AN ECOLOGICAL ASSESSMENT OF WATER RESOURCES, KANE AND TWO MILE RANCHES, EASTERN ARIZONA STRIP: 30 SEPTEMBER 2005 DRAFT FINAL REPORT

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

Project Purpose and Scope

Under contract with the Grand Canyon Trust (GCT), Grand Canyon Wildlands Council, Inc. (GCWC) performed an assessment of water resources of the Kane and Two Mile ranches and associated grazing allotments on the eastern Arizona Strip in the summer of 2005. Five tasks were accomplished, including: 1) acquisition of water resource distribution and ecological data, as available, to use for initial study site selection; 2) compilation of an historical land use account for the eastern Arizona Strip; 3) conduct of an aerial reconnaissance of the Paria and Kaibab plateaus to identify previously unrecognized water sources; 4) conduct of field site visits to develop a database of available hydrologic and biological data associated with water sources; and 5) providing assessment and recommendations regarding water resources inventory, management, priorities, and protocols to the GCT.

Task 1: We combined data provided in GC Wildlands (2002) with data from a list of named water resource sites on U.S. Geological Survey topographic maps of the eastern Arizona Strip (Fig. 1; Appendix A). We added additional data for sites described in the literature, from our conversations with land managers and other researchers, and unpublished data. We identified a total of 316 water resource sites between Kanab Creek and the eastern corner of the Arizona Strip. We categorized the sites as to type of resource on the basis of their names and available information, including: springs (including seeps), perennial streams, natural ponds, wells, tanks, reservoirs, and guzzlers or other artificial water supplies. We developed site selection criteria by designating a 1 (low) to 5 (high) scale ranking system for 10 variables considered relevant to the ecological and economic importance of these sites (Table 2). We then summed these factor scores to create an overall score for each site (maximum possible = 50), with higher values indicating higher priority for initial inventory. This approach is limited by inadequate Level I survey data, but we were able to select a dozen sites that appeared appropriate for initial Level II inventory and assessment.

Task 2: Human history on the eastern Arizona Strip has been one of survival through exploitation and competition over limited resources. This history likely extends back more than 2000 years when early Puebloans occupied the landscape. They were followed by Paiute and Navajo cultures. Nearly a century after the Dominguez-Escalante expedition explored the region, Jacob Hamblin was sent by Brigham Young to locate routes and sites for Mormon settlement of the region, which began in earnest in the 1870's. Grazing, hunting and logging were primary impacts early Anglo settlers on the landscape. In 1906 Theodore Roosevelt declared Buckskin Mountain (the Kaibab Plateau) a national game preserve, a status that still remains; however, human impacts from resource exploitation characterize the region today.

Task 3: Aerial reconnaissance was conducted on 3 August 2005 with Dr. Stevens, Mr. Aumack, and Jeri Ledbetter (pilot). The staff flew across much of the study area, noting and georeferencing the locations of unusual-looking ponds and springs, and the routes by which those sites might be accessed.

Task 4: Ten sites were visited and inventoried in mid-July 2005. Sites included: Bear and Crane lakes; Big, Kane Aqueduct, Coyote (HRV), Lower and Upper Tater, and "South Sandcrack" springs; and North Canyon Creek and the Lower Paria River. Measurements recorded at the site included: source geomorphology, field water chemistry (temperature, pH, and specific conductance), floral diversity and structure, and faunal diversity. Each water resource study site is described in detail.

Task 5: We used springs and stream-riparian assessment protocols to evaluate ecosystem health of each of the visited water resource study sites. The assessment process provides a quantitative score of six categories of study site characteristics, and protocols that yields both site-specific and comparable scores for rapid assessment and management prioritization. The data compiled demonstrated a wide range of human impacts. Assessment scores demonstrated considerable variation in ecological health among the springs, ponds, and streams selected for site visits. These sites ranged in health from virtually pristine conditions to complete obliteration of the water source areas. These assessment criteria and results are designed to assist GCT prioritize their water resource management actions. We make general and specific recommendations about the management and rehabilitation or restoration of water resources in this region.

INTRODUCTION

The Grand Canyon Trust (GCT) supported an ecological assessment of water resources of the Kane and Two Mile ranches, and other lands on the eastern Arizona Strip. Water resources in this region consist of rare, isolated, and little known springs, seeps, natural ponds, tinajas, and a few streams. Knowledge of the hydrology and biology of these water resources is essential for long-term land management. Grand Canyon Wildlands Council, Inc. (GCWC) was contracted to the GCT to complete several information-based tasks, including: 1) compilation and synthesis of existing data, augmenting that provided in GCWC (2002); 2) field examination of prioritized water resources; and 3) development of water resources monitoring and research recommendations for the study area. This effort will provide a more comprehensive foundation for scientifically appropriate stewardship of the area's natural waters.

Present knowledge of the water resources and quality on the eastern Arizona Strip is principally drawn from an array of sources: geologic mapping, agency staff, residents, researchers, and previous reports; however, many of those data have not been completely summarized. Of the existing literature, the 2002 GCWC report summarized the analysis of 103 springs and natural ponds across the Arizona Strip, of which 61 were located east of Kanab Creek (Appendix A).

PROJECT TASKS

The tasks associated with this project include: 1) acquire springs distribution and ecological data, as available, to use for initial study site selection; 2) compile an historical land use account for the eastern Arizona Strip; 3) conduct an aerial reconnaissance of the Paria and Kaibab plateaus to identify previously unrecognized water sources; 4) conduct field work to develop a database of available hydrologic and biological data associated with water sources; 5) provide recommendations regarding water resources inventory, management, priorities, and protocols. We classify the water resources of the region using the nomenclature of Springer et al. (in press) for springs, and Stevens et al. (in press a, b), and use the latter for inventory and assessment of riparian and springs ecosystems. Ponds assessment protocols are modified from the springs and riparian techniques, as appropriate. Preliminary assessment is integrated to develop a list of 10 prioritized sites that require inventory and/or assessment during 2005. Most of the existing environmental data are found in GCWC (2002, 2004), Stevens et al. (in press a, b), numerous publications of Abe Springer and his associates, and L.E. Stevens (unpublished data).

TASK 1: EXISTING DATA ON WATER RESOURCE DISTRIBUTION AND ECOLOGICAL CONDITION

METHODS

Study Site Selection

We combined data provided in GC Wildlands (2002) with data from a list of named water resource sites on U.S. Geological Survey topographic maps of the eastern Arizona Strip (Fig. 1; Appendix A). We added additional data for sites described in the literature, from our conversations with land managers and other researchers, and unpublished data. We identified a total of 316 water resource sites between Kanab Creek and the eastern corner of the Arizona Strip.

Two factors constrain the utility of this approach for site prioritization. First, there are many unnamed sites in the landscape and therefore this list is far from complete. The completeness of mapping varies according to topographic variability: although most springs that have been used for livestock production in the region appear to be both named and mapped on plateau flatlands, only a low percent of springs have been mapped in cliff- and canyon-bound areas on lands not used for grazing. For example, Abe E, Springer (NAU Geology, personal communication) estimates that fewer than 10 percent of the springs and seeps on the south side of Grand Canyon have been mapped. A second issue is that, in the absence of direct experience at these sites, the condition of the water resources are unknown. Even if springs are named and mapped, they may be dry: Grand Canyon Wildlands Council, Inc (GCWC; 2002) reported that nearly 20 percent of the named springs they visited on the Arizona Strip were dry in Year 2000.

Keeping the above constraints on site selection in mind, we categorized the sites as to type of resource on the basis of their names and available information, including: springs (including seeps), perennial streams, natural ponds, wells, tanks, reservoirs, and guzzlers or other artificial water supplies. Our intent was to select 2-4 examples of each water resource type in the 2005 inventory, to maximize diversity of sites and conditions.

We developed site selection criteria by designating a 1 (low) to 5 (high) scale ranking system for 10 variables considered relevant to the ecological and economic importance of these sites (Table 2). We estimated scores where data were available and left cells blank where data were not available. We then summed the individual factor scores to create an overall score for each site (maximum possible = 50), with higher values indicating higher priority for initial inventory.

Field site visits were conducted and coordinated by L.E. Stevens and R.J. Johnson for GCWC.

RESULTS AND DISCUSSION

Our preliminary site selection criteria yielded a total of 14 sites, with an array of low- and higher-elevation springs, streams, and ponds, to maximize the diversity of sites and the applicability to previous water resource studies in the region (Table 2. These sites received higher site scores than others, and were proposed for the 2005 inventory of 10 sites. With the caveats of limited pre-existing information on site conditions and access, we selected 10 study sites that appeared likely to help the Grand Canyon Trust better understand its water resources.

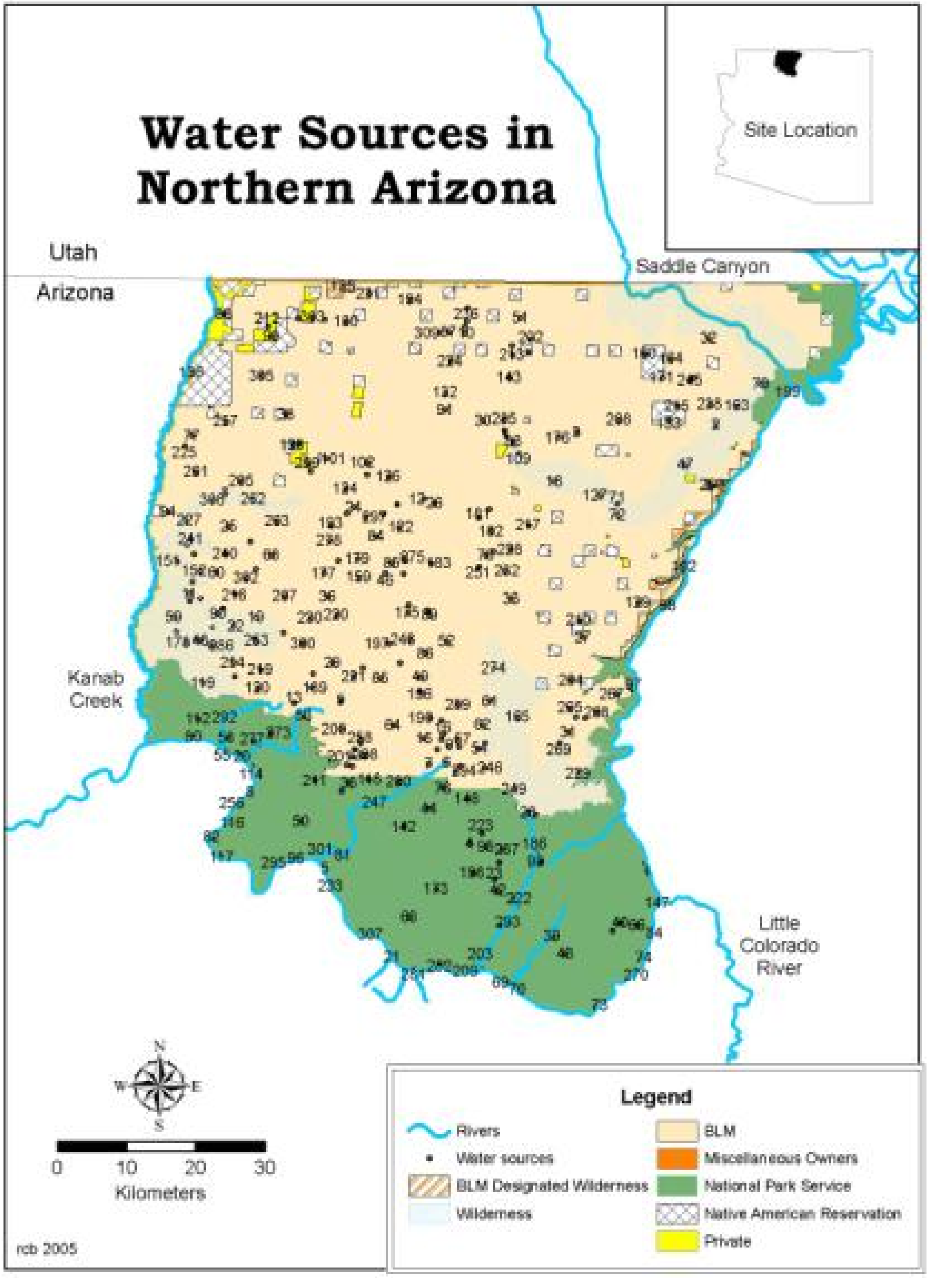

Fig. 1: Map of the eastern Arizona Strip. Numbers are water resource sites listed in Appendix

Table 1.1: Water resource site scoring and ranking criteria.

Characteristic	Ranking Criteria (1-5)
Flow	1=dry, 2=moist but no collectable flow, 3=small flow (<1L/min), 4=medium flow (1-100 L/min), 5=large (>100 L/min)
Open water area (m^2)	1=0 m^2, 2=<1 m^2, 3=2-10 m^2, 4=10-100 m^2, 5>100 m^2
Water quality	1=low quallity, polluted WQ, 5=pristine WQ
Wetland/riparian area	1=0 m^2, 2=1-10 m^2, 3=10-100 m^2, 4=100-1000 m^2, 5>1000 m^2
Isolation	Nearest water source of same type is: 1<10 m away, 2=10-100 m away, 3=100-1000 m away, 4=1000-10000 m away, 5>100000 m away
Biological diversity, including Wildlife use	1=low biotic diversity, 5 = high biotic diversity, with use by numerous wildlife species
Endangered or endemic spp.	1=no endangered or endemic species, 2=1 species, 3=2 species, 4=3 species in different trophic levels, 5>3 species in multiple trophic levels
Ecological health	1=low ecological health, 5=pristine condition
Human use/need	1=low levels of human use/need, 5=all water appropriated for human use
Site uniqueness	1=site is one of many examples in the region, 5=the site is unique in the region

Table 1.2: Primary (*) and alternate sites used for inventory in 2005. Data in bold have estimated values based on unpublished data and observations.

Site Name	Ranking Scores										Site Score
	Flow	Open water area	WQ	Wtlnd/rip area	Iso-lation	Diversity, Wldlf Use	Sens. Spp.	Ecolog'l Health	Human use	Unique-ness	
Badger Spr. (3)	2	2	5	3	4	4	3	3	5	4	35
Bear Lake (7) *	5	5	5	5	4	4	4	4	3	4	43
Big Springs (311) *	4	4	5	4	4	3	3	4	5	5	41
Kane Aqueduct Spring (319) *	**4**	**1**	**5**	**2**	**4**	**3**	**2**	**1**	**5**	**5**	**32**
Cottonwood Spr. (49)	2	2	5	3	4	4	3	3	5	4	35
Coyote Spring *	3	4	5	3	4	4	3	2	5	4	37
Crane Lake (53) *	5	5	5	5	4	4	4	4	4	4	44
Crazy Jug Spr. (54)	**3**	**3**	**5**	**3**	**5**	**4**	**4**	**4**	**3**	**5**	**39**
Four Springs (84)	4	3	5	3	3	3	2	2	5	4	34
Jacobs Pool (128) *	**4**	**4**	**5**	**4**	**3**	**3**	**2**	**3**	**5**	**4**	**37**
Kanab Creek (142.5)	5	5	3	5	5	4	5	3	5	5	45
North Canyon Cr. (193) *	5	5	5	5	5	4	3	4	5	5	46
Paria River (200) *	5	5	3	5	5	4	5	3	5	5	45
Tater Canyon Spr. (2) *	4	3	5	3	4	5	3	3	5	4	39

We used existing springs and riparian inventory and assessment protocols to evaluate hydrological, geomorphic, biological, and anthropogenic conditions (Stevens et al. in press a, b). However, field site visits proved challenging in that: 1) not all of the selected sites proved accessible (e.g. Crazy Jug Spring); 2) several sites were mismapped on the USGS topographic sheets (e.g., Coyote Springs in House Rock Valley); 3) several sites were not actually water sources (e.g., Jacob Pools was a dry spring-fed stock tank: we selected nearby “South Sandcrack” Spring as an alternative); and 4) some sites had multiple, previously unmapped sources (e.g., Upper and Lower Tater Canyon Springs). In several cases we chose nearby alternate sites that appeared to have sufficiently high site selection values.

RECOMMENDATIONS

The following task reports contain information that provides a good test of site selection and field sampling protocols. We recommend that the Trust consider conducting a system-wide Level I inventory of its water resources. Level-I inventories involve locating and georeferencing the springs within a prescribed region, taking a photograph on a 10-minute site visit, estimating flow, and quickly analyzing field water quality parameters. This is likely to require approximately 2 months of field time for a 1-2 person, 1-2-vehicle team, and could be accomplished for less than $35,000. We enclose an example of a Level I springs inventory protocol from our springs inventory work with the National Park Service, which would have to be modified to account for other water resource types (i.e., wells, stock tanks, guzzlers, natural and artificial ponds, tinajas, etc.). The data generated from such a report would be used to fully evaluate water resource condition and distribution in relation to landscape planning.

TASK 2:
HISTORICAL LAND USE OF THE EASTERN ARIZONA STRIP

A Brief History of House Rock Valley and the North Kaibab Forest

By Kim Crumbo

Prehistory

Human history on the eastern Arizona Strip has been one of survival through exploitation and competition over limited resources. This history likely extends back more than 2000 years when early Puebloans occupied the landscape. They were followed by Paiute and Navajo cultures.

Exploration and Settlement

Nearly a century after the Dominguez-Escalante expedition explored the region, in the late 1850's, and under the guidance of Jacob Hamblin, the first Anglo-Americans entered the unknown realms of northern Arizona. In 1869, when John Wesley Powell made the first of his two famous trips down the Colorado River, the Mormons had settled the Arizona Strip and constructing a fortified ranch at Pipe Spring, Arizona. Kanab, Utah, located just north of the Kaibab Plateau, was established in 1874, and in 1876, 500 Mormons left Utah to establish settlements along the Little Colorado River (Fairley In Press?).

In the upper drainages below the Vermilion Cliffs, two large rocks fallen together formed a shelter. Sometime before 1871, a traveler used the low refuge and inscribed with charcoal along the top of the rock "Rock House Hotel." A nearby seep soon acquired the name House Rock Spring, and eventually House Rock Valley received its label, or so the story goes (Dellenbaugh 1965:304).

House Rock Valley consists of the undulating terrain of the western Marble Platform cut by a series of major drainages tending roughly eastward from the Kaibab Plateau to the Colorado River. Its elevations range from about 3,100 feet at Lees Ferry in the northeastern corner to about 6,000 feet along the western foothills of the Kaibab Plateau (O'Farrell 1995:2). Annual precipitation is generally below 11 inches with most occurring in the late summer monsoon period. Most of the area is administered by the Bureau of Land Management (BLM) with private lands consisting of approximately 640 acres (O'Farrell 1995:2).

Around 1870, Jacob Hamblin became the valley's first landholder when he apparently acquired "Kane Spring" and perhaps the pool with his namesake (Woodbury 1950:190). The "Buckskin Apostle" left his name across the Arizona Strip including Jacob Pools and Jacob Lake. According to legend, the Mormon explorer shot a badger in the upper drainage of what is now called Badger Canyon. Later, he boiled the badger in alkaline water. In the morning Jacob discovered that the badger's fat had turned, not into breakfast, but into soap. Soap Creek enters Marble Canyon at Mile 11.

The Kaibab range was controlled for about a decade after 1877 by the United Order of Orderville, Utah, an church-support enterprise that wintered livestock in House Rock Valley and moved them in summer up to DeMotte Park, often called VT Park (Hughes 1978:43). In 1887, John Young, a son of the Mormon leader Brigham Young, formed the Kaibab Land and Cattle Company (Hughes 1978:44). In 1897, The Kaibab Land and Cattle Company sold the VT spread, and, by 1899, the Bar-Z cattle outfit acquired the House Rock and Kaibab ranges (Reilly 1999).

The headquarters of the Bar-Z was a stone house at the mouth of Cane Canyon (Reilly 1999:195). In 1902-03, Frank Rider built another stone house one-half mile south of Jacob's Pools and water piped down from the spring created the "Lower Pools" near the house site (Reilly 1999:195). By 1904, the Bar-Z acquisitions included important water sources at Frank, Crane, Snipe, Kane, Sunset, and Alaska Lodes (Reilly 1999:193)

Preston Nutter, a cattleman who served in the Colorado legislature, purchased range and water rights north of the Grand Canyon following 1893 (Hughes 1977:44). By 1904, Preston Nutter and the Bar-Z controlled the livestock business on the Arizona Strip (Reilly 1999:194). Preston, always the pragmatist, seriously entertained a proposal by J.N. "Ding" Darling, a cartoonist and head of the U.S. Biological Survey, to turn the Arizona strip into a big game preserve. Unfortunately, the Dept Interior had not funds allocated for this purpose and negotiations ended (Price and Darby 1964:251).

E.J. Marshall, a cattle baron with over two million acres of ranches in Mexico and Texas, set up the Grand Canyon Cattle Company to acquire the Bar-Z. In 1907, he bought all the improvements, water rights held through mining claims, and the VT and Bar Z brands (Reilly 1999:209). In1909. The Grand Canyon Cattle Company acquired Lees Ferry and the company then controlled the entire range from Cane Beds to the Colorado River

In 1908, Jim Emett, the land baron's eternal antagonist, filed for Soap Creek and Cottonwood Springs (Reilly 1999: 210). He later sold his claims at Soap Creek, Hibben Lode, Millsite, and Cottonwood Spring.

Mann and Locke (1931) reported that in 1887 and 1889, at least 200,000 sheep and 20,000 cattle were using the Kaibab Plateau and surrounding desert grasslands. While those numbers were suspect (see Russo 1964:35), the Forest Service waited until 1934 to effectively control livestock use (Russo 1964:35). The grazing of sheep on the North Kaibab forest ended in 1945 (Russo 1964:37).

House Rock Valley's generally arid climate and long history of livestock grazing, it also qualifies as some of the region's most biologically degraded landscapes. In 1906, sheepherder J.D. Newman moved 800 sheep from Utah's high country to hot July sun of House Rock Valley (Reilly 1999). The Bar-Z local cattlemen drained the few small, precious watering reservoirs and springs available for stock (Rider 1985). Before long 800 thirst-crazed sheep stampeded toward the canyon rim near Cathedral Wash and, as sheep will launch themselves to unlimited water 300 vertical feet below. The expansive, irresistible fluffy flow of bleats, bones, blood and wool cascaded over the edge (Rider 1985:67; Reilly 1999).. Not all the sheep perished. Soon afterwards, Jim Emett found a quarter of the flock alive and returned the animals to their legal, if irresponsible owner. Later, at least five sheepish survivors were happily grazing near Soap Creek rapid when Julius Stone's hungry river party shot and ate one (Stone 1932).

In 1941, the biologist Rasmussen described the "severe overgrazing" within House Rock Valley, reported that only in years of abundant rainfall" did the area regain "the aspect ascribed to it before the great herds of cattle both wintered and summered there" (Rasmussen 1941:267). Today, The Nature Conservancy classifies most of House Rock Valley as "at risk" grasslands with less than five percent perennial native grass cover and/or severe soil erosion (Schussman and Gori 2004:21). These areas have the potential to be restored back to functioning grassland communities if grazing pressure is removed (Schussman and Gori 2004:45).

Researchers reported that pronghorn antelope were once common in the grassland adjoining the plateau (Rasmussen 1941:238). Early inhabitants exploited this significant food resource. Paiutes would patiently wait in concealed pits until the antelope approached near enough to be shot by bow and arrow, a practice that apparently did not threaten the population's long-term viability (Rasmussen 1941:267). Pronghorn extermination occurred shortly after the arrival of white settlers (Rasmussen 1941:238). Current populations consist of stock derived from reintroduced animals.

Grand Canyon Game Preserve

Recognition and concern for the Kaibab Plateau's forest values led to early preservation efforts (Morehouse 1996:32,34-35). Clarence Dutton, a seasoned explorer and geologist, described the mountain in 1880 as "the most enchanting region it has ever been our privilege to visit." Concerns over forest degradation led to the establishment of a forest reserve surrounding Grand Canyon in 1893. By 1905, Congress and President Theodore Roosevelt recognized that forests like the Kaibab should be set aside "*for the wild forest creatures"* …[to] *afford perpetual protection to the native fauna and flora*" (U.S. Congress 1905; see Miller 1996:4). In 1906, and in accordance with earlier Congressional authorization, Theodore Roosevelt established the 658,000-acre[i] Grand Canyon National Game Preserve for "the protection of game animals… recognized as a breeding place therefore…" (USDA 1987:119; see Roosevelt 1908)."[ii]

From the Preserve's inception in 1906 to the present wildlife protection remains, in theory, the Forest Service's raison d'etre on the Kaibab Plateau. The 1908 Executive Order creating the Kaibab National Forest reiterated presidential commitment to the original Grand Canyon Game Preserve's purpose (Miller 1996:6). In 1992, the Office of the General Counsel for the Department of Agriculture reaffirmed that the Forest Service is bound by the law creating the Grand Canyon Game Preserve, and that "the activities on the preserve cannot be in conflict with its stated purpose which is the protection of game animals within its boundaries" (see Miller 1996:17). Whether or not the U.S. Forest Service has provided such protection is problematic, but protection of the full spectrum of native wildlife has not resulted from forest management practices.

Logging

In 1913, the Forest Service began advertising the sale of one billion feet of timber, over 80 percent of which was Western yellow pine, located on the North Kaibab National Forest (USDA 1913:1). The agency conservatively estimated the North Kaibab contained over two billion feet of "merchantable timber," eighty percent ponderosa pine, 12 inches or greater in diameter (dbh) (USDA 1913:3). The "common maximum diameter" of ponderosa pine was estimated at 42 inches "although occasional trees with a diameter…of 60 inches occur" (USDA 1913:4).

The Forest Service promoted the idea of a railroad to exploit the regions livestock and farming products, coal, iron, timber, oil, extensive agricultural lands" and tourism to the North Rim (USDA 1913:7-8). They estimated the cost of a line from Marysvale to Bright Angel Point at $2,720,000 (USDA 1913). The agency also noted that the timbered portion of the Forest "embraces a rolling plateau [where] logging conditions are ideal." They emphasized that logging roads could be “constructed almost anywhere at very small cost,” and that the forest’s numerous open parks offer excellent camp sites and “sufficient springs available for camp and logging purposes” (USDA 1913:4-5).

While the agency noted that “the forest naturally has many enemies of which fire and insects are the worst” (Lang et al. 1909:18). Old fires extended over large areas at higher altitudes, amounting to several square miles [and] evidence indicates light ground fires over practically the whole forest, some of the fines stands of yellow pine show only slight charring of the bark and very little damage to poles and undergrowth (Lang et al. 1909:19).

The Forest Service also recognized that the Kaibab Plateau, “[b]eing a great game country it was undoubtedly frequented by Indians who set fires to aid in their hunting expeditions” (Land et al. 1909:19). “Insect infestation,” according to the agency in 1909, has attained enormous proportions over the whole forest and the injury is going on steadily year after year.”

> “The old fallen trunks, existing in all stages of decay, argue that this pest has been working for many decades, probably hundreds of years, and the extent of damage wrought is unequalled, even by fire “ (Lang et al. 1909:19).

The Forest Service advocated selective cutting with the explicit aim “to remove all large, mature, partially defective trees” (Lang et al. 1909:14, the “only class of trees [that] can be cut at a profit” (Lang et al. 1909:13). This practice continues today as the agency’s philosophical *leit motif* regarding forest management.

As late as 1941, the renowned biologist Irvin Rasmussen described the Plateau’s ponderosa forest as “one of the nation’s finest and largest undisturbed stands.” In 1964, the Secretary of Interior established the Kaibab National Natural Landmark to protect the Kaibab squirrel and its old growth habitat. Unfortunately, protection of the Landmark's values is voluntary. Despite its enormous ecological importance, logging activities have adversely impacted squirrel habitat (Patton 1985; Dodd et al. 1998; Allred and Gaud 1994).

Ecologists (Noss et al. 1995) and conservationists (Noss and Peters 1995) have determined that old growth ponderosa pine forests constitute one of America’s most endangered ecosystems. They report that old-growth ponderosa pine has suffered an estimated 85-98% area loss due to destruction, conversion to other uses, and significant degradation in structure, function, and composition. Logging is one of the principal causes of this decline. The Kaibab Plateau contains, along with areas in the Gila National Forest, the most extensive stands of old-growth ponderosa remaining in the Southwest. The North Kaibab Ranger District offers a unique opportunity to manage for old-growth conditions at the landscape level. The preservation of these stands, and restoration of degraded ponderosa habitat on the Plateau, is of regional, national, and global significance. The Southwest Forest Alliance, Sierra Club and the Center for Biological Diversity are leading the effort to establish a "Kaibab Forest Old Growth Preserve" (Southwest Forest Alliance, et al. 2000). The old growth preserve would remain an important component of the larger wildlife preserve.

An important species imperiled throughout the western United States is the northern goshawk, which attains its highest breeding population densities on the Kaibab Plateau. Since logging constitutes one of the principal factors in the goshawks’ decline, the goshawks’ continued survival depends substantially on greater protection of the forest’s old-growth trees and vegetation (Crocker-Bedford 1990; Crocker-Bedford and Chaney 1988; Beier and Drennan 1997; Reynolds 1992).

Grazing

Theodore Roosevelt established the forest reserves to protect from the "great injury done by livestock," (see Miller 1996:4). Sheep and cattle have altered the ecoregion’s soils and biotic communities (Stevens and Burke 2000:84), while current agency grazing management practices continue to impact native biota. While most of the early range evaluations remain anecdotal, recent agency documents demonstrate that, even under long-term grazing management supervision, the Forest Service allotment’s range resource values remain in a “poor to very poor” conditions (USDA 2000:19). The impact of grazing, especially when sustained by federal subsidies and pro-grazing agency bias, contributes to the region’s loss of native biodiversity (Sheridan 1981:3,121-122; Dregne 1977:325).

TASK 3:
AERIAL RECONNAISSANCE OF THE EASTERN ARIZONA STRIP

INTRODUCTION

Larry Stevens (GCWC Consultant) and Ethan Aumack (GCT Project Coordinator) were flown by Ms. Jeri Ledbetter of Flagstaff on an aerial reconnaissance of the eastern Arizona Strip on 3 August. The team departed from Flagstaff Airport at 7:00 a.m., landed briefly at Marble Canyon, refueled at Kanab, UT, and returned to Flagstaff at 13:00. This flight was an opportunity to evaluate drainage connections in the project area and search for additional water resources. We were able to take some aerial photographs of sites of interest (Appendix C –electronic only), examine access routes into difficult terrain, and obtain approximate GPS readings for sites considered worthy of further examination, particularly in the Kanab Creek drainage.

Several observations of interest from this overflight were made, including those indicated in Table 3.1. In addition, we noted the following: 1) Willow Canyon (tributary to Kanab Creek) has a spring near its head; 2) springs in Little Canyon appear to have relatively easy access from the south side, with at least two trails apparent); 3) numerous springs emerge from the base of the Coconino Sandstone in the vicinity of Sowats Canyon, some of them apparently quite large (no other data have been available on these large springs).

Aerial photographs were taken of some sites, and are included in Appendix 3.1.

RECOMMENDATIONS

Overall, the flight demonstrated that a large number of unnamed, unmapped springs and rim ponds exist in the Kanab Creek drainage in the western portion of the GCT allotments. These water resources should be visited on the ground and georeferenced. Such site visits are the purpose of the proposed Level I inventory.

Table 3.1: Several apparently unmapped water resources on or immediately adjacent to GCT allotments that may be of potential interest (GPS in NAD27).

Waypoint	Locality	N	W
1	Stock tanks along road in PJ on east side of East Kaibab Monocline	N 37°00.348'	W112°05.646'
2	2 stock tanks and a natural pond near north boundary of GCT allotment	N 36° 45.887'	W 112° 11.841'
3	Small pond with fencing ca 1 mile south of Hwy 89A (2-3 mi upslope from Scenic Viewpoint turnout)	N 36° 45.735'	W 112° 17.311'
4	Natural pond near "T" confluence of two well-maintained roads in central western GCT allotment	N 36° 32.199	W 112° 21.432'
5	Natural pond in central western GCT allotment	N 36° 29.352'	W 112° 17.996'
6	Cluster of 2-3 natural? ponds in central western GCT allotment	N 36° 25.460'	W 112° 13.741'

TASK 4:
FIELD SITE VISITS TO 10 PRIORITIZED GCT WATER RESOURCE SITES

INTRODUCTION

Larry Stevens and his colleagues have developed rapid assessment protocols for springs and riparian zones on the southern Colorado Plateau that, with minor modification, may also be applicable to natural ponds and other water sources. We employed these protocols during site visits to 10 selected water resources on GCT allotments during a field trip from 10-16 July 2005. Field work was conducted by Larry Stevens (ecologist), R.J. Johnson (hydrologist), and Shondene Griswold (field assistant).

METHODS

At each site the team measured and/or evaluated the following variables (Appendices 4.1-4.3): flow, field water quality data (temperature, pH, and specific conductance); develop a sketchmap of the site; field map vegetation cover by species and stratum (surface, ground, shrub, mid-canopy, and tall canopy); vertebrate presence; aquatic and terrestrial invertebrate distribution; aquatic invertebrate density/m^2 (where possible); and human uses and impacts on the site. Photographs were taken of each site as well. The protocols for data collection at these prioritized sites were based on Stevens et al. (2005, in press a). Data were compiled and synthesized with the existing GC Wildlands (2002) and Stevens (unpublished data) for the region. We invited GCT to provide qualified volunteers to assist with data collection.

RESULTS AND DISCUSSION

Site Descriptions

We describe the flow, water quality, vegetation, fauna, and anthropogenic use and impacts of each of the 10 sites visited. These results are presented for each site, with site-specific data provided in Appendix 4.1, site photographs in Appendix 4.2, and site sketchmaps in Appendix 4.3.

Bear Lake

Bear Lake is a natural pond located in North Kaibab National Forest at GPS N36.37086 W112.14638 (NAD27), at an elevation of 2807 m (Fig. 1; Appendices 4.1-4.3). The pond is nearly circular and 47.5 m in diameter, not exceeding 1 m in depth. It occupies 1793.8 m^2, including 427.2 m^2 of open water and a central vegetated patch that is approximately 30 m in diameter. A sketch map of the site can be found in Appendix 4.2. We visited the site on 12 July 2005 and conducted field sampling of vegetation, invertebrates, and observation of vertebrates for approximately 3 hr. Bear Lake lies in the Kaibab Limestone, and like many ponds on the North Rim, rests in a sink that may be the top of a breccia pipe. Several other unconnected, unnamed ponds lie in the immediate vicinity of Bear Lake.

The water of Bear Lake is apparently permanent, having existed during the droughts of 2000 and 2002, and as attested to by the abundance of native wetland vegetation (Appendix 4A). Its water quality is comparable to that of other natural, heavily shaded forest ponds on the Kaibab Plateau and North Rim (GCWC 2002), with water temperature roughly tracking that of ambient air temperature, a very low pH of 4.10, and a low specific conductance of 19.8 µS/s.

The vegetation of Bear Lake is dominated by wetland plants, particularly *Carex nebraskensis* and *C. aquatilis*, and the pond is surrounded by rather dense, second growth mixed conifer forest. In all, we detected 10 plant species at Bear Lake, of which none were listed or endemic. GCWC (2002) reported an additional 8 species that we did not detect during our site visit, probably because of different seasonal timing of those site visits.

The invertebrates of Bear Lake are likewise typical of North Kaibab ponds, but has the highest recorded species diversity of gerrid water striders known from the region, with co-occurring *Gerris gillettei, G. commatus,* and *Limnoporus notabilis* . The low pH of the pond's surface sediments may preclude the occurrence of some benthic invertebrate taxa, but the presumably ombotrophic conditions of this pond make it a prime example of an unusual high-elevation pond.

The pond is heavily used by wildlife, and we have detected sign of *Bison*, desert mule deer, and we saw a female teal with young on the pond. This is one of the highest breeding elevations for waterfowl in Arizona.

The pond is much used by hunters, as attested to by several hunting stands in trees surrounding the pond, and the forest has been extensively used for grazing and some logging. Aspen trees at the pond contain graffiti as old as 1934. The pond is not fenced.

Crane Lake

Crane Lake is a natural pond located in North Kaibab National Forest at GPS N36.52980 W112.14984, at an elevation of 2603 m (Fig. 1; Appendices 4.1-4.3). The pond is nearly circular and is 100 m-diameter pond, not exceeding 1 m in depth. It occupies 8057 m^2, including 7854 m^2 of open water, with peripheral 203.1m^2 of wetland vegetation. A sketch map of the site can be found in Appendix 4.2. We visited the site on 13 July 2005 and conducted field sampling of vegetation, invertebrates, and observation of vertebrates for approximately 3 hr. Crane Lake lies in the Kaibab Limestone, and like many ponds on the North Rim, rests in a sink that may be the top of a breccia pipe. Several other unconnected, unnamed ponds are found in these same North Rim meadows.

The water of Crane Lake is apparently permanent, having existed during the droughts of 2000 and 2002, and as attested to by the abundance of native wetland vegetation (Appendix 4A). Its water quality differs from forest ponds on the Kaibab Plateau, having a water temperature that track more closely tracks the ambient air temperature, a nearly neutral pH of 6.41, and a specific conductance of 41µS/s.

The vegetation of Crane Lake is dominated by wetland plants, particularly *Carex sp.* and *Potamogeten natans*, and the pond is surrounded by a large, open meadow set in second-growth mixed conifer forest. In all, we detected 9 plant species at Crane Lake, of which none were listed or endemic. GCWC (2002) reported an additional 13 species that we did not detect during our site visit, probably because of different seasonal timing of those site visits.

The invertebrates of Crane Lake appear to be typical of North Kaibab meadow ponds, with: Corixidae (*Cenocorixa wileyae),* Dytiscidae *(Colymbetes incognitos* and *Hygrotus nfuscatus),* Haliplidae *(Haliplus immaculicollis),* Tricophoplera *(Limnephilus sp*.), various Odonata, and Mollusc*a (Planorbella cf. trivolvis),* as well as shoreline Saldidae *(Saldula pallipes).*

The pond is heavily used by wildlife, particularly desert mule deer, various waterfowl, and wild turkey, and we have observed cattle feeding in the pond. The pond is heavily used by numerous non-aquatic avifauna, which come to water there (Appendix 4).

The pond is fenced with aspen poles, which occasionally fall down, allowing livestock to trespass. The fence may be rather high for deer to leap. The adjacent forest has been extensively used for grazing and some logging.

Big Springs, NKNF

Big Springs emerges as a gushet from the base of the Coconino Sandstone located in North Kaibab National Forest at GPS N36.37086 W112.14638, at an elevation of 2170 m (Fig. 1; Appendices 4.1-4.3). The springs flow ca. 80 m into an artificial, 50 m-diameter pond, not exceeding 1 m in depth. The springs occupy 2043 m^2, which includes approximately 150 m^2 of open water and the remainder covered by wetland vegetation. A sketch map of the site can be found in Appendix 4.1. We visited the site on 12 July 2005 and conducted field sampling of vegetation, invertebrates, and observation of vertebrates for approximately 3 hr. Several other unconnected springs occur within 10 km of Big Springs.

The discharge of Big Springs is permanent, having flowed continuously through the droughts of 2000 and 2002, and as attested to by the abundance of native wetland vegetation (Appendix 4.1). Flow during our site visit was measured at a permanent flume at 11.167 L/s. The springs' water quality is similar to other forest springs on the Kaibab Plateau, having a water temperature that remains cold (9.5^{o}C) year-round, a pH of 7.46, and a specific conductance of 363 µS/s.

The vegetation of Big Springs is dominated by wetland plants, particularly *Nasturtium officinale* and *Urtica diotica*, and the pond is surrounded by second growth Ponderosa pine-mixed conifer forest. In all, we detected 29 plant species at Big Springs, of which none were listed or endemic. GCWC (2002) reported an additional 6 species that we did not detect during our site visit, probably because of different seasonal timing of those site visits.

The invertebrates of Big Springs appear to be typical of North Kaibab springs, with several butterflies, including Lycaenidae (*Plebejus acmon*), Hesperiidae (*Ochlodes sylvanoides*), wasps - Vespidae (*Vespula atropilusa*), beetles - Scarabaeidae (*Diplotaxis brevicollis*), landsnails - Oreohelicidae (*Oreohelix strigosa*), and aquatic taxa, including Baetidae (*Baetis tricaudatus),* Limnephilidae (*Hesperophylax*), Heptageniidae (*Epeorus longimanus*) and Coenagrionidae (*Ischnura perparva*).

The springs are used to some extent by mammals, particularly desert mule deer, montane voles, and Kaibab squirrels. The pond is heavily used by numerous non-aquatic avifauna, which come to water there (Appendix 4).

The pond is adjacent to a National Forest Service fire and research facility, and therefore experiences heavy human use. The cracks in the wall source from which Big Springs emerges have been extensively filled with concrete to focus the flow, and a piping system captures the flow 5 m from the source and abstracts approximately 25 percent of the flow down to the National Forest Service station below. This component of the flow is not accounted for in our measured discharge of the springs (which was measured in the permanent flume, as mentioned above). The adjacent forest has been extensively used for grazing, some logging, and more than a decade of Northern Goshawk research.

Kane Aqueduct Springs

Kane Aqueduct Spring is a contact springs that emerges from the base of the Coconino Sandstone in Kane Canyon on GCT land about 3 km upstream from Kane Ranch, at GPS N36.58303 W112.04678, at an elevation of 1891 m (Fig. 1; Appendices 4.1-4.3). The spring is diverted by some flow leaks ca. 5 m down onto the adjacent steep, rocky hillside, where it loses flow. The spring occupies 225 m^2, including approximately 13.5 m^2 of open water in a qanat (excavated tunnel), with the remainder dominated by wet backwall and wetland vegetation. A sketch map of the site can be found in Appendices 4.2. We visited the site on 15 July 2005 and conducted field sampling of vegetation, invertebrates, and observation of vertebrates for approximately 3 hr. Another unconnected springs occurs approximately 100 m W of this spring.

The flow of Kane Aqueduct Spring appears to be permanent, as attested to by the abundance of native wetland vegetation and the efforts expended to capture its flow (Appendix 4.1). Flow during our site visit was estimated at <0.01 L/s. The springs' water quality is similar to other upper elevation, Coconino aquifer springs on the Kaibab Plateau, having cold water temperature (14.0^{o}C), a normal pH of 7.70, and a specific conductance of 722 µS/s.

The vegetation of Kane Aqueduct Spring is dominated by sedges, orchids, and facultative springs plants, particularly *Solidago canadensis*, and the pond is surrounded by second growth mixed conifer woodland. In all, we detected 25 plant species at Kane Aqueduct Spring, of which none were listed or endemic.

The aquatic invertebrates of Kane Aqueduct Spring are few, but typical of small North Kaibab springs, and include Notonectidae (*Notonecta kirbyi*).

The spring is used to some extent by mammals, particularly desert mule deer (Appendix 4). The spring is on GCT land, and has historically been subject to intensive human exploitation, including the construction of the qanat and diversion flow for livestock and wildlife watering. The adjacent forest / woodland uplands have been extensively used for grazing.

Coyote Springs and Stockpond

Coyote Springs is a former hillslope spring that originally emerged near the floor of upper House Rock Valley, probably from the Kayenta Formation or from the Chinle Formation. It is located on GCT land at GPS N36.95415 W 112.02383, at an elevation of 1608 m (Fig. 1; Appendices 4.1-4.3). The spring flow is captured in a subterranean piping system and flows ca. 200 m across the drainage to a cattle yard pond that is approximately 30 m in diameter pond and does not exceed 1 m in depth. The area of the original spring cannot be determined, but appears to be less than 250 m^2. The pond spring occupies 861 m^2, including approximately 443 m^2 of open water, with the remainder covered by peripheral wetland vegetation. A sketch map of the site can be found in Appendix 4.2. We visited the site on 16 July 2005 and conducted field sampling of vegetation, invertebrates, and observation of vertebrates for approximately 3 hr. No other springs occur within several km this springs.

The flow of Coyote Springs appears to be permanent, as much effort has been made to capture it in the pond (Appendix 4). Flow during our site visit was measured from the pond inflow pipe at 0.076 L/s. The spring's water quality is probably typical of springs emerging on the east side of the base of the Vermilion Cliffs, having warm water temperature (24.2^{o}C), a pH of 7.3, and a specific conductance of 624 μS/s.

The vegetation of Coyote Springs Pond is dominated by wetland plants, particularly algae and *Agropyron sp*., and the pond is surrounded by overgrazed desert dysclimax shrublands. In all, we detected 17 plant species at Coyote Spring, of which none were listed or endemic.

The invertebrates of Coyote Springs appear to be typical of other Vermilion Cliffs springs, with: Apidae (*Apis mellifera*) and Coenagrionidae (*Ischnura*, *Enallagma*). Of note was the first presence of thee first Coconino County record for the tiny rust-colored libellulid dragongly *Perithemis intensa.*

The spring pond was previously used for livestock, and is now used primarily by by numerous non-aquatic avifauna, which come to water there (Appendix 4) The adjacent desert scrublands have been severely overgrazed.

North Canyon Creek

North Canyon Creek is a small perennial stream located at GPS N36.41214 W112.07736, at an elevation of 2829 m (Fig. 1; Appendices 4.1-4.3). The stream flows approximately 2 km from its emergence points in upper North Canyon Wilderness Area, Crystal Springs on the East Rim, and various unnamed springs along the canyon floor. It is a losing stream and disappears after flowing into the lower Hermit Shale Formation.

We visited the site on 13 July 2005 and conducted field sampling of vegetation, invertebrates, and observation of vertebrates for approximately 4 hr, including surveying of three cross sections to determine channel geometry. Sketch maps of the site can be found in Appendices 4.2.

The surface flow of North Canyon Creek is permanent, having existed continuously since the middle of the past century and during the droughts of 2000 and 2002, and as attested to by the presence of Apache trout and abundant native wetland vegetation (Appendix 4). Its water quality is comparable to other high elevation, spring-fed streams on the Kaibab Plateau and North Rim of Grand Canyon (GCWC 2002). The water temperature is 9.5^{o}C, the pH is 8.26, and the specific conductance is 343 μS/s, indicating a relatively short flow path for locally derived (primarily snowmelt) groundwater.

The vegetation of North Canyon Creek is abundant and diverse, with 26 species detected. GCWC (2002) reported an additional 22 species that we did not detect during our site visit, probably because of different seasonal timing of those site visits. A rare large white *Aquilegia* occurs immediately upstream at North Canyon Springs, and *Goodyera oblongifolia* occurs along the upper terraces of the creek.

Aquatic invertebrates in North Canyon Creek are typical of high elevation, cold water streams, with Baetidae (*Baetis tricaudatus*), Tenebrionidae (*Eleodes*), Nemouridae (*Malenka*) and Limnephilidae (*Hesperophylax*).

North Canyon provides abundant habitat for forest wildlife. The stream is an important habitat for Apache trout (*Onchorhynchus apache*), which was introduced there during the past century (Haynes and Schuetze, 1997). This species is federally threatened and is regarded as an Arizona species of special concern. It is endemic to Arizona, and is restricted to streams of upper Salt, Blue, and Little Colorado drainages in White Mountains. During the past century, it was introduced into North Canyon Creek, as well as into Grant

Creek on Mount Graham. We observed many trout in the artificially constructed pools in North Canyon Creek, and the trout population appears to be healthy and reproducing.

Lower Paria River

Lower Paria River is a surprisingly small perennial stream, given the enormity of its drainage basin. We sampled the creek approximately 5 km upstream from its confluence with the Colorado River, at a GPC location of N36.88574 W111.60876 and an elevation of 970 m (Fig. 1; Appendices 4.1, 4.2).

We visited the site on 14 July 2005 and conducted field sampling of vegetation, invertebrates, and observation of vertebrates for approximately 4 hr, including surveying of three cross sections to determine channel geometry. A sketch map of the site can be found in Appendix 4.2.

The surface flow of the Paria River is permanent, having existed continuously since the middle of the past century and during the droughts of 2000 and 2002. In part, this stream is fed by the only surface water importation on the Colorado Plateau, with the diversion of the East Fork of the Sevier River south of Bryce Canyon National Park, and into the Tropic and then into upper Tropic Creek, and thence into the Paria River.

Paria River water quality is comparable to other low elevation streams on the southern Colorado Plateau (GCWC 2002), with naturally high levels of turbidity augmented by overgrazing of the adjacent uplands. Graf et al. (1994) documented a silt concentration in Paria River floodwaters in excess of 750,000 mg/L. On the afternoon of our visit, air temperature exceeded 45^{o}C, and the stream water temperature reached 37^{o}C, sufficient to kill all fish in the creek (speckled dace and native suckers were observed). The pH is 8.48, and the specific conductance is 497 μS/s, indicating a relatively short flow path for locally derived (primarily snowmelt) groundwater.

The vegetation of the lower Paria River consists of sparse desert riparian grass/herbs and shrubs, dominated by *Vulpia octoflora* and *Pluchea sericea*. The Paria River provides little cover or plant species diversity and rare plants have not been detected. The only trees along the Paria River are Fremont cottonwood, and those are sparse, with low recruitment. Some evidence suggests that more extensive stands of cottonwood previously occupied the area, but were removed for fuel and construction by early Mormon settlers.

Aquatic invertebrates in the Paria River are sparse, but we detected a population of semi-aquatic toad bugs (*Gelastocoris o. oculatus*).

The Paria River and its sparse vegetation provides little habitat for wildlife. The stream was formerly an important breeding locality for endangered humpback chub and other endangered fishes, which apparently spawned in the mouth area during mainstream Colorado River floods. Conditions in the creek are too hot to allow any species to exist there through the summer months, a condition that was likely exacerbated by the loss of Fremont cottonwood trees and the cooling effects of their overstory shade.

"South Sandcrack" Springs

"South Sandcrack" Springs are a contact-hillslope spring that emerges from the base of the Vermilion Cliffs on GCT land at GPS N36.72759 W111.89743, at an elevation of 1629 m (Fig. 1; Appendices 4.1-4.3). The springs appear to be largely captured through a dysfunctional piping system for Lower Jacob Pools, approximately 1 km to the east. The leakage out of the piping system at the springs source flows ca. 75 m down a severely overgrazed steep cienega, losing flow across its course. The springs occupy 5751 m^2, including only about 1 m^2 of open water, with the remainder covered by facultative and some obligate wetland vegetation. A sketch map of the site is presented in Appendix 4.2. We visited the site on 14 July 2005 and conducted field sampling of vegetation, invertebrates, and observation of vertebrates for approximately 2 hr. Two other unconnected springs occur within 2 km of this spring.

The flow of “South Sandcrack” Spring appears to be permanent, as attested to by the extensive efforts to capture and direct it to Jacobs Pools. Flow during our site visit was estimated to be <0.063 L/s. The spring’s water quality is similar to other springs emerging from the base of the Vermilion Cliffs, having relatively warm water temperature (20.4°C), a pH of 7.64, and a specific conductance of 452 µS/s.

The vegetation of “South Sandcrack” Spring is dominated by wetland plants, particularly *Juncus balticus* and *Stanleya pinnata*, and the springs are surrounded by sparse, severely overgrazed desert shrubland habitat. In all, we detected 19 plant species at “South Sandcrack” Spring, of which none were listed or endemic.

The aquatic invertebrates of “South Sandcrack” Spring were few, with most flow diverted or lost in the decomposing piping system. Terrestrial invertebrates particularly included native *Bombus* (nr. *morrissoni*) and non-native honey bees (*Apis mellifera*).

The spring is used to some extent by mammals, including desert mule deer and black-tailed jackrabbit (Appendix 4).

The spring lies on Grand Canyon Trust land, and therefore is subject to rather heavy human use, including livestock and wildlife watering. The adjacent desert shrublands have been extensively used for grazing.

Tater Canyon Springs, Upper

Upper Tater Canyon Spring is a spring that emerges from underneath the base of the Coconino Sandstone on North Kaibab National Forest land at an elevation of approximately 2000 m (Fig. 1; Appendices 4.1-4.3). The spring flows 2 m into a small constructed pool, from which water is diverted into a nearby pipe, and apparently transported to one or more stocktanks at least 10 km to the base of the East Kaibab Monocline. The spring occupies 25.7 m^2, including approximately 2 m^2 of open water, with the remainder covered by wetland vegetation. A sketch map of the site is presented in Appendix 4.2. We visited the site during a vigorous hike on 15 July 2005, and conducted field sampling of vegetation, invertebrates, and observation of vertebrates for approximately 1.5 hr. No other springs are known within approximately 3 km of this spring.

The waters of Upper Tater Canyon Spring appear to be permanent, as they have been the subject of considerable manipulation and flow regulation, and as attested to by the presence of orchids and other native wetland vegetation (Appendix 4). Flow during our site visit was estimated to be <0.017 L/s. The spring’s water quality is similar to that emerging from the base of the Coconino Sandstone at similar elevations elsewhere on the Kaibab Plateau, having cool water temperature (17.6°C), a relatively high pH of 7.97, and a specific conductance of 349 µS/s.

The vegetation of the wet backwalls of Upper Tater Canyon Spring is dominated by wetland plants, particularly moss, and the pond is surrounded by second growth mixed conifer woodland and forest conifers. In all, we detected 8 plant species at Upper Tater Canyon Spring, of which none were listed or endemic.

No aquatic invertebrates were detected at Upper Tater Canyon Spring appear to be typical of North Kaibab springs, but several bees and wasp species have been observed there.

The spring is used to some extent by mammals, particularly desert mule deer (Appendix 4.1).

The spring lies on National Forest Service land, and has been the focus of considerable water harvesting activities. subject to rather heavy human use, including livestock and wildlife watering. The adjacent forested or woodland uplands have been extensively used for grazing and some logging.

Tater Canyon Springs, Lower

Lower Tater Canyon Spring is a spring that apparently emerges from the Paleozoic Hermit Shale. The spring is located on North Kaibab National Forest land at GPS N36.49519 W112.06845, with at an elevation of 2284 m (Fig. 1; Appendices 4.1-4.3). The springs flow ca. 5 m into a steep hillslope, from whence it is captured. The springs occupy 108.4 m^2, including <0.1 m^2 of open water, with the remainder covered by dense wetland vegetation. A sketch map of the site can be found in Appendix 4. We visited the site on 15 July 2005 and conducted field sampling of vegetation, invertebrates, and observation of vertebrates for approximately 3 hr. Other unconnected springs occur within 200 m of this spring.

The flow of Lower Tater Canyon Spring is permanent, having flowed throughout the droughts of 2000 and 2002, and as attested to by the abundance of native wetland vegetation (Appendix 4). Flow during our site visit was estimated at 0.259 L/s. The springs' water quality is similar to/ other woodland springs that emerge from the Coconino aquifer on the Kaibab Plateau, having cold water temperature (11.5^oC), a pH of 8.05, and a specific conductance of 323 µS/s.

The vegetation of Lower Tater Canyon Spring is dominated by wetland plants, particularly *Juncus balticus*, and the pond is surrounded by second growth mixed conifer forest. In all, we detected 11 plant species at Lower Tater Canyon Spring, of which none were listed or endemic.

The invertebrates of Lower Tater Canyon Spring appear to be typical of middle and upper elevation North Kaibab springs. The spring is used to some extent by mammals, particularly desert mule deer (Appendix 4.1).

The springs appear to lie on GCT land, and therefore are subject to rather heavy human use, including livestock and wildlife watering. The adjacent woodland uplands have been extensively used for grazing and some logging.

TASK 5: WATER RESOURCES ASSESSMENT AND RECOMMENDATIONS

INTRODUCTION

The purpose of this study was to evaluate the ecological health of 10 selected water resources on the GCT allotments on the eastern Arizona Strip, and use that information to recommend site-specific management actions, area-wide management actions, and identify further research and monitoring needs for GCT, as well as to collaboratively assist GCT develop a management strategy for the water resources of the Kane and Two Mile Ranch area. In this chapter we present the results of our rapid ecological assessments of each site, including site-specific management recommendations. We then propose regional water resource management activities. When GCT has examined the information presented in this draft report, we will schedule a meeting to discuss the results and recommendations, and collaboratively assist GCT develop a monitoring, research, and conservation strategy for the water resources of the Kane and Two Mile Ranch area.

Here we present ecosystem health assessments of the 10 water resources sites visited in 2005. This section provides GCT with information on management and monitoring strategies for the sites visited, as well as a test of these methods to determine whether they are compatible with program planning. When this draft final report has been reviewed by GCT, we will revise it and resubmit it to the GCT. We recommend that it then be reviewed by the GCT Science Advisors..

METHODS

General Methods

The methods used included the springs ecosystem assessment protocol (SEAP; Stevens et al. in press) for springs, a modification of that format for natural ponds, and the rapid stream-riparian assessment (RSRA; Stevens et al. 2005) methods for stream segments.

The SEAP Methods

Rationale: Springs ecosystem health assessment protocols are needed to guide management, but these criteria previously have not been broadly developed or used. Basic inventory of springs at most landscape scales generally has been neglected, and little agreement has previously existed on how to classify springs or which variables should be measured at springs (but see Springer et al., in press b). Trends assessment requires reliably collected and archived monitoring information, but relatively few springs have been subjected to comprehensive, long-term monitoring. Collectively, the lack of systematic data has retarded the development of springs ecosystem ecology, and has hampered springs health assessment, conservation and restoration. In this paper we present efficient, effective assessment ecosystem health assessment protocols to help improve springs management and conservation.

Ecosystem assessment must be an efficient, scientific process that uses quantified information on human impacts to the existing ecosystem condition, and incorporates spatio-temporal considerations of site uniqueness, an approach adopted by many stream ecosystem health studies. An efficient assessment protocol must provide insight into human impacts, and guidance on management, conservation and restoration potential and priorities within and among the springs in a landscape. In particular, three elements are needed for springs ecosystem assessment: 1) compilation of diverse inventory information on the ecosystem characteristics and processes of individual springs across a region; 2) a systematic scoring of the condition of individual ecosystem characteristics or processes at each springs, as well as a scoring of whole springs ecosystems; and 3) prioritization of management actions by evaluating a springs' ecological condition and importance in relation to competing socioeconomic variables.

Our SEAP checklist (Appendix 5.1) and scoring criteria (Appendix 5.2) are based on the conceptual springs ecosystem model of Stevens et al (in press), the springs classification scheme of Springer et al. (in press a), and informed by the springs inventory protocols (Stevens et al., in press b). This SEAP advances and augments the springs assessment protocols proposed by Sada et al. (2001) for western North American springs.

Scoring: SEAP scoring is conducted on numerous variables among six categories of springs characteristics (Appendices 5.1-5.2). The scope of the assessment extends from the aquifer and pre-orifice environment through the first 100 m of runout stream(s), where such exist. Each natural microhabitat that occurs or is expected to occur at the springs being assessed is examined, including natural and anthropogenically-influenced cave, orifice, madicolous habitats, spray zones, wet wall, adjacent dry wall pool, springs run-out stream(s), wetlands, riparian, and adjacent uplands microhabitats. Individual variable scores range from 1 to 5 and are given on the basis of background synthesis data and field inventory data:

- *Dysfunctional Condition* (DFC, score = 1): springs have been entirely destroyed by direct or indirect human activities and exist, if at all, in a fully degraded condition with no likelihood for rehabilitation.
- *Jeopardized Functional Condition* (JFC, score = 2): springs largely destroyed by human activities but still retain limited natural flow, native species, and with <33% natural ecological function and some rehabilitation potential.
- *Functioning at Risk* (FAR, score = 3): springs with obvious and threatening impairment of ecological function and integrity because human impacts on the aquifer, the landscape at and surrounding the orifice, or regional-global climate, with 33-67% of natural function, good rehabilitation potential, and some restoration potential.
- *Altered Functioning Condition* (AFC, score = 4): springs with minor but detectable anthropogenic impacts on ecosystem health, and where the natural condition can be readily restored, with 67-95% of natural function and high restoration potential
- *Natural Functioning Condition* (NFC, score = 5): springs at which human impacts are not readily detectable, with >95% of natural ecological function and no immediate need for restoration.

A score of "n/a" (not applicable) is given when the variable is not applicable, and the score is left blank if data are not available for the springs. Blank cells should be filled as soon as appropriate data become available.

Analyses of the regional processes are critical to understanding the ecological condition and context of individual springs, and several components of the SEAP scoring require analysis of regional patterns (i.e., aquifer threats, springs distribution, isolation, and relative size).

Qualifiers: Two important qualifiers modify SEAP scoring: dewatering a springs, and obliteration of the orifice area (Appendix 5.2). Discharge, whether seasonal or perennial, is a fundamental ecosystem component, and dewatering or flow augmentation strongly affects springs ecosystem characteristics. If a known perennial springs has recently been dewatered through aquifer depletion or pre-orifice abstraction, most functional components and processes are likely to be interrupted or eliminated (Stevens and Springer, this volume). Dewatering a springs even briefly is likely to decimate aquatic and some wetland species, and prolonged dewatering will eliminate most or all springs-dependent species and alter site geomorphology. Unfortunately, historical hydrography data may not be available for individual springs, and flow patterns often must be inferred from published accounts of springs; detailed analyses of sediments, soils, or dendro-chronology; interviews with elders; or analyses of historic photographs. Similarly, springs orifices are sometimes entirely obliterated by site or water development projects, including well drilling, water extraction, springhouse construction, and other human activities.

SEAP Category Scores: Using the scoring criteria presented in Appendix 5.2, the percent total possible variable score is calculated as a percentage equaling 100 times the sum of all variable scores within a category, divided by the maximum possible category score (5 times the number of variables within the category). In general, category scores of 0-10 percent represent a fully degraded condition (DFC) with no opportunity for rehabilitation, scores of 10-33 percent indicate a JFC, scores of 33-66 percent indicate a FAR condition, scores of 66-95 percent indicated an AFC, and scores >95 percent indicate NFC.

If the spring has been dewatered and/or the orifice has been obliterated, the AFWQ category automatically receives a score of 0 percent, a non-functioning score. If the springs have been dewatered, the AFWQ, geomorphology (GEO), and ecosystem and trophic dynamics (ETD) categories are given scores of 0, and strong impacts are expected on numerous other physical and biological assessment variables. If the orifice environment has been obliterated, the GEO and ETD categories are given scores of 0 percent, and low scores are likely for most other habitat, ecosystem function, and biological variables and categories.

Ecological Health Assessment of Natural Ponds

We slightly modified the SEAP methods (above) to evaluate natural ponds. The adjustments needed from the SEAP methods particularly involved scoring flow (AFWQ 2) and runout stream geomorphology (GEO 2) as “n/a”, and eliminating considerations of the aquifer in AFWQ 1 and FHI 1 (unless subsurface springs inflow was suggested at the site).

The RSRA Methods

Rationale: We used the rapid stream-riparian assessment (RSRA) protocols checklist, scoring criteria, and guidelines of Stevens et al. (2005) to measure the ecological functionality of stream habitats on the eastern Arizona Strip (Appendices 5.3-5.4). This protocols emphasizes the need for scientific credibility, simplicity and sampling efficiency. RSRA was designed for use in low to middle elevations in the Southwest, where strong soil moisture, soil texture, and vegetation gradients predominate across riparian-upland boundaries.

Approach: RSRA protocols are based on assessment of a suite of variables that are critical to stream ecosystem functioning. As with SEAP, individual ecosystem variables are grouped into categories, and scored during field site visits. Several factors strongly modify scoring of these variables and the desired condition of the reach is defined by its management criteria. Geomorphic consistency is a potentially strong modifier for all variables.

We modified RSRA to include the freedom from human impacts category score, and we recalculated RSRA scores as percent total possible, as was used in the SEAP scoring. We combined the fish / aquatic habitat, riparian vegetation, and wildlife habitat variable scores from the RSRA to generate scores for the ecosystem trophic dynamics and biogeographic significance in SEAP.

RESULTS

SEAP and RSRA protocols provide a relatively wide range of variable, category, and whole-site assessment scores that reveal clear differences in conditions and rehabilitation/ restoration potential of the 10 sites examined thus far (Table 5.1). Of all sites examined, Coyote Springs in House Rock Valley is in the worst condition, with the spring source entirely obliterated, and water abstracted to a cattle pond. North Canyon Creek is in the best condition, as it is preserved in a Wilderness Area, and has few signs of recent human impacts other than non-native plant incursion. Prioritization of management actions will require in-depth discussion with the GCT.

This assessment indicate that human impacts are strongly negatively related to the ecosystem function categories, and vary among ecosystem categories (Fig. 5.1). The position (stacking) of these lines indicates that geology and geomorphic conditions (GEO) appears relatively less affected by human impacts, while aquatic habitat – water quality (AFWQ) tend to be most strongly affected. However, the slopes of these regression lines indicates that resilience of the various ecosystem components is structured in the following manner:

BG >> ETD > GEO > AFWQ

Table 5.1: Overall results of GCWC's ecological health assessment of 10 GCT water resources on the eastern Arizona Strip.

SEAP Categories	Kane Aquiduct Spring	Coyote Springs, HRV	Tater Cyn Spr, Lower	Tater Cyn Spr, Upper	Big Springs, NKNF	"South Sandcrack" Spr	Bear Lake, NKNF	Crane Lake, NKNF	No Cyn Cr.	Paria R.
AFWQ	90.0	0.0	90.0	95.0	90.0	80.0	80.0	80.0	93.3	66.7
GEO	68.0	0.0	56.0	64.0	72.0	52.0	60.0	55.0	80.0	65.0
ETD	76.0	20.0	50.0	76.0	80.0	60.0	72.0	60.0	94.3	55.2
BG	68.0	32.0	56.0	68.0	80.0	65.0	80.0	84.0	76.0	68.0
FHI	74.3	40.0	80.0	80.0	77.1	57.1	80.0	71.4	94.3	60.0
AC	65.0	55.0	56.7	71.4	77.1	68.6	73.3	60.0	70.0	75.0
Overall Score	72.4	41.2	59.4	72.9	74.1	59.4	68.2	62.4	87.9	60.6

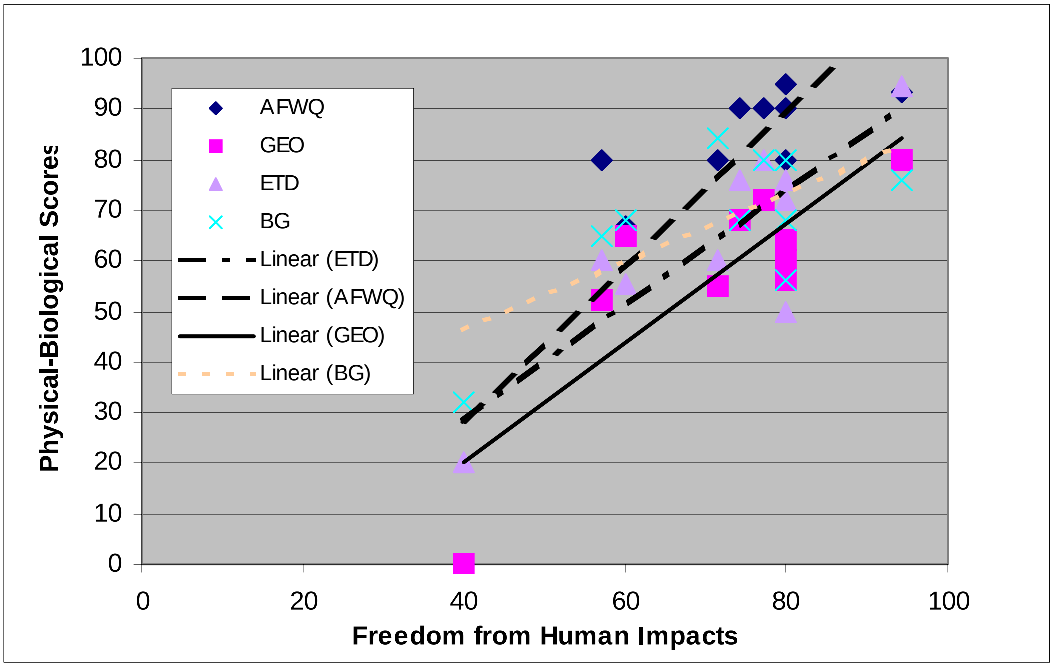

Fig. 5.1: Relativized scores of physical and ecological characteristics categories in relation to the freedom from human impacts category score for 10 water resource study sites on the eastern Arizona Strip. Categories in clued AFWQ – aquatic and fish habitat, and water quality, BG – biogeographic significance, ETD – ecology and trophic dynamics, and GEO – geology and geomorphic condition.

GENERAL RECOMMENDATIONS

We make the following general recommendations to the GCT regarding its water resources:

1) Develop a general strategic landscape / ecosystem management, monitoring, and research plan, so that management activities will be: a) logically prioritized; b) conducted in a cost effective, scientifically credible manner; and c) administered efficiently. The strategic plan should also serve as the framework for long-term information storage, to document work accomplished and challenges, and ultimately provide an administrative history for GCT land management.
2) Conduct a regional Level I inventory of water resources (Appendix 1)
3) Develop a long-term data archival and management system and library
4) Because species-area effects are strong among water resources in the region, plan on rehabilitation or restoration of larger sites first
5) Consider restoring water resource sites not for recovery of usually unknown or unclear pristine conditions, but to maximize functionality and native biological diversity – this is usually accomplished by increasing and improving microhabitat diversity
6) Use native stock taken from within 100 km of the site for habitat restoration projects
7) Continue Level II inventories and site assessments and archive/manage data
8) Conduct basic research on the roles of water resources on local adjacent ecosystems

9) For springs:

a) Leave some flow at the source as water for habitats and wildlife
b) If a site is to be repeatedly visited for water manipulation, monitoring, or restoration, create and maintain a trail ("stepping stones" may be best) to limit visitor impacts to the site
c) If springs are to be exploited for domestic or livestock water supplies, monitor and maintain the flow capture mechanisms and piping, and repair damaged pipes
d) Develop a reliable groundwater model for each groundwater basin to predict aquifer responses to well drilling
e) Protect sources from livestock trampling and damage

10) For ponds:

a) Conduct and support studies of wildlife use, long-term environmental change, water balance, pond ecosystem ecology, and other topics related to springs, natural ponds, and streams
b) Remove non-native species, where possible
c) Protect sources from livestock trampling and damage

11) For streams:

a) Conduct studies to determine wildlife corridor and use of stream habitats
b) Restore streams to maximize native biological diversity
c) Remove non-native species, where possible, including livestock
d) Protect sources from livestock trampling and damage

SITE-SPECIFIC RECOMMENDATIONS

Bear Lake

1) Further faunal inventories and habitat use studies (especially for aquatic leeches, worms, Heteroptera, beetles, and Diptera, as well as waterfowl, other birds, small mammals, and ungulates, including *Bison*)
2) Fence out Bison, if necessary

Big Springs, NKNF

1) Construct a trail to the source to reduce anthropogenic disturbance and erosion
2) More consistent monitoring of flow to determine seasonal and interannual variation
3) Repair piping and remove old, broken pipes
4) Further faunal inventories and habitat use studies (especially for aquatic leeches, worms, Heteroptera, beetles, and Diptera, as well as avifaunal, *Microtus* voles, and Kaibab squirrel)

Kane Aqueduct Spring

1) Trail needed to source
2) Repair piping and remove old, broken pipes
3) Clean up qanat tailings
4) Remove signage from tank half way up canyon
5) Allow for additional flow at source

Coyote Springs

1) Develop a strategic management plan for the ranch, pond, and springs
2) If springs restoration is an option, turn it into a research project to learn how to rehabilitate entirely devastated springs; if not, consider maintaining pond for avifauna and distinctive invertebrate life, and using the ranch to raise native plants for restoration
3) Restore or rehabilitate adjacent uplands
4) Remove unnecessary roads

Crane Lake

1) Further faunal inventories and habitat use studies (especially for aquatic leeches, worms, Heteroptera, beetles, and Diptera, as well as waterfowl, wild turkey, other birds, small mammals, and ungulates)
2) Maintain fences to keep Bison out, but allow deer and other species access to the pond
3) Restore adjacent meadow and forest habitats

Lower Paria River

1) Remove non-native plant species where possible
2) Consider cottonwood stand restoration along lower Paria River
3) Construct ponds in the gravel pits at the mouth of Paria River, with inflow channels of cold Colorado River water, as a native fish propagation and research site

North Canyon Creek

1) Declare North Canyon Creek a Research Study Area or similar designation
2) Develop and implement a long-term riparian monitoring and research program, including monitoring of Apache trout and terrestrial fauna
3) Remove non-native species, where possible
4) Maintain wilderness area hiking trail so as to minimize impacts on the stream

"South Sandcrack" Spring

1) Develop a site rehabilitation plan
2) Clean up site, remove unused piping
3) Re-establish flow to the hillslope cienega
4) Continue to inventory flora and fauna

Tater Canyon Spring, Upper

1) Clean up and repair damaged piping
2) Allow flow to continue into the runout stream
3) Monitor rare plants and continue faunal inventory and habitat use studies

Tater Canyon Spring, Lower

1) Clean up site and restore flow to steep hillslope cienega
2) Remove old road and restore the slope
3) Monitor rare plants and continue faunal inventory and habitat use studies

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APPENDIX 1.1:
SPRINGS, NATURAL PONDS, AND OTHER NATURAL AND ANTHROPOGENIC WATER SOURCES ON THE EASTERN ARIZONA STRIP

KEY: Site names are derived from U.S. Geological Survey maps or, in a few cases, local names; Project ID Number relates to Fig. 1.

Site Name	Project No.	Type	Land Unit	UTM	Lat Long	Elev (m)
Aspen Tank	1	Reservoir		E 397588 N 4027888	36.39250 -112.14194	2745
Awatubi Creek	2	Stream		E 426185 N 4009848	36.23250 -111.82139	836
Badger Spring	3	Spring		E 436053 N 4074418	36.81528 -111.71694	1474
Badger Tank	4	Reservoir		E 416021 N 4073359	36.80417 -111.94139	2035
Basin Spring	5	Spring		Zone 12 400493.7 S 4014100.0	36.26639 -112.10722	2508
Bear Lake	7	Pond	NKNF	Zone 12 397114.2 S 4025626.9	36.37139 -112.14639	2774
Bear Spring	8	Spring		E 394642 N 4025365	36.36944 -112.17444	2656
Bee Spring	10	Spring	NKNF	Zone 12 381896.5 S 4034761.7	36.45111 -112.31778	2390
Bentonite Reservoir	11	Reservoir		E 399734 N 4087650	36.93139 -112.12583	1976
Big Cove Tank	12	Reservoir		E 360119 N 4049988	36.58694 -112.56361	1709
Big Ridge Tank	13	Reservoir		E 393968 N 4063712	36.71500 -112.18722	2361
Big Saddle Tank	14	Reservoir		E 375127 N 4034162	36.44639 -112.39333	2138
Big Spring	311	Spring	NKNF	Zone 12 379386.8 S 4051599.3		2149
Bitter Spring	15	Spring		E 361079 N 4043284	36.52667 -112.55167	1207
Blow Down Tank	16	Reservoir		E 393889 N 4029073	36.40278 -112.18333	2682
Blowdown Tank	17	Reservoir		E 396688 N 4029748	36.40917 -112.15222	2779
Blue Canyon Well	18	Well		E 421189 N 4001203	36.15417 -111.87611	1418
Blue Clay Reservoir	19	Reservoir		E 412702 N 4066242	36.73972 -111.97778	1608
Bone Hollow Tank	20	Reservoir		E 369662 N 4046571	36.55750 -112.45639	1951
Bonita Creek	21	Stream		E 367613 N 4026415	36.37556 -112.47583	643
Box Elder Spring	23	Spring		E 366435 N 4045296	36.54556 -112.49222	1577
Bright Angel Spring	24	Spring		E 404078 N 4008708	36.22028 -112.06722	2467
Buck Farm Spring	312	Spring	GCNP	---		945
Buck Lake	25	Pond		E 383728 N 4062489	36.70278 -112.30167	2350

Buckhorn Tank	26	Reservoir		E 365689 N 4059670	36.67500 -112.50306	1756
Buffalo Hill Tank	27	Reservoir		E 395473 N 4063015	36.70889 -112.17028	2401
Buffalo Tanks	28	Reservoir		E 416900 N 4043704	36.53694 -111.92833	1589
Burn Tank	29	Reservoir		E 408973 N 4018331	36.30750 -112.01389	2684
Burnt Corral Tank	30	Reservoir		E 380711 N 4039969	36.49944 -112.33194	2393
Burro Spring	31	Spring		E 402484 N 4075013	36.81778 -112.09333	1974
Burro Tank	32	Reservoir		E 414773 N 4029920	36.41250 -111.95056	1785
Bush Head Tank	33	Reservoir		E 435108 N 4086906	36.92778 -111.72861	1780
Butte Fault lower	313	Spring	GCNP	---		1050
Butte Fault upper	314	Spring	GCNP	---		1050
Carbon Creek	35	Stream		E 426684 N 4000847	36.15139 -111.81500	822
Castle Lake	36	Pond		E 383064 N 4022617	36.34333 -112.30306	2329
Castle Spring	37	Spring	NKNF	Zone 12 379981.8 S 4049754.9	36.58611 -112.34139	2195
Cedar Ridge Reservoir	39	Reservoir		E 374023 N 4075879	36.82222 -112.41250	1655
Cheyava Falls	40	Falls		E 412410 N 4000392	36.14611 -111.97361	1804
Chuar Creek	41	Stream		E 422350 N 4002394	36.16500 -111.86333	1095
Clear Creek	42	Stream		E 406786 N 3993332	36.08194 -112.03528	750
Cliff Dweller Spring	43	Spring		E 404584 N 4007038	36.20528 -112.06139	2379
Cliff Spring	44	Spring	GCNP	E 414335 N 3997940	36.12417 -111.95194	2361
Coffee Lake	45	Pond		E 394638 N 4018894	36.31111 -112.17361	2594
Comanche Creek	46	Stream		E 425576 N 3996912	36.11583 -111.82694	820
Corral Lake	47	Pond		E 388320 N 4052997	36.61778 -112.24889	2494
Cottonwood Spring	48	Spring		E 431695 N 4068659	36.76306 -111.76528	1411
Cottonwood Spring	49	Spring		E 361651 N 4043244	36.52639 -112.54528	1291
Cougar Lake	50	Pond		E 393401 N 4037954	36.48278 -112.19000	2668
Cougar Spring	51	Spring		E 376153 N 4017073	36.29250 -112.37917	2058
Coyote Spring	52	Spring		E 407824 N 4089870	36.95222 -112.03528	1606
Crane Lake	53	Pond	NKNF	Zone 12 397074.9 S 4043349.2	36.53000 -112.14833	2604
Crazy Jug Spring	54	Spring		E 376521 N 4032415	36.43083 -112.37750	2197
Crystal Spring	55	Spring	NKNF	---	36.39028 -112.09583	2681
Dead Duck	315	Spring	GCNP	---		808
Deer Creek	56	Stream		E 364743 N 4027846	36.38806 -112.50806	596
Deer Creek Falls	57	Falls		E 364669 N 4027877	36.38833 -112.50889	596

Deer Creek Spring near river	316	Spring	GCNP	---		808
Deer Creek Spring upper	317	Spring	GCNP	---		899
Deer Lake	58	Pond	NKNF	Zone 12 398587.8 S 4029158.9	36.40222 -112.12972	2652
Deer Spring	59	Spring		E 365387 N 4029130	36.39972 -112.50111	843
Dinner Pockets Trick Tank	60	Reservoir		E 357801 N 4046636	36.55639 -112.58889	1720
Divide Tank	61	Reservoir		E 363995 N 4053039	36.61500 -112.52083	1753
Dog Canyon Tank	62	Reservoir		E 403491 N 4034445	36.45222 -112.07694	2596
Dog Lake	63	Pond	NKNF	Zone 12 401714.6 S 4027641.4	36.42167 -112.08889	2681
Dragon Creek	64	Stream		E 391749 N 4003212	36.16944 -112.20361	1020
Dry Park Lakes	65	Pond		E 389478 N 4030946	36.41917 -112.23278	2572
Dugway Tank	66	Reservoir		E 387624 N 4037750	36.48028 -112.25444	2484
East Fork Carbon Creek	67	Stream		E 424744 N 4001973	36.16139 -111.83667	1029
East Lake	68	Pond		E 394415 N 4047619	36.57000 -112.18000	2642
East Side Tank	69	Reservoir		E 371859 N 4055507	36.63833 -112.43333	1915
Emmett Spring	72	Spring		E 421875 N 4062980	36.71111 -111.87472	1584
Emmett Wash	73	Stream		E 421834 N 4061316	36.69611 -111.87500	1497
Escalante Creek	74	Stream		E 419291 N 3990466	36.05722 -111.89611	786
Faver Tank	76	Reservoir		E 364858 N 4047847	36.56833 -112.51028	1866
Fawn Spring	77	Spring		E 396718 N 4021859	36.33806 -112.15083	2657
Fence Fault north	318	Spring	GCNP	Zone 12 0424309 S 4042597.0		890
Filarea Tank	78	Reservoir		E 360442 N 4072855	36.79306 -112.56417	1485
Findley Tank	79	Reservoir		E 402907 N 4055531	36.64222 -112.08611	2074
Fisher Spring	80	Spring		E 442584 N 4080288	36.86861 -111.64417	1255
Flint Creek	82	Stream		E 382250 N 4012211	36.24944 -112.31056	936
Four Springs	84	Spring		E 406813 N 4072006	36.79111 -112.04444	1910
Fracas Canyon Tank	85	Reservoir		E 386973 N 4058253	36.66500 -112.26472	2401
Fracas Lake	86	Pond		E 389283 N 4054432	36.63083 -112.23833	2522
Franks Lake	87	Pond		E 394090 N 4041366	36.51361 -112.18278	2641
Franks Reservoir	88	Reservoir		E 397533 N 4087831	36.93278 -112.15056	1949
Fredonia Dam	89	Dam		E 364960 N 4090383	36.95167 -112.51667	1429
Glen Canyon Dam	81	Dam				
Glenn Lakes	90	Pond		E 394729 N 4046875	36.56333 -112.17639	2669

Goose Neck Trick Tank	91	Reservoir		E 364200 N 4047118	36.56167 -112.51750	1868
Government Reservoir	92	Reservoir		E 397001 N 4076557	36.83111 -112.15500	2095
Greenland Lake	93	Pond	GCNP	Zone 12 410926.8 S 4011255.6	36.24306 -111.99111	2570
Greenland Spring	94	Spring		E 410122 N 4011263	36.24389 -112.00028	2471
Gunsight Tank	95	Reservoir		E 356911 N 4061846	36.69333 -112.60167	1593
Hades Lake	96	Pond	GCNP	Zone 12 402742.1 S 4013569.4	36.26194 -112.08111	2573
Hanging Springs	98	Spring		E 424249 N 4036828	36.47556 -111.84556	1019
Hatch Brothers Tank	100	Reservoir		E 371889 N 4087224	36.92417 -112.43833	1457
Hatch Tank	101	Reservoir		E 375845 N 4071691	36.78472 -112.39139	1753
Henrie Tank	102	Reservoir		E 379756 N 4069478	36.76528 -112.34722	1879
Hidden Lake	103	Pond		E 385800 N 4068964	36.76139 -112.27944	2279
Hidden Lake Trick Tank	104	Reservoir		E 385652 N 4067178	36.74528 -112.28083	2327
Holloway Tank	105	Reservoir		E 402360 N 3995692	36.10278 -112.08472	820
Horse Spring	108	Spring		E 359662 N 4057055	36.65056 -112.57000	1471
Horsespring Tank	109	Reservoir		E 360660 N 4055743	36.63889 -112.55861	1719
House Rock Spring No. 1	110	Spring		E 407637 N 4070364	36.77639 -112.03500	1757
House Rock Spring No. 2	111	Spring		E 405804 N 4072757	36.79778 -112.05583	1801
House Rock Trick Tank	112	Reservoir		E 403380 N 4062213	36.70250 -112.08167	1991
Hualapai Spring	113	Spring		E 361344 N 4031875	36.42389 -112.54667	1303
Hundred and Thirtythree Mile Creek	115	Stream		E 369063 N 4025036	36.36333 -112.45944	632
Hundred and Twentyeight Mile Creek	116	Stream		E 366628 N 4019124	36.30972 -112.48556	621
Hundred and Twentyseven Mile Creek	117	Stream		E 365370 N 4016833	36.28889 -112.49917	630
Hundred and Twentytwo Mile Creek	118	Stream		E 364744 N 4011849	36.24389 -112.50528	639
Ikes Spring	119	Spring		E 385913 N 4023133	36.34833 -112.27139	2421
Indian Hollow Spring	120	Spring		E 362050 N 4037073	36.47083 -112.53972	1496
Indian Hollow Trick Tank	121	Reservoir		E 369906 N 4036335	36.46528 -112.45194	2001
Indian Lake	122	Pond		E 398982 N 4027871	36.39250 -112.12639	2659
Jack Tank	123	Reservoir		E 390367 N 4059596	36.67750 -112.22694	2438
Jackson Tank	124	Reservoir		E 391299 N 4054777	36.63417 -112.21583	2515
Jacob Canyon Tank	125	Reservoir		E 382648 N 4065184	36.72694 -112.31417	2033
Jacob Lake	126	Pond		E 390111 N 4062897	36.70722 -112.23028	2400
Jacob Reservoir	127	Reservoir		E 388848 N 4066890	36.74306 -112.24500	2303
Jacobs Pool	128	Pond		E 419255 N 4064176	36.72167 -111.90417	1590
Jensen Tank	129	Reservoir		E 374900 N 4071459	36.78250 -112.40194	1743

Jensen Tanks	130	Reservoir		E 424876 N 4048748	36.58306 -111.83972	1548
Jensen Trick Tank	131	Reservoir		E 360521 N 4051800	36.60333 -112.55944	1727
Joes Mud Hole	132	Pond		E 391641 N 4048423	36.57694 -112.21111	2585
Joes Reservoir	133	Reservoir		E 397056 N 4078991	36.85306 -112.15472	2046
Joes Tank	134	Reservoir		E 429369 N 4075087	36.82083 -111.79194	2005
Johnson Reservoir	135	Reservoir		E 379571 N 4089669	36.94722 -112.35250	1512
Johnson Spring	136	Spring		E 382235 N 4094409	36.99028 -112.32333	1602
Johnson Wash	137	Stream		E 360443 N 4081947	36.87500 -112.56583	1378
Judd Tank	138	Reservoir		E 377548 N 4067691	36.74889 -112.37167	1842
Jumpup Spring	139	Spring		E 361599 N 4049286	36.58083 -112.54694	1548
Jumpup Tank	140	Reservoir		E 360520 N 4051708	36.60250 -112.55944	1724
Jumpup Trick Tank	141	Reservoir		E 360103 N 4049032	36.57833 -112.56361	1744
Kaibab Wash	142	Stream		E 377739 N 4089664	36.94694 -112.37306	1488
Kanab Creek	142.5	Stream		---	36.50000 -112.65000	600
Kanabownits Spring	143	Spring	GCNP	Zone 12 391005.6 S 4016472.7	36.28694 -112.21306	2422
Kane Springs	34	Spring		E 406564 N 4049204	36.58556 -112.04444	1882
Kitchens Tank	144	Reservoir		E 406368 N 4081226	36.87417 -112.05056	1756
Kwagunt Trick Tank	145	Reservoir		E 366645 N 4037987	36.47972 -112.48861	1979
Ladder Reservoir	146	Reservoir		E 409008 N 4084987	36.90833 -112.02139	1791
Lambs Lake	147	Pond		E 388058 N 4061537	36.69472 -112.25306	2363
Lees Ferry Spring	320	Spring	GCNRA	Zone 12 0448584 S		953
Little Park Lake	149	Pond	GCNP	Zone 12 400146.8 S 4020508.9	36.32444 -112.11139	2677
Little Reservoir	150	Reservoir		E 375739 N 4089878	36.94861 -112.39556	1485
Little Sowats Spring	151	Spring		E 369490 N 4043460	36.52944 -112.45778	1752
Little Spring	152	Spring		E 358283 N 4054734	36.62944 -112.58500	1466
Little Spring Tank	153	Reservoir		E 361638 N 4053262	36.61667 -112.54722	1755
Locust Spring	154	Spring		E 384743 N 4028912	36.40028 -112.28528	2453
Lone Tree Reservoir	155	Reservoir		E 406618 N 4085908	36.91639 -112.04833	1668
Lookout Canyon Tank	156	Reservoir		E 385130 N 4039231	36.49333 -112.28250	2376
Lookout Lakes	157	Pond		E 393447 N 4035673	36.46222 -112.18917	2670
Lower Cottonwood Spring	158	Spring		E 363035 N 4042636	36.52111 -112.52972	1404
Lower Jumpup Spring	159	Spring		E 358140 N 4044534	36.53750 -112.58472	1239
Lower Moquitch Tank	160	Reservoir		E 384585 N 4052398	36.61194 -112.29056	2413
Lower Reservoir	161	Reservoir		E 425959 N 4084700	36.90722 -111.83111	1805

Lower Thompson Spring	162	Spring		E 404828 N 4011073	36.24167 -112.05917	2544
Lower Two Spring	163	Spring		E 382775 N 4025271	36.36722 -112.30667	2305
Lowrey Spring	164	Spring		E 439219 N 4077137	36.84000 -111.68167	1472
Lynn Tank	165	Reservoir		E 429641 N 4083991	36.90111 -111.78972	1802
Mackelprang Tank	166	Reservoir		E 407549 N 4032151	36.43194 -112.03139	1903
Malgosa Creek	167	Stream		E 425921 N 4011022	36.24306 -111.82444	836
Manzanita Creek	168	Stream		E 407257 N 4004760	36.18500 -112.03139	1378
Mason Well	169	Well		E 399199 N 4025033	36.36694 -112.12361	2670
Middle Big Spring	321	Spring	GCNP	Zone 12 386939.9 S 4020025.1		2316
Middle Burnt Corral Tank	170	Reservoir		E 377852 N 4038407	36.48500 -112.36361	2250
Middle Reservoir No. 1	171	Reservoir		E 400196 N 4091220	36.96361 -112.12111	1961
Middle Reservoir No. 2	172	Reservoir		E 428330 N 4081228	36.87611 -111.80417	1891
Mile 142 lower	322	Spring	GCNP	---		585
Mile-and-a-half Lake	173	Pond		E 391026 N 4052839	36.61667 -112.21861	2536
Milk Creek	174	Stream		E 395746 N 4007294	36.20667 -112.15972	1470
Milk Creek Spring	323	Spring	GCNP	Zone 12 397263.6 S 4014610.4		2505
Moquitch Spring	175	Spring		E 381487 N 4054784	36.63306 -112.32556	2233
Moquitch Tank No. 1	176	Reservoir		E 391576 N 4047222	36.56611 -112.21167	2559
Moquitch Tank No. 2	177	Reservoir		E 413288 N 4072555	36.79667 -111.97194	2034
Morning Dove Spring	178	Spring		E 379474 N 4052931	36.61611 -112.34778	2209
Mountain Sheep Spring	179	Spring		E 359680 N 4042906	36.52306 -112.56722	1132
Mourning Dove Spring	324	Spring	NKNF	Zone 12 379325.6 S 4053230.9		2182
Mud Lake	180	Pond		E 384396 N 4054990	36.63528 -112.29306	2437
Muggins Reservoir	181	Reservoir		E 382757 N 4089347	36.94472 -112.31667	1544
Murray Tank	182	Reservoir		E 401852 N 4060967	36.69111 -112.09861	1969
Murray Trick Tank	183	Reservoir		E 403642 N 4059036	36.67389 -112.07833	1990
Murrays Lake	184	Pond	NKNF	Zone 12 394897.9 S 4054579.5	36.63139 -112.17556	2598
Nankoweap I mile	325	Spring	GCNP	---		975
Natural Lake	326	Pond	GCNP	Zone 12 404347.7 S 4009750.3		2495
Navajo Tank	186	Reservoir		E 417185 N 4032054	36.43194 -111.92389	1754
Neal Spring	187	Spring	GCNP	Zone 12 409896.2 S 4012903.3	36.25694 -112.00167	2523
Ninetyone Mile Creek	189			E 396813 N 3996156		
No Name Lake	327	Pond	GCNP	Zone 12 397599.0 S 4013417.3		2530
No Name Spring	328	Spring	GCNP	Zone 12 405276.9 S. 4010231.9		2499

North Big Saddle Trick Tank	190	Reservoir		E 377698 N 4036375	36.46667 -112.36500	2320
North Big Spring	329	Spring	GCNP	Zone 12 387446.9 S 4020350.6		2347
North Blow Down Tank	191	Reservoir		E 394871 N 4032019	36.42944 -112.17278	2706
North Canyon Spring	192	Spring		E 402800 N 4028382	36.39750 -112.08389	2499
North Canyon Spring all	330	Spring	NKNF	---		2469
North Canyon Spring lower	331	Spring	NKNF	---		2524
North Canyon Spring middle	332	Spring	NKNF	---		2493
North Canyon Spring upper	333	Spring	NKNF	---		2499
North Canyon Wash	193	Stream		E 431653 N 4053898	36.63000 -111.76444	973
Oak Spring	194	Spring		E 380562 N 4059727	36.67750 -112.33667	2060
Old Arizona Catchment	195	Reservoir		E 391976 N 4092492	36.97417 -112.21361	1710
Onemile Spring	196	Spring		E 405466 N 4073562	36.80500 -112.05972	1767
Oquer Lake	197	Pond		E 390489 N 4039932	36.50028 -112.22278	2597
Oquer Spring	198	Spring		E 388809 N 4042789	36.52583 -112.24194	2536
Outlet Spring	199	Spring		E 401016 N 4009574	36.22778 -112.10139	2466
Paria River	200	Stream		E 446514 N 4079153	36.85861 -111.60000	939
Parissawampitts Spring	201	Spring	NKNF	Zone 12 381940.7 S 4030578.9	36.41333 -112.31639	2369
Pasture Spring	202	Spring	NKNF	Zone 12 383553.1 S 4026594.2	36.37778 -112.29778	2413
Paw Hole	203	Reservoir		E 409448 N 4086770	36.92444 -112.01667	1793
Phantom Creek	204	Stream		E 402176 N 3997173	36.11611 -112.08694	832
Pigeon Spring	205	Spring		E 365204 N 4065072	36.72361 -112.50944	1493
Pigeon Tank	206	Reservoir		E 367604 N 4066267	36.73472 -112.48278	1644
Pine Flat Tank	207	Reservoir		E 373558 N 4044325	36.53778 -112.41250	2083
Pine Hollow Trick Tank	208	Reservoir		E 373910 N 4049651	36.58583 -112.40944	2070
Pinnacle Valley Well	209	Well		E 422184 N 4075119	36.82056 -111.87250	1949
Pipe (Fort) Spring	334	Spring	PSNM	Zone 12 344929.9 S 4081099.6		1518
Pleasant Valley Outlet	211	Stream		E 416350 N 4046022	36.55778 -111.93472	1543
Powell Spring	212	Spring		E 378207 N 4022961	36.34583 -112.35722	1906
Pratt Reservoir	213	Reservoir		E 371390 N 4088648	36.93694 -112.44417	1472

Press Tank	214	Reservoir		E 406701 N 4084489	36.90361 -112.04722	1691
Quaking Aspen Spring	215	Spring	NKNF	E 385035 N 4026504	36.37861 -112.28167	2371
Quaking Aspen Tank	216	Reservoir		E 430648 N 4077111	36.83917 -111.77778	1983
Ranger Pass Trick Tank	217	Reservoir		E 366556 N 4049947	36.58750 -112.49167	1880
Red Point Tank	218	Reservoir		E 409038 N 4059870	36.68194 -112.01806	1598
Ribbon Falls	219	Falls		E 405128 N 4001886	36.15889 -112.05472	1145
Rice Hollow Trick Tank	220	Reservoir		E 370393 N 4038947	36.48889 -112.44694	2041
Riggs Spring	221	Spring		E 381278 N 4046866	36.56167 -112.32667	2258
Road Hollow Tank	222	Reservoir		E 383744 N 4037986	36.48194 -112.29778	2425
Roaring Springs	223	Spring		E 406944 N 4005873	36.19500 -112.03500	1535
Robbers Roost Spring	224	Spring	GCNP	Zone 12 402199.7 S 4015612.7	36.28000 -112.08833	2519
Rock Canyon Reservoir No. 1	225	Reservoir		E 397829 N 4083635	36.89500 -112.14667	1997
Rock Canyon Reservoir No. 2	226	Reservoir		E 359351 N 4071331	36.77917 -112.57611	1495
Rock Canyon Trick Tank	227	Reservoir		E 403957 N 4056105	36.64750 -112.07444	2061
Rock Spring No. 1	228	Spring		E 359448 N 4060665	36.68306 -112.57306	1322
Rock Spring No. 2	229	Spring		E 406443 N 4056386	36.65028 -112.04667	1798
Saddle Canyon	335	Spring	GCNP	---		1000
Saddle Canyon Tank	230	Reservoir		E 416285 N 4023990	36.35917 -111.93306	1890
Sawmill Tank	231	Reservoir		E 377543 N 4046455	36.55750 -112.36833	2267
Seaman Wash	232	Stream		E 385979 N 4093372	36.98139 -112.28111	1561
Seegmiller Trick Tank	233	Reservoir		E 405614 N 4053313	36.62250 -112.05556	2092
Shearing Corral Reservoir	237	Reservoir		E 400077 N 4089465	36.94778 -112.12222	1986
Shearing Shed Reservoir	238	Reservoir		E 399794 N 4088605	36.94000 -112.12528	1975
Shed Valley Tank	239	Reservoir		E 435283 N 4077352	36.84167 -111.72583	2028
Sheep Spring Wash	240	Stream		E 429672 N 4048676	36.58278 -111.78611	903
Slide Elbow Tank	241	Reservoir		E 365255 N 4055731	36.63944 -112.50722	1710
Slide Spring	242	Spring		E 360346 N 4057845	36.65778 -112.56250	1480
Slide Tank	243	Reservoir		E 368809 N 4057495	36.65583 -112.46778	1825
Snipe Lake	244	Pond		E 391851 N 4043367	36.53139 -112.20806	2608
Soap Creek Number One Tank	245	Reservoir		E 432910 N 4081191	36.87611 -111.75278	1953
Soap Creek Number Two Tank	246	Reservoir		E 432461 N 4080825	36.87278 -111.75778	1951
Sourdough Well	247	Well		E 402635 N 4024779	36.36500 -112.08528	2695
South Big Spring	248	Spring	GCNP	Zone 12 386877.6 S 4019978.8	36.31833 -112.26028	2321
South Blow Down Tank	249	Reservoir		E 395887 N 4027416	36.38806 -112.16083	2708

South Canyon Spring	250	Spring		E 407039 N 4021742	36.33806 -112.03583	2569
South Fork Soap Creek	251	Stream		E 435542 N 4065701	36.73667 -111.72194	1031
South Rock Tank	252	Reservoir		E 401895 N 4053847	36.62694 -112.09722	2122
South Side Tank	253	Reservoir		E 369643 N 4053537	36.62028 -112.45778	1904
Sowats Spring	254	Spring	NKNF	E 369786 N 4043240	36.52750 -112.45444	1829
Sowats Spring A	336	Spring	NKNF	---		1829
Sowats Spring B	337	Spring	NKNF	---		1835
Sowats Trick Tank	255	Reservoir		E 366353 N 4040056	36.49833 -112.49222	1974
Spare Tank	256	Reservoir		E 410043 N 4018043	36.30500 -112.00194	2660
Spooks Knoll Reservoir	258	Reservoir		E 365334 N 4074933	36.81250 -112.50972	1558
Squaw Spring	259	Spring		E 384761 N 4028326	36.39500 -112.28500	2459
Suttle Tank	260	Reservoir		E 377144 N 4068899	36.75972 -112.37639	1822
Swamp Lake	261	Pond	GCNP	Zone 12 381962.3 S 4021737.6	36.33306 -112.31472	2359
Swapp Tank	262	Reservoir		E 361076 N 4067634	36.74611 -112.55611	1589
Table Rock Spring	263	Spring		E 369301 N 4063652	36.71139 -112.46333	1607
Table Rock Tank	264	Reservoir		E 372803 N 4060486	36.68333 -112.42361	1851
Tank Meadow pond	339	Pond	GCNP	Zone 12 389847.2 S 4022469.4		2457
Tank Number Eight	265	Reservoir		E 415222 N 4037496	36.48083 -111.94639	1683
Tank Number Five	266	Reservoir		E 415182 N 4033460	36.44444 -111.94639	1710
Tank Number Four	267	Reservoir		E 415842 N 4032160	36.43278 -111.93889	1736
Tank Number Seven	268	Reservoir		E 421773 N 4035463	36.46306 -111.87306	1698
Tank Number Six	269	Reservoir		E 419010 N 4032807	36.43889 -111.90361	1735
Tank Number Three	270	Reservoir		E 413537 N 4028331	36.39806 -111.96417	1829
Tapeats Creek	272	Stream		E 368252 N 4025850	36.37056 -112.46861	605
Tapeats Spring	274	Spring		E 371826 N 4029803	36.40667 -112.42944	1143
Tater Canyon Springs	275	Spring		E 404116 N 4039215	36.49528 -112.07056	2363
Three Lakes	276	Pond		E 390932 N 4055243	36.63833 -112.22000	2524
Thunder River	277	Stream		E 369907 N 4028197	36.39194 -112.45056	745
Thunder Spring	278	Spring		E 369267 N 4028670	36.39611 -112.45778	1062
Tilton Springs	279	Spring		E 380360 N 4057665	36.65889 -112.33861	2150
Timp Spring	280	Spring	NKNF	Zone 12 383758.3 S 4027742.7	36.38750 -112.29472	2414
Tipover Spring	281	Spring	GCNP	Zone 12 389954.5 S 4022812.7	36.34611 -112.22222	2499
Trap Tank	282	Reservoir		E 392483 N 3995808	36.10278 -112.19444	1017
Trinity Creek	283	Stream		E 396263 N 3996132	36.10611 -112.15250	730

Tunnel Spring	340	Spring	PSNM	Zone 12 344929.9 S 4081099.6		1518
Two Mile Reservoir	286	Reservoir		E 405559 N 4075256	36.82028 -112.05889	1805
Unnamed Spring No. 2	338	Spring	GCNP	Zone 12 401693.5 S 4012326.9		2505
Upper Cottonwood Spring	287	Spring		E 363579 N 4042473	36.51972 -112.52361	1467
Upper Thompson Spring	288	Spring	GCNP	Zone 12 405275.7 S 4013133.9	36.25917 -112.05500	2548
Upper Two Spring	289	Spring	NKNF	E 383545 N 4025014	36.36500 -112.29806	2371
V T Lake	290	Pond		E 398954 N 4033943	36.44722 -112.12750	2690
V T Ridge Number One Tank	291	Reservoir		E 396461 N 4031599	36.42583 -112.15500	2797
V T Ridge Number Two Tank	292	Reservoir		E 396503 N 4028887	36.40139 -112.15417	2778
Vaseys Paradise	341	Spring	GCNP	---		884
Vaughn Spring	293	Spring		E 365134 N 4032062	36.42611 -112.50444	1130
Wall Creek	294	Stream		E 406083 N 4002492	36.16444 -112.04417	1196
Wall Lake	295	Pond		E 398517 N 4024333	36.36056 -112.13111	2768
Warm Springs	297	Spring	NKNF	Zone 12 382755.7 S 4061815.9	36.69500 -112.31250	2131
Warm Springs Lake	298	Pond		E 385520 N 4061047	36.69000 -112.28139	2355
Watts Spring	299	Spring	NKNF	E 385636 N 4026651	36.38000 -112.27500	2468
West Cabin Spring	342	Spring	PSNM	Zone 12 344877.3 S 4081113.0		1518
West Fork Carbon Creek	300	Stream		E 424744 N 4001973	36.16139 -111.83667	1029
West Lake	301	Pond		E 376570 N 4042771	36.52417 -112.37861	2292
West Lake (east)	301.1	Pond	NKNF	Zone 12 376515.9 S 4043013.6		2304
West Lake (west)	301.2	Pond	NKNF	Zone 12 376515.9 S 4043013.6		2304
White Creek	302	Stream		E 380937 N 4012969	36.25611 -112.32528	845
White Pockets Tank	303	Reservoir		E 368307 N 4052294	36.60889 -112.47250	1854
White Sage Wash	304	Stream		E 377967 N 4090000	36.95000 -112.37056	1489
White Spring	305	Spring		E 363347 N 4045097	36.54333 -112.52667	1378
Whiting Tank	306	Reservoir		E 370514 N 4081480	36.87222 -112.45278	1524
Wildband Spring	307	Spring		E 365192 N 4064302	36.71667 -112.50944	1542
Willow Spring	309	Spring		E 363492 N 4063557	36.70972 -112.52833	1482
Winter Road Catchment	310	Reservoir		E 396171 N 4087662	36.93111 -112.16583	1946

APPENDIX 3.1: AERIAL PHOTOGRAPHS OF GCT WATER RESOURCE, 3 AUGUST 2005

(Electronic Version Only)

APPENDIX 4.1: RESULTS OF 10 WATER RESOURCE SITE VISITS IN JULY 2005 (Electronic data only)

Subappendices in Appendix 4.1 include:

Appendix 4.1 A – Site ownership and date of site visit.
Appendix 4.1 B-Georeferencing
Appendix 4.1 C-Geology and geomorphology
Appendix 4.1 D-Solar pathfinder data
Appendix 4.1 EF-Q methods
Appendix 4.1 F-Flow and field water quality measurements
Appendix 4.1 G-Paria R flow data from the USGS gauging station near the mouth, 1923-2004
Appendix 4.1 H: Microsite and soil characteristics of 10 GCT eastern Arizona Strip water resource sites
Appendix 4.1 I-List of plant species detected at water resource sites across the AZ Strip
Appendix 4.1 J: Vegetation percent cover and species richness at 10 GCT water resource sites on the eastern Arizona Strip
Appendix 4.1 K: Invertebrates identified to at least the family level from the eastern Arizona Strip in the Museum of Northern Arizona and other regional collections
Appendix 4.1 L: Herpetofauna observed at 10 GCT Arizona Strip water resource sites, July 2005
Appendix 4.1 M : Avifauna observed at 10 GCT Arizona Strip water resource sites, July 2005
Appendix 4.1 N: Mammals observed or detected at 10 GCT Arizona Strip water resource sites, July 2005
Appendix 4.1 O: Human uses of 10 GCT Arizona Strip water resource sites
Appendix 4.1 P: Human impacts on 10 GCT Arizona Strip water resource sites, July 2005

APPENDIX 4.2: SITE PHOTOS OF 10 GCT WATER RESOURCE STUDY SITES IN JULY 2005
(Electronic Version Only)

APPENDIX 4.3: SITE SKETCHMAPS OF 10 GCT WATER RESOURCE STUDY SITES, JULY 2005
(Electronic Version Only)

APPENDIX 5.1:
SEAP CHECKLIST FOR GCT SPRINGS ASSESSMENTS

SEAP Categories	SEAP Variable (Data Source)	Rationale for Variable	Caveats	References	Variable Score	Comments
Overall Ecosystem Qualifier	Dewatering (X, F)	Dewatering of the aquifer, pre-orifice, orifice, or post-orifice environments often strongly alters springs geomorphology, microhabitats, and community composition and structure.	Understanding the natural hydrograph is essential for interpreting flow data; however, historical hydrography data are often unavail-able for springs. Flow from springs with small discharges, as well as those with multiple sources, such as hanging gardens, may not be readily measured, and therefore wetted area (i.e., areas of wet rock, pools, and streams) should be considered as being important monitoring variables.	Richards 1987; Stromberg 1993,;Rosgen 1996; Stanford et al. 1996; Jowett 1997; Poff et al. 1997; Kreamer and Springer, this volume; Unmack and Minckley, this volume; Stevens and Meretsky, this volume		
Aquifer, Flow and Water Quality (AFWQ) 1	Aquifer functionality (X, F)	Delivery of water by the aquifer is the primary affector of springs presence and ecosystem health.	Determination of the aquifer status often requires detailed groundwater data, modeling and analyses.	Stevens and Springer (this volume)		

AFWQ 2	Flow (F, X)	Flow affects aquatic and terrestrial: springs geomorphology; potential productivity; habitat area; and ecosystem integrity and function. Many measurements of hydrology and fluvial geomorphology have been devised, but wetted area (wet rock or soil, pools, streams) are particularly useful for small springs.	Hydrographic data must be rigorously compiled; historical gauge data and site photographs are useful; flow may naturally vary considerably inter-seasonally and interannually	Hupp 1988; Stromberg and Patten 1992; Stanford et al. 1996; Poff et al. 1997; Richter et al. 1996, 2003		
AFWQ 3	Water quality (F, L, X)	WQ includes temperature, pH, specific conductance, nutrient concentration, and other impacts affect aquatic biota and productivity.	Desert streams, particularly those flowing through shale bedrocks and those with calcium-enriched groundwaters, may naturally have low WQ, as defined by the U.S. E.P.A.	http://www.epa.gov/waterscience/standards/		
AFWQ 4	Turbidity (F)	Increased turbidity reduces aquatic productivity, and may result from ground- or surface water pollution or poor land use practices	Some naturally occurring springs, particularly calcium-rich waters, have high dissolved loads and naturally low water clarity	Kirk 1983		
AFWQ Summary	Category Score					

Geomorphology (GEO) Qualifier	Site Obliteration (X, F)	Springs orifice and post-orifice environments are sometimes entirely eliminated by human activities, including excavation and piping of the source, constructing a springhouse on the orifice, or bulldozing the entire ecosystem. Such activities may eliminate all traces of natural hydrogeoomorpho-logical function, as well as most or all ecosystem characteristics.	Site history may not be known or interpretable, and site loss through geomorphic alteration may be secondary to groundwater dewatering or other impacts.	Stevens and Springer, this volume		
GEO 1	Surface geomorphology (X, F)	The geomorphology of springs forms the physical template on which the springs ecosystem develops. Disruption of the site through human impacts to water quality, surface landforms, or channel alteration may affect ecosystem characteristics and functionality	Historical photo or other analyses are needed to define the pristine condition	Stevens and Springer (this volume)		

GEO 2	Runout stream channel geometry (X, F)	Channel configuration is affected by gradient, discharge, sediment transport, flow regulation, vegetation colonization, and direct human manipulations. Anomalously straight alluvial channels may indicate reduced flow or other anthropogenic modifications.	Sinuosity may be limited in constrained reaches or in wet meadows.	Leopold 1994, Rosgen 1996		
GEO 3	Soil integrity (F)	Springs soils reflect site integrity, flow dynamics, vegetation development, management practices, and affect wildlife habitat distribution and quality.	Springs soils vary substantially across the microhabitat array, from none on steep bedrock surfaces, to poorly developed entisols along surfaceflow- dominated streams, to well developed mollisols around undisturbed springs orifices.	Brock 1985; Day et al. 1988, Stevens et al. 1995, Grand Canyon Wildlands Council 2004; Stevens and Springer. this volume		

GEO 4	Microhabitat diversity (F)	Springs microhabitat diversity and patch size (see BG2 below) affect diversity, as well as fish and wildlife population health. Microhabitat functionality assessment indicates the condition of each microhabitat type at a springs.	Geomorphically constrained springs ecosystems, including rheocrene springs that are regularly flooded by surface flows, may not support a high diversity of aquatic habitats.	Stacey 1995; Stevens 1997; Stevens and Springer, this volume		
GEO 5	Natural disturbance regimes (X, F)	Alteration of physical disturbance regimes (i.e., flooding, rockfall) by flow regulation or geomorphic alteration, strongly affects ecosystem structure and microhabitat function. The timing, duration, frequency, magnitude, and (for discharge) ramping rate of flooding and rockfalls are important structuring elements of springs and adjacent habitats.	Prehistoric and historic human impacts may be difficult to detect and interpret.	Sousa 1984; Haynes this volume; Stevens and Springer, this volume		
GEO Summary	Category Score					

Ecosystem and Trophic Dynamics (ETD) 1	Microhabitat functionality (F)	Microhabitats functional ecology includes providing habitat, food resources, and feedback to the ecosystem through production and decomposition. Loss of functionality often results in the decline or disappearance of species and feedback processes.	Microhabitat functionality may require in-depth research, and impacts on ecosystem function may not be apparent	Stevens and Springer, this volume		
ETD 2	Native population dynamics (X, F)	The natural population dynamics of aquatic, wetland, riparian, and upland plants, invertebrates, and vertebrates constitute the basis of the trophic structure and functionality of springs ecosystems.	Determination of the natural range of population variation, including natural rates of colonization and extirpation, is challenging and is likely to vary considerably among even closely spaced springs.	Odum 1957; Karr 1991; Kennedy et al. 2000; Walters et al. 2000; Stevens and Springer, this volume		
ETD 3	Non-native species rarity (F)	The diversity of non-native species is an indicator of springs disturbance and ecosystem health.	Non-native species diversity may be positively related to native species diversity.	USDA 1985, 1992; Noble 1989, Lonsdale 1999, Stohlgren et al. 1999, Karr 1991; Kennedy et al. 2000, Stevens and Ayers 2002		

ETD 4	Native species ecological roles (X, F)	The extent to which native (as opposed to non-native) species are involved in trophic interactions affects natural ecosystem functionality.	The ecological roles of native species may be obscured or eliminated at highly manipulated springs	Stevens and Ayers 2002		
ETD 5	Ecological efficiency (F, X)	Energy transfer among trophic levels, including primary producers and consumers, secondary and tertiary consumers, and decomposers, is essential for ecosystem sustainability and functionality.	Trophic structure may depend on allochthonous input. Inversion of trophic structure may occur in aquatic herbivore-dominated springs microhabitats.	Odum 1957; Stevens and Springer, this volume		
ETD Summary	Category Score					
Freedom from Human Impacts (FHI) 1	Aquifer integrity (F, X)	Human impacts on aquifer integrity include the long-term threats of dewatering and pollution, often permanently impairing springs discharge and ecosystem health.	Determination of the aquifer threats requires complex groundwater data, modeling and analyses.	Stevens and Springer (this volume)		

FHI 2	Flow regulation (F, X)	Pre-or post-orifice flow regulation may reduce or eliminate aquatic, wetland, and riparian microhabitats, and may disrupt ecological linkages among springs microhabitats and adjacent uplands	Research is needed to determine threshold responses of springs microhabitats to reduced flow and altered flow timing.	Johnson et al. 1985; Naiman et al. 1995; Stanford et al. 1996; Stevens and Springer, this volume		
FHI 3	Mammalian herbivory (X, F).	Livestock and managed mammalian herbivores can reduce water quality; trampling reduces geomorphic stability and soil quality; grazing reduces vegetation complexity, diversity, cover and resilience; and the presence of livestock may negatively influence invertebrate and native wildlife distribution. Livestock are often concentrated at springs, greatly exacerbating impacts of grazing and trampling.	Springs on private lands are often managed specifically to provide water for livestock, regardless of the resulting ecosystem damage.	Fleischner 1994, Belsky et al. 1999, Jones 2000, Holechek 2001, Stevens et al. in press.		

FHI 4	Condition of adjacent uplands (X,F)	Upland conditions may strongly affect springs geomorphology and ecosystem health, particularly vegetative cover and growth. Loss of upland vegetation may increase erosion, sediment loading in runout streams, and the impacts of flooding.	Uplands in which the parent materials are shale or silfstone are likely to have high erosion rates, high sediment loading, strong flood impacts, and naturally support little aquatic, wetland, and riparian vegetation.	Ellison 1960, Graf et al. 1999		
FHI 5	Construction impacts (X, F)	Many kinds of human construction and development activities affect springs ecosystem integrity, including construction of water tanks, springs houses or other buildings, campgrounds, parking lots, agriculture and mining (including wastes, fertilizer and pesticide impacts), and urbanization.	Springs ecosystem integrity is often sacrificed for development objectives	Holling 1978, National Research Council 1986, Gunderson et al. 1995, Naiman et al. 1995, Stanford et al. 1996, Poff et al. 1997, Stevens et al. in press.		
FHI 6	Fencing (F, X)	Fencing may limit wildlife movement, or concentrate wildllife and livestock use of springs. Exclosures may allow springs ecosystems to recover from poor land management practices.	Excluding mammalian herbivores from springs may result in overgrowth of vegetation and desiccation of surface water.	Grand Canyon Wildlands Council 2002		

FHI 7	Road and trail impacts (X, F)	Roads and trails may severely affect springs ecosystem integrity through impacts on slopes, channels, hydrologic processes, wetland and riparian vegetation, and nutrient transport. The relative areal extent of road and trail construction impacts on the springs may be large, particularly at small springs. The proximity of roads or trails to a springs may also be an important impact.	Construction of a trail may help protect the spring by reducing trampling and other impacts of recreational visitors.	Froehlich 1978; Burroughs and King 1989; Forman and Alexander 1998; Forman 2000; Stevens and Ayers 2002; Stevens and Springer, this volume		
FHI Summary	Category Score					
Biogeography (BG) 1	Springs type (F)	The type of springs determines much about its potential diversity, species composition, and ecosystem functionality.	Springs classification is just beginning to be applied, and determination of biodiversity and ecosystem structure of different springs types has yet to be accomplished.	Springer et al., this volume		
BG 2	Geographic isolation (X, F)	The proximity of a springs to other springs should be positively related to its diversity through higher colonization potential and lower extirpation rates.	A spatial isolation analysis requires a comprehensive regional inventory of springs.	MacArthur and Wilson 1965; Stevens and Springer, this volume		

BG 3	Habitat patch size (F)	Microhabitat and overall springs ecosystem patch size are positively related to biodiversity and ecological linkage complexity.	A habitat patch size analysis requires mapping of individual springs.	MacArthur and Wilson 1965; Picket and White 1985; Stevens and Springer, this volume		
BG 4	Microhabitat quality (F)	The quality and integrity of natural springs micro-habitats is essential for attracting and sustaining local and migratory aquatic, riparian, and facultative upland plant, invertebrate, and vertebrate species.	Natural habitat types and distribution may not be highly altered and not readily discernable	Whitmore 1975; Stacey 1995; Skagen et al. 1998; Grand Canyon Wildlands Council 2002; Minckley and Unmack 2003; Stevens and Springer, this volume		
BG 5	Ecosystem longevity (X, F)	Ecosystem persistence through time is an important determinant of levels of endemism (more in paleorefugia) and community structure (weedy species dominate neorefugia). The number of endemic species present at a springs is one indication of a springs longevity.	Determination of the longevity of a springs ecosystem may require detailed geomorphic or paleontological analyses. Small springs are less likely to support endemic species.	Nekola 1999; Haynes, this volume; Springer et al., this volume		

BG 6	Movement corridors, including migration (X)	The integrity of movement corridors is essential for migration and colonization dynamics among springs ecosystems.	Determination of the regional significance of springs as "stepping stones" in wildlife movement or ranges, or as migratory stopover habitat, requires regional-scale research.	Stevens et al. 1977, Skagen et al. 1998		
BG Summary	Category Score					
Administrative Context (AC) 1	Conformance to management plan (F, X)	A management plan has often been implemented for springs, specifying desired ecosystem condition, land uses, resources of concern, and monitoring protocols.	Management planning may not have been conducted, may not be well informed, or management may not be in compliance with stated plans.	Stevens et al. in press		
AC 2	Scientific significance (F, X)	Springs often contain paleontological, biological, or cultural resources or processes that merit protection and research over other uses.	Determination of the scientific value of springs requires inventory and assessment.	Haynes, this volume; Nabhan, this volume; Rea, this volume; Stevens and Meretsky, this volume		

AC 3	Cultural significance (F, X)	Springs often contain archeological sites, are often regarded as sacred sites, and are often traditional cultural properties at which ethnominerological or ethnobiological resources were or are harvested.	Springs cultural values may not be recognized without additional research, and cultural value may exceed economic values	Nabhan, this volume; Rea, this volume		
AC 4	Historical significance (F, X)	Springs often contain historical sites or values as stopover points along exploration routes.	Historical designation may not have been achieved.	Grand Canyon Wildlands Council 2002; Stevens and Meretsky, this volume		
AC 5	Recreational significance (F, X)	Springs may serve as recreational points of interest, or provide recreationists with essential resources (i.e., water, shade)	Monitoring is required to understand recreational values of most springs	Grand Canyon Wildlands Council 2004; Stevens and Meretsky, this volume		
AC 6	Fish and Wildlife Significance (F, X)	Springs may provide important habitat for fish and wildlife, and may provide food and shelter resources for migrating or wide-ranging species.	Fish and wildlife use of springs habitats requires monitoring and population studies, especially for migratory and wide-ranging species.	Stevens and Springer, this volume		
AC 7	Sensitive species population integrity (X, F)	The integrity of listed and sensitive species population dynamics is typically an important consideration in land management.	Trade-offs may exist among the management of multiple sensitive species and their habitats.	Stevens et al. 2002, Unmack and Minckley 2003		

AC 8	Economic values (F, X)	Springs may provide geophysical, property, water, water quality, biological, habitat, or culturally significant economic resources, the extraction of which should be balanced against other values and management needs.	Economic values are usually given priority over other resources, and resulting impacts may obscure or eliminate evidence of other resources and processes.	Grand Canyon Wildlands Council 2004; Stevens and Meretsky, this volume		
AC Summary	Category Score					
Trend Assessment	Change through time (requires multiple site visits; F, X)	Disturbance-prone and highly manipulated springs ecosystems are often characterized by high levels of variability, and monitoring is needed to establish the range of system conditions. Trend assessment monitoring requires repeated visits using the same protocols. Trends in the above categories can be established and provide information on variability and triggers to management actions.	Funding availability, changing administrative interests, changing staff and protocols, lack of data management, and other contingencies all work against trends monitoring, and require careful planning.	Holling 1978, National Research Council 1986, Gunderson et al. 1995, Busch and Troxler 2002		

APPENDIX 5.2:
SEAP SCORING CRITERIA FOR GCT SPRINGS ASSESSMENTS

SEAP Categories	SEAP Variable (Data Source)	Microhabitat and Springs-wide Scoring Criteria				
		1	2	3	4	5
Overall Ecosystem Qualifier	Dewatering (X, F)	If springs dewatered by aquifer depletion or pre-orifice diversion, AFWQ and GEO scores = 1				
Aquifer, Flow and Water Quality (AFWQ) 1	Aquifer functionality (X, F)	Aquifer depleted, springs dewatered	Aquifer major decline, reduced springs flows	Aquifer is declining, but supports springs	Aquifer tapped, but no response to groundwater extraction	Aquifer apparently pristine and functioning naturally
AFWQ 2	Flow (F, X)	Springs dewatered	Springs flow strongly reduced	Flow slightly, but distinctively reduced	Flow only slightly reduced	Flow is natural
AFWQ 3	Water quality (F, L, X)	WQ within <1% of natural condition	WQ within 1-33% of natural condition	WQ 33-66% of natural condition	WQ 67-95% of natural condition	WQ >95% of natural condition
AFWQ 4	Turbidity (F)	WQ within <1% of natural condition	WQ within 1-33% of natural condition	WQ 33-66% of natural condition	WQ 67-95% of natural condition	WQ >95% of natural condition
Geomorphology (GEO) Qualifier	Site Obliteration (X, F)	If springs obliterated by human activities, GEO and ETD scores = 1				
GEO 1	Surface geomorphology (X, F)	Site obliterated	Site geomorphology marginally functional	Site geomorphology functioning but strongly altered	Site geomorphology slightly altered	Site geomorphology naturally f
GEO 2	Runout stream channel geometry (X, F)	Channel obliterated, trenched, or otherwise manipulated	Channel geometry strongly altered, but with slight sinuosity and fluvial landforms	Channel highly altered but with some functionality	Channel slightly altered, mostly functional	Channel functioning naturally

GEO 3	Soil integrity (F)	Natural soils eliminated	Soils thin or eliminated on most of site but slight amount remaining	Soils patchy and compromised, with degrading function	Soils large intact, and only slightly compromised	Soils natural
GEO 4	Microhabitat diversity (F)	<10% original natural microhabitat types remain	10-33% of natural microhabitat types remain	33-66% of natural microhabitat types remain	67-90% of natural microhabitat types remain	Array of microhabitat types natural
GEO 5	Natural disturbance regimes (X, F)	Natural disturbance regime (DR) eliminated	1-33% of DR remaining	33-66% of DR remaining	<67-95% of DR remaining	DR essentially natural
Ecosystem and Trophic Dynamics (ETD) 1	Microhabitat functionality (F)	<10% original natural microhabitat functioning	10-33% of natural microhabitats present and functioning	33-66% of natural microhabitats present and functioning	67-95% of natural microhabitats present and functioning	>95% of microhabitats functioning naturally
ETD 2	Native population dynamics (X, F)	No natural plant or faunal populations remain	10-30 % of natural populations present and self-sustaining	30-60 % of natural populations present and self-sustaining	60-95 % of natural populations present and self-sustaining	Natural populations present and self-sustaining
ETD 3	Non-native species rarity (F)	<10% of the assemblage is native	10-33% of assemblage is native	33-66% of assemblage is non-native	67-95% of assemblage is native	Non-native species rare and ecologically inconsequential
ETD 4	Native species ecological roles (X, F)	Native species dominance in abundance and biomass <10% in each trophic level	Native species dominance in abundance and biomass10-33% in each trophic level	Native species dominance in abundance and biomass 33-66% in each trophic level	Native species dominance in abundance and biomass 66-95% in each trophic level	Native species dominance in abundance and biomass >90% in each trophic level
ETD 5	Ecological efficiency (F, X)	Ecological efficiency (EE) interrupted	EE 1-33% of natural condition	EE 33-66% of natural condition	EE 67-95% of natural condition	EE >95% of natural condition

Freedom from Human Impacts (FHI) 1	Aquifer threats (F, X)	Aquifer depleted, springs dewatered	Aquifer strongly threatened by immanent depletion of water table; reduced springs flows	Significant threats to aquifer, but results uncertain	Aquifer slightly threatened, but no immediate response anticipated	Aquifer functioning and protected or not foreseeably threatened
FHI 2	Flow regulation (F, X)	Flow regulation has dewatered the springs	Flow regulation impacts have reduced flow to 1-33% of natural condition	Flow regulation impacts have reduced flow to 33-66% of natural condition	Flow regulation impacts have reduced flow to 67-95% of natural condition	Flow regulation impacts have reduced flow to >95% of natural condition
FHI 3	Mammalian herbivory (X, F).	Vegetation devastated by mammalian herbivores	Mammalian herbivores impacts threaten springs integrity, with 1-33% of springs showing evidence of trampling, vegetation damage, or feces.	Mammalian herbivores impacts threaten springs integrity, with 33-66% of springs showing evidence of trampling, vegetation damage, or feces.	Mammalian herbivores impacts threaten springs integrity, with 67-95% of springs showing evidence of trampling, vegetation damage, or feces.	No mammalian herbivore impacts apparent
FHI 4	Functionality of adjacent uplands (X,F)	Adjacent uplands devastated	Adjacent uplands with 1-33% natural functionality	Adjacent uplands with 33%-66% natural functionality	Adjacent uplands with 66-95% natural functionality	Adjacent uplands with >95% natural functionality

FHI 5	Construction impacts (X, F)	Orifice and post-orifice environments completely obliterated by channelization, construction materials, piping, tanks, outbuildings, parking lots, or other signs of human activities	Construction impacts leave 1-33% of site intact and functioning	Construction impacts leave 33-66 % of site intact and functioning	Construction impacts leave 67-95% of site intact and functioning	Springs in virtually pristine condition
FHI 6	Fencing (F, X)	Wildlife entirely blocked by fencing	Fencing allows possible but minimal access by wildlife	Site largely but not completely fenced, with few gaps for wildlife access	Site mostly unfenced, with large gaps that allow wildlife access	Site not fenced
FHI 7	Road and trail impacts (X, F)	Large, well-traveled road to, or immediately adjacent to, orifice and runout stream; road virtually precludes springs ecological function	Large or well-traveled road to, or immediately adjacent to, orifice and runout stream; conspicuous impact on springs ecological function	Moderate-sized, moderately heavily-traveled road to, or immediately adjacent to, orifice and runout stream; moderate impact on springs ecological function	Small (unpaved), lightly used road to or near orifice and runout stream, and that road does not adversely affect springs ecological function	No road to or near orifice or springs runout channel
Biogeography (BG) 1	Springs type (F)	Determined from Springer et al. classification system	Determined from Springer et al. classification system	Determined from Springer et al. classification system	Determined from Springer et al. classification system	Determined from Springer et al. classification system
BG 2	Geographic isolation (X, F)	Springs vegetation patches overlap among springs	<100 m between springs	100 m - 1 km between springs	1-10 km between springs	>10 km between springs

BG 3	Habitat patch size (F)	Small (< 10 m^2)	Medium-small (10-1000 m^2)	Medium (10^3-10^4 m^2)	Medium-large (10^4-10^6 m^2)	Large (>10^6 m^2)
BG 4	Microhabitat quality (F)	No microhabitats exist or remain	One microhabitat (none of which is aquatic or wetland) with nearly natural ecosystem function; or all microhabitats scarcely functioning	2-4 microhabitats (of which at least one is aquatic or wetland) have nearly natural ecosystem function; or all microhabitats poorly functioning	>4 microhabitats (of which at least two are aquatic or wetland) with nearly natural ecosystem function; or all microhabitats functioning well	>5 microhabitats (of which at least three are aquatic or wetland) with nearly natural ecosystem function; or all microhabitats functioning in a natural fashion
BG 5	Ecosystem longevity (X, F)	Neorefugium, no springs endemic species present; springs with clear evidence of ephemeral flow	Neorefugium, no springs endemic species present, but one rare species present; evidence the spring has been ephemeral	Quasi-paleorefugium, one springs endemic species present, and several regionally rare species present; springs with some evidence of perenniality	Paleorefugium, several springs endemic species present, and several regionally rare species present; spring appears to be perennial	Paleorefugium, with many endemic springs species present, many regionally rare species; landforms, dendrochronology, and hydrology indicate long-term perennial flow
BG 6	Movement corridors, including migration (X)	Springs plays no role in terrestrial or migratory corridor or as stopover habitat	Springs plays little role as a terrestrial or migratory corridor, or as stopover habitat	Springs plays minor role as a terrestrial and/or migratory corridor, and has a little value as stopover habitat	Springs plays obvious role as a terrestrial and/or migratory corridor, and has modest value as stopover habitat	Springs plays obvious, strong role as a terrestrial and migratory corridor, and has substantial, verified value as stopover habitat

Administrative Context (AC) 1	Conformance to management plan (F, X)	No conceptual, verbal or written management plan; the springs is not managed or considered in land use planning; no inventory or classification information available	No conceptual, verbal or written management plan exists and the springs not managed according to the plan, but some inventory information exists (e.g., georeferencing, qualitative water chemistry) with some data archival	A conceptual, verbal or written management plan exists, but the springs has received only a little management attention; inventory data exist but not classification or assessment; some data archival	A conceptual, verbal and written management plan exists, and the springs has received moderate management attention; inventory and classification completed, but not assessed; data collected and mostly archived	A conceptual, verbal and written management plan exists, and the springs has received substantial management consideration; inventory, classification, and assessment have been completed, and the data archived
AC 2	Scientific significance - natural history (F, X)	No evidence of unique features of flow, water chemistry, geomorphology, paleontology, habitat, or species presence	At least one unique feature related to flow, water chemistry, geomorphology, paleontology, cultural significance, habitat, or species presence	At least 2-5 unique feature related to flow, water chemistry, geomorphology, paleontology, cultural significance, habitat, or species presence	At least 6-10 unique feature related to flow, water chemistry, geomorphology, paleontology, cultural significance, habitat, or species presence	Numerous (>10) unique feature related to flow, water chemistry, geomorphology, paleontology, cultural significance, habitat, or species presence

AC 3	Indigenous cultural significance (F, X)	No indigenous cultural significance: no archeology, traditional cultural properties, or ethnobiological features or resources present	A single indigenous culturally significant feature or resource present	2-5 indigenous culturally significant features or resources present	6-10 indigenous culturally significant features or resources present	Numerous indigenous culturally significant features or resources present, registry as a National Historic Landmark underway or completed
AC 4	Historical significance (F, X)	No documentation of historical significance: no historic features, use of site as part of a trail system, etc.	A single historically significant event or feature exists at the springs	2-3 historically significant events or feature exists at the springs	4-6 historically significant events or feature exists at the springs; National Historic Landmark listing planned	Numerous historically significant features or resources present, registry as a National Historic Landmark underway or completed
AC 5	Recreational significance (F, X)	No recreational significance of the springs for sight-seeing, hiking, hunting, fishing, water source, etc.	Site is rarely visited, and then primarily for a single recreational purpose	Springs receives occasional visitation for several recreational reasons	Site is commonly visited for several recreational reasons	Springs heavily visited for numerous recreational reasons

AC 6	Fish and Wildlife Significance (F, X)	No listed or sensitive species, no critical habitat designation	A single sensitive species has been detected, but no listed species and no critical habitat designation	Several sensitive species have been detected at the springs, and if a listed species has been detected, it does not rely on the site for habitat; no critical habitat designation	Several sensitive and listed species have been detected at the springs, and listed species occur regularly; while not designated as critical habitat, the habitat is recognized as needed to support one or several listed species	Springs provides critical habitat for several to many listed and numerous other sensitive species
AC 7	Sensitive species population integrity (X, F)	No sensitive species remain	All sensitive species population integrity are failing	One or morel sensitive species population integrity declining somewhat	Sensitive and listed species' population health stable but not expanding	Sensitive and listed species' population growing and the springs serves as a population source area
AC 8	Economic value (F, X)	The springs has no economic value	The springs has limited economic value, primarily as a remote, undeveloped water source	The springs has modest economic value, and has been partially developed as a water source (e.g., for livestock, mining, culinary, or hydroelectric power generation)	The springs has considerable economic value, and has been largely developed, but primarily for a single economic purpose	The springs has high economic value, and has been completely developed, perhaps for multiple economic purposes
AC 9	Legal Status (X)	No land or water rights exist for the springs	Land or water rights have been applied for, but remain unresolved	Land or water rights have been obtained for the springs	Land and water rights have been obtained for the springs	Land and water rights are fully adjudicated

Trend Assessment	Change through time (requires multiple site visits; F, X)	No information exists regarding the springs history of flow, water quality, landform and habitat change, species presence, or sociocultural significance; no trend analyses on these resources and processes is possible	A small amount of usually low quality information exists, but the information is highly fragmentary and has not been compiled; no trend analysis is of low quality	A modest amount of high quality information exists, but it has not been compiled; trend analysis may be possible	Much information exists and has been compiled; trend analysis is planned	A thorough history of flow, water quality, landform and habitat change, species presence, and socio-cultural significance has been published; trend analyses have been completed

APPENDIX 5.3: RSRA CHECKLIST (MODIFIED FROM STEVENS ET AL. 2005)

RAPID RIPARIAN ASSESSMENT FIELD CHECKLIST

Stream _____________ Watershed___________ Reach _____________

Survey Date _________ Time _______________ Weather___________

Water Flow ___________In-House worksheet available? ___________

Observers____

UTM Upstrm: N_________ E_________USGS Quad________________

Downstrm N _________E_________Elev (units)_________________

FINAL RATING: ____

SCORE	Resource Category	Question
	WQ	**Water Quality**
	Qualifier	If the study reach is considered to be GC, whether or not flow has been altered, continue. If not and flow has not been affected, this category gets an "n/a" - go to Hydro/Geomorphology. If not because flow has been eliminated, the WQ category receives an overall mean score of 1.
	1 (F)	Is algal growth GC?
	2 (F)	At base flow, is the level of turbidity GC?
	3 (F)	Is the extent of channel shading GC?
	4 (F)	Is water quality GC?
	Mean Score	
	Comments	
	H/G	**Hydrology/Geomorphology**
	Qualifier:	If the study reach is not considered as GC because flow has been eliminated, the HG category receives an overall mean score of 1.
	1 (X,F)	Is sinuosity GC?
	2 (X)	How closely does the hydrograph resemble the GC natural hydrograph (timing, duration, frequency,

		magnitude, ramping rate)?
	3 (X,F)	Is the floodplain inundated in relatively frequent, GC events?
	4 (F)	Is the cover of fine sediment deposition on the streambed GC?
	5 (F)	Is the channel bank GC vertically stable?
	6 (X,F)	Is the channel GC laterally stable?
	7 (F)	Is the diversity of hydraulic habitats (e.g. oxbows, side channels, sand bars, gravel/cobble bars, riffles, pools, islands, cut banks, terraces) GC?
	8 (F)	Is the integrity of riparian surface soils and soil moisture GC?
	9 (F)	Is the density and condition of beaver dams GC?
	Mean Score	
	Comments	
	F/AH	**Fish/Aquatic Habitat**
	Qualifier:	If the stream is no longer perennial, but historically was a fishery, this category receives a mean score of 1.
	1 (F)	Is pool distribution sufficient to provide native fish habitat?
	2a (F)	Does underbank cover provide GC aquatic habitat diversity?
	2b (F)	Does overbank cover provide GC habitat for aquatic species?
	3 (F)	Is the degree of channel floor embeddedness GC to allow for suitable spawning conditions?
	4 (F)	Does large woody debris contribute to aquatic habitat diversity?
	5 (F, X)	Is the number and diversity of aquatic invertebrates consistent with stream type and geomorphic setting?
	6 (F)	Does riparian habitat provide for/enable terrestrial insect contribution into the channel?
	7a (X)	Are native fish and other aquatic faunal populations GC and present in numbers consistent with the management objectives?
	7b (X)	Do non-native fish and other aquatic faunal population levels pose a risk to native species inconsistent with management objectives
	8 (F, X)	Is the amount of habitat in the study reach GC for aquatic species of special concern (e.g., sensitive, T&E, etc.)?
	Mean Score	
	Comments	
	RV	**Riparian Vegetation**
	1 (F)	Is native percent cover in the riparian zone GC?
	2 (F)	Is the riparian vegetation overall structure sufficient to maximize energy dissipation during flooding?
	3 (F)	Is the dominant native shrub/woody tree species demography GC?
	4 (F)	What is the relative extent of non-native plant species cover?
	5 (F)	Does the cover of vegetation contribute to large woody debris production?

	6a (F)	a. Is there evidence of GI mammalian herbivory impacts on ground covering vegetation?
	6b (F)	a. Is there evidence of GI mammalian herbivory impacts on shrub and middle canopy covering vegetation?
	7 (F)	a. Is the vegetation growth normal and vigorous?
	Mean Score	
	Comments	
	WH	**Wildlife Habitat**
	1 (F, X)	Is the amount of habitat in the study reach GC for terrestrial species of special concern (e.g., sensitive, T&E, etc.)?
	2a (F)	Are there GC dense patches of shrubs and do they maximize wildlife habitat availability?
	2b (F)	Are there GC dense patches of middle and upper canopy trees and do they maximize wildlife habitat availability?
	3a (F)	Is the connectedness of shrub cover patches GC (i.e., are there well-connected shrub canopy patches in alluvial reaches)?
	3b (F)	Is the connectedness of middle and upper canopy patches GC (i.e., are there well-connected canopies in alluvial reaches)?
	4 (X, F)	Is the diversity of fluvial habitat types (i.e., pools, wet meadows, marshes, riparian vegetation stands) GC?
	5 (X, F)	Is the distribution of fluvial habitat types (i.e., pools, wet meadows, marshes, riparian vegetation stands) GC?
	Mean Score	
	Comments	
	HI	**Human Impacts/activities**
	1 (X, F)	To what extent is the stream's hydrograph natural and GC (a dewatered stream receives a score of 1)?
	2 (X)	To what extent is the state of the watershed's uplands GC?
	3 (X, F)	If the reach is used for livestock grazing and under a current annual management plan (AMP), is the actual level of grazing consistent with that outlined in the plan and appropriate for the watershed.
	4 (F)	Is the area free of development and other human activities that would affect the condition of the riparian system (i.e., parking lots, campsites, mines)?
	5 (F)	Does channel geomorphology resemble the unaltered condition (e.g., channelization, check dams, irrigation canals, etc)?
	6 (F)	To what extent is the area free of road impacts?
	Mean Score	
	Comments	
	Mean of Mean Scores	**FINAL PFCA RATING (average of scores for WQ-WH, and not including n/a scores or the HI category):**

	TREND	TREND: Upward, static or downward (answerable after one or more repeated visits at least one year apart)
	1 (F, X)	Does the trend in water quality change indicate improvement through time?
	2 (F, X)	Does the trend in geomorphic change indicate improvement through time?
	3 (F, X)	Does the trend in fish/aquatic habitat change indicate improvement through time?
	4 (F, X)	Does the trend in vegetation change indicate improvement through time?
	5 (F, X)	Does the trend in wildlife habitat and indicators indicate improvement through time?
	Mean	
	Comments	

APPENDIX 5.4: RSRA CHECKLIST SCORING DEFINITIONS AND INSTRUCTIONS FOR USE

A score of 1 indicates that extensive, geomorphically inconsistent (GI) alterations of an ecosystem parameter or characteristic have occurred, and a score of 5 indicates that the current state of the variable is geomorphically consistent (GC) and equivalent to what would be observed in natural or undisturbed settings. If a variable is given a score based solely on geomorphic factors (i.e. a steep-walled slickrock canyon receiving a "5" for lateral bank stability), a note should be made in the comment section for that category. An asterix (*) indicates that the question answered includes the use of the in-office worksheet (Appendix C). Some questions may be non-applicable (n/a) or unknown (unk).

Water Quality	Scoring Definitions
WQ Qualifier: Perennial Flow*	Is the study reach considered GC perennial? If not, this category receives a "n/a" - go to Hydro/Geomorphology
WQ 1. Algal Growth	1 pt = >50% GI algal cover
	2 pt = 25-50% GI algal cover
	3 pt = 10-25% GI algal cover
	4 pt = <10% GI algal cover, low diversity
	5 pt = <10% GI algal cover, with diversity
WQ 1. Baseflow Turbidity	1 pt = GI opaque water, or <40% similar to GC reference range value
	2 pt = GI near opaque, or 40-60% similar to GC reference range value
	3 pt = cloudy water, or 60-80% similar to GC reference range value
	4 pt = slight cloudiness, or 80-95% similar to GC reference range value
	5 pt = GC turbidity, >95% similar to GC reference range value
WQ3. Solar Exposure/Shading	1 pt = GI bare banks (completely exposed)

	2pt = GI slight shading
	3 pt = moderate shading
	4 pt = substantially shaded
	5 pt = Shading is GC
WQ4. Water Quality	1 pt = WQ is 0-20% of expected normal concentration
	2pt = WQ is 20-40% of expected normal concentration
	3 pt = WQ is 40-60% of expected normal concentration
	4 pt = WQ is 60-80% of expected normal concentration
	5 pt = WQ is 80-100% of expected normal concentration
Hydrogeomorphology	**Scoring Definitions**
Qualifier: Perennial Flow*	If stream is no longer perennial, but was historically, this category receives a score of "1".
HG 1. Sinuosity* (Fig. 1)	1 pt = GI straight channel (not actively moving)
	2 pt = GI minimal sinuosity
	3 pt = moderate amount of GI movement
	4 pt = Considerable GC sinuosity
	5 pt = actively and GC sinuous
HG 2. Flow Regime*	1 pt = Stream GI dewatered, only erratic storm-related flows
	2 pt = Mean baseflow GI reduced by $\geq$50%
	3 pt = Baseflow equivalent to natural, historic baseflow, but few, non-naturally-timed floods
	4 pt = Baseflow equivalent to natural, historic baseflow, flood frequency and timing >50% of natural condition
	5 pt = Current flow regime is GC and indistinguishable from the natural hydrograph
HG 3. Floodplain inundation (Fig. 2)	1 pt = GI, bankfull/depth ratio > 1.7 x bankfull
	2 pt = GI, 1.5 to 1.7 x bankfull
	3 pt = GI, 1.4 to 1.5 x bankfull

	4 pt = GC, 1.4 to 1.3 x bankfull
	5 pt = GC, 1.0 to 1.2 x bankfull
HG 4. Sediment deposition	1 pt = ≥90% of visible bed with GI deposition of fine sediment (no deposition at all, or excessive deposition)
	2 pt = 60-90% of bed with GI deposition
	3 pt = 30-60% of bed with GI deposition
	4 pt = 15-30% of bed with GI deposition
	5 pt = ≤5% of bed with GI deposition
HG 5. Vertical bank stability (Fig. 2)	1 pt = ≥90% of channel bank is GI vertically unstable
	2 pt = 60-90% of channel bank is GI vertically unstable
	3 pt = 30-60% of channel bank is GI vertically unstable
	4 pt = 5-30% of channel bank is GI vertically unstable
	5 pt = ≤5% channel bank is GI vertically unstable
HG 6. Lateral bank stability * (Fig. 2)	1 pt = ≥90% of channel is GI laterally unstable, widening or narrowing
	2 pt = 60% - 90% of channel is GI laterally unstable
	3 pt = 30% - 60% of channel is GI laterally unstable
	4 pt = 10% - 30% of channel is GI laterally unstable
	5 pt = <10% of channel is GI laterally unstable
HG 7. Hydraulic habitat Diversity (Fig. 3)	1 pt = no diversity of hydraulic habitats, GI
	2 pt = low diversity of hydraulic habitats, GI
	3 pt = moderate diversity of hydraulic habitats
	4 pt = moderately high diversity of GC hydraulic habitats
	5 pt = high diversity of GC hydraulic habitats
HG 8. Riparian soil integrity	1 pt = >50% of riparian soil surface GI disturbed
	2 pt = 25-50% of riparian soil surface GI disturbed
	3 pt = 5-25% of riparian soil surface GI disturbed
	4 pt = 1-5% of riparian soil surface GI disturbed
	5 pt = <1% of riparian soil surface GI disturbed

HG 9. Beavers*	1 pt = no (GC) beaver dams or beaver sign, beaver extirpated
	2 pt = no beaver dams, but limited recent beaver sign
	3 pt = conspicuous recent GC beaver activity, but no dams
	4 pt = much recent GC beaver activity, drags and some dams present (including evidence of those that have been washed out)
	5 pt = much recent GC beaver activity, stream channel dominated by beaver activity
Fish/Aquatic Habitat	**Scoring Definitions**
Note: Perennial Water?*	If stream is no longer perennial, but used to be a fishery, this category receives a score of "1".
F/AH 1. Pool Distribution	1 pt = No pool habitat, GI
	2 pt = 1 to several pools, GI
	3 pt = limited-moderate pool distribution, GI
	4 pt = moderate-abundant pool distribution, GC
	5 pt = abundant (~50%) pools, GC
F/AH 2a. Underbank Cover (Fig. 4)	1 pt = No GC underbank cover (concave bank)
	2 pt = GC underbank cover < 10% of reach
	3 pt = GC underbank cover 10% to 25% of reach
	4 pt = GC underbank cover 25% to 50% of reach
	5 pt = GC underbank cover ≥ 50% of reach
F/AH 2b. Overbank Cover (Fig. 4)	1 pt = No GC overbank cover
	2 pt = GC overbank cover<25% of reach
	3 pt = GC overbank cover in 25-50% of reach
	4 pt = GC overbank cover in 50-90% of reach
	5 pt = >90% GC overbank cover

F/AH 3. Embeddedness (Fig. 5)	1 pt = >50% gravel embedded in riffles with GI fine silt
	2 pt = 40-49% gravel embedded in riffles with GI fine silt
	3 pt = 26-39% gravel embedded in riffles with GI fine silt
	4 pt = 20-25% gravel embedded in riffles with GI fine silt
	5 pt = <20% gravel embedded in riffles with GI fine silt
F/AH 4. Role of Large Woody Debris (LWD)	1 pt = No GC LWD (>10 cm in diameter, >2 m long)
	2 pt = <0.05 GC LWD pieces/m (10 pieces)
	3 pt = 0.05 -0.075 GC LWD pieces/m (15 pieces)
	4 pt = 0.075-0.10 GC LWD pieces/m (20 pieces)
	5 pt = >0.10 GC LWD pieces/m (>20 pieces)
F/AH 5. Benthic Invertebrates*	1 pt = No benthic invertebrates, GI
	2 pt = 1 GC aquatic invertebrate orders (Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Diptera) present, with BCI scores <70)
	3 pt = 2 GC aquatic invertebrate orders present, BCI 70-80
	4 pt = 3 GC aquatic invertebrate orders present, BCI 80-90
	5 pt = 4 GC aquatic invertebrate orders present, BCI >90
F/AH 6. Terrestrial Invertebrate Habitat	1 pt = No GC grass/shrubs/trees overhanging the water)
	2 pt = <10% GC vegetation overhang
	3 pt = 10-25% GC vegetation overhang
	4 pt = 25-50% GC vegetation overhang
	5 pt = >50% GC vegetation overhang
F/AH 7a. Native Fish (NF)*	1 pt = NF historically present but all species extirpated
	2 pt = some NF species present but limited populations
	3 pt = most NF species present but <50% of population is non-native
	4 pt = all NF species present and moderately abundant
	5 pt = all NF species present and abundant

F/AH 7b. Non-native Fish (NNF)*	1 pt = One or more NNF populations dominate the study reach and no NF species present
	2 pt = One or more NNF populations, >75% dominate over NF species present
	3 pt = NNF populations >50% dominate over NF species
	4 pt = NNF present but NF populations 50-75% dominate
	5 pt = NNF present but NF >75% dominate
F/AH 8. Habitat Suitability for Aquatic Sensitive Species	1. No GC habitat available for aquatic invertebrate and vertebrate sensitive species (AIVSS) in study reach
	2 pt = poor GC habitat suitability for AIVSS
	3 pt = Moderate GC habitat suitability for AIVSS
	4 pt = Good GC habitat suitability for AIVSS
	5 pt = Excellent GC habitat suitability for AIVSS
Riparian Vegetation	**Scoring Definitions**
RV 1a, 1e. Native Vegetation Cover	1 pt = <5% native GC plant cover present and GC
	2 pt = 5-20% of native cover is present and GC
	3 pt = 20-40% of native cover is present and GC
	4 pt = 40-60% of native cover is present and GC
	5 pt >60% of native cover is present and GC
RV 2. Vegetation Stream Energy Dissipation	1 pt = <5% vegetation cover can dissipate stream energy during flooding
	2 pt = 5-20% of cover will dissipate flood energy
	3 pt = 20-40% of cover will dissipate flood energy
	4 pt = 40-60% of cover will dissipate flood energy
	5 pt >60% of cover will dissipate flood energy
RV 3. Vegetation Demography	1 pt = no native and GC vegetation age classes (seedlings, saplings, mature, snags) present

	2 pt = one age class present, native vegetation
	3 pt = two age classes present (at least one of which is seedling or sapling)
	4 pt = three age classes present
	5 pt = all age classes present
RV 4. Estimated Non-native Plant Species (NNS) Cover	1 pt = >50% of total cover is from NNS
	2 pt = 25-50% NNS cover
	3 pt = 10-25% NNS cover
	4 pt = 5-10% NNS cover
	5 pt = 0-5% NNS cover
RV 5. Large Woody Debris (LWD) Production on Floodplain	1 pt = no GC vegetation producing LWD (>10 cm in diameter and >2 m long) on floodplain
	2 pt = 1-10% of overall floodplain producing LWD
	3 pt = 10-25% of floodplain producing LWD
	4 pt = 25-50% of floodplain producing LWD
	5 pt = >50% of floodplain producing LWD
RV 6. Mammalian Herbivory Impacts	1 pt = >50% of ground covering plants damaged by mammalian herbivory, ungulate sign, trampling/trailing common
	2 pt = 25-50% of plants damaged, sign and trampling/trails common
	3 pt = 5-25% of plants damaged, sign/trampling/trails fairly uncommon
	4 pt = 1-5% of plants damaged, sign/trampling/trails uncommon
	5 pt = <1% of plants damaged, no sign/trampling/trails
RV 7. LRZ Plant Assemblage and Soil Moisture	1 pt = no GC vegetation, and vegetation inconsistent with geomorphic setting
	2 pt = 1-25% of woody species are phreatophytes, no wetland grass/herb species present, GI

	3 pt = 25-50% of woody species are phreatophytes, <25% of grass/herb are wetland species
	4 pt = 50-75% of woody species are phreatophytes, 10-50% of grass/herb species are wetland species, GC
	5 pt = >90% of woody species are phreatophytes, >50% of grass/herb species are wetland species, GC
RV 8. LRZ Plant Vigor	1 pt = Perennial riparian plants largely dead
	2 pt = >25% of perennial plants dying or dead
	3 pt = 5-25% of perennial plants wilted or dying
	4 pt = 1-5% of perennial plants wilted or dying
	5 pt = <1% of perennial plants wilted or dying stressed
Wildlife Habitat	Scoring Definitions
WH 1. Habitat Suitability for Terrestrial Sensitive Species	1. No GC habitat available for terrestrial sensitive species (TSS) potentially occurring in study reach
	2 pt = poor GC habitat suitability for TSS
	3 pt = Moderate GC habitat suitability TSS
	4 pt = Good GC habitat suitability for TSS
	5 pt = Excellent GC habitat suitability for TSS
WH 2. Shrub Patch Density	1 pt = No GC patches
	2 pt = A few, isolated, small patches
	3 pt = Isolated patches
	4 pt = Few large open areas between large patches, when GC
	5 pt = Almost continuous GC dense shrub cover
WH 3. Mid-Canopy Patch Density	1 pt = No GC patches
	2 pt = A few, isolated, small patches
	3 pt = Isolated patches

	4 pt = Few large open areas between large patches, when GC
	5 pt = Almost continuous GC dense mid-canopy cover
WH 4. Upper Canopy Patch Connectivity	1 pt = No large trees on reach, GI
	2 pt = 1-25% connected GC patches, with a few small, isolated patches or a few large trees
	3 pt = 25-50% of GC canopy patches connected
	4 pt = 50-75% of GC canopy patches connected
	5 pt = >75% of GC canopy patches connected
WH 5. Fluvial Habitat Diversity	1 pt = No other GC fluvial habitats present besides stream channel (i.e., no floodplain ponds or oxbows, sand bars, wet meadows, etc.)
	2 pt = One other GC fluvial habitat present
	3 pt = Two other GC fluvial habitats present
	4 pt = Three other GC fluvial habitats present
	5 pt = Four or more GC fluvial habitats present
Human Activities/Impacts	**Scoring Definitions (these results are not included in the final PFCA rating)**
HI 1. Dewatering?*	1 pt = no stream flow and no remnant pools supporting aquatic life, GI. In-office synthesis reveals that stream has been completely dewatered
	2 pt = no stream flow but a few remnant pools supporting aquatic life, GI
	3 pt = some, but consistent, GC surface flow between remnant pools supporting aquatic life
	4 pt = GC flow slightly reduced from expected or historic condition
	5 pt = stream with GC perennial flow; never dewatered and

	with relatively natural flood frequency.
HI 2. Upland Watershed Condition*	1 pt = Upland range or forest health assessments for watershed determined that upland areas are not functioning properly
	3 pt = Upland range or forests judged functioning at-risk
	5 pt = Upland range or forests judged functioning properly
HI 3. Livestock* (In Relation to Grazing Prescription)	1 pt = levels of livestock grazing are much higher than the grazing prescription (many more cattle than prescribed in AMP)
	2 pt = levels of livestock grazing are somewhat higher than the grazing prescription
	3 pt = does not deviate from grazing prescription
	4 pt = somewhat fewer livestock than prescribed in AMP
	5 pt = far fewer livestock than prescribed in the AMP
HI 4. Human Developments/ Other Impacts	1 pt = 4 different impacts (parking lots, campgrounds, structures, mines, etc.)
	2 pt = 3 different impacts
	3 pt = 2 different impacts
	4 pt = 1 impact
	5 pt = no human developments/impacts
HI 5. Geomorphology Change	1 pt = Multiple, large GI changes from human impacts
	2 pt = Several, moderate GI changes due to human impacts
	3 pt = Moderate GI changes
	4 pt = GC, little altered by human impacts
	5 pt = GC with expected natural condition
HI 6. Road Impacts by Type	1 pt = freeway adjacent to or crossing site
	2 pt = paved road adjacent to or crossing site

	3 pt = maintained dirt/gravel road adjacent to or crossing site
	4 pt = non-maintained jeep track with occasional use on site
	5 pt = no road impacts on site

APPENDIX 5.5:
WATER RESOURCE SITE SCORING RESULTS FOR 10 GCT SITES

Springs Ecosystem Assessment Protocol (Stevens et al. In press)								Ponds	
SEAP Categories	**SEAP Variable (Data Source)**	**Kane Aquiduct Spring**	**Coyote Springs, HRV**	**Tater Cyn Spr, Lower**	**Tater Cyn Spr, Upper**	**Big Springs, NKNF**	**“South Sandcrack” Spr**	**Bear Lake, NKNF**	**Crane Lake, NKNF**
Overall Ecosystem Qualifier	Dewatering (X, F)	n/a	1	n/a	n/a	n/a	n/a	n/a	n/a
Aquifer, Flow and Water Quality (AFWQ) 1	Aquifer functionality (X, F)	5	4	5	5	5	4	5	5
AFWQ 2	Flow (F, X)	3	1	3	4	3	3	5	5
AFWQ 3	Water quality (F, L, X)	5	5	5	5	5	4	3	3
AFWQ 4	Turbidity (F)	5	5	5	5	5	5	3	3
AFWQ Summary	Category % Score	**90.0**	**0.0**	**90.0**	**95.0**	**90.0**	**80.0**	**80.0**	**80.0**
Geomorphology (GEO) Qualifier	Site Obliteration (X, F)	n/a		n/a	n/a	n/a	n/a	n/a	n/a

Stream Segments (RSRA; Stevens et al. 2005)		
Water Quality	**No Cyn Cr.**	**Paria R.**
WQ1. Perennial flow?	yes	yes
WQ2. Absence of excessive algal growth	5	4
WQ3. Turbidity	4	3
WQ4. Channel shading	5	3
Category % Score	**93.3**	**66.7**
Hydrology/Geomorphololgy		
HG1. Sinuosity	5	3

GEO 1	Surface geomorphology (X, F)	3	1	3	3	3	2	3	3
GEO 2	Runout stream channel geometry (X, F)	3	1	2	3	4	2	n/a	n/a
GEO 3	Soil integrity (F)	2	1	2	2	3	3	3	2
GEO 4	Microhabitat diversity (F)	4	2	3	4	3	3	3	3
GEO 5	Natural disturbance regimes (X, F)	5	1	4	4	5	3	3	3
GEO Summary	Category % Score	**68.0**	**0.0**	**56.0**	**64.0**	**72.0**	**52.0**	**60.0**	**55.0**
Ecosystem and Trophic Dynamics (ETD) 1	Microhabitat functionality (F)	3	1	2	3	4	3	3	3
ETD 2	Native population dynamics (X, F)	4	1		4	4	3	3	3
ETD 3	Non-native species rarity (F)	4	1	3	4	4	3	4	3
ETD 4	Native species ecological roles (X, F)	4	1	3	4	4	3	4	3
ETD 5	Ecological efficiency (F, X)	4	1	2	4	4	3	4	3
ETD Summary	Category % Score	**76.0**	**20.0**	**50.0**	**76.0**	**80.0**	**60.0**	**72.0**	**60.0**
Freedom from Human Impacts (FHI) 1	Aquifer integrity (F, X)	4	3	5	5	5	3	5	5

HG2. Hydrograph resembles the natural hydrograph?	5	5
HG3. Floodplain inundation frequency	5	4
HG4. Fine sediment deposition	5	4
HG5. Vertical bank stability	4	3
HG6. Lateral channel stability	4	3
HG7. Hydraulic habitat diversity	3	3
HG8. Beaver sign	1	1
Category % Score	**80.0**	**65.0**
Fish/Aquatic Habitat		
F/AH1. Perennial stream?	yes	yes
F/AH2. Pool distribution	4	3
F/AH3a. Underbank cover	5	2
F/AH3b. Overbank cover	5	3

FHI 2	Flow regulation (F, X)	4	1	3	3	3	3	5	5
FHI 3	Mammalian herbivory (X, F).	5	2	5	5	4	3	3	3
FHI 4	Condition of adjacent uplands (X,F)	3	2	4	3	3	2	3	2
FHI 5	Construction impacts (X, F)	2	1	2	3	3	2	4	3
FHI 6	Fencing (F, X)	5	4	5	5	5	4	5	3
FHI 7	Road and trail impacts (X, F)	3	1	4	4	4	3	3	4
FHI Summary	Category % Score	**74.3**	**40.0**	**80.0**	**80.0**	**77.1**	**57.1**	**80.0**	**71.4**
Biogeography (BG) 1	Springs type (F)	Contact - hanging garden	Hillslope	Hillslope - high gradient cienega	Contact (focused)	Contact-gushet	Contact - hillslope	Natural Pond	Natural Pond
BG 2	Geographic isolation (X, F)	5	3	3	3	4	3	4	5
BG 3	Habitat patch size (F)	2	1	2	2	4	4	5	5
BG 4	Microhabitat functionality (F)	3	1	3	4	4	3	3	3
BG 5	Ecosystem longevity (X, F)	4	1	3	4			4	4
BG 6	Movement corridors, including migration (X)	3	2	3	4	4	3	4	4
BG Summary	Category % Score	**68.0**	**32.0**	**56.0**	**68.0**	**80.0**	**65.0**	**80.0**	**84.0**

F/AH4. Embeddedness	5	4
F/AH5. Large woody debris (LWD) cover	5	3
F/AH6. Aquatic invertebrate distribution	5	3
F/AH7. Terrestrial insect habitat	5	3
F/AH8a. Native fish distribution	5	2
F/AH8b1 Non-native fish distribution	5	4
Category % Score	**97.8**	**60.0**
Riparian Vegetation		
RV1a. LRZ native grass and forb composition	5	3
RV1b. LRZ native shrub composition	5	3
RV1c. LRZ native mid-canopy composition	5	2
RV1d. LRZ native upper canopy composition	5	2
LRZ Subsection Mean	***5.0***	***2.5***
RV1e. URZ native grass/forb composition	5	2

Administrative Context (AC) 1	Conformance to management plan (F, X)	2	5	2	2	3	3	4	4
AC 2	Scientific significance (F, X)	3	2	3	4	4	3	3	3
AC 3	Cultural significance (F, X)	3							
AC 4	Historical significance (F, X)	5	4	3	4	5	5		
AC 5	Recreational significance (F, X)	2	3	2	3	3	2	4	2
AC 6	Fish and Wildlife Significance (F, X)	3	3	2	3	4	3	4	2
AC 7	Sensitive species population integrity (X, F)	3	1		4	3	3	3	3
AC 8	Economic values (F, X)	5	4	5	5	5	5	4	4
AC Summary	Category % Score	**65.0**	**55.0**	**56.7**	**71.4**	**77.1**	**68.6**	**73.3**	**60.0**
Trend Assessment	Change through time (requires multiple site visits; F, X)	n/a							
Overall Score	Overall Site % Score	**72.4**	**41.2**	**59.4**	**72.9**	**74.1**	**59.4**	**68.2**	**62.4**

RV1f. URZ native shrub composition	5	2
RV1g. URZ native mid-canopy composition	5	3
RV1h. URZ native upper canopy composition	5	3
URZ Subsection Mean	***5.0***	***2.5***
RV2a. LRZ %GC to dissipate energy, support wildlife	5	2
RV2b. URZ %GC cover to dissipate energy, support wildlife	4	2
RV3. Plant demography	4	2
RV4a. LRZ non-native plant cover	4	3
RV4b. URZ non-native plant cover	5	2
RV5a. LRZ non-native plant diversity	4	3
RV5b. URZ non-native plant diversity	4	3
RV6. Palatability	5	3
RV7. Potential LWD production	5	2

RV8a. Mammal impacts on soil/ground cover	5	3
RV8b. Mammal impacts on native browse cover?	5	3
RV9. Soil moisture	5	3
RV10a. LRZ plant vigor	5	3
RV10b. URZ plant vigor	5	2
Category % Score	**93.8**	**51.3**
Riparian Vegetation		
WH1a. Aquatic hab. quality for sensitive species	5	1
WH1b. Terr. hab. quality for sensitive species	5	2
WH2a. Shrub patch density	5	5
WH2b. Mid- & upper canopy patch density	5	2
WH3. Upper canopy patch connectivity	5	2
WH4. Fluvial landform diversity	4	3
WH5. Habitat distribution	3	4
Category % Score	**91.4**	**54.3**
Human Impacts/activities		
HI1. Naturalness of hydrograph	5	3
HI2. Upland watershed integrity	4	2
HI3. Livestock grazing within prescription	5	4
HI4. Extent of development	5	3
HI5. Naturalness of channel geomorphology	4	3
HI6a. Extent of road impacts	5	3
HI6b. Proximity of road impacts	5	3

Category % Score	**94.3**	**60.0**
FINAL RSRA % SCORE	**87.9**	**60.6**
TREND: Upward, static or downward*		
T1. Water quality	n/a	n/a
T2. Geomorphology/geology	n/a	n/a
T3. Fish/aquatic habitat	n/a	n/a
T4. Vegetation	n/a	n/a
T5. Wildlife habitat	n/a	n/a
Section Mean	**n/a**	**n/a**

* answerable only after repeated visits

Added SEAP information for stream segments			
BG 2	Geographic isolation (X, F)	4	2
BG 3	Habitat area (F)	2	4
BG 4	Microhabitat functionality (F)	5	2
BG 5	Ecosystem longevity (X, F)	5	5
BG 6	Movement corridors, including migration (X)	3	4
BG Summary	Category % Score	**76.0**	**68.0**

Administrative Context (AC) 1	Conformance to management plan (F, X)	5	3
AC 2	Scientific significance (F, X)	4	4
AC 3	Cultural significance (F, X)	3	4
AC 4	Historical significance (F, X)	2	4
AC 5	Recreational significance (F, X)	3	4
AC 6	Fish and Wildlife Significance (F, X)	4	4
AC 7	Sensitive species population integrity (X, F)	5	2
AC 8	Economic values (F, X)	2	5
AC Summary	Category % Score	**70.0**	**75.0**

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[i] This is approximate totals for the entire North Kaibab Forest (see USDA 1987, pages 121-198). The actual Game Preserve acreage for the Kaibab (North and South) is 612,736 acres (USDA 1987:119-120).

[ii] S 2732, 59th Congress (S 11-8-06, 40, 787).