



Inventory of Spring Ecosystems at Kofa National Wildlife Refuge, Arizona

Physical and Biological Characteristics

Natural Resource Technical Report NPS/CHDN/NRTR—2013/819



ON THE COVER

Wilkinson Seep, Kofa National Wildlife Refuge
Photograph: NPS

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Executive Summary

This report summarizes information gathered during an inventory of Kofa National Wildlife Refuge springs conducted in 2011. The inventory was conducted as part of a cooperative effort between the Inventory and Monitoring Programs of the U.S. Fish and Wildlife Service and the National Park Service. The purpose of the inventory was to provide a consistent base level of information on springs across refuges and parks and to provide information to develop a strategy for long-term monitoring.

Twelve springs were inventoried during this effort. All have been significantly altered by humans, including installation of tanks, dams, and fences. Vegetation is dominated by uplands species, however, riparian species such as cattails, baccharis, and willows are present at some springs. Three non-native species were found, including salt cedar, red brome, and annual rabbitsfoot grass.

The quantity of water was sufficient for water quality analysis at 8 of the 12 springs inventoried. Water quality characteristics were mostly within expected values or standards set by the U.S. Environmental Protection Agency or Arizona Department of Environmental Quality. Exceptions were Budweiser Spring, which had dissolved oxygen concentration of 1.9 mg/L and Holly Seep, which had a pH value of 9.1. Although there is no standard for salt concentration, Dixon Spring had chloride level nearly twice the typical levels found in freshwater. Sulfate concentrations were also higher than usually found in freshwater in all springs except Holly Seep and High Tank 2. Water quality is largely dependent on the geologic features in the area and the size of the aquifer associated with the spring. Springs often present challenging environments for biota, either because of temperature or chemical extremes found naturally in the water.

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Introduction

Water in the Kofa National Wildlife Refuge (NWR), Arizona comes from seasonal runoff, thundershowers, and aquifers that support springs. Runoff and thundershowers often produce scouring flows that quickly pass through ephemeral streams, and springs often provide the only persistent, reliable water for humans and wildlife. Springs support aquatic and riparian systems where groundwater reaches the land surface through natural processes. They provide much of the aquatic environment in arid lands as well as a substantial portion of regional aquatic and riparian biodiversity. Springs and their related ecosystems are considered to be of high priority for providing goods and services to wildlife.

Spring ecosystems are small, relatively rare “biodiversity hot spots” in arid lands. In the desert southwest, these ecosystems historically supported a substantial proportion of aquatic, riparian, and terrestrial species (Myers and Resh 1999). About 80% of the terrestrial animal species, including two-thirds of non-game bird species, use riparian systems associated with springs (Thomas et al. 1979, Saab et al. 1995, Brussard et al. 1998). Springs in arid lands are sparsely distributed on the landscape and critical to the persistence of native biota and many endemic species. Thus, the ecological importance of springs is disproportionate to their spatial extent (Schmitz et al. 2007). As a consequence of their lengthy isolation and long-term persistence, many arid-land springs support an endemic, obligate-spring-dwelling fauna and flora. Several hundred endemic aquatic and riparian species and subspecies dwell in spring ecosystems in the U.S. (Minckley et al. 1986, Hershler et al. 2002).

When they are persistent, springs are generally more stable than arid-land rivers or streams, because seasonal variability in temperature and discharge is much less in springs. Arid-land springs are distinct from springs in more mesic regions because arid-land springs are typically isolated from other waters and more susceptible to drought. Aquifers in these arid regions

are strongly influenced by high elevations, rugged topography, and diverse geology. Characteristics of each aquifer are influenced most by climate, geology, and topography (Freeze and Cherry 1979). In springs unaffected by human activity, water chemistry, temperature, spring morphology, and persistence are primary factors influencing aquatic communities, and soil moisture, chemistry, and soil structure and particle size are factors that most affect riparian vegetation (Resh 1983, Knopf et al. 1988, Cushing 1996, McCabe 1998, Castelli et al. 2000).

Natural and human stressors similarly influence the structure of aquatic and riparian communities. Springs with high water temperature, high chemical concentrations, or that are disturbed by natural events (drought, fire, flood, avalanche scouring, etc.) and humans (reduced discharge from groundwater pumping or surface diversion, livestock trampling, impoundment, recreation, etc.) are harsh environments compared to persistent springs with cooler water that are unaffected by human or natural stressors. The influence of stressors on aquatic and riparian communities generally varies along a gradient of increasing frequency, duration, and magnitude of stressors. Biological communities of springs respond to stressing factors similar to other aquatic and riparian systems (e.g., Resh et al. 1988, Smith et al. 1991, Stromberg and Patton 1992, Fleischner 1994), however, the effect on arid-land spring biota appears to be more severe due to the naturally harsh arid environment, the isolation of springs from other aquatic systems, and challenges that these factors pose to organism dispersal and colonization. As harshness increases, aquatic communities become less speciose, support fewer environmentally intolerant species (e.g., non-baetid mayflies, caddisflies), and become increasingly dominated by environmentally tolerant and vagile species (e.g., beetles, water boatman, and midges; Sada et al. 2005). Harshness also affects riparian communities by decreasing diversity and ground cover, and increasing

the abundance of upland and non-native species (Fleischman et al. 2006).

Surface-water dynamics and water chemistry have strong effects on aquatic biota; therefore, biological assemblages (e.g. aquatic macroinvertebrates) are often excellent indicators of flow regime, water chemistry, and disturbance history. Alteration of surface-water resources within desert ecosystems has profound ecological and management implications, including loss of species diversity, extinction or extirpation of special-status and endemic species, alteration in the composition and distribution of plant and animal communities, alteration of culturally significant sites, and inability of parks to meet legal and policy mandates.

Discharge rates, aquifer sources, and the presence of rare species (e.g., fishes, aquatic macroinvertebrates, rare plants, etc.) are

known for a number of large springs in arid regions of the western U.S., but basic information describing the physical and biological characteristics of most springs is limited. This paucity of knowledge has stifled spring management strategies and little attention has been given to balancing human use with maintaining ecological integrity (Shepard 1993). As a consequence, most springs have been degraded by human activity and few springs resemble their historic biological and environmental condition (Shepard 1993, Sada 2001, Sada and Vinyard 2002).

The purpose of this inventory is to provide a consistent, base level of information on springs across several U.S. Fish and Wildlife Service (USFWS) refuges and National Park Service (NPS) parks and to provide information to develop a strategy for long-term monitoring.

Methods

Twelve springs in Kofa NWR, Arizona were inventoried in October 2011 following the Level 1 procedures described by Sada and Pohlmann (2006; located on enclosed CD). These springs were selected for inclusion in the inventory by USFWS staff led by Steve Cullinan.

The foundation for the protocol developed by Sada and Pohlmann (2006) is a number of hydrological and biological studies of springs in the western U.S. and elsewhere (e.g., Ferrington 1995, Botosaneanu 1998, Meffe and Marsh 1983, Williams and Danks 1991, Thomas et al. 1996, Sada et al. 2005, and many others cited herein) that examined spring physicochemical conditions and their influence on spring-fed aquatic and riparian communities. The Sada and Pohlmann (2006) protocol contains two levels of field procedures. The level of the Sada and Pohlmann (2006) protocol conducted at each spring depends on the amount of spring flow. The Level I procedure compiles information that characterizes salient aspects of each spring's aquatic and riparian environment and the communities that they support. This inventory focused on locating spring sources and recording information to assess their biotic potential, prioritize the importance of individual sites for long-term monitoring, and guide management (see below). The Level I inventory consisted of identifying and recording spring orifices (source or water emergence points) using a Trimble Geo XH GPS

unit; making site maps and descriptions; evaluating current and historic natural and anthropogenic disturbance; collecting benthic macroinvertebrates; and measuring water quality (water temperature, dissolved oxygen, pH, total dissolved solids [TDS], and conductance collected with a YSI ProPlus meter, and alkalinity, chloride, magnesium, sulfate, and calcium concentration with a YSI field spectrophotometer). Water quality meters were calibrated each morning prior to the sampling event, and post-calibration was conducted at the end of each day to ensure the meter remained calibrated throughout the day. Water quality measurements were taken at every orifice with sufficient flow. The crew also measured morphological characteristics such as brook length (if present) or wetted area of pool formations, water depth, discharge, substrate, emergent cover (vegetation), bank cover (vegetation), documented spring type, and took photo points. In addition, the crew documented presence of wildlife and common, rare, or exotic plants. Level I surveys were conducted on five springs at Kofa NWR (Table 1). See Appendix A for a full list of attributes collected during Level I surveys.

Data collected from each spring were compiled in a Microsoft Access® database developed by National Park Service database managers. Data used to prepare this report were analyzed by querying this database (located in enclosed CD).

Table 1. List and locations of springs in Kofa NWR, Arizona.

Spring Code	Spring Name	Survey Level	Date	Spring Type	Latitude	Longitude
KONWR001	Alamo Spring	Level 1	10/13/2011	Rheocrene	33° 24' 37.998" N	113° 55' 27.166" W
KONWR002	Budweiser Spring	Level 1	10/16/2011	Rheocrene; Tinaja	33° 24' 53.462" N	114° 2' 12.155" W
KONWR003	Covered Well Spring	Level 1	10/14/2011	Other	33° 31' 36.131" N	114° 5' 28.676" W
KONWR004	Doc Carter Spring	Level 1	10/17/2011	Cave	33° 1' 7.980" N	114° 8' 19.140" W
KONWR005	High Tank 2 Spring	Level 1	10/15/2011	Rheocrene; Other	33° 25' 46.821" N	113° 58' 22.700" W
KONWR006	High Tank 9 Spring	Level 1	10/16/2011	Rheocrene	33° 24' 15.227" N	114° 1' 35.411" W
KONWR007	Holly Seep	Level 1	10/13/2011	Rheocrene	33° 25' 51.932" N	113° 56' 39.329" W
KONWR008	Indian Seep	Level 1	10/14/2011	Limnocrene	33° 31' 32.335" N	114° 5' 19.597" W
KONWR009	Jasper Spring	Level 1	10/14/2011	Rheocrene; Mound-form	33° 26' 59.833" N	114° 0' 1.491" W
KONWR010	Tunnel Spring	Level 1	10/16/2011	Cave	33° 23' 18.120" N	114° 2' 13.260" W
KONWR011	Wilkinson Seep	Level 1	10/13/2011		33° 25' 44.944" N	113° 55' 7.917" W
KONWR012	Dixon Spring	Level 1	10/17/2011	Rheocrene; Other	32° 59' 39.728" N	114° 4' 42.398" W

Results and Discussion

The twelve springs inventoried include: Alamo Spring, Budweiser Spring, Covered Well Spring, Doc Carter Spring, High Tank 2, High Tank 9, Holly Seep, Indian Seep, Jasper Spring, Tunnel Spring, Wilkinson Seep, and Dixon Spring (Figure 1). All springs inventoried have experienced flow-altering human disturbance, such as dams and enclosures. Data for individual springs are presented in Appendix B.

A list of the plant species detected is included in Appendix C. Note this list reflects dominant or common species and is not intended to be a thorough inventory of plant taxa. Three exotic non-native were detected in the area, salt cedar (*Tamarix* sp.), red brome (*Bromus rubens*), and annual rabbitsfoot grass (*Polypogon monspeliensis*).

Spring Descriptions

Alamo Spring is a rheocene located in a wash and is encircled by a burro fence. A concrete enclosure covered by a tin roof is located in the middle of the fenced area. A gravel-filled holding tank is located about

4 m up the wash from the fenced area. The only water found was in a small (10x10 cm) puddle about 3 m up the wash from the fenced area. Although little water was discovered at the time of the inventory, the presence of wetland vegetation such as *Baccharis* sp. and willows (*Salix* sp.), indicates that the presence of water is common in this area. Other plants present include honey mesquite (*Prosopis glandulosa*), button brittlebrush (*Encelia frutescens*), paloverde (*Parkinsonia* sp.), and *Acacia* spp.

Budweiser Spring is a rheocene that emerges within an enclosure located within a heavily-scoured bedrock wash, containing eroded substrate ranging from sand to boulders. Substrate consisted of 5% fines, 5% sand, 70% gravel, and 20% bedrock. The only water present was located within the enclosure (a 1m² pool about 15 cm deep) and in two small tinajas located about 70 m down the wash from the enclosure. Cattails (*Typha* sp.) were present near the enclosure. The vegetative bank over was about 25% and cover of emergent vegetation was about 20%. The remaining vegetation present

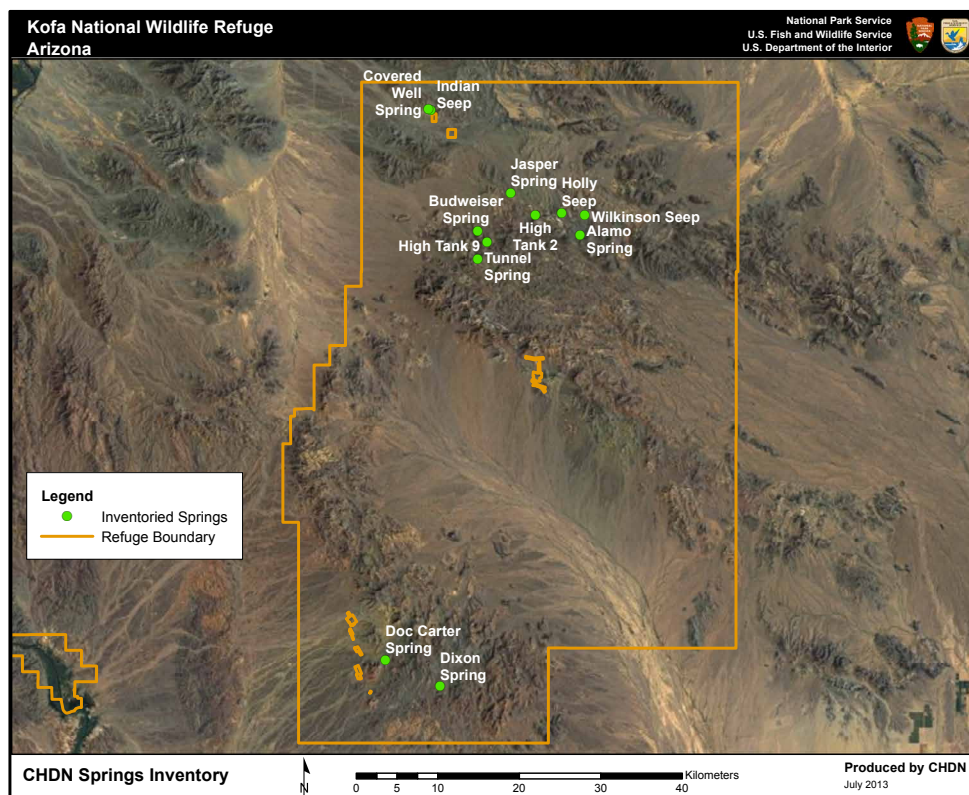


Figure 1. Map of the Kofa National Wildlife Refuge and location of springs.



**A fish hook barrel cactus
found at Holly Seep.**

consisted of upland species, including honey mesquite, jojoba (*Simmondsia chinensis*), *Yucca* sp., and *Acacia* sp. Also present was non-native red brome.

Covered Well Spring emerges in a 10x2 m concrete holding tank. About one-quarter of the tank is filled with water. No vegetation was present inside the tank. The tank was surrounded by a fence. Vegetation in the area included mesquite (*Prosopis* sp.), saguaro (*Carnegiea gigantea*), yellow spider flower (*Cleome lutea*), and seepweed (*Suaeda* sp.).

Doc Carter Spring emerges from cracks in the wall of a cave that appears to be natural, except for the concrete wall at the mouth of the cave. Substrate on the bottom of the cave was 90% gravel and 10% bedrock. An old pipe and box suggest the spring was historically used by humans. Vegetation present in the vicinity of the spring include catclaw acacia (*Acacia greggii*), saguaro, and desert thorn (*Lycium* sp.).

High Tank 2 Spring is a rheocrene that emerges from a crack in a steep side of a wash consisting primarily of bedrock dotted with boulders and flows for about 1 m before disappearing into the ground. A rock and concrete dam is located about 2 m downstream of the primary orifice. Water emerges again about 8 m below the dam and again, flows for about 1 m before disappearing. Substrate in the wash is 75 percent bedrock with an even distribution of fines, sand, gravel, cobble, and boulders.

Two drinking tanks covered by tin roofs are located in the area, and both are filled with water and covered with algae. Tadpoles were observed in the tanks; a Gila Woodpecker (*Melanerpes uropygialis*) was also observed. Vegetation in the vicinity of the spring includes brickellbush (*Brickellia* sp.), mesquite, whitethorn acacia (*Acacia constricta*), oaks (*Quercus* sp.), triangle burr ragweed (*Ambrosia deltoidea*), and saguaro.

High Tank 9 consists of a small seep dammed by boulders and concrete in the middle of a drainage and water flowing from a small cave in the drainage wall. The dam was not holding the water from this rheocrene spring. The wetted area of the spring brook was about 1.5 m long and water was about 30 cm deep. Cover of emergent vegetation was about 25% and vegetative bank cover was about 5%. Vegetation includes *Baccharis* sp., beardgrass (*Bothriochloa* sp.), whitethorn acacia, jojoba, sweetbush (*Bebbia juncea*), triangle goldeneye (*Viguiera deltoidea*), and Arizona centaury (*Centaureium calycosum*). Also present were two non-native species: salt cedar and annual rabbitsfoot grass (*Polypogon monspeliensis*). Substrate in the channel was about 10% fines, 10% sand, 30% gravel, 10% cobble, 20% boulder, and 20% bedrock. Old pipes in the cave indicate historic human use of the spring.

Holly Seep lies in a drainage with steep, igneous rock sides, approximately 5-8 m high. The channel consists primarily of unconsolidated rock and travertine. The orifice is contained within a concrete pool shaded by a tin roof. The water was in a pool about 1m across and 10 cm deep. Substrate within the pool is primarily bedrock, with some fine sediment and gravel. The spring area is enclosed by a burro fence. Vegetation in the area includes arrowweed (*Pluchea sericea*), cattails, paloverde, button brittlebrush (*Encelia frutescens*), and catclaw acacia.

Indian Spring is located on an alluvial fan at the base of small mountains. The spring orifice is protected by a burro fence and the majority of the water is held in a concrete tank choked with cattails (cover >90%). Water in the tank was about 1.5 m deep. Other plants present include mesquite, seepweed, and yellow spiderflower. A Gila

Woodpecker, Gilded Flicker (*Colaptes chrysoides*), and Phainopepla (*Phainopepla nitens*) were also observed.

Jasper Spring is located in a low elevation basin at the base of a solitary rock hill. Water emerges from the banks of a wash that flows to the North. The spring is composed of a series of small seeps inside the basin. The spring is divided into two sections by a burro fence. One section is a damp channel with a small pool. A spring box/well is located off to the side of the bank, from which water is piped to another orifice. Water emerges from a mound consisting of salt deposits. A wildlife trough is also present in the area, however, water is piped in from upstream. Mineral deposits in the channel downstream suggest that heavier flows have been present historically. Vegetation in the area includes arrowweed, mesquite, inland saltgrass (*Distichlis spicata*), baccharis, saguaro, cattails, and creosote (*Larrea tridentata*).

Tunnel Spring is located in a cave about 20 m deep in an igneous rock wall. The orifice is in the back of the cave. Water drips down the cave wall about 1.5 m into a holding tank below and is then diverted through a pipe to a laminar flow channel that runs about 30 m to its terminus outside the cave. Another small holding tank was located about 2 m below the first catchment; however, the tank was dry at the time of the inventory. Emergent plant cover was about 60%. Substrate consisted of 90% bedrock and 10% gravel. Plants present include jojoba, catclaw acacia, broom snakeweed (*Gutierrezia sarothrae*), honey mesquite, skunkbush sumac (*Rhus trilobata*), and cholla (*Cylindropuntia* sp.).

Wilkinson Seep, at the time of survey, consisted of a series of wet spots along the west side of Alamo wash. The “first” (upstream-most) orifice supports a small stand of cattails. The next orifice is just downstream and supports a thick patch of cattail and arrowweed. The third seep is a small wet spot of bedrock and sand. No surface water was observed at any of the orifices. Other plants in the area include baccharis, mesquite, saguaro, and paloverde. A partial burro fence surrounds the area and an old concrete structure marks the terminus.

Dixon Spring lies in the bed of a wash surrounded by small mountains. The orifice is contained in a concrete holding tank covered by a tin roof. The tank measures 5x2 m and is 2.5 m deep. Water in the tank is 1x1 m and 20 cm deep. A concrete dam spans the wash below the enclosure and a burro fence also encloses the area. Vegetation present include desert holly (*Atriplex hymenelytra*), paloverde, cholla, saguaro, acacia, ocotillo (*Fouquieria* sp.), and creosote.

Water Quality

A sufficient quantity of water for water quality measurements was present at 8 of the twelve springs inventoried. Water temperatures were fairly warm, ranging from 16.2 to 22.1°C. Dissolved oxygen (DO) concentrations ranged from 1.45 to 7.34 mg/L. DO data are only available for Jasper Spring, High Tank 2 Spring, and Budweiser Spring, as the meter failed to pass post-calibration on the days the other springs were sampled. The level of DO necessary to protect fish and other aquatic life is



NPS

Cattails at Indian Seep.



Jasper Spring.

4 mg/L according to the U.S. Environmental Protection Agency (EPA) standard, and 6.0 mg/L DO standard for the Arizona Department of Environmental Quality (AZDEQ) for warm waters. DO levels at Budweiser Spring fail to meet both criteria. DO level of 4.94 at Jasper Spring meets EPA standards, but not AZDEQ. High Tank 2 Spring had DO values higher than 6.0, meeting both standards. pH levels varied from 7.4 to 9.1. pH was lowest at Budweiser and Jasper Springs and highest at Holly, Dixon, and Covered Well Springs. The AZDEQ standard for pH is between 4.5 and 9.0. Holly Seep fails to meet this criterion. Highly alkaline water is common in catchments containing igneous rock. Total dissolved solids (TDS) ranged from 319 to 2847 mg/L. The EPA doesn't have a standard for TDS, and AZDEQ has set one only for the Colorado River. Electrical conductance ranged from 536 to 4,383 $\mu\text{S}/\text{cm}$. Holly Seep had the lowest conductivity level and Dixon Spring had the highest.

Samples were collected for analysis of water quality using a field spectrophotometer. Alkalinity (the water's capacity to neutralize acids) was measured as concentration (in mg/L) of calcium carbonate (CaCO_3), bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}). Alkalinity in water results from any dissolved species (though usually weak acid ions such as carbonic acid) that can accept and neutralize protons. Because carbon dioxide

(CO_2) is soluble and relatively abundant in water, and carbonates are common minerals over much of the Earth, the property of alkalinity of freshwater is determined by the presence of bicarbonates and carbonates. The $\text{CO}_2\text{—HCO}_3^-\text{—CO}_3^{2-}$ equilibrium system is the major buffering system in fresh water. Calcium carbonate levels ranged from 110 to 875 mg/L, bicarbonate levels ranged from 130 to 1,075 mg/L, and carbonate values ranged from 65 to 525 mg/L. These levels are typical for fresh water, given the range of pH values measured in the springs.

In addition to measuring alkalinity, concentration of common ions was also measured, including calcium (Ca^{2+}), chloride (Cl^-), magnesium (Mg^{2+}), and sulfate (SO_4^{2-}), all of which, when combined with bicarbonate and carbonate, constitute total salinity. Salinity of surface water depends on ionic influences of the surrounding land (geology), atmospheric deposition (e.g. wind-blown dust), and evaporation rates relative to precipitation (Wetzel 2001). Calcium is a required nutrient for growth of freshwater flora and fauna and has direct influence on population growth. Many diatoms and invertebrates have calcium as a component of their outer covering or exoskeleton. Chloride is influential in osmotic balance and ion exchange. Magnesium is a component of chlorophyll and is therefore required universally by plants. Sulfur is utilized by all living organisms for protein synthesis, however, our interests are related to pollution from fertilizer and atmospheric deposition.

Calcium levels range from 28 mg/L to 160 mg/L. Calcium concentration greater than 20 mg Ca/L is associated with hard water (Wetzel 2001). Chloride levels ranged from 24 to 205 mg/L. Concentrations between 1 and 100 mg Cl/L are common in freshwater. All springs had Cl concentrations less than 50 mg/L except for Dixon Spring, which had concentration of 205 mg/L. Magnesium levels ranged from less than 1 to 1,000 mg/L. Sulfate concentration ranged from 4 to 370 mg/L. Typical ranges for sulfate concentration in freshwater is about 5 to 30 mg/L. Only Holly Seep and High Tank 2 Spring had sulfate concentrations less than 30 mg/L.

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Appendix A List of Attributes

The following elements were recorded during Level 1 surveys:

- Site Code—identification number for each spring within a national park or refuge. Consists of park or refuge name abbreviation and number
- Date the survey is conducted
- Person (Surveyor) conducting the spring survey
- Park Code—park or refuge name abbreviation
- Access. Record the ease at which the public could visit a spring. Categories 1 through 5. Category 1=inaccessible sites, access only by cross-country hiking; Category 2=sites that can be accessed only by arduous trail hike (e.g., >5 miles); Category 3=sites accessed by easy trail hike (e.g., 1 to 5 miles) and four-wheel drive vehicle; Category 4=sites easily accessed by walking less than 1 mile or a two-wheel drive, high clearance vehicle; and Category 5=sites immediately adjacent to high-quality gravel road or a paved road.
- Description of site access
- Extent of sampling effort with comments
- Sample start and end times
- Total time spent sampling
- Global Positioning System (GPS) location and the datum of the spring source and terminus. Record the UTM zone in the North American Datum of 1983 (NAD83) unless otherwise specified. Document GPS files in a gps log. All geographic information system (GIS) data layers created from GPS files must include FGDC Geospatial and Biological Profile (NBII) compliant metadata. Record PDOP or “+” the number of meters as metrics indicating accuracy of the GPS reading.
- Photos. Photographs should be taken to show the spring and its landscape context. One should overview the spring source and looking downstream, and the second from the spring brook’s end looking upstream. At larger springs, take one photo of the source and a second from a distant area that encompasses as much of the riparian area as possible. Photos should be labeled by site ID number, date, site name, photographer, subject, and GPS coordinates of the point where the photo was taken. Photos should be taken using a digital camera. Maintain a photo log with digital photograph number and description using the Location ID. Note on the site map where photos were taken.
- Site Description—description of overall ecological community and geologic setting in which the spring is situated.
- Site Map—includes locations of orifices, water quality measurements, photo points, and more.
- Important animals and plants. Important species are those that occupy or use the aquatic or riparian environments, and noted during the survey. This list may differ among management areas, and it should be compiled accordingly. It should include (1) rare species, (2) species that are indicative of spring characteristics (e.g., species of woody vegetation, obligatory and facultative wetland vegetation, crenobiontics), (3) species of management interest or concern, and (4) non-native species. Species should be identified, if possible. If a species cannot be identified, the presence of plants and

animals within any of the important groups should be recorded (e.g., native fish and trees, mollusks, aquatic insects, non-native species, etc.). Also note the presence of important terrestrial species, such as bats, if seen. Noting the presence of these types of species provides information that assists with identifying management issues and can be used to determine management priorities. Important species occupy a wide variety of habitats, and they may be very scarce or abundant.

- Aquatic macroinvertebrates can be readily captured from aquatic vegetation, debris, or substrate. Each species prefers a distinct microhabitat, and sampling must include all habitat types that occur in a spring (e.g., sand, gravel, & cobble substrates, all types of emergent and submerged vegetation, all current velocities, mid-channel, backwater, and lateral habitats).
- **Site Condition.** This evaluation qualitatively identifies (1) disturbance factors stressing a spring and (2) the amount of stress of each factor on the spring environment. Influences of flooding are indicated by location of a spring in the bottom of a gully, presence of a naturally incised channel, and usually a paucity of vegetation. The presence of pipes, dikes, or spring box indicates modifications for diversion. Abundance of hoof prints and droppings, and evidence of grazing indicates ungulate use of a spring. The presence of campsites and trash indicates recreation. The most common stressing factors are listed on the field form, and the appropriate factor(s) affecting a spring should be circled. Disturbance may be influenced by multiple factors such as trampling by intensive livestock and diversion into a trough; recreation use along a spring brook that tramples vegetation and the spring brook is channelized away from areas used for picnicking. Each spring is categorized as undisturbed, slightly, moderately, or highly disturbed:
 - **Undisturbed** springs have been unaffected by recent or historical factors or activities. All evidence of trampling, diversion, fire, or drying is absent. Since most springs have been altered by humans, drought, fire, or flood, these types of springs are rare and most undisturbed springs are naturalizing from past disturbances.
 - **Slightly Disturbed** springs exhibit little evidence that vegetation or soil have been disturbed. Vegetation shows slight signs of browsing and foraging, and animal footprints and scat are present but not prominent. Recreation may be evident, but its impact on riparian or aquatic environments is minimal. Evidence of fire or flooding in the distant past may be visible but these events occur infrequently; riparian vegetation is vigorous.
 - **Moderately Disturbed** springs exhibit evidence of recent, comparatively high disturbance. Use by native and non-native ungulates, and recreation has reduced vegetation height and coverage from natural conditions. Vegetation covers, hoof prints, footprints, and scat are common. Where there has been diversion, a spring box may be present but at least 50% of natural discharge remains within the natural spring brook. Neither the spring nor spring brook has been impounded. Where flooding or fire is apparent, >50% of the spring brook banks are covered by vegetation; flood and fire are infrequent and the spring is naturalizing.
 - **Highly Disturbed** springs have little similarity to undisturbed springs. Less than 50% of their banks are covered by vegetation, their spring brooks contain <50% of natural discharge, they are impounded or dredged, or spring boxes collect water. All impounded springs are highly disturbed because flow has been interrupted and functional characteristics of the aquatic system have been highly altered. Hoof prints and scat are abundant where ungulate use is heavy, and campsites are large, trashy, and vehicle use evident. These activities have decreased vegetative cover of spring brook banks to <50%. Springs affected by drought (springs that are dry

when sampled or experience seasonal or annual drying) should also be categorized as highly disturbed. These springs can be identified by the presence of upland riparian species and absence of obligatory wetland plants. Riparian vegetation is sparse at springs recently affected by fire or flooding, there is recent evidence of elevated discharge, and spring brooks are usually incised.

- Dissolved Oxygen Concentration, (D.O., in mg/liter) using a field meter measured as close to the spring source as possible and in flowing water if available.
- Water Temperature in degrees Centigrade
- Conductivity (also called electrical conductance). Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current. This ability is dependent on the amount of dissolved ions, and is therefore an indicator of total dissolved solids in the solution. Conductivity provides insight into water sources and it is important to aquatic life because of requirements to maintain osmoregulatory balance. Conductivity is measured using a field meter and recorded in microsiemens.
- pH. pH is the measure of hydrogen activity, which indicates the acid/basic qualities of water.
- Total dissolved solids (TDS) in mg/L. Measure of all organic and inorganic substances dissolved in the water.
- The following are measured field spectrophotometer using water samples collected in the field:
 - Alkalinity—the water’s capacity to neutralize acids—measured as concentration (in mg/L) of calcium carbonate (CaCO_3), bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}).
 - Chloride concentration in mg/L
 - Magnesium concentration in mg/L
 - Sulfate concentration in mg/L
 - Calcium concentration in mg/L
- Spring Brook Length, measured in meters. Use a tape to measure distance from the spring source (upstream limit of surface water) to the downstream limit of surface water.
- Estimated discharge by recording the length of time required to fill a container with a known volume. Unfortunately, it is usually not possible to use this method because most arid land springs are very small and it is difficult to capture water in a container (their small size also prevents using a water current velocity meter to measure discharge). While these factors limit the precision of most discharge estimates, the amount of water issuing from spring sources should be estimated in liters/minute. These estimates combined with water width, depth, and spring brook length provide sufficient information to characterize spring discharge rates.
- Average Water Depth. This is a qualitative estimate of the vertical distance from substrate to water surface (in centimeters) that is found throughout the aquatic habitat.
- Average Water Width. This is a qualitative estimate of the distance covered by water (and perpendicular to its flow) that lies between banks of the spring brook, less islands, emergent rocks, etc., in centimeters. (This is formally described as the length of wetted contact between flowing or standing water and the spring brook bank in a vertical plane at right angles to the direction of flow.)

- **Emergent Cover.** Estimate to the nearest 10 percent the vegetative, debris, or other material that arises within the water width and covers the water surface.
- **Vegetative Bank Cover.** Estimate to the nearest 10 percent the proportion of spring brook banks that is covered by live vegetation.
- **Substrate Composition.** Qualitatively estimate using a Wentworth particle scale analysis, which describes the substrate by the proportional composition of materials, where materials are classified as: fines (<1 mm), sand (1-5 mm), gravel (>5-80 mm), cobble (>80-300 mm), boulder (>300 mm), or bedrock. Size is defined as the minimum particle size of substrate as measured on a two-dimensional axis, as would pass through a substrate sieve.
- **Spring Type, as:** **Rheocrene** (a spring that discharges into a defined channel), **Limnocrene** (a spring that discharges into a ponded or pooled habitat before flowing into a defined channel), **Helocrene** (similar to a Limnocrene, but marshy and comparatively shallow, not an open pond or pool), or unknown. In some areas, springs have been altered by native peoples or settlers by excavating the source to create a **Qanat**, which is a type of hand-dug well. Where these occur, water is regionally scarce and where surface water is scarce. Also record if a site is a mechanically dug **Well** (usually with rock, metal, or plastic casing). Record **Other** when the source is something else, such as a cliff face, boil, etc. Record spring type as **Unknown** at highly disturbed sites where no semblance of natural characteristics of a spring remains, or where the spring is dry. Examples of disturbances that prevent identifying spring type include impoundment by dikes, sources in a spring box, or dredging and filling to capture water in a pipe leading to a trough. Spring alterations and spring condition are assessed, and recorded, in the Site Condition section below. If further description is necessary, it can be summarized in the Notes Section.
- **Notes,** to include additional pertinent information. This may include observations further describing site condition, use of the spring by other animals (e.g., bats, wild horses, etc.), clarification of difficulties in accessing the spring, etc.

Appendix B Spring Data

The following are data collected at each Kofa National Wildlife Refuge spring.

KONWR001—Alamo Spring

Sample Date: 10/13/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	0
Discharge (L/min)	0.01
Mean Water Depth (cm)	2.00
Mean Water Width (cm)	15.00
Emergent Cover (%)	0.00
Vegetated Bank Cover (%)	0
Fines (%)	0.00
Gravel (%)	0.00
Cobble (%)	100.00
Boulder (%)	0.00
Sand (%)	0.00
Comments	Dry channel. Small puddle.

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	2
Hiking	1
RecUse	2
FlowMod	4
Livestock	1
Contemp	2
Historic	4
Flood	1
Wind	1
Graze	1
Insect	1
Fire	1
Drying	4
Flow Mod	TRUE
Modification Type	Pipe Diversion; Dam Diversion; Open Trough/Tank; Encasement; Excavation

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ACACI	<i>Acacia</i> sp.	acacia	N/A		
BASA2	<i>Baccharis sarothroides</i>	desertbroom	Native		
ENFR	<i>Encelia frutescens</i>	button brittlebush	Native		
PAMI5	<i>Parkinsonia microphylla</i>	yellow paloverde	Native		
PRGL2	<i>Prosopis glandulosa</i>	honey mesquite	Native		
SALIX	<i>Salix</i> sp.	willow	N/A	YES	CHDN

Water quality characteristics. Water was insufficient for measurement.

KONWR002—Budweiser Spring

Sample Date: 10/16/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	0
Discharge (L/min)	0
Mean Water Depth (cm)	15
Mean Water Width (cm)	150
Emergent Cover (%)	20
Vegetated Bank Cover (%)	25
Fines (%)	5
Gravel (%)	5
Cobble (%)	70
Boulder (%)	0
Sand (%)	0
Comments	dug out pool with rock cover

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	1
Hiking	1
RecUse	1
FlowMod	4
Livestock	1
Contemp	1
Historic	4
Flood	1
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow Mod	TRUE
Modification Type	Open Trough/Tank; Encasement; Excavation

Vegetation observations. For Wetland Indicator, OBL=wetland obligate.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ACGR	<i>Acacia greggii</i>	catclaw acacia	Native		
BRRU2	<i>Bromus rubens</i>	red brome	Non-native		
PRGL2	<i>Prosopis glandulosa</i>	honey mesquite	Native		
SICH	<i>Simmondsia chinensis</i>	jojoba	Native		
TYAN	<i>Typha angustifolia</i>	dwarf cat-tail	Native	OBL	USDA
YUCCA	<i>Yucca</i> sp.	yucca	N/A		

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter	Value
Orifice	1
Shade	Shade
Temp	19.6
DO (mg/L)	1.45
DO (%)	15.9
pH	7.40
TDS	626.5
EC (μS)	
Notes	Taken from pool under cover bridge. Other orifices not sampled.
Alka_CaCO ₃	300
Alka_HCO ₃ ⁻	370
Alka_CO ₃ ²⁻	180
Chloride	50
Magnesium	250
Sulphate (SO ₄ ²⁻)	60
Sulphur (S)	20
Calcium (Ca)	56
Location	
Notes	

KONWR003—Covered Well Spring

Sample Date: 10/14/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	
Discharge (L/min)	
Mean Water Depth (cm)	30.00
Mean Water Width (cm)	1.00
Emergent Cover (%)	
Vegetated Bank Cover (%)	
Fines (%)	
Gravel (%)	
Cobble (%)	
Boulder (%)	
Sand (%)	
Comments	Above measurements are for tank.

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	2
Hiking	1
RecUse	2
FlowMod	4
Livestock	1
Contemp	1
Historic	4
Flood	1
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow Mod	TRUE
Modification Type	Open Trough/Tank; Encasement; Excavation; Other

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ACGR	<i>Acacia greggii</i>	catclaw acacia	Native		
CAGI10	<i>Carnegiea gigantea</i>	saguaro	Native		
POUN3	<i>Polanisia uniglandulosa</i>	Mexican clammyweed	Native		
PROSO	<i>Prosopis</i> sp.	mesquite	N/A		
	<i>Suaeda</i> sp.	seepweed			

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter	Value
Orifice	
Shade	Shade
Temp	20.7
DO (mg/L)	
DO (%)	
pH	8.56
TDS	1469
EC (μS)	2257
Notes	Taken in covered tank. DO failed post calibration
Alka_CaCO ₃	875
Alka_HCO ₃ ⁻	1075
Alka_CO ₃ ²⁻	525
Chloride	25
Magnesium	440
Sulphate (SO ₄ ²⁻)	195
Sulphur (S)	65
Calcium (Ca)	44
Location	concrete pool
Notes	Concrete pool with a steel roof

KONWR004—Doc Carter Spring

Sample Date: 10/17/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	0
Discharge (L/min)	0
Mean Water Depth (cm)	4
Mean Water Width (cm)	10
Emergent Cover (%)	0
Vegetated Bank Cover (%)	0
Fines (%)	0
Gravel (%)	10
Cobble (%)	90
Boulder (%)	0
Sand (%)	0
Comments	There is a small 10x10 cm puddle, approx. 4 cm deep.

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	1
Hiking	1
RecUse	1
FlowMod	1
Livestock	1
Contemp	1
Historic	1
Flood	1
Wind	1
Graze	1
Insect	1
Fire	1
Drying	4
Flow Mod	FALSE
Modification Type	

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ACCO2	<i>Acacia constricta</i>	whitethorn acacia	Native		
CAGI10	<i>Carnegiea gigantea</i>	saguaro	Native		
LYCIU	<i>Lycium</i> sp.	desert-thorn	N/A		

Water quality characteristics. Water was insufficient for measurement.

KONWR005—High Tank 2 Spring

Sample Date: 10/15/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	0
Discharge (L/min)	0.01
Mean Water Depth (cm)	0.01
Mean Water Width (cm)	5.00
Emergent Cover (%)	0.00
Vegetated Bank Cover (%)	0
Fines (%)	5.00
Gravel (%)	5.00
Cobble (%)	5.00
Boulder (%)	5.00
Sand (%)	5.00
Comments	

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	1
Hiking	1
RecUse	1
FlowMod	4
Livestock	2
Contemp	1
Historic	1
Flood	1
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow Mod	TRUE
Modification Type	Pipe Diversion; Dam Diversion; Open Trough/Tank

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ACGR	<i>Acacia greggii</i>	catclaw acacia	Native		
AMDE4	<i>Ambrosia deltoidea</i>	triangle burr ragweed	Native		
BRICK	<i>Brickellia</i> sp.	brickellbush	N/A		
BRRU2	<i>Bromus rubens</i>	red brome	Non-native		
CAGI10	<i>Carnegiea gigantea</i>	saguaro	Native		
PROSO	<i>Prosopis</i> sp.	mesquite	N/A		
QUERC	<i>Quercus</i> sp.	oak	N/A		

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter	Value
Orifice	Tank
Shade	Shade
Temp	18.7
DO (mg/L)	6.64
DO (%)	77
pH	8.17
TDS	319.15
EC (μS)	
Notes	Round tank under shade cover; Not enough water in orifice or upper pools.
Alka_CaCO ₃	190
Alka_HCO ₃ ⁻	235
Alka_CO ₃ ²⁻	115
Chloride	36
Magnesium	130
Sulphate (SO ₄ ²⁻)	4
Sulphur (S)	1
Calcium (Ca)	32
Location	Tank with shade roof
Notes	

KONWR006—High Tank 9 Spring

Sample Date: 10/16/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	1.5
Discharge (L/min)	0.01
Mean Water Depth (cm)	0
Mean Water Width (cm)	30
Emergent Cover (%)	25
Vegetated Bank Cover (%)	5
Fines (%)	10
Gravel (%)	10
Cobble (%)	30
Boulder (%)	10
Sand (%)	20
Comments	

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	1
Hiking	1
RecUse	1
FlowMod	3
Livestock	1
Contemp	2
Historic	3
Flood	1
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow Mod	TRUE
Modification Type	Dam Diversion

Vegetation observations. For Wetland Indicator, FACW=facultative wetland.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ACGR	<i>Acacia greggii</i>	catclaw acacia	Native		
BASA2	<i>Baccharis sarothroides</i>	desertbroom	Native		
BEJU	<i>Bebbia juncea</i>	sweetbush	Native		
BOTHR	<i>Bothriochloa</i> sp.	beardgrass	N/A		
CECA3	<i>Centaurium calycosum</i>	Arizona centaury	Native	FACW	USDA
POMO5	<i>Polypogon monspeliensis</i>	annual rabbitsfoot grass	Non-native	FACW	USDA
SICH	<i>Simmondsia chinensis</i>	jojoba	Native		
TAMAR2	<i>Tamarix</i> sp.	tamarisk	N/A	YES	CHDN
VIDE6	<i>Viguiera deltoidea</i>	triangle goldeneye	N/A		

Water quality characteristics. Water was insufficient for measurement.

KONWR007—Holly Seep

Sample Date: 10/13/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	0
Discharge (L/min)	0.01
Mean Water Depth (cm)	10
Mean Water Width (cm)	100
Emergent Cover (%)	0
Vegetated Bank Cover (%)	0
Fines (%)	90
Gravel (%)	5
Cobble (%)	5
Boulder (%)	0
Sand (%)	0
Comments	Seep is covered by corrugated tin roof.

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	1
Hiking	1
RecUse	1
FlowMod	4
Livestock	1
Contemp	1
Historic	1
Flood	1
Wind	1
Graze	2
Insect	1
Fire	1
Drying	1
Flow Mod	TRUE
Modification Type	Open Trough/Tank; Encasement

Vegetation observations. For Wetland Indicator, FACW=facultative wetland, OBL=wetland obligate.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ACGR	<i>Acacia greggii</i>	catclaw acacia	Native		
BASA2	<i>Baccharis sarothroides</i>	desertbroom	Native		
ENCEL	<i>Encelia</i> sp.	brittlebush	N/A		
PAMI5	<i>Parkinsonia microphylla</i>	yellow paloverde	Native		
PLSE	<i>Pluchea sericea</i>	arrowweed	Native	FACW	USDA
TYAN	<i>Typha angustifolia</i>	dwarf cat-tail	Native	OBL	USDA

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter	Value
Orifice	1
Shade	Shade
Temp	16.2
DO (mg/L)	
DO (%)	
pH	9.11
TDS	347.75
EC (μS)	535.5
Notes	Measurement taken at pool below orifice. YSI would not log sample (Site name list may be full).
Alka_CaCO ₃	110
Alka_HCO ₃ ⁻	130
Alka_CO ₃ ²⁻	65
Chloride	44
Magnesium	85
Sulphate (SO ₄ ²⁻)	5
Sulphur (S)	2
Calcium (Ca)	28
Location	
Notes	

KONWR008—Indian Seep

Sample Date: 10/14/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	0
Discharge (L/min)	0
Mean Water Depth (cm)	150
Mean Water Width (cm)	100
Emergent Cover (%)	90
Vegetated Bank Cover (%)	100
Fines (%)	50
Gravel (%)	0
Cobble (%)	0
Boulder (%)	0
Sand (%)	0
Comments	

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	2
Hiking	1
RecUse	1
FlowMod	4
Livestock	1
Contemp	2
Historic	4
Flood	1
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow Mod	TRUE
Modification Type	Open Trough/Tank; Encasement; Excavation

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
POUN3	<i>Polanisia uniglandulosa</i>	Mexican clammyweed	Native		
PRGL2	<i>Prosopis glandulosa</i>	honey mesquite	Native		
	<i>Suaeda</i> sp.	seepweed			
TYPHA	<i>Typha</i> sp.	cattail	N/A	YES	CHDN

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter	Value
Orifice	
Shade	Partial
Temp	17.9
DO (mg/L)	
DO (%)	
pH	8.03
TDS	1111.5
EC (μS)	1707
Notes	DO failed to pass post calibration
Alka_CaCO ₃	530
Alka_HCO ₃ ⁻	640
Alka_CO ₃ ²⁻	320
Chloride	27
Magnesium	0.0009
Sulphate (SO ₄ ²⁻)	165
Sulphur (S)	55
Calcium (Ca)	42
Location	
Notes	

KONWR009—Jasper Spring

Sample Date: 10/14/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	6
Discharge (L/min)	
Mean Water Depth (cm)	
Mean Water Width (cm)	
Emergent Cover (%)	0
Vegetated Bank Cover (%)	0
Fines (%)	
Gravel (%)	
Cobble (%)	
Boulder (%)	
Sand (%)	
Comments	

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	2
Hiking	1
RecUse	2
FlowMod	4
Livestock	1
Contemp	1
Historic	2
Flood	1
Wind	1
Graze	3
Insect	1
Fire	1
Drying	1
Flow Mod	TRUE
Modification Type	Pipe Diversion; Dam Diversion; Open Trough/Tank; Encasement; Sealed

Vegetation observations. For Wetland Indicator, FACW=facultative wetland, OBL=wetland obligate.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
BACCH	<i>Baccharis</i> sp.	baccharis species	N/A	YES	CHDN
CAGI10	<i>Carnegiea gigantea</i>	saguaro	Native		
DISP	<i>Distichlis spicata</i>	inland saltgrass	Native		
LATR2	<i>Larrea tridentata</i>	creosote bush	Native		
PLSE	<i>Pluchea sericea</i>	arrowweed	Native	FACW	USDA
POMO5	<i>Polypogon monspeliensis</i>	annual rabbitsfoot grass	Non-native	FACW	USDA
PROSO	<i>Prosopis</i> sp.	mesquite	N/A		
TAMAR2	<i>Tamarix</i> sp.	tamarisk	N/A	YES	CHDN
TYPHA	<i>Typha</i> sp.	cattail	N/A	YES	CHDN

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter	Value	
Orifice	1	2
Shade	Partial	Shade
Temp	16.7	21.9
DO (mg/L)	7.34	4.94
DO (%)	75.1	57
pH	7.82	7.45
TDS	650	481
EC (μS)	996	739
Notes	Has spring box with two pipes.	Man-made pool with pipe diversion
Alka_CaCO ₃	235	215
Alka_HCO ₃ ⁻	285	260
Alka_CO ₃ ²⁻	140	130
Chloride	24	48
Magnesium	215	250
Sulphate (SO ₄ ²⁻)	41	36
Sulphur (S)	14	12
Calcium (Ca)	46	48
Location	Main Spring Box	Pool
Notes		OR2 Pool (wildlife trough) with pipe diversion

KONWR010—Tunnel Spring

Sample Date: 10/16/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	30
Discharge (L/min)	0.01
Mean Water Depth (cm)	0.01
Mean Water Width (cm)	50
Emergent Cover (%)	60
Vegetated Bank Cover (%)	0
Fines (%)	100
Gravel (%)	0
Cobble (%)	0
Boulder (%)	0
Sand (%)	0
Comments	

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	1
Hiking	1
RecUse	1
FlowMod	4
Livestock	1
Contemp	4
Historic	2
Flood	3
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow_Mod	TRUE
Mod_Type	Dam Diversion; Open Trough/ Tank; Encasement; Excavation

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ACGR	<i>Acacia greggii</i>	catclaw acacia	Native		
GUSA2	<i>Gutierrezia sarothrae</i>	broom snakeweed	Native		
OPUNT	<i>Opuntia</i> sp.	pricklypear	N/A		
PRGL2	<i>Prosopis glandulosa</i>	honey mesquite	Native		
QUERC	<i>Quercus</i> sp.	oak	N/A		
RHTR	<i>Rhus trilobata</i>	skunkbush sumac	Native		
SICH	<i>Simmondsia chinensis</i>	jojoba	Native		

Water quality characteristics. Measurements not taken as source could not be safely accessed.

KONWR011—Wilkinson Seep

Sample Date: 10/13/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	0
Discharge (L/min)	0
Mean Water Depth (cm)	0
Mean Water Width (cm)	0
Emergent Cover (%)	0
Vegetated Bank Cover (%)	0
Fines (%)	
Gravel (%)	
Cobble (%)	
Boulder (%)	
Sand (%)	
Comments	

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	4
Hiking	1
RecUse	1
FlowMod	1
Livestock	2
Contemp	1
Historic	1
Flood	1
Wind	1
Graze	2
Insect	1
Fire	1
Drying	4
Flow Mod	FALSE
Modification Type	

Vegetation observations. For Wetland Indicator, FACW=facultative wetland.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
BACCH	<i>Baccharis</i> sp.	baccharis species	N/A	YES	CHDN
CAGI10	<i>Carnegiea gigantea</i>	saguaro	Native		
HYMEN3	<i>Hymenoclea</i> sp.	Burrobrush	N/A		
PLSE	<i>Pluchea sericea</i>	arrowweed	Native	FACW	USDA
PROSO	<i>Prosopis</i> sp.	mesquite	N/A		
TYPHA	<i>Typha</i> sp.	cattail	N/A	YES	CHDN

Water quality characteristics. Water was insufficient for measurement.

KONWR012—Dixon Spring

Sample Date: 10/17/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	0
Discharge (L/min)	0
Mean Water Depth (cm)	20
Mean Water Width (cm)	100
Emergent Cover (%)	0
Vegetated Bank Cover (%)	0
Fines (%)	10
Gravel (%)	10
Cobble (%)	80
Boulder (%)	0
Sand (%)	0
Comments	

Disturbance. Scores for natural and anthropogenic disturbance. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed.

Parameter	Value
Roads	1
Hiking	1
RecUse	1
FlowMod	4
Livestock	1
Contemp	4
Historic	2
Flood	3
Wind	1
Graze	1
Insect	1
Fire	1
Drying	1
Flow Mod	TRUE
Modification Type	Dam Diversion; Open Trough/ Tank; Encasement; Excavation

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ACCO2	<i>Acacia constricta</i>	whitethorn acacia	Native		
ACGR	<i>Acacia greggii</i>	catclaw acacia	Native		
ATHY	<i>Atriplex hymenelytra</i>	desert holly	Native		
CAGI10	<i>Carnegiea gigantea</i>	saguaro	Native		
ENCEL	<i>Encelia</i> sp.	brittlebush	N/A		
FOSP2	<i>Fouquieria splendens</i>	ocotillo	Native		
LATR2	<i>Larrea tridentata</i>	creosote bush	Native		
PARKI2	<i>Parkinsonia</i> sp.	palo verde	N/A		
PHORA	<i>Phoradendron</i> sp.	mistletoe	N/A		

Water quality characteristics. Except for pH, all units are mg/L unless otherwise indicated.

Parameter	Value
Orifice	1
Shade	Partial
Temp	22.1
DO (mg/L)	
DO (%)	
pH	8.48
TDS	2847
EC (μS)	4383
Notes	Taken in well tank. DO failed post calibration
Alka_CaCO ₃	650
Alka_HCO ₃ ⁻	800
Alka_CO ₃ ²⁻	400
Chloride	205
Magnesium	1000
Sulphate (SO ₄ ²⁻)	370
Sulphur (S)	120
Calcium (Ca)	160
Location	
Notes	

Appendix C List of Plants Detected

Table C1. List of plants detected at Kofa National Wildlife Refuge springs.

Scientific Name	Common Name	Nativity
<i>Acacia</i> sp.	acacia	
<i>Acacia constricta</i>	whitethorn acacia	Native
<i>Acacia greggii</i>	catclaw acacia	Native
<i>Ambrosia deltoidea</i>	triangle burr ragweed	Native
<i>Atriplex hymenelytra</i>	desert holly	Native
<i>Baccharis</i> sp.	baccharis species	
<i>Baccharis sarothroides</i>	desertbroom	Native
<i>Bebbia juncea</i>	sweetbush	Native
<i>Bothriochloa</i> sp.	beardgrass	
<i>Brickellia</i> sp.	brickellbush	
<i>Bromus rubens</i>	red brome	Introduced
<i>Carnegiea gigantea</i>	saguaro	Native
<i>Centaurium calycosum</i>	Arizona centaury	Native
<i>Cleome lutea</i>	yellow spiderflower	Native
<i>Distichlis spicata</i>	inland saltgrass	Native
<i>Encelia</i> sp.	brittlebush	
<i>Encelia frutescens</i>	button brittlebush	Native
<i>Fouquieria splendens</i>	ocotillo	Native
<i>Gutierrezia sarothrae</i>	broom snakeweed	Native
<i>Hymenoclea</i> sp.	burrobrush	Native
<i>Larrea tridentata</i>	creosote bush	Native
<i>Lycium</i> sp.	desert-thorn	
<i>Opuntia</i> sp.	pricklypear	
<i>Parkinsonia microphylla</i>	yellow paloverde	Native
<i>Parkinsonia</i> sp.	palo verde	
<i>Phoradendron</i> sp.	mistletoe	
<i>Pluchea sericea</i>	arrowweed	Native
<i>Polypogon monspeliensis</i>	annual rabbitsfoot grass	Non-native
<i>Polanisia uniglandulosa</i>	Mexican clammyweed	Native
<i>Prosopis glandulosa</i>	honey mesquite	Native
<i>Prosopis</i> sp.	mesquite	
<i>Quercus</i> sp.	oak	
<i>Rhus trilobata</i>	skunkbush sumac	Native
<i>Salix</i> sp.	willow	
<i>Simmondsia chinensis</i>	jojoba	Native
<i>Tamarix</i> sp.	tamarisk	
<i>Typha angustifolia</i>	dwarf cattail	Native
<i>Typha</i> sp.	cattail	
<i>Viguiera deltoidea</i>	triangle goldeneye	
<i>Yucca</i> sp.	yucca	

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