



Inventory of Spring Ecosystems at Bitter Lake National Wildlife Refuge, New Mexico

Physical and Biological Characteristics

Natural Resource Technical Report NPS/CHDN/NRTR—2013/817



ON THE COVER

Sago Spring, Bitter Lake National Wildlife Refuge
Photograph: NPS

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Executive Summary

This report summarizes information gathered during an inventory of springs in Bitter Lake National Wildlife Refuge 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.

Ten springs were inventoried during this effort. Seven of the ten springs were heavily influenced by humans, either by excavation or damming, that modified spring flow. All springs had water flowing despite severe drought conditions. Typical wetland plants were found at the springs, including cottonwoods, baccharis, cattails, and a variety of grasses and forbs. Two species of exotic plants were detected, prickly Russian thistle at Lost River Spring and tamarisk at Hondo River, Hunter's Marsh Ditch, Hunter's Marsh Fence 1 and 2, and Unit 15 North Slope.

Water was sufficient for water quality analysis at all springs inventoried. Water quality characteristics were mostly within expected values or standards set by the U.S. Environmental Protection Agency or New Mexico Environment Department. Exceptions were with dissolved oxygen concentrations. Only one spring, Hondo River, met levels required to support aquatic life. 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.

Acknowledgments

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Introduction

Water in the Bitter Lake National Wildlife Refuge (NWR), New Mexico 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

Ten springs in Bitter Lake NWR (Figure 1, Table 1) were inventoried in 13-15 December 2011 following the 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 inventory was conducted as part of a larger spring inventory effort in national parks in southeastern New Mexico and west Texas and wildlife refuges in New Mexico and Arizona.

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

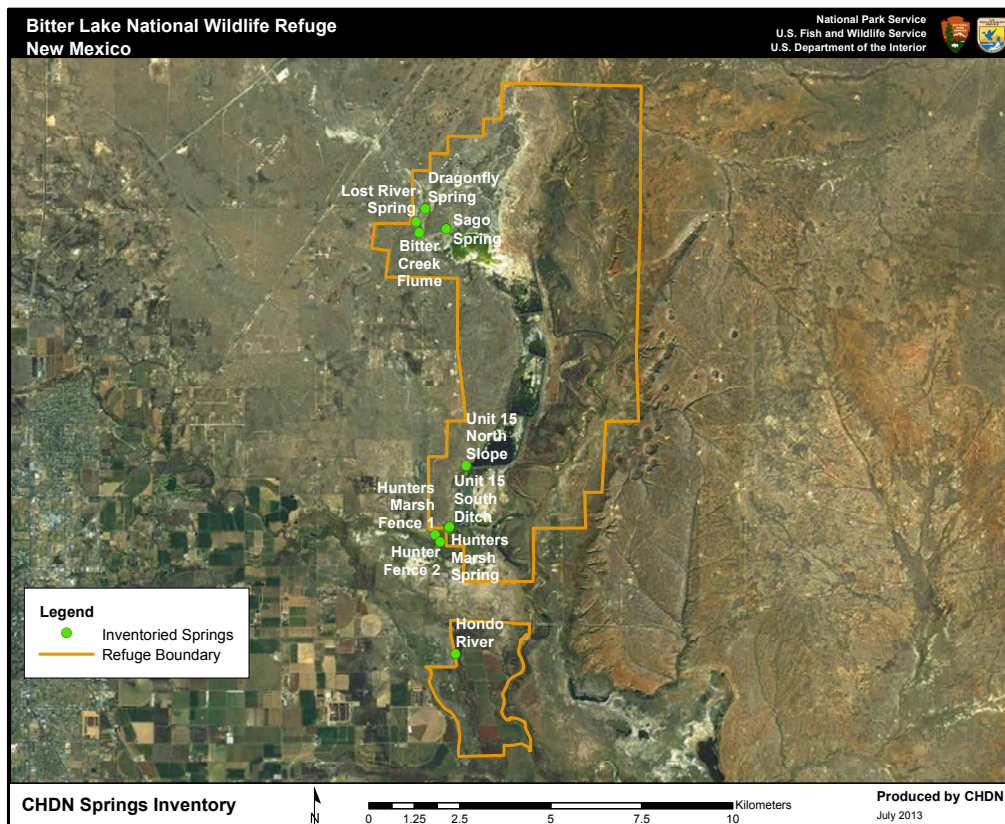


Figure 1. Map of springs surveyed at Bitter Lake National Wildlife Refuge.

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 Bitter Lake 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. Springs included in the inventory at Bitter Lake National Wildlife Refuge including the date and level of sampling.

Spring ID	Spring Name	Date	Level
BLNWR001	Bitter Creek Flume	12/13/2011	1
BLNWR002	Dragonfly Spring	12/13/2011	1
BLNWR003	Hondo River	12/15/2011	1
BLNWR004	Hunter's Marsh Ditch	12/14/2011	1
BLNWR005	Hunter's Marsh Fence 1	12/14/2011	1
BLNWR006	Hunter's Marsh Fence 2	12/14/2011	1
BLNWR007	Lost River Spring	12/13/2011	1
BLNWR008	Sago Spring	12/13/2011	1
BLNWR009	Unit 15 North Slope	12/14/2011	1
BLNWR010	Unit 15 South Ditch	12/14/2011	1

Results and Discussion

Overall, 2011 was a very dry year and New Mexico experienced one of its worst wildfire seasons. The southern half of the state, including Bitter Lake NWR was under D4 exceptional drought conditions, which is the most intense category in the U.S. Drought Monitor Index. Prior to monsoon season, Bitter Lake received less than 0.5 inches of rain January-August 2011. In spite of this drought, all springs inventoried had sufficient flow to maintain well-developed riparian vegetation communities. Surface water was present at 8 of the 10 springs inventoried. Although surface water was not present at Dragonfly Spring and Unit 15 North Slope, both springs had sufficient water to support wetland obligate plant species. These conditions are better than findings across the region. Of the 502 springs sampled in New Mexico and west Texas during the inventory, 199 or 40% were dry or had insufficient water for water quality measurements. Data for Bitter Lake NWR springs are located in Appendix B.

Disturbance

Anthropogenic disturbance to springs is fairly high. Twenty three percent of springs inventoried across New Mexico and west Texas have some kind of flow modification. Seven Bitter Lake NWR springs (70%) have had some kind of flow modification historically: dam diversion at Bitter Creek

flume, Unit 15 North Slope, Unit 15 South, and Hunters Fence 1; and excavation at Hondo River, Hunters Marsh Ditch, and Hunters Fence 2. Sixty percent of Bitter Lake NWR springs are undisturbed or are slightly disturbed for roads (Table 2). Ninety four percent of springs in the southern New Mexico and west Texas are undisturbed or slightly disturbed relative to roads (Figure 2). Except for the Hondo River area, none of the Bitter Lake NWR springs were

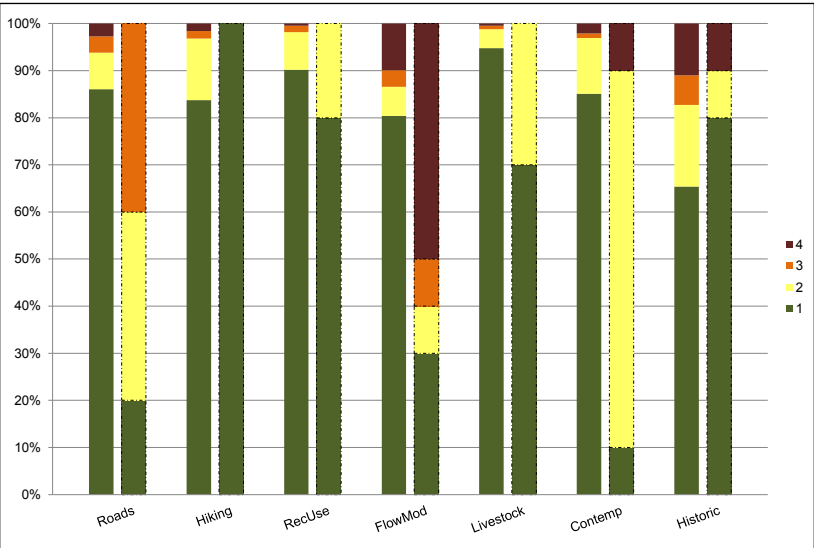


Figure 2. Comparison of levels of anthropogenic disturbance in parks and refuges across New Mexico and west Texas (bars not outlined) and in Bitter Lake National Wildlife Refuge (bars with dashed outline). Graph shows proportion of springs rated in each disturbance category. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed. See Appendix A for additional information.

Table 2. Scores for anthropogenic disturbance in Bitter Lake NWR springs. Disturbance types include effect of roads, hiking trails, recreation use, flow modification, livestock presence/grazing, presence of flow modification and type of flow modification. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed. See Appendix A for additional information.

Spring ID	Title	Roads	Hiking	RecUse	FlowMod	Livestock	Contemp	Historic
BLNWR001	Bitter Creek Flume	2	1	1	2	1	2	1
BLNWR002	Dragonfly Spring	2	1	1	1	1	2	1
BLNWR003	Hondo River	3	1	1	4	2	4	4
BLNWR004	Hunter's Marsh Ditch	3	1	2	4	1	2	1
BLNWR005	Hunter's Marsh Fence 1	1	1	1	4	2	1	1
BLNWR006	Hunter's Marsh Fence 2	1	1	1	3	2	2	2
BLNWR007	Lost River Spring	2	1	1	1	1	2	1
BLNWR008	Sago Spring	2	1	1	1	1	2	1
BLNWR009	Unit 15 North Slope	3	1	1	4	1	2	1
BLNWR010	Unit 15 South Ditch	3	1	2	4	1	2	1

affected by other forms of anthropogenic disturbance, such as the presence of hiking trails, recreational use, or livestock grazing. The area around Hondo River is agricultural and some livestock use was apparent.

Effects of natural disturbance were also minimal in Bitter Lake NWR springs. All springs are in the undisturbed or slightly disturbed categories for all types of disturbance (Table 3). These results are similar to springs across New Mexico and Texas, except for drying. None of springs inventoried in Bitter Lake NWR were moderately or highly disturbed by drying or drought, compared to 48% across the other inventoried springs (Figure 3). Although no surface water was present at Unit 15 North Slope, a number of riparian plant species were present including cattails, rushes, and baccharis, and appeared to be healthy, thus impacts of drying were not apparent at the time of survey.

Water Quality

Water quality measurements were taken at each spring with sufficient water (8 of 10 springs). Water temperatures were fairly warm, ranging from 8.6 to 18.5°C (Table 4). Temperatures were warmest in the Hondo River and Sago Spring. Dissolved oxygen (DO) concentrations were 0.8-8.8 mg/L. The level necessary to protect fish and other aquatic life, according to the U.S. Environmental Protection Agency (EPA) standard for DO, is 4 mg/L. The DO standard for the New Mexico Environment Department (NMED) for warm waters is 5.0 mg/L. Only one measurement at the Hondo River, met these standards. pH levels varied from 6.7 to 7.7, meeting NMED standards of 6.6-9.0. Total dissolved solids (TDS) ranged from 2,711 to 10,322 mg/L. The EPA doesn't have a standard for TDS and NMED has set them only for specific river basins, however, TDS values in Bitter Lake springs are fairly high. Of the more than 500 springs sampled, only the Salt Ponds in White Sands National Monument had TDS values higher than 4,000 mg/L. Electrical conductance ranged from 3,647 to 15,886 $\mu\text{S}/\text{cm}$. Standards have not been set for conductivity, however, these values are higher than what is typical in freshwater.

At 8 springs, 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 155 to 380 mg/L, bicarbonate levels ranged from 190 to 470 mg/L, and carbonate values ranged from 90 to 230 mg/L. These levels are typical for fresh water, given the range of pH values around neutral (Table 5).

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 had 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 interested are related to pollution from fertilizer and atmospheric deposition.

Calcium levels in the springs were not detectable (our instruments cannot detect values less than 5 mg/L). Calcium concentration greater than 20 mg Ca/L is associated with hard water (Wetzel 2001). Chloride levels ranged from 8.4 to 12.5

Table 3. Scores for natural disturbance in Bitter Lake NWR springs. Disturbance types include effect floods, wind, herbivore grazing (non-livestock), insect damage, fire, and drying or drought. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed. See Appendix A for additional information.

Spring ID	Title	Flood	Wind	Graze	Insect	Fire	Drying	Flow_ Mod	Mod_Type
BLNWR001	Bitter Creek Flume	1	1	1	1	1	1	YES	Dam Diversion
BLNWR002	Dragonfly Spring	1	1	1	1	2	1	NO	
BLNWR003	Hondo River	1	1	2	1	1	1	YES	Excavation
BLNWR004	Hunter's Marsh Ditch	1	1	1	1	2	1	YES	Excavation
BLNWR005	Hunter's Marsh Fence 1	1	1	2	1	1	1	YES	Dam Diversion; Excavation
BLNWR006	Hunter's Marsh Fence 2	1	1	1	1	1	1	YES	Excavation
BLNWR007	Lost River Spring	1	1	1	1	2	1	NO	
BLNWR008	Sago Spring	1	1	1	1	1	1	NO	
BLNWR009	Unit 15 North Slope	1	1	1	1	1	1	YES	Dam Diversion; Excavation
BLNWR010	Unit 15 South Ditch	1	1	1	1	2	1	YES	Dam Diversion; Excavation

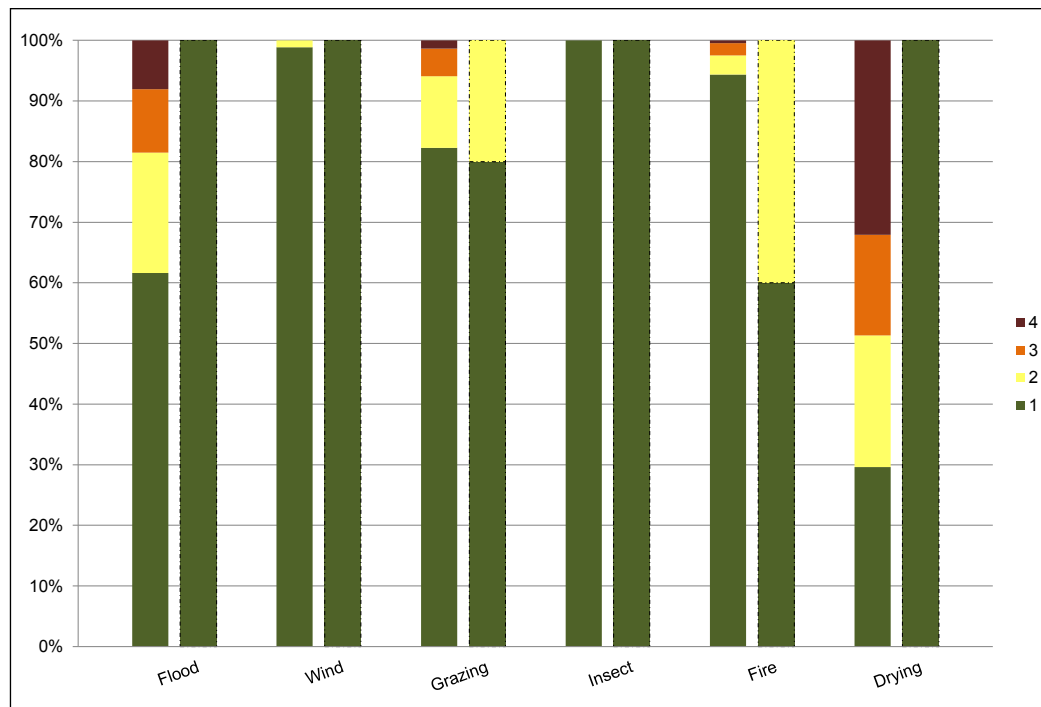


Figure 3. Comparison of levels of natural disturbance in parks and refuges across New Mexico and west Texas (bars not outlined) and in Bitter Lake National Wildlife Refuge (bars with dashed outline). Graph shows proportion of springs rated in each disturbance category. Categories are 1=undisturbed, 2=slightly disturbed, 3=moderately disturbed, 4=highly disturbed. See Appendix A for additional information.

Table 4. Water quality values including temperature (°C), dissolved oxygen (DO; mg/L), pH, total dissolved solids (TDS; mg/L), and electrical conductance (EC; μ S/cm). Also shown is whether the measurement was taken in sun or shade, whether the spring was dry, and notes about quality assurance and quality control. Dashes indicate no data.

Title	Orifice	Temp	DO	pH	TDS	EC	Shade	Dry	QA/QC Notes
Bitter Creek Flume	Flume	8.6	3.55	7.26	6623.5	7001	Shade	NO	
Dragonfly Spring		--	--	--	--	--	--	NO	No surface water
Hondo River	3	18.5	2.16	6.84	2710.5	3647	Shade	NO	From south fork of Y on west side of bank
Hondo River	River	12	8.82	7.67	4420	5124	Sun	NO	River = A swiftly flowing river, 8 m upstream from Vent A
Hondo River	1	18	2	6.92	6136	8159	Shade	NO	Vent A = in a vent, to the west side of river
Hondo River	2	17.7	1.7	6.91	6259.5	8296	Shade	NO	Vent B = in a vent, to the west side of river
Hunter's Marsh Ditch	Single	12.1	2.1	6.97	8261	9591	Shade	NO	
Hunter's Marsh Fence 1	Pool 3	15.2	2.19	6.84	6727	8422	Partial	NO	
Hunter's Marsh Fence 1	Pool 1	15.5	2.15	7.37	6870	10575	Partial	NO	Cattle pool: along west bank cut
Hunter's Marsh Fence 1	Pool 2	10.6	0.83	6.74	10322	15886	Sun	NO	Saltgrass flats: 10 m from slope in flats in natural opening
Hunter's Marsh Fence 2	Pool	14.2	3.62	7.09	6454.5	7899	Partial	NO	Full sun, shaded by bullrushes, muddy bottom
Lost River Spring	Single	10.2	2.46	7.19	6526	7205	Partial	NO	
Sago Spring	1	17.9	3.27	6.97	5603	7453	Partial	NO	
Sago Spring	2	17.9	2.56	6.98	5603	7459	Partial	NO	
Sago Spring	2	17.9	2.56	6.98	5603	7459	Partial	NO	
Sago Spring	3	17.9	2.65	7.01	5603	7452	Partial	NO	
Unit 15 North Slope		--	--	--	--	--	--	NO	Did not sample; no surface water
Unit 15 South Ditch	2	8.6	4.62	7.39	6688.5	7062	Shade	NO	
Unit 15 South Ditch	1	9.4	2.27	7.12	7995	8658	Sun	NO	

Table 5. Water quality values (mg/L) for calcium carbonate (CaCO₃), bicarbonate (HCO₃), carbonate (CO₃), chloride (Cl), magnesium (Mg), sulfate (SO₄), and calcium (Ca). Dashes indicate no data. ND indicates the parameter was not detected.

Title	Orifice	CaCO ₃	HCO ₃	CO ₃	Cl	Mg	SO ₄	Ca	Location
Bitter Creek Flume	Flume	220	270	135	10	1900	195	ND	Sample taken just upstream of flume
Dragonfly Spring		--	--	--	--	--	--	--	Did not sample
Hondo River	1	270	325	160	10.5	2400	1040	ND	In a vent/ pool along side of river
Hondo River	2	210	255	125	11	2800	1160	ND	In a vent/ pool along side of river
Hondo River	3	205	250	125	11	4800	1450	ND	From vent along west side of bank
Hunter's Marsh Ditch	Single	285	350	170	12.5	750	1000	ND	1 m below orifice in wetland/ marsh
Hunter's Marsh Fence 1	Pool 3	240	290	145	11	1600	1450	ND	
Hunter's Marsh Fence 2	Pool	220	265	130	8.4	1400	1100	ND	Bullrush pond
Lost River Spring	Single	285	350	170	9.8	500	195	ND	Sample taken in pool at orifice
Sago Spring	1	155	190	90	12	1700	1750	ND	Sample taken from primary vent/ orifice
Unit 15 North Slope		--	--	--	--	--	--	--	Did not sample
Unit 15 South Ditch	1	380	470	230	9.1	1400	1750	ND	Sample taken upstream in ditch

mg/L. Concentrations between 1 and 100 mg Cl /L are common in freshwater. Magnesium levels ranged from 500 to 4,800 mg/L. Sulfate concentration ranged from 195 to 1,750 mg/L. Typical ranges for sulfate concentration in freshwater is about 5-30 mg/L.

Vegetation

Typical wetland plants are found at the springs, including cottonwoods (*Populus* sp.), willows (*Salix* sp.), baccharis (*Baccharis* sp.), cattails (*Typha* sp.), and a variety of grasses

and forbs. A list of the species detected at all springs in the refuge is located in Appendix C. Note this list reflects dominant or common species and is not intended to be a thorough inventory of plant taxa. Bitter Lake NWR staff specifically requested that we not do more detailed vegetation surveys to avoid trampling the endangered Pecos sunflower (*Heliopsis parviflora*). Two species of exotic plants were detected, prickly Russian thistle (*Salsola tragus*) at Lost River Spring and tamarisk (*Tamarix* sp.) at Hondo River, Hunter's Marsh Ditch, Hunter's Marsh Fence 1 and 2, and Unit 15 North Slope.

Data for all springs are located in Appendix B.

Spring Descriptions

Bitter Creek Flume was chosen as a sample site because the refuge routinely takes water quality measurements here. Not a spring, just a place to sample a representation of characteristics of Bitter Creek. Water flows through a phragmites-choked channel, and swiftly flows through the flume. Other vegetation species in the channel include alkali sacaton (*Sporobolus airoides*), iodine bush (*Allenrolfia accidentalis*), and seepweed (*Suaeda* sp.). The channel the flume was located in was more than 1 km in length. Water was, on average, about 1.5 m wide and 30 cm deep. Vegetation completely covered the banks of the channel, and about there was about 10% cover of emergent vegetation in the channel. Substrate in the channel was composed of fines.

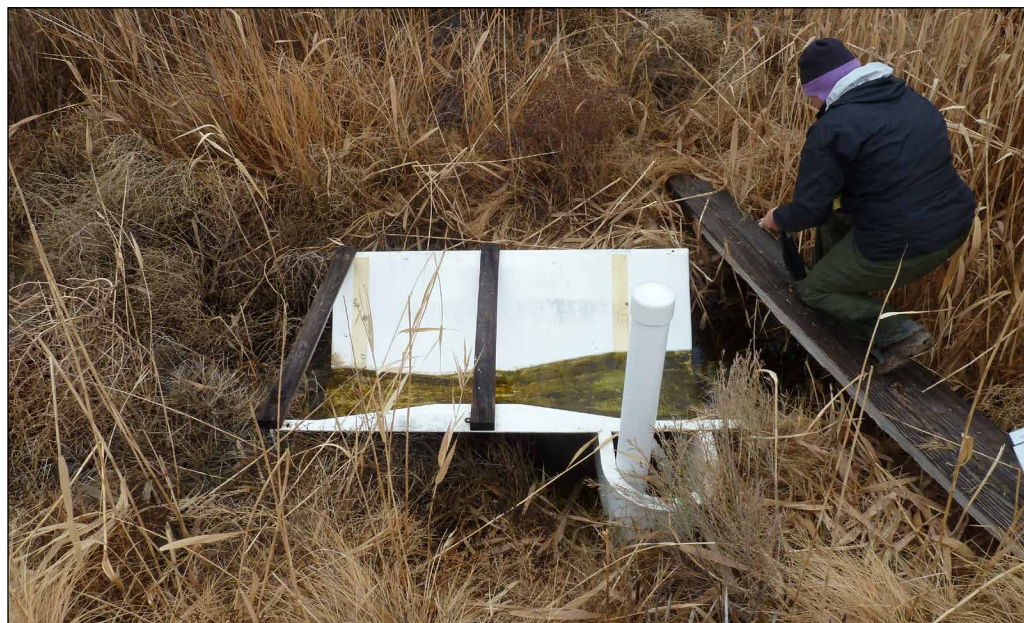
While there is plenty of water in **Dragonfly Spring**, no orifice(s) that could account for increase in flow along Bitter Creek were located. The area appears to be generally moist where water is diffusely coming to surface. Vegetation along creeks and pools is dominated by phragmites (*Phragmites australis*). The “upland” flats are dominated by alkali sacaton, iodine bush, and pickleweed (*Salicornia bigelovii*). Other species detected include Pecos sunflower, New Mexico olive (*Forestiera pubescens*) and

inland saltgrass (*Distichlis spicata*). Area has been heavily treated for tamarisk (*Tamarix chinensis*) removal.

The **Hondo River** site is on west bank of Hondo River in South/Farm Tract on Bitter Lake NWR and consists of a complex of spring orifices spread along the west side of the river. Orifice A is a hole in the bank (80 cm diameter) down to river level, but appears to have its own water output. No brook is visible, so it likely joins at or below current river level. Immediately upslope are three tamarisk and the bank is covered by phragmites and inland saltgrass. Bank cover by vegetation is 100%. The Hondo River has been channelized throughout the tract and has agriculture on both sides. Bank feels soft and saturated from river to 4 m upslope, and continues as such until Orifice B, which is approximately 50 m downstream in small bank cut (2 m long, 0.5 m wide, 0.5 m deep). Output is visibly bubbling up from substrate. Upstream on bank bench is phragmites and tamarisk in a stagnant pool of water which may be drainage of diffuse seep, making the bank saturated. Area has gypsum in bedrock and soil.

Hunter’s Marsh Ditch orifice emerges as a barely noticeable flowing ripple, discharge is estimated to be less than 1 L/min. Water seeps for about 1 m out of an excavated ditch (water width about 30 cm and depth about 5 cm) and joins an excavated wetland system known as Hunter’s Marsh. The ditch runs

NPS



Bitter Creek Flume.



Hondo River with a water quality probe.

parallel to the road. Cordgrass (*Spartina pectinata*) and saltgrass grow along ditch with cattails (*Typha angustifolia*) and phragmites growing in wetland. Vegetative bank cover is 100% and cover of emergent vegetation is about 20%. The area appears to have been treated for tamarisk, as evidenced by a few re-sprouts. The observed flow could be caused by recent rain showers as runoff drains down the ditch. No other obvious vents were discovered nearby (south of road). Surrounding area is more of a heleoecrene, it's not really a flowing stream. Valley contains gypsum bedrock and soils.

Hunter's Marsh Fence 1 is in the section of Bitter Lake NWR that is a large, 4-5 acre, piece of wet saltgrass meadow, with small open water puddles, pools, and larger ponds. The substrate is dominated by fines. Bullrush (*Scirpus* sp.), tamarisk, and cattails inhabit lower depressions that hold water. Much of the saltgrass grows over a wet surface about 10 cm deep. Vegetative bank cover is 100% and emergent cover is about 95%. Other species present include scratch grass (*Muhlenbergia asperifolia*), and Pecos sunflower. Water appears to seep out of the northwest hill, but most of the water is probably from countless diffuse orifices throughout the marsh. Ditches and ponds appear to be dug out of the marsh to direct water slowly down towards the refuge. Some ditches cross over the property into the refuge and give the appearance of springs, but they are probably just dug down into

the ground water table. (The majority of this section occurs on Roswell city property). Valley contains gypsum bedrock/soil.

Hunter's Marsh Fence 2 is approximately 150 m south of Hunter's Marsh Fence 1 on Roswell city property (Bitter Lake NWR has permission to enter and study springs than run onto the refuge). The channel appears less entrenched/dug as Hunter's Fence 1. The channel is dominated by dense bullrush with some saltgrass and scratch grass along edges and in openings; tamarisk is also present. There are various sporadic openings revealing water and fish. Site begins in a shallow "Y," almost T-shape, likely draining separate areas. Surrounding areas do not appear as wet as at HMF1. At fence, vegetation changes to phragmites. Valley contains gypsum bedrock/soils.

Lost River Spring begins as a 1 x 0.5 m vertical vent at what is now the start of Lost River. The brook splits near the vent and flows approximately 20 m before joining Bitter Creek. Water in the spring brook is about 2 m wide and 20 cm deep. The substrate is composed entirely of fines. The banks are densely vegetated (100% cover) with Pecos sunflower and phragmites. Uplands are dominated by alkalai sacaton with large open spaces between plants with (gypsum?) precipitate. Other plant species present include Pecos sunflower, saltgrass, and sea lavender (*Limonium limbatum*); non-native Russian thistle was also present.



Lost River Spring.

Water is clear and has a sulfur odor. Pecos gambusia and endangered spring snails are of concern for future monitoring (in addition to Pecos sunflower), but timing of sampling may sufficiently mitigate impacts. Area has gypsum in bedrock and soil.

Sago Spring is a sink hole with three orifices. Orifice 1 is in the northwest corner of the sinkhole, with water emerging from the bank cut. Orifice 2 is smaller than 1, and emerges near the southwest bank from the bottom of the pool. Orifice 3 is in a large pool on the northeast end of the hole, and currently has little to no output. Historically it did have output (according to Bitter Lake NWR staff), but a recent bank collapse may have blocked the orifice. All orifices/pools are connected with water flowing from orifice 1 to 3. Additional pools/holes are in the immediate area, but none appear to have output. Below/downstream of Orifice 3 water disappears, but historic accounts link sinkhole 31 to Sago hydrologically. Substrate is fine soil with precipitate (gypsum?). Vegetation is dominated by saltgrass with wideongrass (*Ruppia maritima*) in water. Also present was sea lavender and iodine bush. Tamarisk has been cut and treated. This is an active snail and amphipod monitoring at site. *Gammarus desperatus*, Koster's springsnail (*Juturnia kosteri*), Roswell springsnail

(*Purgulopsis roswellensis*), Pecos pupfish (*Cyprinodon pecosensis*), and round-nosed minnows (*Dionda* sp.) were identified by Bitter Lake NWR staff during the visit. Pool 1: 2 x 0.5 m, 50 cm deep. Pool 2: 6 x 3 m, 30 cm deep. Pool 3: 5 x 3 m, 70 cm deep. All pools are located in bottom of a depression with vertical sides (1.5+ m). Valley has bedrock and gypsic soils.

Unit 15 North Slope is located in the northwest corner of unit 15 along slope below the Wildlife Viewing Road. Wetland vegetation (bullrush, cattails) extends about 7 m upslope above pool of water, indicating the possible presence of a diffuse contact seep. While there is no surface water on the slope itself, the soil is saturated more than soil near the top of the slope. This appears to be the case further south along the slope though the vegetation becomes dominated by phragmites beyond this point. The pool at the base of the slope appears to be connected to the impoundment via a narrow channel to the south along the slope. Both bank cover and emergent vegetation cover are 100%. The rest of the pool is isolated from the impoundment by a shallow ridge vegetated with iodine bush. Bulrush and cordgrass dominate the bank cut orifice and 15-m drainage to the cattail-dominated pool. Tamarisk re-sprouts are located just above the orifice. The pool itself is ~30x20 m. Valley contains bedrock and gypsum soils.

Unit 15 South Ditch runs alongside the road at the south end of unit 15. As such, we are uncertain if this is truly a spring orifice (a finger of impounded wetland) or just a drainage ditch. Recent rains may have filled the ditch over normal levels, but presence of bulrush and baccharis within 15 m of marked orifice indicate the ditch usually contains water. Other common plant species include cordgrass, saltgrass, iodine bush, and scratchgrass. Endangered Pecos sunflower was also observed. Water at this site flows down a gentle grade from western "bluffs" along valley. The ditch is ~2 m wide, 1 m deep, and 75 m long and consisted of fine substrates. Water depth was about 8 cm. The channel was thickly vegetated. The surrounding area is a heleocrene-like marsh, which has been dammed to collect water. Valley contains bedrock and gypsum soils.

Literature Cited

- Botosaneanu, L. (ed.). 1998. Studies in Crenobiology. The Biology of Springs and Springbrooks. Backhuys Publishers, Leiden, The Netherlands.
- Brussard, P. F., D. A. Charlet, and D. S. Dobkin. 1998. The Great Basin-Mojave Desert Region. Pages 505-542 in M. J. Mac, P. A. Opler, C. E. Puckett-Haecker, and P. D. Doran, editors. The status and trends of the nation's biological resources. U.S. Geological Survey, Reston, VA.
- Castelli, R. M., J. C. Chambers, and R. J. Tausch. 2000. Soil-plant relations along a soil-water gradient in Great Basin riparian meadows. *Wetlands* 20:251-266.
- Cushing, C. E. 1996. The ecology of cold desert spring-streams. *Archiv für Hydrobiologie* 135:499-522.
- Fleischner, T. L. 1994. Ecological costs of livestock grazing in western North America. *Conservation Biology* 8:629-644.
- Fleishman, E., D. D. Murphy, and D. W. Sada. 2006. Effects of environmental heterogeneity and disturbance on the native and non-native flora of desert springs. *Biological Invasions* 8:1091-1101.
- Freeze, R. A. and J. A. Cherry. 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.
- Hershler, R., Madsen, D. B. and Currey, D. (eds). 2002. Great Basin aquatic systems history. Smithsonian Contributions to the Earth Sciences No. 33. Washington, D.C.
- Knopf, F. L., R. R. Robinson, T. Rich, F.B. Samson, and R.C. Sazo. 1988. Conservation of riparian ecosystems in the United States. *Wilson Bulletin* 100:272-284.
- McCabe, D. J. 1998. Biological communities in springbrooks. Pages 221-228. in L. Botosaneanu (ed.). Studies in Crenobiology. The Biology of Springs and Springbrooks. Backhuys Publishers, Leiden, The Netherlands.
- Meffe, G. K. and P. C. Marsh. 1983. Distribution of aquatic macroinvertebrates in the Sonoran Desert springbrooks. *Journal of Arid Environments* 6:363-371.
- Minckley, W. L., D. A. Hendrickson, and C. E. Bond. 1986. Geography of western North American freshwater fishes: Description and relationships to intracontinental tectonism. Pages 519-614. In C. H. Hocutt and E. O. Wiley (eds.). The Zoogeography of North American Freshwater Fishes. John Wiley and Sons Publishing, New York, NY.
- Myers, M. J. and V. H. Resh. 1999. Spring-formed wetlands of the arid west. Islands of aquatic invertebrate biodiversity. Pages 811- 828. In D. P. Batzer, R. B. Radar, and S. A. Wissner (eds.). Invertebrates in Freshwater Wetlands of North America: Ecology and Management. John Wiley and Sons, New York, NY, USA.
- Resh, V. H. 1983. Spatial differences in the distribution of benthic macroinvertebrates along a springbrook. *Aquatic Insects* 5:193-200.
- Resh, V. H., A. V. Brown, A. P. Covich, M. E. Gurtz, H. W. Li, W. Minshall, S. R. Reice, A. L. Sheldon, J. B. Wallace, and R. C. Wissmar. 1988. The role of disturbance in stream ecology. *Journal of the North American Benthological Society* 7:433-455.
- Saab, V. A., C. E. Brock, T. D. Rich, and D. S. Dobkin. 1995. Livestock grazing effects in western North America. Pages 311-353 In T. E. Martin and D. M. Finch (eds.). Ecology and management of Neotropical migratory birds. Oxford University Press, New York.
- Sada, D. W. 2001. Demography and habitat use of the Badwater snail (*Assimineae infima*), with observations on its

- conservation status. *Hydrobiologia* 466:255-265.
- Sada, D. W. and K. F. Pohlmann. 2006. U.S. National Park Service, Mojave Inventory and Monitoring Network, Spring Survey Protocols: Levels I and II. Unpublished report, U.S. National Park Service, Mojave Inventory and Monitoring Network, Boulder City, Nevada.
- Sada, D. W. and G. L. Vinyard. 2002. Anthropogenic changes in historical biogeography of Great Basin aquatic biota. Pages 277-293. In R. Hershler, D. B. Madsen, and D. Currey (eds.). Great Basin Aquatic Systems History. Smithsonian Contributions to the Earth Sciences No. 33.
- Sada, D. W., E. Fleischman, and D. D. Murphy. 2005. Associations among spring-dependent aquatic assemblages and environmental and land use gradients in a Mojave Desert mountain range. *Diversity and Distributions* 11:91-99.
- Schmitz, D., B. McGlynn, and D. Patten. 2007. Development of a spring ecosystem monitoring protocol in Bighorn Canyon National Recreation Area. Final Report Submitted to Greater Yellowstone Network Inventory and Monitoring Program, National Park Service. Land Resources and Environmental Sciences, Montana State University.
- Shepard, W. D. 1993. Desert springs—both rare and endangered. *Aquatic Conservation: Marine and Freshwater Ecosystems* 3:351-359.
- Smith, S. D., A. B. Wellington, J. L. Nachlinger, and C. A. Fox. 1991. Functional responses of riparian vegetation to streamflow diversion in the eastern Sierra Nevada. *Ecological Applications* 1:89-97.
- Stromberg, J. C. and D. T. Patten. 1992. Mortality and age of black cottonwood stands along diverted and undiverted streams in the eastern Sierra Nevada, California. *Madrono* 39:205-223.
- Thomas, J. W., C. Maser, and J. E. Rodiek. 1979. Wildlife habitats in managed rangelands: the Great Basin of southeastern Oregon. Riparian Zone. US Bureau of Land Management General Technical Report PNW-80. Washington, D.C.
- Thomas, J. M., A. H. Welch, and M. D. Dettinger. 1996. Geochemistry and isotope hydrology of representative aquifers in the Great Basin region of Nevada, Utah, and adjacent states. U.S. Geological Survey Professional Paper 1409-C.
- Wetzel, R. G. 2001. Limnology: Lake and river ecosystems. 3rd Edition. Academic Press, San Diego, CA. 1006 pp.
- Williams, D. D. and H. V. Danks (eds). 1991. Arthropods of springs, with special reference to Canada. Memoirs of the Entomological Society of Canada, No. 155.

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 Bitter Lake National Wildlife Refuge spring.

BLNWR001—Bitter Creek Flume

Sample Date: 12/13/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	>1000
Mean Water Depth (cm)	30
Mean Water Width (cm)	150
Emergent Cover (%)	10
Vegetated Bank Cover (%)	100
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
Flood	1
Wind	1
Grazing	1
Insect	1
Fire	1
Drying	1
Roads	2
Hiking	1
RecUse	1
FlowMod	2
Livestock	1
Contemp	2
Historic	1
Flow Mod	YES
Modification Type	Dam Diversion

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

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ALOC2	<i>Allenrolfea occidentalis</i>	iodine bush	Native	FACW	USDA
HEPA4	<i>Heliopsis parvifolia</i>	mountain oxeye	Native		
PHRAG	<i>Phragmites</i> sp.	phragmites	Non-native		
SPAI	<i>Sporobolus airoides</i>	alkali sacaton	Native		
	<i>Suaeda</i> sp.	seepweed			

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

Parameter	Value
Orifice	Flume
Shade	Shade
Temp	8.6
DO (mg/L)	3.55
DO (%)	31.4
pH	7.26
TDS	6623.5
EC (μS)	7001
Notes	Cloudy day, also in shade. Just upstream of flume
Alka_CaCO ₃	220
Alka_HCO ₃ ⁻	270
Alka_CO ₃ ²⁻	135
Chloride	10
Magnesium	1900
Sulphate (SO ₄ ²⁻)	195
Sulphur (S)	65
Calcium (Ca)	ND
Location	Sample taken just upstream of flume
Notes	Sample likely came in contact with soil

ND indicates the parameter was not detected

BLNWR002—Dragonfly Spring

Sample Date: 12/13/2011

Physical characteristics. Measurements not taken

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

Parameter	Value
Flood	1
Wind	1
Grazing	1
Insect	1
Fire	2
Drying	1
Roads	2
Hiking	1
RecUse	1
FlowMod	1
Livestock	1
Contemp	2
Historic	1
Flow Mod	NO
Modification Type	

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

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
DISP	<i>Distichlis spicata</i>	inland saltgrass	Native		
	<i>Forestiera</i> sp.	swamp privet	N/A		
FOPU2	<i>Forestiera pubescens</i>	stretchberry	Native		
HEPA4	<i>Heliopsis parvifolia</i>	mountain oxeye	Native		
PHRAG	<i>Phragmites</i> sp.	phragmites	Non-native		
PHAU7	<i>Phragmites australis</i>	common reed	Native	FACW	USDA
POPUL	<i>Populus</i> sp.	cottonwood	N/A	YES	CHDN
	<i>Salicornia</i> sp.	pickleweed	N/A	YES	CHDN

Water quality characteristics. Water quality measurements not taken, diffuse flow, no detectable orifice

BLNWR003—Hondo River

Sample Date: 12/15/2011

Physical characteristics.

Parameter	Value
Mean Water Depth (cm)	22
Mean Water Width (cm)	80
Vegetated Bank Cover (%)	100
Comments	Depth and width for A. B = 15 depth, 70 width. Small vents along side of river

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

Parameter	Value
Flood	1
Wind	1
Grazing	2
Insect	1
Fire	1
Drying	1
Roads	3
Hiking	1
RecUse	1
FlowMod	4
Livestock	2
Contemp	4
Historic	4
Flow Mod	YES
Modification Type	Excavation

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
BASA	<i>Baccharis salicina</i>	Emory's baccharis	Native	FACW	USDA
DISP	<i>Distichlis spicata</i>	inland saltgrass	Native		
HEPA4	<i>Heliopsis parvifolia</i>	mountain oxeye	Native		
PHAU7	<i>Phragmites australis</i>	common reed	Native	FACW	USDA
TAMAR2	<i>Tamarix</i> sp.	tamarisk	N/A	YES	CHDN

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

Parameter	Value			
Orifice	1	River	2	3
Shade	Shade	Sun	Shade	Shade
Temp	18	12	17.7	18.5
DO (mg/L)	2	8.82	1.7	2.16
DO (%)	22.4	84	18.4	23.3
pH	6.92	7.67	6.91	6.84
TDS	6136	4420	6259.5	2710.5
EC (µS)	8159	5124	8296	3647
Notes	Vent A = in a vent, to the west side of river	River = A swiftly flowing river, 8 m upstream from Vent A	Vent B = in a vent, to the west side of river	From south fork of Y on west side of bank
Alka_CaCO ₃	270		210	205
Alka_HCO ₃ ⁻	325		255	250
Alka_CO ₃ ²⁻	160		125	125
Chloride	10.5		11	11
Magnesium	2400		2800	4800
Sulphate (SO ₄ ²⁻)	1040		1160	1450
Sulphur (S)	340		380	500
Calcium (Ca)	ND		ND	ND
Location	In a vent/pool along side of river.		In a vent/pool along side of river	From vent along west side of bank
Notes	ORA - in vent/pool along the side of a river. All samples from vent along west side of bank.		ORB - in vent/pool along the side of a river; all samples from vent along west side of bank	ORG. From south fork of Y. Mg needed diluted. Came into contact with soil; all samples from vent along west side of bank

ND indicates the parameter was not detected

BLNWR004—Hunter's Marsh Ditch

Sample Date: 12/14/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	3
Discharge (L/Min)	1
Mean Water Depth (cm)	5
Mean Water Width (cm)	30
Emergent Cover (%)	20
Vegetated Bank Cover (%)	100
Fines (%)	100
Gravel (%)	0
Cobble (%)	0
Boulder (%)	0
Sand (%)	0
Comments	Joins with standing marsh water

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

Parameter	Value
Flood	1
Wind	1
Grazing	1
Insect	1
Fire	2
Drying	1
Roads	3
Hiking	1
RecUse	2
FlowMod	4
Livestock	1
Contemp	2
Historic	1
Flow Mod	YES
Modification Type	Excavation

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ATCA2	<i>Atriplex canescens</i>	fourwing saltbush	Native		
BASA	<i>Baccharis salicina</i>	Emory's baccharis	Native	FACW	USDA
CIWR	<i>Cirsium wrightii</i>	Wright's thistle	Native		
DISP	<i>Distichlis spicata</i>	inland saltgrass	Native		
HEPA4	<i>Heliopsis parvifolia</i>	mountain oxeye	Native		
ISPL	<i>Isocoma pluriflora</i>	southern goldenbush	Native		
SPPE	<i>Spartina pectinata</i>	prairie cordgrass	Native	OBL	USDA
TACH2	<i>Tamarix chinensis</i>	five-stamen tamarisk	Non-native	YES	CHDN
TYAN	<i>Typha angustifolia</i>	dwarf cattail	Native	OBL	USDA

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

Parameter	Value
Orifice	Single
Shade	Shade
Temp	12.1
DO (mg/L)	2.1
DO (%)	20.5
pH	6.97
TDS	8261
EC (μS)	9591
Notes	EC/SPL: 12728. Foggy and cloudy. Rained in last 24 hr. Used cup to get deeper water at start of draw (north short fork of ditch)
Alka_CaCO ₃	285
Alka_HCO ₃ ⁻	350
Alka_CO ₃ ²⁻	170
Chloride	12.5
Magnesium	750
Sulphate (SO ₄ ²⁻)	1000
Sulphur (S)	340
Calcium (Ca)	ND
Location	1 m below orifice in wetland/marsh
Notes	Likely came into contact with soil; Gypsum bedrock and soil in area

ND indicates the parameter was not detected

BLNWR005—Hunter's Marsh Fence 1

Sample Date: 12/14/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	
Mean Water Depth (cm)	10
Mean Water Width (cm)	
Emergent Cover (%)	95
Vegetated Bank Cover (%)	100
Fines (%)	100
Gravel (%)	0
Cobble (%)	0
Boulder (%)	0
Sand (%)	0

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

Parameter	Value
Flood	1
Wind	1
Grazing	2
Insect	1
Fire	1
Drying	1
Roads	1
Hiking	1
RecUse	1
FlowMod	4
Livestock	2
Contemp	1
Historic	1
Flow Mod	YES
Modification Type	Dam Diversion; Excavation

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ALOC2	<i>Allenrolfea occidentalis</i>	iodine bush	Native	FACW	USDA
DISP	<i>Distichlis spicata</i>	inland saltgrass	Native		
HEPA4	<i>Heliopsis parvifolia</i>	mountain oxeye	Native		
MUAS	<i>Muhlenbergia asperifolia</i>	scratchgrass	Native	FACW	USDA
SCIRP	<i>Scirpus</i> sp.	bulrush	N/A	YES	CHDN
SPORO	<i>Sporobolus</i> sp.	dropseed	N/A		
TACH2	<i>Tamarix chinensis</i>	five-stamen tamarisk	Non-native	YES	CHDN
TYAN	<i>Typha angustifolia</i>	dwarf cattail	Native	OBL	USDA

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

Parameter	Value		
Orifice	Pool 1	Pool 2	Pool 3
Shade	Partial	Sun	Partial
Temp	15.5	10.6	15.2
DO (mg/L)	2.15	0.83	2.19
DO (%)	22.2	8.4	22.3
pH	7.37	6.74	6.84
TDS	6870	10322	6727
EC (µS)	10575	15886	8422
Notes	Cattle pool: along west bank cut	Saltgrass flats: 10 m from slope in flats in natural opening	Typha Pool: 10 m from top of typha on sedge in small pool with pelvis bone
Alka_CaCO ₃			240
Alka_HCO ₃ ⁻			290
Alka_CO ₃ ²⁻			145
Chloride			11
Magnesium			1,600
Sulphate (SO ₄ ²⁻)			1,450
Sulphur (S)			500
Calcium (Ca)			ND
Location			From Typha Pool: 10 m from top of typha on south edge in small pool with pelvis bone
Notes			

ND indicates the parameter was not detected

BLNWR006—Hunter's Marsh Fence 2

Sample Date: 12/14/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	
Mean Water Depth (cm)	8
Mean Water Width (cm)	
Emergent Cover (%)	95
Vegetated Bank Cover (%)	100
Fines (%)	100
Gravel (%)	0
Cobble (%)	0
Boulder (%)	0
Sand (%)	0
Comments	Marsh 8 x 100 m

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

Parameter	Value
Flood	1
Wind	1
Grazing	1
Insect	1
Fire	1
Drying	1
Roads	1
Hiking	1
RecUse	1
FlowMod	3
Livestock	2
Contemp	2
Historic	2
Flow Mod	YES
Modification Type	Excavation

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

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ALOC2	<i>Allenrolfea occidentalis</i>	iodine bush	Native	FACW	USDA
DISP	<i>Distichlis spicata</i>	inland saltgrass	Native		
MUAS	<i>Muhlenbergia asperifolia</i>	scratchgrass	Native	FACW	USDA
PHAU7	<i>Phragmites australis</i>	common reed	Native	FACW	USDA
SCIRP	<i>Scirpus</i> sp.	bulrush	N/A	YES	CHDN
TAMAR2	<i>Tamarix</i> sp.	tamarisk	N/A	YES	CHDN

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

Parameter	Value
Orifice	Pool
Shade	Partial
Temp	14.2
DO (mg/L)	3.62
DO (%)	35.2
pH	7.09
TDS	6454.5
EC (µS)	7899
Notes	Full sun, shaded by bullrushes; muddy bottom
Alka_CaCO ₃	220
Alka_HCO ₃ ⁻	265
Alka_CO ₃ ²⁻	130
Chloride	8.4
Magnesium	1400
Sulphate (SO ₄ ²⁻)	1100
Sulphur (S)	360
Calcium (Ca)	ND
Location	Bullrush pond
Notes	Muddy bottom

ND indicates the parameter was not detected

BLNWR007—Lost River Spring

Sample Date: 12/13/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	20
Mean Water Depth (cm)	20
Mean Water Width (cm)	200
Emergent Cover (%)	10
Vegetated Bank Cover (%)	100
Fines (%)	100
Gravel (%)	0
Cobble (%)	0
Boulder (%)	0
Sand (%)	0
Comments	Vent is 1 m across and 1 m deep. Flow visible

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

Parameter	Value
Flood	1
Wind	1
Grazing	1
Insect	1
Fire	2
Drying	1
Roads	2
Hiking	1
RecUse	1
FlowMod	1
Livestock	1
Contemp	2
Historic	1
Flow Mod	NO
Modification Type	

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

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
DISP	<i>Distichlis spicata</i>	inland saltgrass	Native		
HEPA4	<i>Heliopsis parvifolia</i>	mountain oxeye	Native		
LILI4	<i>Limonium limbatum</i>	Trans-Pecos sea lavender	Native	FACW	USDA
PHAU7	<i>Phragmites australis</i>	common reed	Native	FACW	USDA
SATR12	<i>Salsola tragus</i>	prickly Russian thistle	Non-native		
SPAI	<i>Sporobolus airoides</i>	alkali sacaton	Native		

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

Parameter	Value
Orifice	Single
Shade	Partial
Temp	10.2
DO (mg/L)	2.46
DO (%)	22.6
pH	7.19
TDS	6526
EC (μS)	7205
Notes	Cloudy. First measurement 1 m from orifice.

Alka_CaCO ₃	285
Alka_HCO ₃ ⁻	350
Alka_CO ₃ ²⁻	170
Chloride	9.8
Magnesium	500
Sulphate (SO ₄ ²⁻)	195
Sulphur (S)	65
Calcium (Ca)	ND
Location	Sample taken in pool at orifice.
Notes	

ND indicates the parameter was not detected

BLNWR008—Sago Spring

Sample Date: 12/13/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	
Mean Water Depth (cm)	40
Mean Water Width (cm)	200
Emergent Cover (%)	5
Vegetated Bank Cover (%)	50
Fines (%)	100
Gravel (%)	0
Cobble (%)	0
Boulder (%)	0
Sand (%)	0
Comments	A series of pools in a sinkhole

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

Parameter	Value
Flood	1
Wind	1
Grazing	1
Insect	1
Fire	1
Drying	1
Roads	2
Hiking	1
RecUse	1
FlowMod	1
Livestock	1
Contemp	2
Historic	1
Flow Mod	NO
Modification Type	

Vegetation observations.

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ALOC2	<i>Allenrolfea occidentalis</i>	iodine bush	Native	FACW	USDA
LILI4	<i>Limonium limbatum</i>	Trans-Pecos sea lavender	Native	FACW	USDA
RUMA5	<i>Ruppia maritima</i>	widgeon grass	Native	OBL	USDA
SPAI	<i>Sporobolus airoides</i>	alkali sacaton	Native		

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

Parameter	Value		
Orifice	1	2	3
Shade	Partial	Partial	Partial
Temp	17.9	17.9	17.9
DO (mg/L)	3.27	2.56	2.65
DO (%)	35.3	27.6	28.8
pH	6.97	6.98	7.01
TDS	5603	5603	5603
EC (µS)	7453	7459	7452
Notes	Cloudy. Water is warm; see hand-drawn map for OR locations	Cloudy	Cloudy; water is warm; see hand-drawn map for OR locations
Alka_CaCO ₃	155		
Alka_HCO ₃ ⁻	190		
Alka_CO ₃ ²⁻	90		
Chloride	12		
Magnesium	1700		
Sulphate (SO ₄ ²⁻)	1750		
Sulphur (S)	550		
Calcium (Ca)	ND		
Location	Sample taken from primary vent/orifice		
Notes			

ND indicates the parameter was not detected

BLNWR009—Unit 15 North Slope

Sample Date: 12/14/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	
Mean Water Depth (cm)	
Mean Water Width (cm)	
Emergent Cover (%)	10
Vegetated Bank Cover (%)	100
Fines (%)	100
Gravel (%)	0
Cobble (%)	0
Boulder (%)	0
Sand (%)	0
Comments	Wet ground along side of a hill

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

Parameter	Value
Flood	1
Wind	1
Grazing	1
Insect	1
Fire	1
Drying	1
Roads	3
Hiking	1
RecUse	1
FlowMod	4
Livestock	1
Contemp	2
Historic	1
Flow Mod	YES
Modification Type	Dam Diversion; Excavation

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

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ALOC2	<i>Allenrolfea occidentalis</i>	iodine bush	Native	FACW	USDA
BACCH	<i>Baccharis</i> sp.	baccharis	N/A	YES	CHDN
SCIRP	<i>Scirpus</i> sp.	bulrush	N/A	YES	CHDN
SPPE	<i>Spartina pectinata</i>	prairie cordgrass	Native	OBL	USDA
TACH2	<i>Tamarix chinensis</i>	five-stamen tamarisk	Non-native	YES	CHDN
TYAN	<i>Typha angustifolia</i>	dwarf cattail	Native	OBL	USDA

Water quality characteristics. No surface water, did not collect.

BLNWR010—Unit 15 South Ditch

Sample Date: 12/14/2011

Physical characteristics.

Parameter	Value
Brook Length (m)	100
Mean Water Depth (cm)	8
Mean Water Width (cm)	150
Emergent Cover (%)	100
Vegetated Bank Cover (%)	100
Fines (%)	100
Gravel (%)	0
Cobble (%)	0
Boulder (%)	0
Sand (%)	0
Comments	Defined ditch, but much of surrounding land is also wet and marshy

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

Parameter	Value
Flood	1
Wind	1
Grazing	1
Insect	1
Fire	2
Drying	1
Roads	3
Hiking	1
RecUse	2
FlowMod	4
Livestock	1
Contemp	2
Historic	1
Flow Mod	YES
Modification Type	Dam Diversion; Excavation

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

USDA Code	Scientific Name	Common Name	Nativity	Wetland Indicator	WI Source
ALOC2	<i>Allenrolfea occidentalis</i>	iodine bush	Native	FACW	USDA
BASA	<i>Baccharis salicina</i>	Emory's baccharis	Native	FACW	USDA
DISP	<i>Distichlis spicata</i>	inland saltgrass	Native		
HEPA4	<i>Heliopsis parvifolia</i>	mountain oxeye	Native		
MUAS	<i>Muhlenbergia asperifolia</i>	scratchgrass	Native	FACW	USDA
SCIRP	<i>Scirpus</i> sp.	bulrush	N/A	YES	CHDN
SPPE	<i>Spartina pectinata</i>	prairie cordgrass	Native	OBL	USDA

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

Parameter	Value	
Orifice	1	2
Shade	Sun	Shade
Temp	9.4	8.6
DO (mg/L)	2.27	4.62
DO (%)	20.8	41.1
pH	7.12	7.39
TDS	7995	6688.5
EC (µS)	8658	7062
Notes	WQ1 = upstream, within grass, clear.	WQ2 = downstream, within rushes, muddy. Took two samples to see if the upstream portion of ditch was just rain water, but it appears to be just as salty as the rest.
Alka_CaCO ₃	380	
Alka_HCO ₃ ⁻	470	
Alka_CO ₃ ²⁻	230	
Chloride	9.1	
Magnesium	1400	
Sulphate (SO ₄ ²⁻)	1750	
Sulphur (S)	550	
Calcium (Ca)	ND	
Location	Sample taken upstream in ditch	
Notes	Gypsum bedrock/soil in valley	

ND indicates the parameter was not detected

Appendix C List of Plants Detected

Table C1. List of plants detected at Bitter Lake National Wildlife Refuge.

Scientific Name	Common Name	Nativity	Wetland Indicator
<i>Allenrolfea occidentalis</i>	iodine bush	Native	FACW
<i>Atriplex canescens</i>	four-wing saltbush	Native	
<i>Baccharis</i> sp.	baccharis	N/A	YES
<i>Baccharis salicina</i>	Emory's baccharis	Native	FACW
<i>Cirsium wrightii</i>	Wright's thistle	Native	
<i>Distichlis spicata</i>	inland saltgrass	Native	
<i>Forestiera</i> sp.	swamp privet	N/A	
<i>Forestiera pubescens</i>	New Mexico olive	Native	
<i>Heliopsis parvifolia</i>	Pecos sunflower	Native	
<i>Isocoma pluriflora</i>	southern goldenbush	Native	
<i>Limonium limbatum</i>	Trans-Pecos sea lavender	Native	FACW
<i>Muhlenbergia asperifolia</i>	scratchgrass	Native	FACW
<i>Phragmites</i> sp.	phragmites	Native	
<i>Phragmites australis</i>	common reed	Native	FACW
<i>Populus</i> sp.	cottonwood	N/A	YES
<i>Ruppia maritima</i>	widgeongrass	Native	OBL
<i>Salicornia</i> sp.	pickleweed	N/A	YES
<i>Salsola tragus</i>	prickly Russian thistle	Non-native	
<i>Scirpus</i> sp.	bulrush	N/A	YES
<i>Spartina pectinata</i>	prairie cordgrass	Native	OBL
<i>Sporobolus airoides</i>	alkali sacaton	Native	
<i>Sporobolus</i> sp.	dropseed	N/A	
<i>Sueada</i> sp.	seepweed	N/A	FACW
<i>Tamarix</i> sp.	tamarisk	Non-native	YES
<i>Tamarix chinensis</i>	five-stamen tamarisk	Non-native	YES
<i>Typha angustifolia</i>	dwarf cattail	Native	OBL

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