermal springs allows for the possibility for the springsnail to persist even through colder winter periods since the snails are highly mobile within a system.

Substrate at Pakoon Springs is similar to that of Grapevine Spring (silt). Tassi Springs shows a much greater occurrence of sands and gravel than Pakoon. Pakoon is also developing a travertine section that may support springsnails in the future. It is suggested that for maximum results from introduction that the amount of hard substrate, preferably rough stones and rocks be set in shallow water in such a way as to provide habitat and a firm substrate for the springsnails. The substrate in the wash, too flashflood prone for springsnails, on the other hand, is composed primarily of gravels and cobbles. This moderately flowing system is good habitat for speckled dace. The intermediate sections of the system, barring any deep pools, provide the appropriate substrate and flow variability for *R. onca*.

One of the primary suspected drivers of relict leopard frog extirpation at springs within its range is the presence of American bullfrog. The bullfrogs, while declining due to several years of sustained efforts by Arizona Game and Fish Department (AGFD), persist at Pakoon Springs. AGFD remain committed to extirpation of American bullfrog at Pakoon Springs and, at this time, propose that relict leopard frog not be introduced until the bullfrog is gone.

The non-native mosquito fish (*Gambusia* sp.) at Pakoon Springs appears to have minimal habitat overlap with all three species. While *Gambusia* population levels are currently high, there is some evidence that the population may decline somewhat given the more accessible nature of the water to predators and the conversion of the system into fast moving, extremely shallow water areas. This suggests that the food requirements for speckled dace, in particular, may be met in areas outside the direct influence and presence of *Gambusia*. However, high levels of *Gambusia* recently observed suggest a more aggressive response may be needed, including a pesticide treatment.

The snails recently found at Pakoon Springs have been identified as *Physa acuta*. These snails compete for space and food source with *P. bacchus*. However, the presence of rocky substrates and watercress indicate that *Physa* and *P. bacchus* can most likely occupy their own niches within the ecosystem of the springs.

The vegetation at Pakoon Springs, particularly the introduction site of Arena 4, continues to change rapidly. At present, the area is dominated by cattails, which is not desirable for any of the species to be introduced. Willow and arrowweed are expanding in the old pond and will shade much of the spring area. It may be necessary to augment this by pole planting cottonwoods and

willows to speed up the conversion to a light shade canopy system where watercress and algae will flourish and all three species will do well.

Pakoon Springs continues to change as the ground surface settles after the last major earthmoving in 2015. Small springheads continue to appear and disappear and vegetation continues to expand from the islands of vegetation remaining after each period of ground manipulation. The main spring complex in Arena 4 appears to have stabilized into a linear pool-riffle-run system until it intersects the wash. Water quality, flow and temperature in this system appear to be stable. Ongoing work by AGFD has severely decreased the invasive bullfrog population. *Gambusia* continue to be an issue, though AGFD experts differ on how much the population would impact relict leopard frog and Grand Wash springsnail.

Since the completion of Task 7, several new factors have come into play. AGFD now recommends that the speckled dace source population be from the Virgin River Gorge population due to the small size of the population at Tassi Springs. This other population should be able to sustain multiple introduction events since it is likely that *Gambusia* will not be removed from Pakoon Springs. Pakoon Spring monitoring in Arena 4 by Mojave Desert Inventory and Monitoring Network (MOJN) found a sudden increase in *Physa* snails in the last year. This species will need to be watched and may decline by itself, as it has done at other spring sites in the southwest once spring restoration efforts finish. Finally, to support the local rare bat population, provide the hard substrate necessary for successful Grand Wash springsnail and guarantee shallow open water for relict leopard frog, the bat “pond”, now bat “run”, is in the planning stages. Because this was not considered in previous environmental compliance documents the run does not have final approval at this time.

The following workplans for each species were updated after the workshop as specialists were able to verify if each step was complete. Starred steps were determined to be complete as of August 2016.

Grand Wash Springsnail (*P. bacchus*)

1. Verify water quality is within parameters known to support *P. bacchus*.*
2. Determine level of substrate manipulation necessary to bring about appropriate surface habitat.*
3. Determine areas of spring system where introduction is most likely to succeed.*
4. Determine if other springsnail exists in system.*
5. Determine if *Physa* will decrease effectiveness of *P. bacchus* introduction. *
6. Determine if *Gambusia* is at acceptable levels for #3.
7. Introduce *P. bacchus* to main flowing springs.
8. Monitor for *P. bacchus* distribution and density in spring system.
9. If necessary, introduce second or third population until *P. bacchus* is determined to be successfully recruiting in the system.

Speckled Dace (*R. osculus*)

1. Verify water quality is within parameters known to support *R. osculus*.*

2. Determine level of substrate manipulation necessary to bring about appropriate surface habitat.*
3. Determine areas of spring system where introduction is most likely to succeed.*
4. Determine if *Gambusia* is at acceptable levels for #3.
5. Introduce *R. osculus* to wash below main springs.
6. Monitor for *R. osculus* distribution and density in wash.
7. If necessary, introduce second or third population until *R. osculus* is determined to be successfully recruiting in the system.

Relict Leopard Frog (*R. onca*)

1. Verify water quality is within parameters known to support *R. onca*.*
2. Determine level of substrate manipulation necessary to bring about appropriate surface habitat.*
3. Determine areas of spring system where introduction is most likely to succeed.*
4. Determine if American bullfrog is extirpated.
5. Determine if *Gambusia* is at acceptable levels for #3.
6. Introduce late-stage tadpoles or juvenile frogs from about April into early June in varying numbers to main springs each year for 5 years.
7. Monitor for *R. onca* distribution and density in springs and wash.

TASK 8 IMPLEMENT RIPARIAN HABITAT MONITORING PLAN

Site Repeat Photography

In general, the site photos over time demonstrate rehabilitation of native vegetation with rapid growth, increase in cover, and high survivorship. Figure 11 (view toward the northeast) illustrates this change. The changes are most noticeable near Arena 4 and 4E with an increase in surrounding vegetation, especially woody types.



B

Figure 11. Panoramic view of Pakoon Springs from hill at Pakoon (Photopoint 2) on A) July 10, 2009, B) June 1, 2016. For images of intermediate stages, see Appendix E.

Images taken at Photopoint 5 (Figure 12) show the gradual change in vegetation after removal of the pond from Arena 4. No plantings occurred in the recontoured areas, yet the vigorous colonization of bare soil by a full suite of upland, aquatic and riparian plants suggests the site maintains a sizable seed bank and the naturally occurring and planted vegetation are providing a continuing seed source.



Figure 12. Photopoint 5. Top: December 9, 2015 (9 months after pond removal). Bottom: June 1, 2016.

Vegetation Survey (See Appendix F for year by year data)

By the end of the first AWPf grant (#06-137WPF), 46 species or genera of vascular plants had been detected at Pakoon Springs. At the start of the present grant, in 2012, 46 species or genera of vascular plants were also detected, though not necessarily the same species. By 2016, that number had grown to 108 species or genera (Table 7). Thirteen species have not been previously reported for the Monument.

Table 7. Vascular plants observed at Pakoon Springs 2010-2016.

Species	Year Observed				
	2010	2012	2013	2015	2016
<i>Acamptopappus sphaerocephalus</i>					x
<i>Allenrolfea occidentalis</i>					x
<i>Allionia incarnata</i>				x	x
<i>Amaranthus blitoides</i>				x	x

Species	Year Observed				
	2010	2012	2013	2015	2016
<i>Ambrosia dumosa</i>				X	X
<i>Amphipappus fremontii</i>					X
<i>Amsinckia tessellata</i>					X
<i>Anemopsis californica</i>	X	X	X	X	X
<i>Aristida purpurea</i>					X
<i>Atriplex canescens</i>	X	X		X	X
<i>Atriplex confertifolia</i>				X	X
<i>Atriplex laevis*</i>		X	X		
<i>Atriplex lentiformis</i>	X	X	X	X	X
<i>Baccharis salicifolia</i>	X	X	X	X	X
<i>Baccharis sergiloides</i>	X	X	X		
<i>Bassia</i> sp.	X				
<i>Brickellia longifolia</i>	X				
<i>Bromus catharticus</i>					X
<i>Bromus rubens</i>	X	X	X		X
<i>Calycoseris parryi</i>					X
<i>Chaenactis carphoclinia</i>					X
<i>Chaenactis fremontii</i>					X
<i>Chaenactis macrantha</i>					X
<i>Cheilanthes feei</i>					X
<i>Chenopodium berlandieri</i>					X
<i>Chilopsis linearis</i>				X	X
<i>Chorizanthe brevicornu</i>					X
<i>Chorizanthe rigida</i>					X
<i>Chylismia brevipes</i>					X
<i>Convolvulus</i> sp.		X	X		
<i>Cryptantha barbigera</i>					X
<i>Cryptantha decipiens</i>					X
<i>Cryptantha nevadensis</i>					X
<i>Cylindropuntia bigelovii</i>				X	X
<i>Cylindropuntia whipplei</i>		X	X	X	X
<i>Cynodon dactylon</i>	X	X	X	X	X
<i>Dalea mollis</i>					X
<i>Dasyochloa pulchella</i>					X
<i>Datura wrightii</i>	X	X	X	X	X
<i>Descurainia incana</i>					X
<i>Descurainia pinnata</i>					X

Species	Year Observed				
	2010	2012	2013	2015	2016
<i>Distichlis spicata</i>	x	x	x	x	x
<i>Eleocharis</i> sp.	x	x			
<i>Encelia farinosa</i>		x		x	x
<i>Encelia frutescens</i>					x
<i>Enceliopsis argophylla</i>				x	x
<i>Epilobium</i> sp.	x				
<i>Eriogonum brachypodum</i>				x	x
<i>Eriogonum deflexum</i>					x
<i>Eriogonum fasciculatum</i> var. <i>polifolium</i>					x
<i>Eriogonum inflatum</i>					x
<i>Eriogonum</i> sp.				x	
<i>Eriophyllum lanosum</i>					x
<i>Erodium cicutarium</i>		x			
<i>Eschscholzia minutiflora</i>					x
<i>Euphorbia fendleri</i>					x
<i>Eustoma exaltatum</i>		x	x		
<i>Helianthus annuus</i>		x	x	x	x
<i>Helianthus</i> sp.	x				
<i>Heliotropium curassavicum</i>		x		x	
<i>Heliotropium curassavicum</i> var. <i>oculatum</i>					x
<i>Heliotropium</i> sp.	x		x		
<i>Hilaria rigida</i>					x
<i>Hordeum murinum</i> ssp. <i>leporinum</i>					x
<i>Isocoma acradenia</i>	x	x	x		
<i>Isocoma drummondii</i>				x	x
<i>Juncus torreyi</i>			x		x
<i>Krameria bicolor</i>					x
<i>Lactuca serriola</i>	x	x	x		
<i>Langloisia setosissima</i>					x
<i>Larrea tridentata</i>	x	x	x	x	x
<i>Lepidium densiflorum</i> var. <i>pubecarpum</i>					x
<i>Lepidium lasiocarpum</i>					x
<i>Lycium pallidum</i>					x
<i>Lycium</i> sp.			x		
<i>Malva parviflora</i>					x

Species	Year Observed				
	2010	2012	2013	2015	2016
<i>Marrubium vulgare</i>	x	x	x		
<i>Melilotus albus</i>				x	x
<i>Melilotus officinalis</i>					x
<i>Melilotus sp.</i>	x	x	x		
<i>Mentzelia tricuspis</i>					x
<i>Morus sp.</i>		x	x		
<i>Nasturtium officinale</i>	x				
<i>Nicotiana obtusifolia</i> var. <i>obtusifolia</i>	x				x
<i>Oligomeris linifolia</i>					x
<i>Opuntia basilaris</i>				x	x
<i>Opuntia phaeacantha</i>	x	x	x	x	x
<i>Packera multilobata</i>		x	x		
<i>Parietaria pensylvanica</i>					x
<i>Perityle emoryi</i>					x
<i>Phacelia crenulata</i> var. <i>ambigua</i>					x
<i>Phoenix dactylifera</i>					x
<i>Phoradendron californicum</i>	x	x	x	x	x
<i>Physalis crassifolia</i>					x
<i>Physaria tenella</i>					x
<i>Plantago ovata</i>					x
<i>Plantago patagonica</i>					x
<i>Pluchea carolinensis</i>				x	x
<i>Pluchea sericea</i>	x	x	x	x	x
<i>Polypogon monspeliensis</i>	x		x		x
<i>Populus fremontii</i>	x	x	x	x	x
<i>Porophyllum gracile</i>					x
<i>Prosopis glandulosa</i>	x	x	x	x	x
<i>Prosopis glandulosa</i> var. <i>torreyana</i>				x	x
<i>Prosopis pubescens</i>	x	x	x		
<i>Psilostrophe cooperi</i>					x
<i>Psoralea fremontii</i>				x	x
<i>Rafinesquia neomexicana</i>					x
<i>Rubus bifrons</i>					x
<i>Rubus sp.</i>				x	
<i>Rumex salicifolius</i>					x
<i>Rumex sp.</i>	x				
<i>Salix exigua</i>	x	x	x	x	x

Species	Year Observed				
	2010	2012	2013	2015	2016
<i>Salix gooddingii</i>	x	x	x	x	x
<i>Salsola tragus</i>	x	x	x	x	x
<i>Sarcobatus vermiculatus</i>	x				
<i>Schoenoplectus acutus</i>	x				
<i>Schismus arabicus</i>					x
<i>Schismus</i> sp.					x
<i>Schoenoplectus americanus</i>		x	x		x
<i>Senecio flaccidus</i>				x	
<i>Senecio flaccidus</i> var. <i>douglasii</i>					x
<i>Senecio flaccidus</i> var. <i>monoensis</i>					x
<i>Senecio</i> sp.	x				
<i>Senegalia greggii</i>	x	x	x	x	x
<i>Sidalcea</i> sp.		x			
<i>Sisymbrium irio</i>					x
<i>Solanum angustifolium</i>	x	x	x		
<i>Solanum elaeagnifolium</i>				x	x
<i>Sonchus asper</i>					x
<i>Sphaeralcea ambigua</i>					x
<i>Sphaeralcea</i> sp.		x	x		
<i>Suaeda calceoliformis</i>					x
<i>Suaeda nigra</i>				x	x
<i>Suaeda</i> sp.	x	x	x		
<i>Symphyotrichum subulatum</i>	x	x	x		
<i>Symphyotrichum subulatum</i> var. <i>ligulatum</i>				x	x
<i>Tamarix ramosissima</i>		x			
<i>Tamarix</i> sp.	x			x	
<i>Typha domingensis</i>	x	x	x	x	x
<i>Veronica</i> sp.	x		x		
<i>Vitis arizonica</i>	x	x	x		x
<i>Washingtonia filifera</i>	x				
<i>Washingtonia</i>		x	x		
<i>Xanthisma spinulosum</i> var. <i>gooddingii</i>					x
<i>Xanthium strumarium</i>			x		
<i>Yucca brevifolia</i>	x	x	x	x	x

* - possible misidentification

As can be seen in Table 8, between 2012 and 2013, percent cover changed drastically in Arena 4 and 4E. This was related to the sustained draw down of the pond for bullfrog removal. The increased soil surface layer available for colonization resulted in a surge of growth and percent cover primarily by cattails (*Typha*). Arena 4E also showed an increase in species richness as this area has been disturbed most recently just prior to 2012 during recontouring and then was revegetated.

Table 8. Change in visually estimated percent cover (VE% Cover) and plant species richness (Spp. Rich.) among restoration arenas from November 2012 to December 2013 at Pakoon Springs, Grand Canyon-Parashant National Monument, Arizona.

Variable	Stratum	Arena						Pakoon Cr.	Ag Fields 1-3
		1	2	3	4	4E	5		
VE% Cover	AQ	0.01	0.01	0.20	75.00	1.00	0.00	2.00	0.00
VE% Cover	GC	7.00	5.10	-11.80	-1.49	-26.93	-5.71	-7.22	-5.80
VE% Cover	SC	4.90	4.40	3.70	-13.20	1.00	-2.99	-30.90	-5.30
VE% Cover	MC	0.00	0.00	-1.00	1.00	2.00	0.00	-1.00	0.00
VE% Cover	TC	-1.00	0.00	-1.50	0.00	-3.00	0.00	-2.00	0.00
Spp. Rich.	AQ	1	1	2	1	1	0	1	0
Spp. Rich.	GC	6	3	-1	5	3	-2	-1	-4
Spp. Rich.	SC	10	5	10	3	7	9	10	8
Spp. Rich.	MC	2	0	1	1	0	0	0	0
Spp. Rich.	TC	0	2	1	0	0	0	0	0

Surveys conducted in 2015, 6 months after the removal of the pond from Arena 4, revealed a complex structural diversity developing at the site. The vegetative structure surveys suggest a north-south gradient in vegetative cover complexity. The disturbed and undisturbed areas were most noticeably different at the north end of the transects. The north end of the disturbed zone was clearly impacted by historic and more recent activities at the property and the plant community was missing many species present in the undisturbed area. Figure 13 gives an overall picture of how common the different vegetation heights were in the three zones studied. Vegetation was most dense and the most complex along the riparian habitat. Given that dense monocultures of opportunistic plants occupy some of the disturbed habitat, but were not included in this particular session, the disturbed zone data underestimate the average shrub and woody perennial cover likely present at the site as a whole.

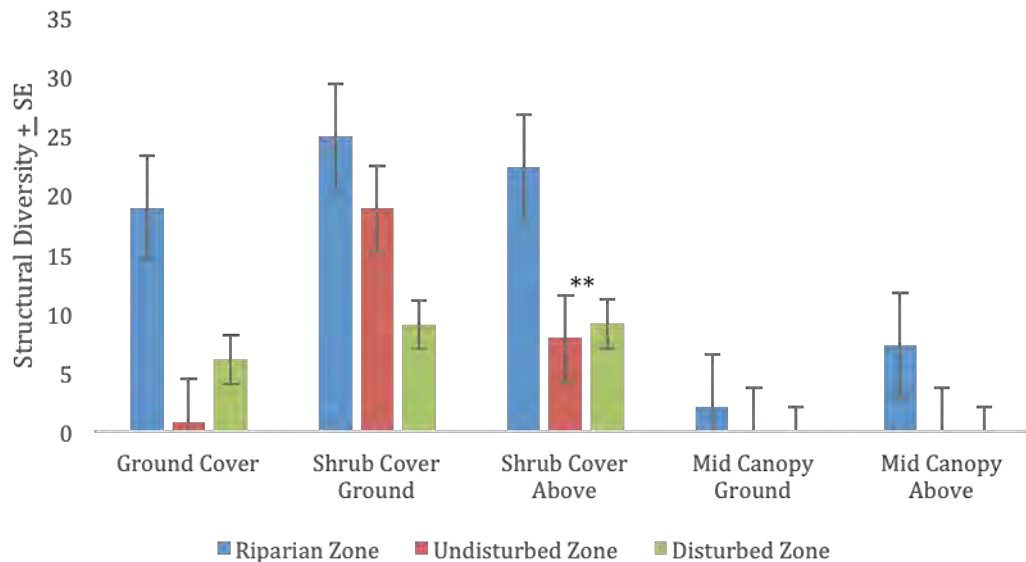


Figure 13. The average frequency of each vegetation type in the three zones studied.
 ** - not statistically different.

Vegetation shifts to shrubs and a woody overstory in Arenas 2 and 3 were set back to an annual and perennial forb mix in 2013, mostly likely due to the incursion of burros and a fire that killed several large cottonwoods and willows in the arenas. The burros grazed on many of the saplings and young shrubs while the fire increased to available light, both encouraged the growth of unpalatable forbs. Once the burros were fenced out in 2015, Arena 3 has experienced rapid growth of willow and cottonwood saplings, especially to the east side where the water is now seeping across the road. Arena 2 has also had rapid growth to the east in the form of cattails and sunflowers. Arena 1, not as impacted by the burros, continues to be a mix of cattails, willows and cottonwoods. Arena 4E, despite the decrease in water from Arena 4 and the flooding that damaged vegetation near the wash, continues to be dominated by willows and sunflowers.

The most notable vegetation change in the Arenas has occurred at Arena 4. The removal of the pond necessitated the removal of much of the surviving vegetation around the pond. The *Tessaria* (now known as *Pluchea*) noted as doing well in Arena 4 in 2013 was virtually nonexistent except in one small patch by 2015. The low survival rate of transplants coupled with the pond drawdown, the placement of frog fence and plastic and the periodic removal of vegetation as requested by AGFD for bullfrog removal effectively extirpated the population around the pond. Conversion of the pond to a springbrook included tapering the slope of the pond edge. The planted willows, already stressed by 2 years of minimal water would not have survived transplantation. However, pushing the willows with the dirt into the pond bottom would potentially cause the willows to resprout. With the goal of maintaining seed stock and potentially boosting the number of willows through a “transplantation”, all vegetation was pushed into the pond bottom except the vegetation surrounding the upper spring of the pond. (This spring is nearly its own pond and was only connected to the main pond via a shallow channel). Repeated visits to the springbrook found a rapid growth of cattails, saltgrass and Bermuda grass in the summer of 2015 along with the establishment of watercress and a true aquatic plant in the new springbrook. By December 2015, small willows were observed lining the springbrook. By March 2016, the willows had not leafed out yet (nor had many of the other trees at the site), cattails were dominating the springbrook and *Pluchea* was colonizing the salty area where several springs from the pond periodically appear. In addition, a mix of invasives and native vegetation was colonizing the recently recontoured slope to the west of the pond when the site was visited in July 2016.

Vertebrate Surveys

A total of 16 species of birds were observed across habitats (Table 9). The most common species observed was the white-crowned sparrow while most of the species were only seen once or twice.

Table 9. Avian Survey Data from March 2015. The species are listed by common name with the total number of individual number of birds of that species found and the type of habitat where they were observed.

Species	Number found	Habitat
Gambel's Quail	1	Desert
Cooper's Hawk	1	Riparian
Northern Flicker	1	Riparian
Common Raven	1	Desert
Phainopepla	7	all habitats
Marsh Wren	1	Marsh
Blue-gray Gnatcatcher	2	Desert
Verdin	3	Upland/Desert
Ruby-crowned Kinglet	2	Riparian

Species	Number found	Habitat
Lucy's Warbler	1	Upland
Song Sparrow	4	Marsh
White-crowned Sparrow	8	Upland
Black throated Sparrow	2	Desert
Spotted Towhee	1	Desert
Lesser Goldfinch	2	Riparian
House Finch	2	Upland/Riparian

A survey conducted in January 2016 found no sign of bullfrogs, though the air temperature may have decreased the frog's movements. Five Woodhouse toads were observed.

During the June 2015 bat survey, 61 bats representing 4 species were observed: *Antrozous pallidus*, *Eptesicus fuscus*, *Parastrellus hesperus*, and *Tadarida brasiliensis*. The bat specialist noted the site is "absolutely critical for water across multiple species" and "recovery to natural conditions appear to be successful" (Buecher, informal report). The researcher also noted that there were members of two of the species pregnant or lactating indicating a nearby maternity colony.

Small mammal trapping in May 2016 resulted in the capture of 7 different species of rodents. Overall trapping success was 49%, an unusually high success rate.

Additional vertebrates were noted during site visits. Table 10 shows all the vertebrates identified by sight or by tracks. In the 24 hours after the pond was removed, several bighorn sheep tracks, coyote tracks and cat-like tracks were found next to the new springbrook. Tracks from these animals continue to be observed during subsequent visits.

Table 10. Vertebrates or their sign observed at Pakoon Springs.

Taxon	Common Name	Family: Scientific Name	2012	2013	2014	2015	2016
Bird	American Coot	<i>Fulica americana</i>	x	x		x	
Bird	American Kestrel	<i>Falco sparverius</i>		x			
Mammal	Arizona Pocket Mouse	<i>Perognathus amplus</i>					x
Mammal	Bighorn Sheep	<i>Ovis canadensis nelsoni</i>		x			x
Bird	Black Throated Sparrow	<i>Amphispiza bilineata</i>				x	
Mammal	Brush Mouse	<i>Peromyscus boylii</i>					x
Amphibian	Bullfrog	<i>Lithobates (Rana) catesbiana</i>	x		x	x	x
Mammal	Cactus Mouse	<i>Peromyscus eremicus</i>					x
Bird	Cooper's Hawk	<i>Accipiter cooperii</i>	x				
Mammal	Cottontail	<i>Sylvilagus sp.</i>		x			x
Mammal	Coyote	<i>Canis latrans</i>		x	x	x	x
Mammal	Desert Woodrat	<i>Neotoma lepida</i>					x
Mammal	Feral Burro	<i>Equus asinus</i>	x	x	x	x	x
Mammal	Gray Fox	<i>Urocyon cinereoargenteus</i>		x			
Bird	House Finch	<i>Carpodacus mexicanus</i>	x			x	
Bird	Lesser Goldfinch	<i>Carduelis psaltria</i>	x			x	
Bird	Loggerhead Shrike	<i>Lanius ludovicianus</i>		x			
Bird	Mallard	<i>Anas platyrhynchos</i>		x			
Bird	Marsh Wren	<i>Cistothorus palustris</i>	x	x			
Mammal	Merriam's Kangaroo Rat	<i>Dipodomys merriami</i>					x
Bird	Mourning Dove	<i>Zenaida macroura</i>					x
Mammal	Muskrat	<i>Ondatra zibethicus</i>	?				
Bird	Phainopepla	<i>Phainopepla nitens</i>	x	x	x	x	
Mammal	Pocket Gopher	<i>Thomomys bottae</i>	x	x			
Amphibian	Red-Spotted Toad	<i>Anaxyrus punctatus</i>			x	x	
Mammal	Rock Pocket Mouse	<i>Chaetodipus intermedius</i>					x
Bird	Ruby-Crowned Kinglet	<i>Regulus calendula</i>		x			

Taxon	Common Name	Family: Scientific Name	2012	2013	2014	2015	2016
Reptile	Side-Blotched Lizard	<i>Uta stansburiana</i>	x				
Mammal	Silky Pocket Mouse	<i>Perognathus flavus</i>					x
Bird	Song Sparrow	<i>Melospiza melodia</i>	x			x	
Bird	Spotted Towhee	<i>Pipilo maculatus</i>		x		x	
Mammal	Striped Skunk	<i>Mephitis sp.</i>		x			
Bird	Vesper Sparrow	<i>Pooecetes gramineus</i>	x				
Reptile	Western Banded Gecko	<i>Coleonyx varigatus</i>				x	
Fish	Western Mosquitofish	<i>Gambusia affinis</i>	x	x	x	x	x
Bird	White-Crowned Sparrow	<i>Zonotrichia leucophrys</i>	x	x		x	
Amphibian	Woodhouse Toad	<i>Anaxyrus woodhousii</i>				x	x
Bird	Woodpecker Sp.	<i>Picidae</i>	x				
Mammal	Pallid Bat	<i>Antrozous pallidus</i>				x	
Mammal	Big Brown Bat	<i>Eptesicus fuscus</i>				x	
Mammal	Canyon Bat	<i>Parastrellus hesperus</i>				x	
Mammal	Mexican Free-Tailed Bat	<i>Tadarida brasiliensis</i>				x	

Invertebrate Survey

The data, collected immediately after the Arena 4 realignment, provides a baseline for determining stream health. The identified invertebrates were used to generate initial diversity, tolerance and richness metrics. Initial data from Arena 4 and 4E (Appendix G) show a high proportion of Simuliidae, often indicative of a highly disturbed system. This is not surprising since these samples were taken only days after the removal of the pond. They do suggest the rapid response of the invertebrates to a new system, with nearly 3000 larvae found in a newly created rocky riparian area. It is anticipated that the 2016 sample will provide the first point of comparison to determine if the system is “settling” into a stable ecosystem. Unfortunately the data is not yet available. One interesting caveat at this point is the presence of only one species of Odonata. Previous terrestrial visual observations have found 5 species of dragon and damselflies. (Table 11).

The springsnail survey conducted in 2015 found no Grand Wash springsnails at Pakoon. However, an abundance of *Physa* was found in all areas surveyed. A genetic analysis revealed physa to be *Physa acuta*, a worldwide invasive species to areas of recent riparian disturbance.

Table 11. Invertebrates observed at Pakoon Springs 2012-2015.

Life Stage	Class or Order	Scientific Name	2012	2013	2015
Aquatic	Arachnida	Acari			x
Aerial	Odonata	Aeshnidae	x	x	
Aerial	Hymenoptera	Apidae: <i>Apis mellifera</i>	x	x	
Aquatic	Ephemeroptera	Baetidae: <i>Fallceon</i>			x
Aquatic	Diptera	Ceratopogonidae: <i>Ceratopogoninae</i>			x
Aquatic	Diptera	Chironomidae: <i>Chironominae</i>			x
Aquatic	Diptera	Chironomidae: <i>Orthocladiinae</i>			x
Aquatic	Diptera	Chironomidae: <i>Tanypodinae</i>			x
Aquatic	Odonata	Coenagrionidae: <i>Argia</i>			x
Aquatic	Diptera	Culicidae			x
Aquatic	Coleoptera	Dryopidae: <i>Postelichus</i>			x
Aquatic	Coleoptera	Elmidae: <i>Microcylloepus</i>			x
Aquatic	Diptera	Ephydriidae			x
Aerial	Lepidoptera	Hesperiidae: <i>Pyrgus communis</i> complex	x		
Aquatic	Gastropoda	Hydrobiidae: <i>Neotaenioglossa</i>			x
Aquatic	Coleoptera	Hydrophilidae: <i>Enochrus</i>			x
Aquatic	Coleoptera	Hydrophilidae: <i>Helochares</i>			x
Aquatic	Ephemeroptera	Leptohyphidae: <i>Tricorythodes</i>			x
Aerial	Lepidoptera	Lestidae: <i>Archilestes grandis</i>	x		

Life Stage	Class or Order	Scientific Name	2012	2013	2015
Aerial	Lepidoptera	Libellulidae: <i>Libellula saturata</i>	x		
Aerial	Lepidoptera	Libellulidae: <i>Sympetrum pallipes</i>	x	x	
Aerial	Lepidoptera	Lycaenidae: <i>Brephidium exile</i>	x		
Aquatic	Diptera	Muscidae			x
Aerial	Lepidoptera	Nymphalidae: <i>Danaus gilippus strigosa</i>	x		
Aerial	Lepidoptera	Nymphalidae: <i>Danaus plexippus</i>	x		
Aerial	Lepidoptera	Nymphalidae: <i>Libytheana carinenta</i>	x		
Aerial	Lepidoptera	Nymphalidae: <i>Vanessa annabella</i>	x		
Aquatic	Oligochaeta	Other_Oligochaeta			x
Aquatic	Gastropoda	Physa_Physella (Basommatophora)			x
Aerial	Lepidoptera	Pieridae: <i>Abaeis nicippe</i>	x		
Aerial	Lepidoptera	Pieridae: <i>Colias eurytheme</i>		x	
Aerial	Hymenoptera	Pompilidae: <i>Hemipepsis ustulata</i>	x		
Aquatic	Diptera	Simuliidae			x
Aquatic	Diptera	Stratiomyidae: <i>Nemotelus</i>			x
Aquatic	Diptera	Tabanidae			x
Aerial	Hymenoptera	Vespidae: <i>Polistes</i>	x		

Hydrological Monitoring and Geomorphology

In late 2013, with the seasonal decrease in evapotranspiration resulting in some surface flow, water quality measurements were taken in multiple Arenas (Table 12).

Table 12. Flow and water quality monitoring data for Pakoon Springs, Grand Canyon-Parashant National Monument, December 17, 2013. Note: data was taken in 3 Arenas and the springbrook. Arena 4 was measured at 3 locations within its boundary.

Variable	Arena					
	3.1a	4.0	4.5	4.7	5	Springbrook
Air Temp (°C)	20.0	18.3	19.4	16.1		20.0
Water Temp (°C)	9.2	23.1	28.7	30.1		15.4
Conductivity (µM/cm@25)	713	469	462	455		705
pH	7.7	7.1	7.7	7.0		7.9
Discharge (gpm)	3.3	83.8	6.0	30.0	1.5	94.6
Discharge Direction	East	South	East	South	South	All

The monitoring flume installed by NPS was destroyed and all but 2 months of data lost in 2013. Repeat flow measurements at the pond outflow prior to pond removal reliably showed a flow of approximately 90 gallons per minute (gpm). After pond removal, surface flows of sufficient size to measure discharge were only visible in Arena 3, 4 and 4E. Arenas 3 and 4E were categorized as low flow (under 1 gpm). Table 13 provides the specific measurements taken at Arena 4.

Table 13. Water quality and quantity measurements from Pakoon Springs.

Date	Location	Water Temp (°C)	pH	Conductivity (µS/cm)	Discharge (gpm)	Dissolved Oxygen %	Dissolved Oxygen mg/L
4/1/2015	Spring brook	31.21	7.55	253		78.4	5.79
7/21/2015	Upper Pool	30.7	7.38	474	low		
7/21/2015	Springbrook				moderate		
3/24/2016	Springbrook	30.93	7.82	407		63.2	4.7
4/2/2016	Springbrook	24	7.48	510	28.5 (partial flow only)		7.35

Figure 14 shows the continuous water temperature (F) and discharge (ft/s) measurements taken in April 2016. Once the permanent weir is replaced, such information is expected to be more

regularly available. In addition, soluble reactive phosphorus and dissolved inorganic nitrogen were measured in April 2016. They were respectively 0.092 mg/L and 0.26 mg/L.

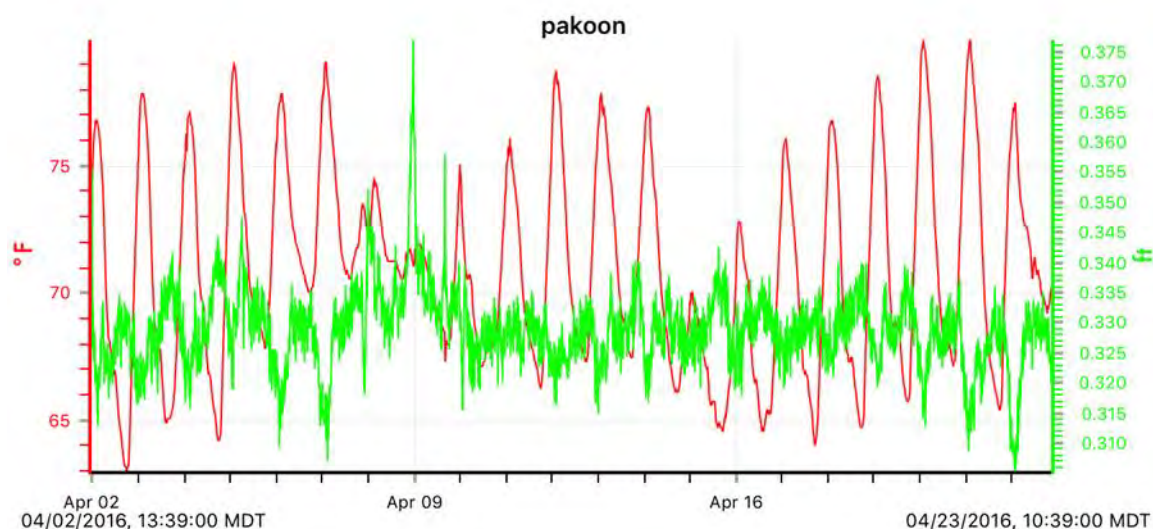


Figure 14. Water temperature (F) and discharge (ft/s) at temporary weir site, Arena 4.

The underlying clays in Arenas 1-4E continued to be periodically exposed. Surface flows are minimal from Arenas 1 and 2. During winter, surface water seeps were observed at the north end of the road. Arena 3 has some ponding caused by the road. Water from Arena 2 and 3 appears to be wearing away at the road rather than flow through the small drain that was installed prior to 2012. Arena 4 continues to settle after the removal of the pond. Small springs that appeared in the modified areas appear to have primarily become damp soil, as opposed to springs bubbling through the newly placed soil. However, this area is becoming thickly crusted with salts, indicating a significant mineral source below the surface. The new springbrook appears to be laying down a travertine layer as the water slows prior to entering the wash. Arena 4E now appears to have several springs and seeps, many above the water level of the drawdown pond and now the springbrook. This area was not disturbed during the pond removal; several of the seeps have appeared and disappeared repeatedly in 2015 indicating perhaps shifts in the area's water table or perhaps the fault system. The wash has also undergone several shifts due to monsoon and winter flows and continues to form a periodically braided channel. The wash is increasingly notably graveled and cobbled in the areas where agricultural soil was pushed into the wash bottom prior to 2004.

Table 14. Pakoon physical data from all arenas, 20 November 2012. Pakoon Creek corresponds to eastern dry wash. Ag Fields 1-3 are the southern agricultural fields (Figure1)

Variable	Arena 5	Arena 1	Arena 2	Arena 3	Arena 4	Arena 4E	Pakoon Cr.	Ag Fields 1-3
% Clay	14.9	30	20	20	30	20	8	30
% Silt	35	40	40	40	60	30	25	70
% Sand	20	0	0	0	0	7	40	0
% Fine Gravel	10	0	0	0	0	7	6.9	0
% Coarse Gravel	10	0	0	0	0	6	5	0
% Large Boulders	5	0	0	0	0	0	4	0
% Small Boulders	0	0	0	0	0	0	1	0
% Bedrock	5	0	0	0	0	0	0.1	0
% Organic soil	0.1	30	40	60	10	30	10	0
% Wet	0	90	60	6	90	35	85	1
Soil Moisture	1	8	6	90	10	8	9	1
% Litter Cover	5	98	98	1	95	85	95	0.01
% Dead Wood Cover	0.01	0.1	0.1	0.1	0	0.1	2	0
Area of open water	0	0.2	0.1	2	1965	8	150	7
Slope Angle	10	1	1	2	0	5	2	7
Area (m ²)	1000	4600	5310	6200	3700	1800	6500	35000
% Precipitation	2	3	2	1	3	2	2	1
Water Depth (cm)	0	2	1	1	200	5	20	0
Slope Variability	medium	low	low	low	low	low	low	medium

Soil data was collected in 2012 (Table 14). This soil profile is expected to be relatively constant until decaying vegetative material builds up at the site. In 2014, AGFD produced a highly detailed slope analysis map to help guide restoration efforts (Figure 15). The map was used to determine the berms at the south end of the fenced area were indeed blocking overland flow.

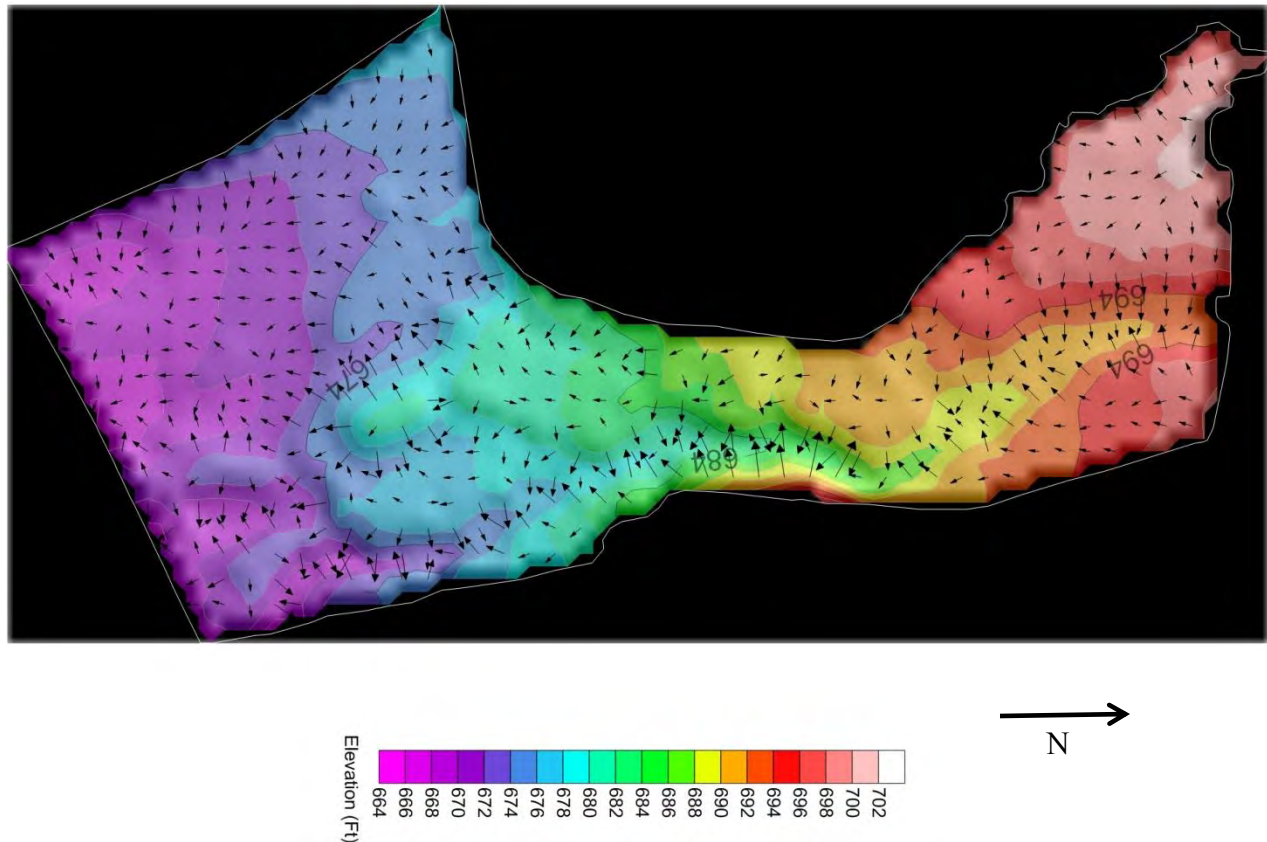


Figure 15. Vector map of slope and expected overland flow.

TASK 9. IMPLEMENT TRANSLOCATION OF LOCAL RARE SPECIES

In light of the new factors and the continued presence of *Gambusia* and bullfrog, AGFD and USFWS have not determined the site is ready for any of the translocation activities onsite.

Parashant National Monument, USFWS and AGFD remain committed to translocating these three species once the environmental and legal conditions are appropriate. Once AGFD and USFWS are satisfied the site is ready for successful introduction of each species, Parashant staff will provide assistance as needed.

TASK 10. IMPLEMENT VISITOR EDUCATION AND OUTREACH

Visitor outreach at this time is a combination of informal contacts and educational infrastructure provided under other funding sources. Several questions are received per week at the visitor center during cooler months regarding directions to the springs. Few questions go beyond directions, though if a visitor appears interested, they may be treated to a story of the infamous alligator at Pakoon Springs.

A three panel information kiosk was installed at the current parking location with funding from an Arizona Off Highway Vehicle grant (Figure 16). The kiosk includes a map, OHV and travel safety, site etiquette, story of Clem the alligator and basic information about Pakoon Springs.



Figure 16. An information kiosk at Pakoon Springs was funded by an Arizona Off Highway Vehicle grant.

This kiosk continues to provide the major source of information at the site for visitors. In addition, carsonite signs indicating Arizona statue § 17-308 (no camping within $\frac{1}{4}$ mile of water) were posted in 2013 within the perimeter fence of Pakoon Springs.

Once environmental compliance is completed for the proposed new parking area, the current kiosk would be moved to the edge of the parking area. Additional signage indicating the trail would be developed to help visitors find the new pass through gate in the outer boundary fence.

The Interagency Information Center is still in the very early planning stages and no plans for specific exhibits have been developed.

Pakoon Springs will continue to be highlighted in Parashant interpretive materials. It is anticipated that the avenues of visitor outreach and education outlined in Task 3.5 will continue to be followed as requirements of policy and the Self Evaluation and Transition Plan³ (SETP) evaluation allow. Until the SETP team can provide their evaluation (Fall 2016), all new interpretive products on Parashant are on hold. Steps that are anticipated within the next year include:

1. Updating the information (with image) in the Parashant National Monument brochure map
2. Moving the information kiosk at Pakoon Springs to a new location nearer the main county road
3. Incorporating Pakoon Springs more fully in the National Park Service website for Parashant National Monument

TASK 11. IMPLEMENT CONSTRUCTION OF VISITOR FOOTPATHS AND BOARDWALKS

Considerations for staff safety, including extreme temperatures, SETP requirements, additional environmental compliance and heavy equipment scheduling has delayed the field implementation of this phase of the project until Fall 2016. With the changes to the site to better guide visitors in their approach to the springs and protect the investment in riparian rehabilitation, additional environmental compliance was necessary. This process, while not complete, should result in visitor infrastructure in compliance as well with the Architectural Barriers Act of 1968.

The trail design now has additional considerations. A SETP for accessibility for persons with disabilities is in process at the Monument. Trail design features and future visitor outreach and education materials (interpretive materials) will be informed by this plan.

In Fall 2016, construction is planned once environmental compliance is complete, temperatures have decreased to a safe level and heavy equipment is available. This construction includes elements from several aspects of the project.

1. Replace weir/flume damaged during Fall 2013 flood
2. Build bat run for wildlife and as a visitor focal point
3. Move parking area to new location and rehabilitate old parking area
4. Move kiosk to new parking area

³ Self Evaluation and Transition Plan (SETP) is part of a National Park Service initiative to “mak[e] facilities, programs, services, and employment accessible for visitors and employees with disabilities through compliance with the Architectural Barriers Act of 1968, the Rehabilitation Act of 1973, and the Americans with Disabilities Act of 1990.” (<https://www.nps.gov/aboutus/accessibilityforvisitors.htm>). Once the Monument was notified it would be undergoing a SETP evaluation, under Service First authority, all public use facilities and visitor outreach projects that were not already completed were temporarily paused until the evaluation could take place. This included the visitor infrastructure at Pakoon Springs to be constructed or implemented during this grant.

5. Install outer fence gate on new trail
6. Following any short-term recommendations from the SETP, build/indicate trail inside the outer fence.

As funding and equipment become available

1. Build new inner fence
2. Install trail gates in fence
3. Incorporate any long-term recommendations from the SETP.

DISCUSSION AND CONCLUSIONS⁴

EARTHWORK

Over the life of the entire Pakoon Springs rehabilitation project, earthmoving activities have generally shifted the hardscape to a more natural-appearing landscape. Ponds now resemble spring mounds and seeps; flattened agricultural fields have dips and sways. During this grant, though not part of the funding request, the final pond was removed, making the entire site look much more like an unmodified desert spring complex. Also, the artificial berms at the southern end of the fenced ranch core were removed, reconnecting the area to the existing wash system to the west of the large dry wash on the eastern edge of the fenced area.

Under this grant, specifically, the agricultural fields were recontoured to mimic landforms in the Pakoon Basin and gabions were placed to reduce headcutting due to the new flows from Arena 4. The contouring did indeed help change the share of the agricultural fields from a flat series of steps to a more gently rolling appearance. Due to the nature of the soils, however, erosion on the new slopes and swales is quite noticeable at this time. It was discovered, using aerial imagery not available at the time the recontouring occurred, that the predominant direction of the swales prior to agricultural use was in a north-south direction, not an east-west orientation as was constructed. Though this reorientation may have decreased the erosion activity in the agricultural fields, the fine particle clays would still should severe erosion until the site can support much more vegetation and biological soil crusts.

Gabions were placed in the dry wash in response to headcutting in a wash where annual and perennial flow was largely unknown for any distance after the site was developed agriculturally until the new outfall from Arena 4 was constructed. The wash no longer resembled the more natural sections of wash to the north or south of the Pakoon Springs ranch due in part to the deposition of spoil dirt in the wash while the agricultural fields were being created and maintained. Again, lack of data hampered the effectiveness of the modifications under this grant. Only recently was a program readily available to determine the expected flows down what appeared to be a wash that almost never flooded. Unfortunately the gabions, with the exception of Gabion 1 acted in a manner contradictory to their purpose. Headcutting was minimized at those chosen installation locations temporarily. The earthmoving during installation did help slow the headcutting until new cuts were discovered behind two of the structures the following the monsoon season. At the same time, pool were developing either behind or below three of the gabions, providing another habitat for invasive American bullfrog to successfully breed. The gabions were contradictory to their purpose the first year of high flows the year after installation. They constricted the monsoon rain flow through the wash, decreasing the ability the water to widen the wash bottom and remove some of the agricultural fields that had encroached on the probable historic wash bottom. The increase in force was sufficient to damage severely three

⁴ To more fully discuss the aspects of this project, some activities not covered under this current grant may be incorporated into the discussion.

gabions and actually entirely move a fourth. The tangled mass of wire and rock was removed from the wash for aesthetic reasons and also to avoid harm to wildlife.

The gabion damage did have an unanticipated positive outcome. The rock collected for the gabions was left in the wash bottom after the gabion were removed, armoring sections, and to this date, preventing active headcutting in the channel. In addition, the creation of swales in the agricultural fields did expose the mollisol (organic rich and fertile) layer in the agricultural fields, most likely from the riparian/bosque areas that were plowed under after 1950. While the mollisols are not near the surface (rough estimate was at least 4 feet under the surface layer), it does show the site has the ability to develop an organic layer from leaf litter over time.

VEGETATION

As Pakoon Springs has recovered from the several earthmoving events, invasion by burros, and flooding during the rehabilitation process, the vegetative structure and species prevalence has changed dramatically. The vegetation of Pakoon Springs was on a positive trajectory in 2012. The number of species and growth forms was increasing and vegetative cover of scraped bare ground was expanding. Plantings of some species were doing well, other planting were less successful, due to several factors including a shifting water table and the difficulty of successfully transplanting certain species. By late 2012, even though there had been an incursion by trespass cattle, the vegetative community was doing well. In 2012 and 2013, however, burros began seriously impacting the site. Combined with the death of several large cottonwoods, Arenas 1-3 shifted from a community dominated by trees and shrubs to one primarily of yerba mansa. Arena 4, in part due to the activities necessary to continue bullfrog removal, saw a decrease in species diversity, with nearly all the plants in Arena 4 belonging to only 3 species. However, the pond drawdown necessary to remove bullfrogs illuminated a surprising fact; there existed a riparian seedbank in the agricultural fields. The flood in 2013 showed that there was a viable seedbank for upland species as well.

The Pakoon Spring complex is undergoing rapid shifts in vegetation and flow as the site responds to rehabilitation work and natural successional processes (Figures 17-19). The site vegetation is becoming more complex as species react to increasing zonation in light and soil moisture by partitioning the site into areas of mixed species and monocultures based on acceptable environmental variables for each species. It is expected that this resource partitioning will continue.



Figure 17. April 2011. Arena 3 &5. Note standing water indicated by red arrow.



Figure 18. May 2012. Arena 3. No open standing water found in Arenas 1-3, 5. All surface water in those arenas dominated by *Typha*.



Figure 19. July 2014. Arena 2-3. No standing water found in Arenas 1-3, 5. Note shift to willow and *Anemopsis*-dominated landscape.

The large increase in the number of species observed from 2010 to 2016 is not necessarily indicative of an increase in actual number of species. In 2015 and 2016, surveys were done by professional botanists in a rigorous survey pattern; previously the identifications had been done by an evolutionary ecologist who is not a taxonomic expert on Mojave Desert vascular plants on an ad hoc basis. This situation would be expected to generate a larger species list of the Pakoon Springs Ranch once primary subject matter experts were involved. However, in general, the number of species does appear to be increasing in response to a larger riparian/wetland area, decreased disturbance from earthmoving and agricultural activities and a robust seed bank.

Invasive plants will continue to be at Pakoon Springs for some time to come. Plants that could be readily removed after the work done by EPMT were dealt with during this grant, and will continue to be removed. Larger scale invasives are at the springs, though not necessarily annually. Brome, or cheatgrass, is in the area. Treating it at the springs is not a viable option since the surrounding landscape also is infested with brome. Other invasives such as Russian thistle are at the site and may be treated with herbicides used for outbreaks of other invasive plants. Russian thistle is quickly evolving resistance to a wide variety of herbicides, so the best course of action may be to allow the biological soil crust to develop and the soil surface to “seal”. A notable outbreak of *Schismus* sp. occurred in 2015, covering the agricultural fields in a uniform green layer. The grass disappeared after a brief monsoonal downpour in late summer, and though the grass persists at the site, it is found only a a very limited area.

FAUNA

Surveys conducted over the span of this grant have found that Pakoon Springs is used by a diverse group of organisms. Baseline data has been collected for aquatic insects after the removal of the Arena 4 pond and for bats under other fund sources. Small mammal baseline data has been collected under this grant. Other data has been collected for birds, large mammals, amphibians and aerial insects. While this latter set of data is not exhaustive, it does provide insight into the animals at the springs. In 2012, casual observations found 16 species of vertebrate animals at Pakoon Springs. In 2015 and 2016 surveys and casual observations found 28 species. It is anticipated that when the reptile survey is completed this number will grow.

Invasive animals continue to be a stumbling block for the future introduction of rare vertebrates to Pakoon Springs. The continued occurrence of American bullfrog and mosquitofish, hamper the anticipated introduction of Grand Wash springsnail, speckled dace and relict leopard frog. Once they are determined to no longer be a detriment, introductions can begin.

On a positive note is the evidence the springs are being used by high conservation priority rare bats and bighorn sheep, in addition to a group of animals that are representative of the eastern Mojave Desert. As the site vegetation and water resources continue to develop, it is expected that an increasing number of species may visit or inhabit the site. With the conversion of the site to seeps and shallow water, the springs complex may begin to attract shallow water wading birds in greater numbers as well as mammals that would forage in the shallow waters.

HYDROLOGY

The surface flows at Pakoon Springs continue to rapidly change. As might be expected after the major earthmoving in 2008, surface water has appeared and disappeared and changed flow direction throughout the springs complex. Some early extrapolations based on geology of pre-development flow patterns have been verified by aerial photography going back to 1950. Other predictors of flows patterns have been less precise. As the soils settle and vegetation expands at the site, surface flows are expected to continue changing. Major flows are seen to the east from Arena 4 from the old pond. Smaller flows are seen from Arena 3 and 4E, both to the east. These seem, at this time, to be perennial flows.

Flows into the dry wash are now much more variable than when the pond was in Arena 4. Changing the steep sided pond into a springbrook increased the riparian area, increasing vegetation taking up water. Shifts in the wash bottom in response to high water events has created sinks where water may travel underground for a distance and then reappear downstream one year and long linear flows the next.

Beyond the springs complex, Pakoon Springs Ranch has become reconnected on the west and south to the surrounding floodplain. Western connection was accomplished by the 2013 high water event with naturally occurring flows interacting with the upper agricultural fields (Figure 10). Southern connection was accomplished during pond and gabion removal. Based on the

surface flow modeling done by AGFD (Figure 15) and the historic aerial imagery (Figure 20), the two berms near the southern end of the fenced ranch core blocked predevelopment overland flow from the north and from the hill next to the springs. While the northern wash is still blocked by the access road, opening the southern end does provide an alternate flow path for rainwater flowing down the hill.

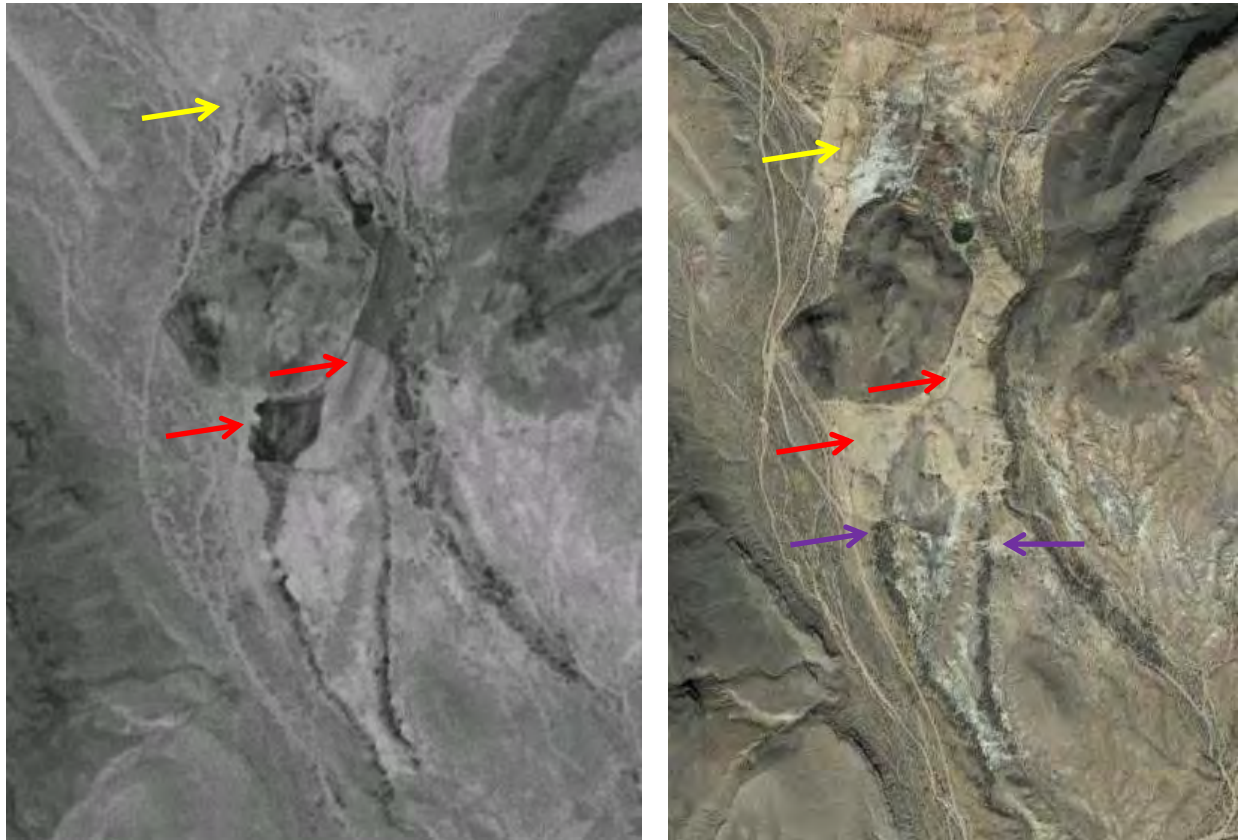


Figure 20. Aerial imagery Pakoon 1950 (left), 2013 (right). Red arrows denote southern washes no longer connected to surrounding landscape by 2013. Yellow arrow indicates northern wash turned into agricultural fields and partially reconnected to the surrounding landscape following the high water event of 2013. Purple arrows indicate berms removed to relink Pakoon Springs to the surrounding landscape.

Monitoring wells will continue to provide insight into the larger hydrology of the springs. After a cobble layer with water was discovered ten feet underground in the agricultural fields well away from the springs and their anticipated direction of subsurface flow, Pakoon Springs continues to challenge our expectations.

CONFOUNDING FACTORS

Overall this project completed six out of twelve tasks, completed another two tasks that will continue (weed and invasive animal eradication) and partially completed a ninth (not all monitoring activities in Task 8 were completed before the end of the grant). The incomplete tasks will be done over the coming years as the site develops and as part of the Monument's commitment to the rehabilitation of Pakoon Springs. Several factors slowed the project and are addressed here.

- Sequestration

In October 2013, the federal government was shutdown. This meant that all work on federal lands was halted until mid-October, including work under outside grants and by cooperators. Planned activities such as monitoring for Fall 2013 did not occur. Under sequestration, funds were removed from several projects, including Pakoon Springs Rehabilitation to cover agency shortfalls. The period of sequestration and government shutdown had a secondary effect in that heavy equipment was not available until late Spring 2014 for this project, which intersected with Factor 2 below.

- Security risks in the area (government employee safety concerns)

Starting in March 2014, access to Parashant National Monument was restricted for federal employees ("safety stand down"). Specific to the Monument, this varied from complete avoidance of the Arizona Strip to a closure of the Pakoon Basin. All planned work in 2014 at Pakoon Springs was delayed due to security concerns. Table 3 shows the only approved site visit in 2014 after the March safety stand down.

To date, the western access to the Monument remains closed to non-essential federal staff. Periodic safety stand downs in 2015 and 2016 have had less of an effect on monitoring and later steps in the grant.

- Weather/Climate

While trips in summers and winters for bullfrog removal and monitoring are feasible, heavy equipment modifications and revegetation efforts are not. Equipment operators must work during daylight hours for weeks at a time, a difficult work environment. During winters, with the new cross-Monument travel routes required due to the safety concerns, equipment must be transported over dirt roads in mud, snow and ice. This is strongly discouraged by management for personal safety and also because of the damage to the roads. Revegetation work has the greatest result during ideal climatic conditions, depending on species. Planting too soon to winter cold and summer heat greatly reduces the viability of even transplanted plants. This limits certain of the tasks in this grant to Fall and Spring. Missing a window due to other issues means the project may be set back 6 months to a year.

- Monsoonal water

The high water of 2013 and subsequent damage was unexpected. New data suggests that the return interval for the sort of event in 2013 may be as low as five years. The damage to the infrastructure placed under this grant directly caused by the event is not the focus in this section, except to note that extensive work was necessary to deal with the damage. Instead, this section focuses on the problems and surprises this high water event presented.

The road closure due to the event delayed the anticipated September riparian monitoring until 4 days before the October 2013 government shutdown – too short a time period for cooperators to schedule a trip from their base in Flagstaff. The monitoring cooperator, Grand Canyon Wildlands Council (GCWC) was not able to schedule a trip until December 2013.

Over 800 linear feet of boundary fence was damaged by the high water event. Combined with other factors, this fence was not repaired until 2015, thus allowing burros to freely access the site. This restricted new vegetation establishment.

The high water also provided a chance for Pakoon Springs to once again be visibly connected to the surrounding watershed. The upper agricultural fields regained a more typical rocky Mojave Desert soil surface due to flows down the main wash. The dry wash to the east also began to take on the characteristics seen north of the modified area, with a soft silty wash bottom becoming a mix of rock, cobble, sand and silt.

This event ultimately damaged the modifications to the site constructed under the grant but provided valuable large scale site changes that aided in the site rehabilitation to a more natural Mojave Desert landscape.

- New directives

Over the life of this and the previous grant, changes in policy and understanding of the spring complex modified how the project was approached. Two examples are: 1) initially, the pond in Arena 4 was kept for many reasons, including as a fire “dip”. Once the site was no longer by the BLM fire division, and the growing understanding that the pond was providing excellent breeding habitat for American bullfrog while posing a hazard to visitors and large wildlife, the pond was removed. 2) bat surveys showed that Pakoon Springs was being used by five species of bats listed as BLM Sensitive Species. Maintenance of habitat suitable for bats became incorporated into the design of the site. While this is outside the grant, these considerations came to light during the life of the grant. Other shifts included large scale priority changes at the agency level.

- Pesticide moratorium

The short-term moratorium on the use of rotenone (February 2011-June 2012), while not a major factor in the overall grant, did reduce the ability to remove mosquitofish. This

had a cascading effect on the introduction of rare species. While the use of rotenone may not be as effective as when the pond was in place, its use has not been ruled out. It may be revisited once the backlog of high priority uses by AGFD has been dealt with.

- Changes in personnel

Over the life of this project, there have been two project managers, two subcontractors (mix of agreements and contracts), two Monument managers and multiple technical representatives at the Monument alone. Other changes occurred with our partner agencies as well. Each time there was a shift in personnel, delays occurred as the new person or group was read in on the project. Changes did not occur during downtimes and were rarely scheduled. Over the span of a 5 year project, this turnover is not surprising, but it did slow the project.

RECOMMENDATIONS

This project was a success in moving Pakoon Springs toward a more natural system capable of acting as a self-sustaining Mojave Desert spring complex. The following are recommendations on how to improve on such projects, especially ones with many interdependent components.

- Timelines

This project assumed that each step would be quickly and completed and finalized and that no other factors would interfere with task completion. AWPf was kind enough to provide extensions to this grant. As can be seen in the above section, however, few steps were able to be finalized or completed exactly as scheduled. Timelines need to be flexible to account for delays beyond the control of the grantee such as weather, safety concerns and direction from other agencies (AGFD and USFWS will decide when the springs are ready for species introductions) or levels of control (federal government shut down). They also need to be flexible for changes needed after the task is assumed to be complete, such as the flood damage to the gabions after the task was formally completed. This becomes particularly important when several later tasks are predicated on the stability and finalization of a single previous task.

- Site visits

If possible, site visits to the project area by the grantor would be helpful. Especially with staff turnover, this would help bolster the connection between the grantee and the grantor as well as provide on the ground feedback for the grantee on the project's progress.

- Outside agency considerations

This grant could not have been carried out without the support of AGFD, USFWS and NPS. Each agency had its own considerations that needed to be dealt with for this project. For example, AGFD had to consider other workload, a moratorium on rotenone use and changes in personnel. NPS had new directives that directly impacted this project for the final tasks because the Monument is managed under the Service First authority. USFWS could not permit introductions of potentially Endangered Species Act listed species to occur without the habitat being acceptable.

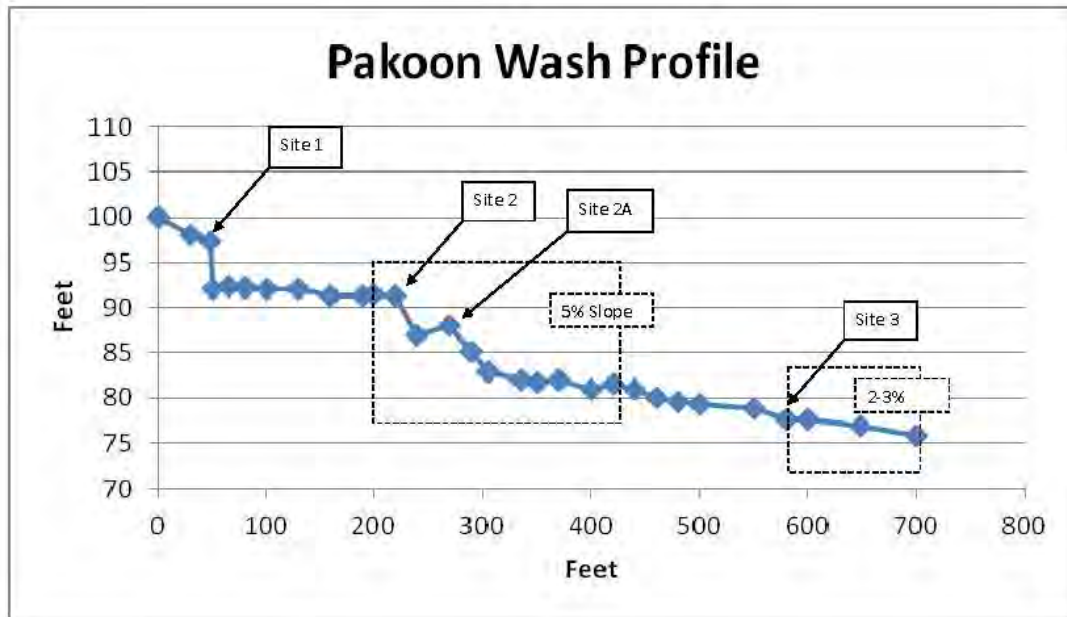
While this project is an example of four agencies working together very well, the other agency priorities, schedules and needs should have been accounted for and directly stated in the planning phase.

LITERATURE CITED

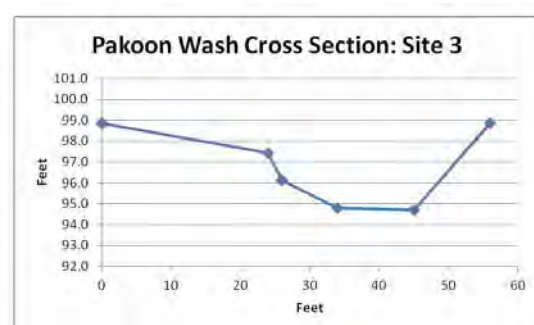
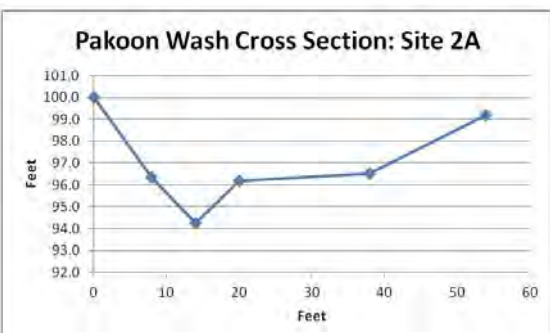
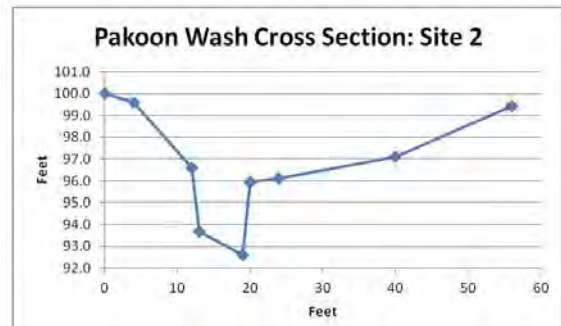
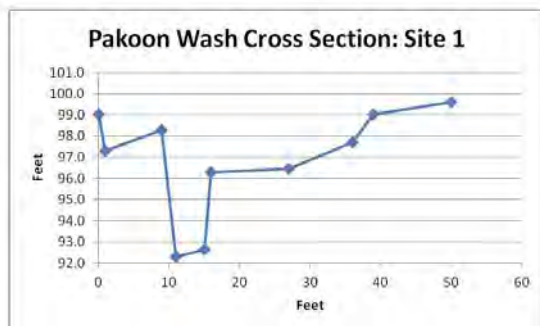
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APPENDIX A. EARTHWORK AND GABIONS

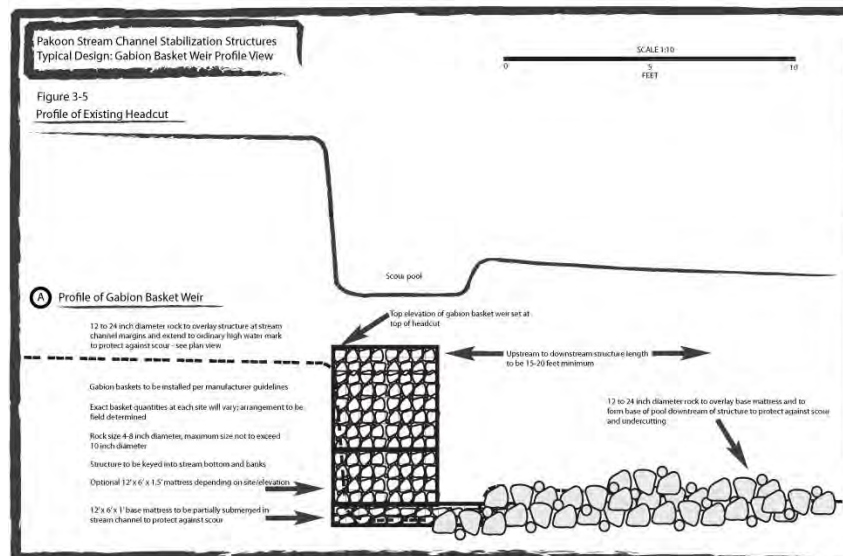
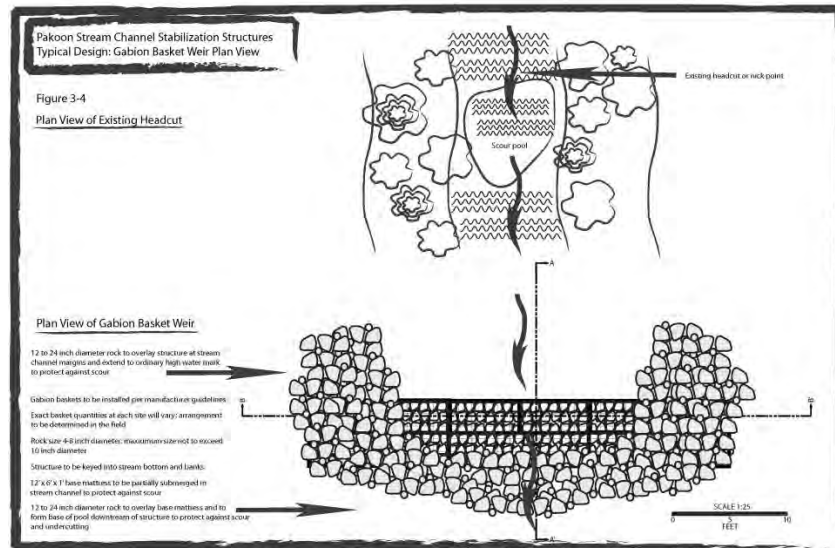
Pakoon Wash Profile prior to installation of gabions

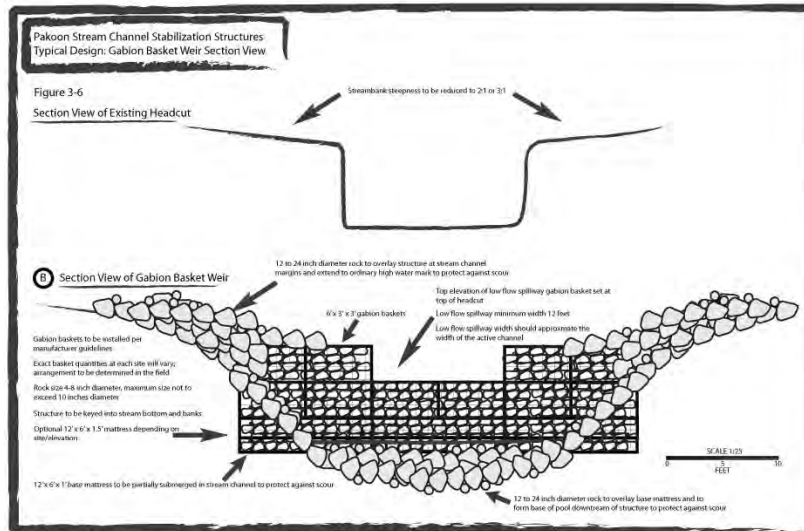


Cross sections of each chosen gabion site prior to gabion installation



Gabion design specifications





Immediate pre and post gabion construction 2011-2012



Site 1 pre-construction upstream view March 2011.



Site 1 post-construction upstream view April 2012.



Site 1 post-construction upstream view April 2012.



Site 1 post-construction upstream view April 2012.



Site 2 pre-construction upstream view March 2011.



Site 2 and Site 2A construction sequence March 2012.



Site 2 and Site 2A construction sequence March 2012.



Site 2 and Site 2A construction sequence completion March 2012.



Site 2B pre-construction upstream view March 2011.



Site 2B upstream view April 2012.



Site 3 pre-construction upstream view March 2011.



Site 3 construction sequence March 2012.



Site 3 construction sequence March 2012.



Site 3 construction sequence completion March 2012.

Movement of materials from wash bottom to agricultural fields



Gabion Monitoring

Gabion 1



6/6/2012



4/10/2013



9/22/2013



12/17/2013

Gabion 2

	
6/6/2012	4/10/2013
	
9/22/2013	12/17/2013

Gabion 3

	
6/6/2012	4/10/2013
	
	12/17/2013

Gabion 4



6/6/2012



4/10/2013



9/22/2013



12/17/2013

Gabion 5



6/6/2012



4/10/2013



9/22/2013



12/17/2013

**APPENDIX B. LAKE MEAD EXOTIC PLANT MANAGEMENT TEAM INVASIVE
PLANT REMOVAL 2010-2011 AT PAKOON SPRINGS.**

Date	Taxon	Treatment	Infested (acre)	Inventoried (acre)	Treated (acre)
3/30/2010	<i>Centaurea stoebe</i> <i>ssp. micranthos</i>	Foliar-Ground-Spot	0.13	13.04	0.13
3/30/2010	<i>Centaurea stoebe</i>	Pull/Dig-Manual	0.0007	0.004	0.0007
4/4/2010	<i>Centaurea stoebe</i> <i>ssp. micranthos</i>	Foliar-Ground-Spot	0.045	34	0.045
4/4/2010	<i>Salsola tragus</i>	Foliar-Ground-Spot	0.106	34	0.106
4/4/2010	<i>Tamarix</i> <i>ramosissima</i>	Cut/Stump	0.0069	34	0.0069
4/27/2010	<i>Centaurea stoebe</i> <i>ssp. micranthos</i>	Foliar-Ground-Spot	0.0003	89	0.0003
4/27/2010	<i>Salsola tragus</i>	Foliar-Ground-Spot	0.135	89	0.135
4/27/2010	<i>Salsola tragus</i>	Pull/Dig-Manual	0.001	0	0.001
4/27/2010	<i>Tamarix</i> <i>ramosissima</i>	Foliar-Ground-Spot	0.0002	0	0.0002
4/27/2010	<i>Tamarix</i>	Pull/Dig-Manual	0.003	89	0.003
4/28/2010	<i>Centaurea melitensis</i>	Foliar-Ground-Spot	0.116		0.116
4/28/2010	<i>Salsola tragus</i>	Foliar-Ground-Spot	0.014		0.014
4/26/2011	<i>Centaurea melitensis</i>	Foliar-Ground-Spot	0.017	79.26	0.017
4/26/2011	<i>Salsola tragus</i>	Foliar-Ground-Spot	0.017	79.26	0.017
4/26/2011	<i>Strigosella africana</i>	Foliar-Ground-Spot	0.017	79.26	0.017
4/27/2011	<i>Brassica tournefortii</i>	Pull/Dig-Manual	0	0	0
4/27/2011	<i>Centaurea melitensis</i>	Foliar-Ground-Spot	0.168	0	0.168
4/27/2011	<i>Salsola tragus</i>	Foliar-Ground-Spot	0.168	0	0.168
4/27/2011	<i>Strigosella africana</i>	Foliar-Ground-Spot	0.168	0	0.168
4/28/2011	<i>Centaurea melitensis</i>	Foliar-Ground-Spot	0.05	0	0.05
4/28/2011	<i>Centaurea melitensis</i>	Foliar-Ground-Spot	0.124	0	0.124
4/28/2011	<i>Salsola tragus</i>	Foliar-Ground-Spot	0.25	0	0.25
4/28/2011	<i>Salsola tragus</i>	Foliar-Ground-Spot	0.01	0	0.01
4/28/2011	<i>Strigosella africana</i>	Foliar-Ground-Spot	0.01	0	0.01
4/28/2011	<i>Strigosella africana</i>	Foliar-Ground-Spot	0.25	0	0.25
4/29/2011	<i>Centaurea melitensis</i>	Foliar-Ground-Spot	0.1	0	0.1
4/29/2011	<i>Salsola tragus</i>	Foliar-Ground-Spot	0.1	0	0.1
4/29/2011	<i>Strigosella africana</i>	Foliar-Ground-Spot	0.2	0	0.2
4/29/2011	<i>Tamarix</i>	Basal Bark	0.006	0	0.006
4/30/2011	<i>Centaurea melitensis</i>	Foliar-Ground-Spot	0.264	0	0.264

4/30/2011	<i>Marrubium vulgare</i>	Foliar-Ground-Spot	0.001	0	0.001
4/30/2011	<i>Salsola tragus</i>	Pull/Dig-Manual	0.132	0	0.132

APPENDIX C. RARE SPECIES WORKSHOP PARTICIPANTS.

Name	Title	Affiliation
Jennifer Fox	Ecologist	NPS-Parashant
Tom Jones	Amphibians and Reptiles Program Manager	AGFD
Susi McVean	Nongame Specialist	AGFD
Steve Rosenstock*	Habitat Program Manager, Flagstaff Region	AGFD
Jeff Sorensen	Native Fish and Invertebrate Program Manager	AGFD
Mike Sredl	Coordinator, Ranid Frogs Program	AGFD
Mark Wimmer	Acting Monument Manager	BLM-Parashant
Brian Wooldridge	Fish and Wildlife Biologist	USFWS
Jeff Young	Wildlife Biologist	BLM-Parashant

* unable to attend, however consulted with several attendees prior to workshop

APPENDIX D. WATER QUALITY PARAMETER COMPARISONS

Location	Discharge l/m	Temperature C	Conductivity μS	pH	Dissolved Oxygen mg/L	Salinity ppt	Sum* TDS mg/l	Data Source
Grapevine Spring	10	20.9	639	7.8	1.02	0.2		MOJN 2006
Pakoon Spring	220	30.0	491	6.9	122.3		442	GCWC 2000
Pakoon Spring C**	100	19.4	480	7.6	5.47	0.3		MOJN 2006
Pakoon Spring D (lower wash)	5	18.5	740	7.6	2.4	0.4		MOJN 2006
Pakoon Spring E (lower wash)	40	19.5	650	7.3	0.72	0.4		MOJN 2006
Pakoon Upper pool	low	30.7	474	7.38				AGFD 2015
Pakoon-New Spring	low	26.1	538	7.44				AGFD 2015
Tassi Spring	288	24.7	567	6.9	83.1		129	GCWC 2000
Tassi Spring		24.3	528	7.43	6.82			MOJN 2014
Tassi Spring	100	25	500	7.8	6	0.2		MOJN 2006
Tassi Spring	13	24.8	538	7.5	n/a		98	GCWC 2001
Whiskey Spring	low	23.9	709	7.53				AGFD 2015
Whiskey Spring	1	19.1	626	6.7	6.1		383	GCWC 2000
Whiskey Spring	damp							MOJN 2006

Location	Ca mg/l	Mg ml/l	Na mg/l	K mg/l	Cl mg/l	SO ₄ mg/l	HCO ₃ ALK mg/l	CaCO ₃ Alk mg/l	NO ₃	NH ₃	PO ₄	Data Source
Pakoon Spring	99.2	19.0	18.0	13.0	57.2	50.3	185	152	0.8	0	0	GCWC 2000
Tassi Spring	45.7	28.0	25.2	2.6	27.2	84.0	169	139	2.60	<0.0 3	0.00	GCWC 2000
Tassi Spring	43.5	21.9	21.3	3.1	8.6	106. 3	161	132	2.20	0.02	0.05	GCWC 2001
Whiskey Spring	50.6	26.5	17.0	2.1	8.1	88.4	190	156	0.1	<0.0 2	0.0	GCWC 2000

Location	Water Depth Avg cm	Water Width cm	Emergent Cover %	Bank Cover %	Silt %	Sand %	Gravel %	Cobble %	Boulder %	Bedrock %	Data Source
Grapevine Spring	1	10	100	100	100	0	0	0	0	0	MOJN 2006
Pakoon Spring C**	10	500	100	100	100	0	0	0	0	0	MOJN 2006
Pakoon Spring D (lower wash)	30	150	100	100	100	0	0	0	0	0	MOJN 2006
Pakoon Spring E (lower wash)	8	100	40	100	100	0	0	0	0	0	MOJN 2006
Tassi Spring	5	75	80	100	10	20	70	0	0	0	MOJN 2006

* Sum of cations and anions

** Measurements were not taken in Arena 4 during MOJN 2006 survey. Spring C (Arena 3) is closest analog to Arena 4/Upper Pool

APPENDIX E.

REPEAT IMAGERY

Photopoint 1



11/2012



1/17/2014

Photopoint 1 & 2 overlap

AWPF #11-180WF



3/11/2016

Photopoint 2



11/20/2012



12/17/2013



3/11/2016



6/1/2016

Photopoint 3



2/13/2013



AWPF #11-180WF

3/11/2016

Photopoint 4



10/17/2012

AWPF #11-180WF

Photopoint 5



4/8/2015



7/22/2015

AWPF #11-180WF



3/11/2016



6/1/2016

APPENDIX F. VEGETATION DATA COLLECTED 2012-2016

Table A1. Pakoon Vegetation by Stratum within Arenas. November 20, 2012: Strata: GC - Ground Cover (Deciduous, Non-Woody); SC - Shrub Cover (0-4 M Woody); MC - Middle Canopy (4-10 M Woody); TC - Tall Canopy (>10 M Woody).

Species	Stratum	Visually estimated percent cover by arena							
		Arena 5	Arena 1	Arena 2	Arena 3	Arena 4	Arena 4E	Pakoon Cr.	Ag Fields 1-3
<i>Anemopsis californica</i>	GC	5.00	3.00	5.00	8.00	0.01		3.00	
<i>Aster subulatus</i>	GC		0.20				0.20		
<i>Atriplex laevis</i>	GC		1.00			0.10			5.00
<i>Bromus rubens</i>	GC	1.00					0.10		
<i>Eustoma exaltatum</i>	GC					0.01			
Chenopodiaceae (white annual)	GC		0.10	0.10	0.10	0.10			
<i>Convolvulus</i>	GC			0.10					
<i>Cynodon dactylon</i>	GC		2.00	8.00	8.00	8.00	8.00	0.10	3.00
<i>Datura wrightii</i>	GC		0.10	0.10	0.10	0.10	0.10	0.10	0.20
<i>Distichlis spicata</i>	GC		18.00	10.00	8.00	5.00			
<i>Eleocharis</i>	GC		1.00	1.00	2.00	0.10	5.00	2.00	
<i>Erodium cicutatum</i>	GC		0.50			0.10	2.00	0.10	1.00
<i>Heleotropium curassavicum</i>	GC		0.01			0.10		0.30	
<i>Helianthus annuus</i>	GC		12.00	15.00	18.00	6	40.00	8.00	1.00
<i>Lactuca nr. seriola</i>	GC						0.20		
<i>Marrubium vulgare</i>	GC			0.10					
<i>Melilotus</i>	GC		1.00	1.00	0.10	1.00	1.00	0.10	
<i>Populus fremontii</i>	GC								
<i>Prosopis glandulosa</i>	GC							0.10	
<i>Salix gooddingii</i>	GC			0.10					
<i>Salsola iberica</i>	GC		0.50	0.10	0.10	1.00	1.00	1.00	9.00
<i>Schoenoplectus americanus</i>	GC		1.50	3.00	10.00		2.00	2.00	
<i>Senecio multilobatus</i>	GC							0.01	0.01
<i>Sidalcea</i>	GC						0.01		
<i>Solanum angustifolia</i>	GC		0.20	0.10		0.20	0.01		
<i>Sphaeralcea</i>	GC	0.01						0.10	
<i>Tamarix ramosissima</i>	GC						0.01	0.01	
<i>Typha domingensis</i>	GC		8.00	20.00	5.00	15.00	5.00	10.00	
Vine sp	GC							0.1	
<i>Morus</i> spp. (mulberry)	MC				0.01				
<i>Populus fremontii</i>	MC		4.00	4.00	1.00				

<i>Salix gooddingii</i>	MC		8.00	7.00	7.00	3.00	10.00	10.00	
<i>Acacia greggii</i>	SC							1.00	3.00
<i>Atriplex canescens</i>	SC							0.1	1.50
<i>Atriplex lentiformis</i>	SC		2.50	2.00	12.00	2.00	1.00		
<i>Baccharis salicifolia</i>	SC	0.20	0.10			1.00	3.00	18.00	1.00
<i>Baccharis sergiloides</i>	SC	0.50	0.30						
<i>Cylindropuntia whipplei</i>	SC								0.20
<i>Encelia farinosa</i>	SC								0.10
<i>Isocoma acedenus</i>	SC	30.00	13.00	4.00	10.00	1.00	5.00	5.00	1.20
<i>Larria tridentata</i>	SC				0.20			1.00	
<i>Morus</i> spp. (mulberry)	SC				0.50				
<i>Opuntia phaeacantha</i>	SC				0.30				
<i>Phoradendron californicum</i>	SC							0.20	1.00
<i>Populus fremontii</i>	SC		4.00	2.00	1.00				
<i>Prosopis glandulosa</i>	SC	8.00	1.00	0.10	2.00	1.00	1.00	8.00	3.00
<i>Prosopis pubescens</i>	SC		2.00	1.00	0.3	0.10	1.00		1.00
<i>Salix exigua</i>	SC		4.00		0.30			5.00	
<i>Salix gooddingii</i>	SC		8.00	18.00	10.00	10.00	18.00	20.00	
<i>Sueda</i>	SC		10.00	2.00	2.00	0.10	2.00	1.00	
<i>Tamarix ramosissima</i>	SC							0.10	
<i>Tessaria sericea</i>	SC				3.00	15.00	5.00	8.00	4.00
<i>Vitis arizonica</i>	SC							3.00	0.10
<i>Washingtonia</i>	SC			0.10					
<i>Yucca brevifolia</i>	SC				0.10				
<i>Populus fremontii</i>	TC			5.00	1.50				
<i>Salix gooddingii</i>	TC			6.00	2.00		3.00	2.00	

Table A2. Pakoon Vegetation by Stratum within Arenas. December 17, 2013. Strata: GC - ground cover (deciduous, non-woody); SC - shrub cover (0-4 m woody); MC - middle canopy (4-10 m woody); TC - tall canopy (>10 m woody).

Species	Stratum	Visually estimated percent cover by arena						
		1	2	3	4	4E	5	Pakoon Cr.
Algae	AQ	0.01	0.01	0.1	75	1		2
<i>Veronica</i> sp.	AQ			0.1				
<i>Lactuca serriola</i>	GC	0.01						
<i>Salsola iberica</i>	GC	0.1	0.1	0.1	2	0.1		2
<i>Baccharis salicifolia</i>	GC	0.1						
<i>Aster subulatus</i>	GC	0.1			0.01	0.1		

<i>Xanthium strumarium</i>	GC	0.1						0.1
<i>Polypogon monspeliensis</i>	GC	0.1						
<i>Senecio multilobatus</i>	GC	0.1						
<i>Melilotus</i> sp.	GC	0.5	1	0.2				0.1
<i>Atriplex laevis</i> *	GC	1			5			0.2
<i>Skeletonweed</i>	GC	2	0.5	1		0.1	0.1	1
<i>Scirpus americanus</i>	GC	2	3	10	1	1		1
<i>Anemopsis californica</i>	GC	2	5	8		1		2
<i>Cynodon dactylon</i>	GC	3	9	8	7	10		0.2
<i>Typha domingensis</i>	GC	10	25	7	9	5		10
<i>Helianthus annuus</i>	GC	15	15	5	6	20		3
<i>Distichlis spicata</i>	GC	20	10	8	3			
<i>Convolvulus</i> sp.	GC		0.1					
<i>Solanum angustifolium</i>	GC		0.1					
<i>Datura wrightii</i>	GC			0.1				0.1
<i>Eustoma exaltatum</i>	GC			0.2	0.3			
<i>Juncus torreyi</i>	GC			0.2				
<i>Bromus rubens</i>	GC				0.01	0.2		
Purple butterflyweed	GC				0.1			
<i>Marrubium vulgare</i>	GC				1			
Unk perr. Grass 1	GC				1			
<i>Heliotropium</i> sp.	GC					0.1		
<i>Salix gooddingii</i>	GC					0.1		
<i>Sphaeralcea</i> sp.	GC						0.2	0.1
<i>Populus fremontii</i>	MC	4	4	2				
<i>Salix gooddingii</i>	MC	8	7	5	4	12		9
<i>Malus mulberry</i>	MC			0.01				
<i>Baccharis sergiloides</i>	SC	0.1					0.5	
<i>Phoradendron californicum</i>	SC	0.1					1	0.2
<i>Tessaria sericea</i>	SC	0.3		2	6	6		8
<i>Baccharis salicifolia</i>	SC	0.3			2	2		2
<i>Prosopis glandulosa</i>	SC	1	0.1	2		1	8	5
<i>Prosopis pubescens</i>	SC	2		0.3		1		
<i>Populus fremontii</i>	SC	4	3	3				
<i>Atriplex lentiformis</i>	SC	4	3	13		1		0.1
<i>Salix exigua</i>	SC	5		2				2
<i>Salix gooddingii</i>	SC	8	20	10	8	20		15

<i>Suaeda</i> sp.	SC	10	2	2	1	1		0.1
<i>Isocoma acredenina</i>	SC	15	5	10		5	20	2
<i>Washingtonia</i>	SC		0.5					
<i>Yucca brevifolia</i>	SC			0.1			1	
<i>Larrea tridentata</i>	SC			0.2			2	
<i>Opuntia phaeacantha</i>	SC			0.3				
<i>Malus mulberry</i>	SC			0.5				
<i>Cylindropuntia whipplei</i>	SC						0.01	
<i>Cylindropuntia whipplei</i>	SC						0.2	
<i>Acacia greggii</i>	SC						3	
<i>Lycium</i> sp.	SC							0.1
<i>Vitis arizonica</i>	SC							5
<i>Populus fremontii</i>	TC		5	2				
<i>Salix gooddingii</i>	TC		6					

* Possible misidentification

TABLES A 3-5 PAKOON VEGETATION BY STRATUM WITHIN ZONES, SEPTEMBER 15, 2015.

Table A3. Riparian zone transects 1 closest to Arena 4. Codes used are 0- nothing at that level, W- standing water, 2- herbaceous vegetation, 3- shrubs (up to 4 meter), and 4- tall canopy (4-10 meter).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6		Transect 7		Transect 8		Transect 9		Transect 10	
Meter	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above
1	0	4	2	0	0	0	0	0	3	3	4	4	2,3, 4W	4	2,3 W	3	2	0	2,3 W	3
2	2	4	2	0	0	0	3	0	3	3	0	4	2,3, 4W	4	3W	3	2	0	2,3 W	3
3	2	4	0	0	3	0	3	0	2,3	3	0	4	2,3, 4W	4	W	3	2	0	2,3 W	3
4	2	4	0	0	2	0	3	0	3W	3	0	4	2,3, 4W	4	2,3 W	3	2	0	2	0
5	2	4	0	0	0	0	3	0	2,3 W	3	0	0	2W	4	W	0	2	3	2	0
6	2	4	2	0	3	0	3	0	3W	3	0	0	2,3 W	4	W	3	2	3	2	0
7	4	4	2	0	0	4	3	0	3W	3	0	3	2,3 W	4	2,3 W	3	2,3	3	2,3 W	3
8	2	4	2	3	0	4	3W	3	3W	3	0	3	2,3 W	4	2,3 W	3	2,3	3	2,3 W	3
9	2	4	2	0	3	4	2,3 W	3	3W	3	3	3	2,3 W	3	2,3 W	3	2,3 W	0	2	3
10	2	4	0	0	3	4	2,3 W	3	3W	3	3	3	2,3 W	3	W	3	2,3 W	3	0	3

11	2	4	0	0	0	4	2,3	3	3W	3	3	3	2,3 W	3	2	0	2,3 W	3	0	3
12	2	0	0	0	3	4	2,3	3	3W	3	0	0	2,3 W	3	2	0	2,3 W	3	0	3
13	2	0	2	0	3	0	2,3	3	3W	3	3	4	3	3	2	0	3W	3	0	3
14	2,4	4	2	0	0	3	2,3	3	3W	3	3	4	3	3	2	0	3W	3	0	3
15	4	4	3	0	3	0	2,3 W	3	3W	3	3	4	3	3	2	0	3W	3	0	3
16	2	0	0	0	3	0	2,3 W	3	3	3	3,4 W	4	3	3	2	0	3W	3	3	3
17	2	0	2	0	3	0	2,3 W	3	3	3	3,4 W	4	3	3	2,3 W	3	3W	3	3	3
18	2	0	2	0	3	0	2,3	3	3	3	3,4 W	4	3	3	2,3 W	3	3W	3	3	3
19	2	0	2	0	0	3	2,3	3	3	0	3W	4	2,3	3	2,3 W	3	2,3 W	3	2,3	3
20	2	0	0	0	2	0	2,3	3	0	0	3W	4	2,3	3	2,3 W	3	3W	3	2,3	3
21	2	0	0	0	0	0	2,3 W	3	2	0	3W	4	2,3	3	2,3 W	3	3W	3	2	3
22	2	0	0	0	3	0	2,3 W	3	0	0	3W	4	2,3 W	3	2,3 W	3	W	3	3	3
23	2	0	3	0	2	0	2,3 W	3	3	0	3W	4	3W	3	2,3 W	3	W	3	0	4
24	2	0	0	0	2	0	2,3 W	3	2	0	3W	3	3W	3	2,3 W	3	W	3	2	4
25	2	0	0	0	3	0	2,3 W	3	0	0	3W	3	3W	3	2,3 W	3	3	3	2,4	4

26	2	0	0	0	3	0	2,3 W	3	0	3	3W	3	3	3	2,3 W	3	2W	3	2,3	4
27	2	0	0	0	3	0	2,3 W	3	0	3	3W	3	3	3	2W	0	2W	3	2,3, 4W	4
28	2	0	0	0	3	0	2,3 W	3	0	0	3W	4	3	3	2W	0	2,3 W	3	2,3 W	4
29	2	0	0	0	0	3	2,3 W	3	0	3	3,4 W	4	3	3	2,3 W	3	2,3 W	3	3W	4
30	2	0	0	0	3	0	2W	0	0	3	3,4 W	4	3	3	2,3 W	3	2W	0	2,3 W	4
31	2	0	0	0	3	0	2,3	3	0	0	3,4 W	4	3	3	2W	0	3W	3	2,3, 4W	4
32	2	0	0	0	0	0	2,3	3	0	0	3W	4	3	3	2W	0	0	0	2,3 W	4
33	2	0	0	0	0	0	3	3	0	0	3W	4	3	3	2W	0	0	0	2,3, 4W	4
34	0	0	0	0	3	0	3	3	0	0	3W	4	3	3	2W	0	0	3	2,3	4
35	0	0	0	0	0	0	3	3	2	0	3W	3	3	3	2,3 W	3	2W	3	2,3	4
36	0	0	0	0	0	0	3	3	0	0	3	3	3	3	2	0	3	3	0	4
37	0	0	0	0	0	0	3	3	2	0	3	3	3	3	2,3	3	3	3	0	4
38	0	3	0	0	0	0	3	3	2	0	3	3	3	3	2	0	2,3 W	3	0	4
39	3	3	0	0	3	0	0	3	0	0	0	3	3	3	0	0	0	3	0	4
40	3	4	0	0	0	0	3	3	0	0	0	0	3	3	0	0	0	3	0	4
41	4	4	0	0	0	0	3	3	0	0	0	0	3	3	0	0	0	3	0	4

42	2	0	0	0	0	0	3	3	3	3	0	0	3	3	0	0	3	3	3	3
43	3	0	0	0	0	0	3	3	0	3	0	0	3	3	0	0	2,3 W	3	3	3
44	2	0	0	0	0	0	3	3	0	3	0	4	3	3	0	3	2,3 W	3	3	3
45	2	0	0	0	0	0	3	3	0	0	2	4	3	3	2,3	3	3	3	0	0
46	0	0	0	0	0	0	3	3	2	3	0	4	3	3	2	0	0	3	0	0
47	2	0	0	0	0	0	3	3	2,3	3	2	4	3	3	2	0	0	3	0	0
48	0	0	0	0	0	0	2W	3	2,3	3	3	4	3	3	2W	0	0	3	0	0
49	0	0	0	0	0	0	3W	3	3	3	3,4	4	3	3	2W	0	2	0	0	0
50	0	3	0	0	3	0	3	3	3	3	4	4	3	3	2,3	3	2,3	3	0	0

Table A4. Undisturbed zone transect. Transects run east to west. Codes used are 0- nothing at that level, W- standing water, 2- herbaceous vegetation, 3- shrubs (up to 4 meter), and 4- tall canopy (4-10 meter).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6		Transect 7		Transect 8		Transect 9		Transect 10 (Fence Line)	
Meter	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above
1	3	0	0	0	0	0	3	0	0	0	0	0	0	0	2,3	3	2	0	0	0
2	3	0	0	0	0	0	3	0	0	0	0	3	0	0	2,3	3	2	3	3	0
3	3	0	0	0	0	0	0	3	0	0	0	0	3	0	0	3	0	0	0	0
4	0	0	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	0	0	0
6	3	0	0	0	0	0	0	3	0	3	0	0	3	0	3	0	3	0	2	0
7	0	0	0	0	0	0	3	0	0	3	0	0	3	0	3	0	3	0	0	0
8	0	0	0	0	0	0	3	0	0	3	0	0	3	0	3	0	0	0	3	0
9	3	0	2	0	0	0	0	3	0	3	3	0	3	0	3	0	0	0	0	0
10	3	0	0	0	0	0	0	3	0	3	0	3	0	0	3	0	0	0	0	0
11	3	0	0	0	0	0	0	3	0	3	3	0	0	0	3	0	3	0	3	0
12	3	0	3	0	3	0	3	0	3	0	3	0	3	0	3	0	3	0	0	0
13	0	0	3	0	0	0	3	0	0	3	3	0	3	0	3	0	3	0	0	0
14	3	0	0	0	0	0	3	0	0	3	3	0	0	3	3	0	3	0	3	0
15	0	3	3	0	0	0	3	0	0	0	3	0	3	0	3	0	3	0	3	0
16	0	3	0	3	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0
17	0	3	3	0	3	0	3	0	3	0	3	0	3	0	3	0	3	0	3	0
18	0	0	3	0	3	0	3	0	0	3	3	0	0	3	3	0	3	0	0	0
19	3	0	3	0	3	0	3	0	0	0	3	0	0	0	0	0	3	0	0	0
20	0	0	0	0	0	0	3	0	3	0	0	0	0	0	3	3	0	0	0	0
21	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0

22	0	0	0	0	0	0	3	0	0	0	0	0	3	0	3	0	3	0	0	0
23	3	0	0	0	3	0	3	0	3	0	3	0	3	0	3	0	0	0	0	0
24	0	0	0	3	0	3	3	0	3	0	0	0	3	0	3	0	3	0	0	0
25	0	0	0	3	0	3	0	3	3	0	0	0	3	0	0	3	3	0	0	0
26	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0	0	3	0	0	0
27	0	0	0	0	3	0	0	0	0	0	3	0	3	0	3	3	3	0	0	0
28	3	0	0	0	0	0	3	0	0	0	0	3	3	0	0	0	3	0	0	0
29	0	0	0	0	3	0	3	0	3	0	3	0	3	0	3	0	3	0	0	0
30	3	0	0	0	0	3	0	0	3	0	3	3	0	0	3	0	3	0	0	0
31	3	0	0	3	0	0	0	0	0	3	0	3	0	0	3	0	3	0	0	0
32	3	0	0	3	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	0
33	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0
34	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3	3	3	0	0	3
35	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0	3	0	0	0	0
36	0	0	0	0	3	0	3	0	3	0	0	3	0	0	0	3	3	0	0	0
37	0	3	0	0	3	0	3	0	0	0	0	0	0	0	0	3	3	0	0	3
38	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	3	0
39	0	0	0	0	3	0	3	0	3	0	0	3	0	3	0	3	3	0	3	0
40	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3	0	0	0
41	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0	3	0
42	0	0	0	0	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0
43	0	3	0	0	3	3	3	0	3	0	0	0	0	0	0	0	0	0	2	0
44	0	3	3	0	0	3	0	0	3	0	0	3	3	0	0	0	3	0	2	0
45	0	3	3	0	0	0	0	0	0	0	3	0	3	0	0	0	3	0	0	3
46	0	0	0	0	0	3	0	0	3	0	0	3	0	0	3	0	0	0	0	0
47	3	0	3	0	3	0	3	0	0	0	0	3	0	0	0	0	3	0	0	0
48	0	0	0	0	3	3	3	0	0	0	0	3	0	3	3	0	0	0	0	0
49	0	0	0	0	0	3	0	0	3	0	3	0	0	3	0	0	3	0	0	0
50	3	0	0	0	0	3	0	0	3	0	3	0	0	0	0	0	0	0	0	0

Table A5. Disturbed Zone transects. Transects run east to west. Codes used are 0- nothing at that level, W- standing water, 2- herbaceous vegetation, 3- shrubs (up to 4 meter), and 4- tall canopy (4-10 meter).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6		Transect 7		Transect 8		Transect 9		Transect 10 (Fence Line)	
Meter	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above	Ground	Above
1	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	3	0	0	0
2	0	0	0	0	0	0	3	0	2	0	3	0	2	0	0	0	0	0	3	0
3	0	0	3	0	0	0	0	3	0	0	0	3	0	0	0	0	2	0	3	0
4	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	3	2	0
5	0	0	0	0	0	0	3	0	3	0	0	3	0	0	2	0	2,3	0	0	0
6	0	0	0	0	0	0	2	0	0	3	0	0	2	0	0	0	0	3	0	0
7	3	0	0	0	2	0	0	0	3	0	0	0	0	0	2	0	0	0	2	0
8	3	0	3	0	0	0	2	0	3	0	0	0	0	0	0	0	2	0	0	3
9	0	0	0	0	0	0	0	0	0	3	2	0	0	3	0	0	0	0	3	0
10	0	0	3	0	2	0	0	0	0	0	0	3	0	0	2	0	0	0	2	0
11	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	2	0	0	0
12	0	0	0	0	0	0	0	0	2	0	0	0	0	3	0	0	3	0	0	0
13	0	0	0	0	0	0	0	0	2	0	0	0	3	0	2	0	3	0	0	0
14	0	0	0	0	0	0	0	0	0	3	0	3	0	3	0	3	3	0	0	0
15	0	0	0	0	0	0	2	0	0	3	3	0	3	0	0	0	2	0	0	0
16	0	0	0	0	0	0	3	0	2	3	0	3	0	0	3	0	0	0	0	3
17	3	0	3	0	0	0	3	0	0	3	0	0	0	3	2	0	0	3	3	3
18	0	0	0	0	0	0	3	0	0	3	0	0	0	3	2	0	0	0	3	0
19	0	0	0	0	0	0	3	0	2	0	0	3	3	0	0	0	0	0	0	0
20	3	0	3	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
21	0	0	3	0	0	0	0	0	0	3	0	0	0	3	0	3	2	3	0	0

22	0	0	0	0	0	0	0	0	2	3	0	0	0	3	0	3	0	0	0	0
23	0	3	0	0	3	0	0	0	2	0	0	0	3	3	0	3	2	0	0	0
24	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	2	0	0	0	0	0	3	0	3	3	2	3	0	0
26	3	0	3	0	3	0	0	0	0	0	0	3	3	0	3	0	2	0	0	0
27	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0	0	2	0	0	0
28	3	0	3	0	0	0	0	0	2	0	0	3	0	0	0	0	2	0	0	0
29	0	0	0	0	3	0	2	0	0	0	0	3	3	0	0	3	0	0	0	0
30	0	0	0	3	2	0	0	0	0	0	0	3	3	0	0	0	2	3	0	0
31	0	0	3	0	0	3	0	0	0	3	0	3	0	3	0	0	3	0	0	0
32	0	0	3	0	0	0	2	0	3	3	0	3	0	3	3	3	0	0	3	0
33	0	0	0	0	2	0	0	0	0	0	0	0	3	0	3	0	2,3	0	3	0
34	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	3	0	2	0
35	0	0	3	0	0	3	2	0	0	0	0	0	0	0	0	0	2	0	0	0
36	0	0	0	0	0	3	0	0	0	0	0	0	3	0	0	3	0	0	0	0
37	0	0	3	0	0	3	0	0	3	0	0	0	3	0	0	0	2	0	3	3
38	0	0	0	0	2	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	3	0	3	3	0	2	3	0	0	3	0	0	3
40	0	3	0	0	0	0	0	3	0	0	0	0	2	0	0	0	3	0	0	0
41	0	0	3	0	0	0	0	3	0	0	0	0	2	0	0	3	0	3	3	0
42	3	0	0	0	0	0	2	0	0	0	0	0	0	0	0	3	0	0	3	0
43	3	0	0	0	0	0	0	0	0	3	0	3	2	3	0	0	2	0	0	3
44	0	0	0	0	0	0	0	0	0	3	3	3	0	3	2	3	2	3	3	0
45	0	0	0	0	3	0	0	0	0	3	0	0	0	3	0	0	0	0	0	3
46	0	0	3	0	3	0	0	0	0	3	0	3	3	3	0	0	0	0	0	0
47	0	0	3	0	0	3	0	0	0	0	0	0	3	3	0	0	0	0	3	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
50	0	0	0	0	0	0	3	0	0	0	0	3	2	0	0	3	0	0	0	0

Table A6. Visually estimated percent vegetation cover (VE%Cover) and species richness (Spp. Rich) by stratum at among restoration arenas at Pakoon Springs, Grand Canyon-Parashant National Monument, Arizona: a) 20 November 2012, b) 17 December 2013. Strata: GC - ground cover (deciduous, non-woody); SC - shrub cover (0-4 m woody); MC - middle canopy (4-10 m woody); TC - tall canopy (>10 m woody).

a) 20 November 2012

Variable	Stratum	Arena						Pakoon Cr.	Ag Fields 1-3
		1	2	3	4	4E	5		
VE%Cover	GC	49.11	63.70	59.60	36.91	64.63	6.01	27.02	19.21
VE%Cover	SC	44.90	29.20	41.70	30.20	36.00	38.70	70.40	16.10
VE%Cover	MC	12.00	11.00	8.01	3.00	10.00	0.00	10.00	0.00
VE%Cover	TC	1.00	11.00	3.50	0.00	3.00	0.00	2.00	0.00
Spp. Rich.	GC	16	15	12	15	15	3	16	7
Spp. Rich.	SC	10	8	13	8	8	4	13	11
Spp. Rich.	MC	2	2	3	1	1	0	1	0
Spp. Rich.	TC	0	2	2	0	1	0	1	0

b) 17 December 2013

Variable	Stratum	Arena						Pakoon Cr.	Ag Fields 1-3
		1	2	3	4	4E	5		
VE%Cover	AQ	0.01	0.01	0.20	75.00	1.00	0.00	2.00	0.00
VE%Cover	GC	56.11	68.80	47.80	35.42	37.70	0.30	19.80	13.41
VE%Cover	SC	49.80	33.60	45.40	17.00	37.00	35.71	39.50	10.80
VE%Cover	MC	12.00	11.00	7.01	4.00	12.00	0.00	9.00	0.00
VE%Cover	TC	0.00	11.00	2.00	0.00	0.00	0.00	0.00	0.00
Spp. Rich.	AQ	1	1	2	1	1	0	1	0
Spp. Rich.	GC	16	11	12	13	11	2	12	7
Spp. Rich.	SC	12	7	13	4	8	9	11	8
Spp. Rich.	MC	2	2	3	1	1	0	1	0
Spp. Rich.	TC	0	2	1	0	0	0	0	0

APPENDIX G

AQUATIC INVERTEBRATES COLLECTED FROM 3 SAMPLING SITES IN ARENA 4
AND 4E.

Phylum	Class	Order	Family	Lowest Identification	PAKOON SOURCE	PAKOON SBROOK	PAKOON SBROOK
Annelida				Other_Oligochaeta	0	0	4
Arthropoda	Insecta	Diptera		Muscidae	0	0	4
Arthropoda				Acari	0	0	9
Arthropoda	Insecta	Coleoptera	Elmidae	Microcylloepus	0	2	0
Arthropoda	Insecta	Odonata	Coenagrionidae	Argia	0	4	0
Arthropoda	Insecta	Ephemeroptera	Leptohyphidae	Tricorythodes	0	4	4
Arthropoda	Insecta	Coleoptera	Dryopidae	Postelichus	0	9	0
Arthropoda	Insecta	Ephemeroptera	Baetidae	Fallceon	0	42	36
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Enochrus	3	0	0
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Helochares	3	0	0
Arthropoda	Insecta	Diptera	Stratiomyidae	Nemotelus	3	0	0
Mollusca	Gastropoda	Neotaenioglossa		Other_Hydrobiidae	6	0	4
Arthropoda	Insecta	Diptera		Ephydriidae	9	0	0
Arthropoda	Insecta	Diptera		Tabanidae	12	0	0
Mollusca	Gastropoda	Basommatophora		Physa_Physella	16	0	0
Arthropoda	Insecta	Diptera	Chironomidae	Orthoclaadiinae	32	49	364
Arthropoda	Insecta	Diptera		Culicidae	81	0	0
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogoninae	110	2	53
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	152	24	67
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	310	7	9
Arthropoda	Insecta	Diptera		Simuliidae	493	164	2740