Fossil Creek

Stream Inventory Report
Coconino National Forest
Tonto National Forest
Santa Fe National Forest
Arizona Public Service
Surveyed: April 2005

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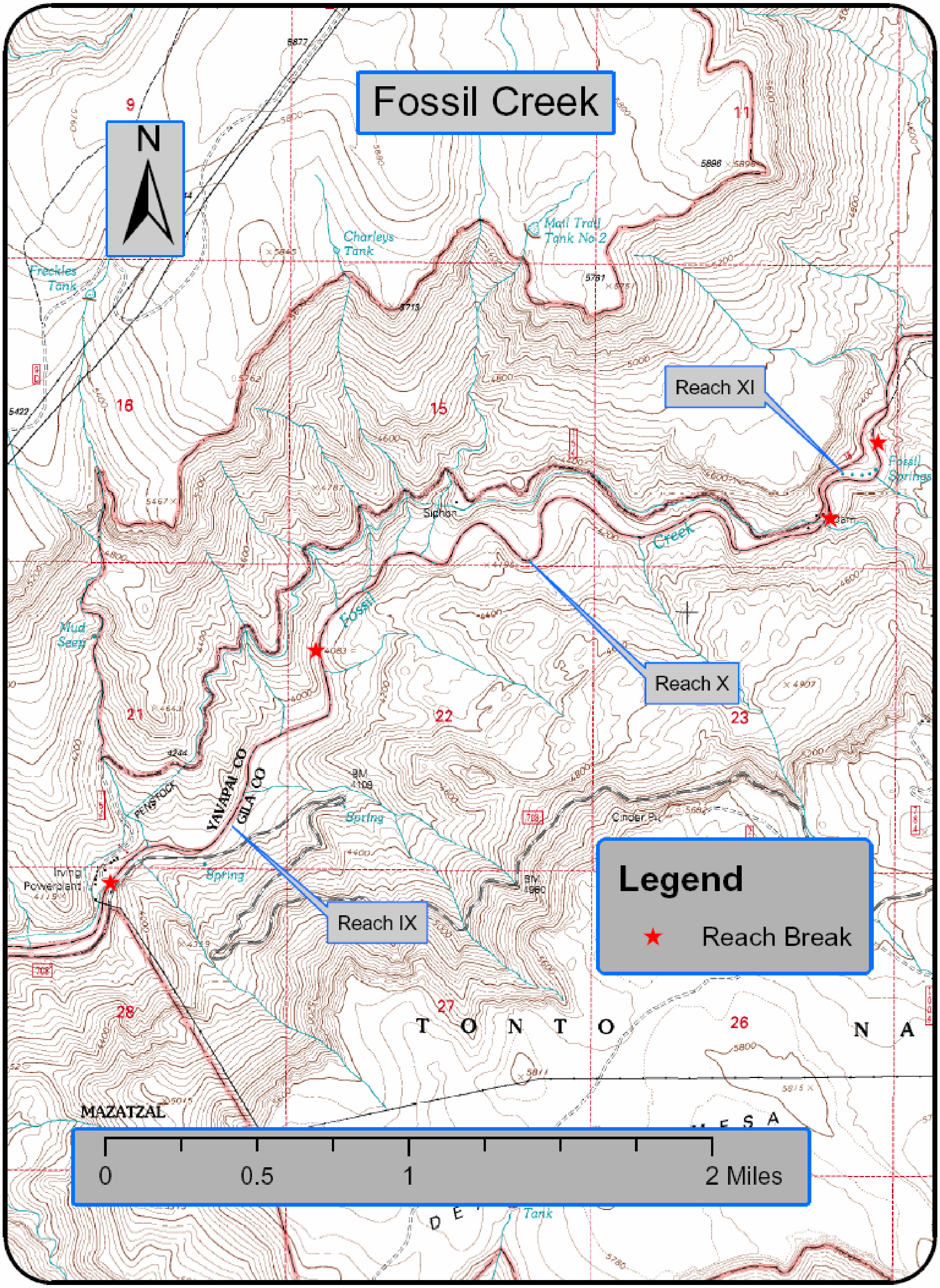

Map 1. Fossil Creek 2005 survey area with reach breaks.

This document is a specialist report. It is meant to assist managers in understanding current conditions of a stream corridor and possibly how those conditions have developed over a period of time.

Readers should note that there is some amount of repetition in this document. The author assumes that readers may only read certain sections; therefore, points or observations may be repeated. A glossary is provided at the end of document to help the reader think like a fish biologist. In addition, appendices provide greater detail on certain data points.

INTRODUCTION

Fossil Creek 2005 Stream Survey

Fossil Creek, located in central Arizona, is one of the largest tributaries to the Verde River. Fossil Creek's substantial watershed encompasses two of the five National Forests in Arizona. The river itself flows through the Coconino and Tonto National Forests. The Santa Fe National Forest Fisheries program conducted a stream survey of Fossil Creek from April 10th to April 15th, 2005. A total of 4.0 miles of stream was surveyed from the Irving Power Plant (T12N, R7E, Sec. 28, elev. 3,760') to the start of perennial stream flow at Fossil Springs (T12N, R7E, Sec. 14, elev. 4,242').

Photo 1. View looking upstream at the Fossil Creek Watershed (15 April 05).

The USDA Forest Service Region 3 stream survey protocol is a modified version of the Hankins/Reeves survey used in the Pacific Northwest Region. Under this protocol, streams are surveyed from the mouth upstream and the river is separated into riffle, pool, side channel, dry channel, culvert, and falls habitat types by specific attributes (USDA FS 2004). Different habitat types require specific measurements relevant to evaluating the habitat (Appendix A). In addition to the habitats located in the primary stream, tributary mouths are also surveyed and classified as a seep, spring, or stream (Appendix B). All habitat types are assigned a Natural Sequence Order number (NSO) in the order that they are surveyed. The stream, as a collection of NSOs, is further organized by homogeneous sections and grouped into a sequence of reaches. Each reach is assigned a number in the order that it is surveyed and analyzed separately, as well as together for a holistic overview of the system.

Global positioning system (GPS) units are utilized for survey data collection. Trimble GeoExplorer 3 units are used to identify specific features throughout the survey (Appendix A). The GPS feature locations are then transferred into a geographical information system (GIS) layer and used to provide graphical representations and spatial analysis of river attributes.

The primary objectives of the Region 3 Hankins/Reeves survey include the compilation of historical information and in-stream habitat data to assist in proper management decisions of the surveyed stream and its watershed. The historical information provides a background of land use and management techniques collected from the Forest Service and a variety of other sources. Previous land use and management practices reflect on the current condition of environmental systems. Historical information helps explain the current condition of the river and is incorporated into the survey. Understanding events that formed the habitat condition enhances decision-maker options. In-stream survey data is collected to provide an overview of the current condition of a stream. Survey data produces a “snapshot” in time of the stream’s habitat condition and the factors affecting it. Survey information can be used to identify both degraded sections as well as ideal areas to be used as a reference or model for other similar sections of stream. By combining the historical and current information pertaining to a stream, management options can be more clearly identified, which is the goal of this document.

Photo 2. Reach IX, NSO 54, R18. Lighter colored rock indicates typical flow line (12 April 05).

BASIN SUMMARY

Table 1. Stream Survey Summary Table for Fossil Creek.

LOCATION:		
County:	Yavapai/Gila	
Forest:	Coconino/Tonto National Forest	
Districts:	Red Rock/Payson	
Drainage:	Fossil Creek	
Tributary to:	Verde River	
Survey Began at:	T12N, R7E, Sec. 28 at 3,760 feet	
WATERSHED:		
5th HUC Codes[1]:	1506020392	
Fossil Creek Watershed Area:	191,677 acres	300 square miles
Stream Order:	4	
Stream Length[2]:	21,124 feet	4.0 miles
AQUATIC BIOTA:		
Native Fish Species: desert sucker (*Pantosteus [Catostomus] clarki*), Sonora sucker (*Catostomus insignis*), headwater chub (*Gila nigra),* roundtail chub³ (*Gila robusta*), longfin dace(*Agosia chrysogaster*), and speckled dace (*Rhinichthys osculus*).		

1 Hydrologic Unit Code used to identify watersheds.
2 Stream length does not include unsurveyed land.
3 Forest Service listed as a sensitive species (1999).

EXECUTIVE SUMMARY

Fossil Creek above the Irving Power Plant is a 4th order stream. The section of Fossil Creek surveyed in 2005 originates at Fossil Springs at the southern boundary of Fossil Springs Wilderness (T12N, R7E, Sec. 14, elev. 4,242') on the Coconino and Tonto National Forest Boundary. The stream travels 4.0 miles and drops 482 feet to the Irving Power Plant at the northern boundary of the Mazatzal Wilderness (T12N, R7E, Sec. 28, elev. 3,760'), following the Coconino and Tonto National Forest Boundary. The surveyed length is managed entirely by the Forest Service. Fossil Creek Watershed encompasses 191,677 acres (300 square miles).

Fossil Creek surveyed length is divided into 3 reaches, each containing relatively homogeneous habitat characteristics. Reach divisions are based on a 2002 stream survey by the Coconino National Forest which used dramatic changes in stream flow and barriers to fish migration. Reaches are numbered sequentially as the survey progresses upstream (Table 2).

The average gradient of the surveyed Fossil Creek is 2.3%, or 132 feet of elevation gain per mile. When evaluated by reach divisions, the gradient ranges from 2.1% in Reach X to 3.8% in Reach IX (see Table 7).

Table 2. Description and length of reaches on Fossil Creek.

Reach	River Miles*	Landmark at Beginning and End	Land Owner
IX	10.40 to 11.35	Irving Power Plant to Falls	Forest Service
X	11.35 to 13.65	Falls to Dam	Forest Service
XI	13.65 to 14.05	Dam to the Last Flow Source at Fossil Springs	Forest Service

* Mapped river miles

Stream flow in Fossil Creek originates from a series of springs above the Fossil Springs diversion dam, which is approximately ¼ mile below the uppermost spring. These springs provide approximately 43 cfs of baseflow. The diversion takes most of the base flow to power the Irving and Childs Power plants downstream. Approximately 1.5 cfs of seepage flow is all that remains in the channel below the dam until the Irving Power Plant where approximately 5.5 cfs is returned to the channel. The rest of the water, approximately 36 cfs, is diverted to Stehr Lake where it is then sent to run Childs power plant and discharged into the Verde River. Snow and storm runoff contribute to flows in excess of the base flows. Summer monsoons produce large runoffs with flashy flow and flooding. Flood flows currently account for the majority of the annual flow volume. This has changed Fossil Creek from a baseflow dominated system to a flood flow dominated system resulting in an unstable flow regime (USDA 2003).

Fossil Creek originates in the Fossil Springs Wilderness on the Coconino National Forest northwest of the Mogollon Rim and south of the Colorado Plateau. Fossil Creek Watershed is made up of flat-lying (low relief) uplands above deep canyons. The uplands are Miocene age (24 million to 5 million year old) lava flows made up of basalt. The weathering of the basalt creates clays in the soil. The canyons expose the cliffs made up of Supai Group (Permian to Pennsylvanian in age – about 285 million years old), the Naco Limestone (Pennsylvanian in age – about 323 to 285 million years old), and the Redwall Limestone (Mississippian in age – about 354 to 323 million years old; Monroe 2002, Gore 2005).

Photo 3. Flume that carries water from Fossil Creek to Irving Power Plant (looking up canyon; 14 April 05).

Fossil Creek is unique because of travertine features that were observed throughout the survey, mainly in reaches IX and X. Many of the pools are formed by natural bedrock formations that have been enhanced by travertine deposition. The Fossil Creek Lower Verde River Watershed Condition Assessment (USDA 2003) describes the process of travertine formation (see Photo 4):

Fossil Spring water is saturated with calcium carbonate and dissolved carbon dioxide. Once exposed to the atmosphere, the partial pressure of carbon dioxide in the water equalizes with that of the atmosphere, a process referred to as “outgassing”. When and if the carbon dioxide is outgassed, “the pH of the solution goes up and the equilibrium solubility with respects to calcium carbonate goes down. The solution becomes increasingly saturated with respect to calcium carbonate, and if this process continues to the point of supersaturation, precipitation of travertine[1] (calcite: calcium carbonate) will occur.” (Mathews 1994) Outgassing of carbon dioxide is enhanced where turbulence is created in the water as it flows over obstructions and channel substrates. Algae also appear to provide a mechanism for outgassing through the consumption of carbon dioxide, and as a possible filter and attachment point for the travertine precipitant (Mathews 1994).

Photo 4. Reach X, NSO 107, P38. Travertine that had formed around roots (14 April 05).

Habitat Characteristics

The 4 surveyed miles (21,124 feet) of Fossil Creek is divided into 158 Natural Sequence Order habitat units (NSOs). The 49 pool habitats comprise 28.4% of the stream habitat length. Riffles comprise the majority of habitat (58.0%) in Fossil Creek (Table 3). Side channels and falls were the only other habitat type in the surveyed Fossil Creek. 35 tributaries were encountered during the survey providing all of the perennial flow to Fossil Creek.

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[1] Travertine is chemically identical to the mineral calcite, which is distinguished from other forms of calcium carbonate by its banded and often porous structure resulting from its mode of deposition.

Table 3. Summary of entire survey habitat types.

Entire Survey				
Gradient 2.5%		Stream Length Surveyed: 21,124 feet 4 miles		
Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length[1] (%)	Stream Habitat[2] (%)
Pool	49	6,873	32.5	28.4
Riffle	47	14,057	66.5	58.0
Culvert	0	-	-	-
Tributary	35	-	-	-
Falls/Chutes	9	194	1.0	0.8
Side Channel	18	3,112	-	12.8
Total	158	24,236	100	100

[1]percent stream length calculated with only riffle, pool, culvert, and falls habitat types.
[2]percent stream habitat calculated using all stream habitat types except tributary.

Riffles are relatively long dominated by mid to large sized substrate. The fine substrate content in riffle habitat was naturally low at 5.5% (see Table 4). Boulder was the dominant substrate type (31.1%).

Table 4. Summary of riffle habitat and substrate composition for the entire survey.

Riffle Habitat Summary (ft)						
Reach	# Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max Depth	
Entire Survey	47	299	23.8*	1.6	2.9	
Substrate Summary (%)						
Reach	Sand	Gravel	Cobble	Boulder	Bedrock	Total
Entire Survey	5.5	13.2	26.2	31.1	24.0	

Orange=Dominant Substrate
* Average corrected width was calculated with less than the required measured units and may not be statistically valid; however there was little difference in the estimated width and corrected width in both pools (0.9' for all pools) and riffles (2.0' for all riffles).

The average pool length was 140 feet (see Table 5) compared to the average riffle length off 299 feet. Pool quality was high with an average residual depth of 5.0' with all of the pools having a residual depth greater than 1 foot. Pool quantity was likely within the natural range of variability. Pool quantity will likely increase with returned flows and increased travertine formation. Fine substrate was also low in pools (8.0%). Dominant substrate in pools was bedrock (33.3%).

Table 5. Summary of pool habitat and substrate composition for the entire survey.

Pool Habitat Summary											
Reach	# Pool Habitats	Avg. Length (ft)	Avg. Width (ft)	Avg. Max Depth (ft)	Avg. PTC (ft)	Avg. Residual Depth (ft)	Pools per mile	# Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/mi.	# Pools w/ Max Depth >3'	Pools w/ Max Depth >3'/mi.
Entire Survey	49	140	29.9*	6.8	1.0	5.0	12.3	49	12.3	48	12

Substrate Summary (%)						
Reach	Sand	Gravel	Cobble	Boulder	Bedrock	Total
Entire Survey	8.0	12.4	21.8	24.5	33.3	100.0

Orange=Dominant Substrate
*Average corrected width was calculated with less than the required measured units and may not be statistically valid; however there was little difference in the estimated width and corrected width in pools (0.9' for all pools).

The total percent of unstable banks is low with only 1.3% of the banks unstable. Some banks had been scoured clean of vegetation by high flows caused by snow melt and rain, but were not considered unstable when consisting of bedrock and boulder. Bank instability was observed when scouring occurred on smaller substrates and soils leaving them bare of vegetation.

Table 6. Habitat characteristics for entire survey.

Reach	Pool:Riffle Ratio	Avg. Bankfull Width:Depth	Pieces of LWD per mile	Total Unstable Banks (ft)	% Unstable Banks
Entire Survey	1:1	19:1	3.2	563	1.3

The amount of large woody debris (LWD) was very low throughout the entire survey. The lack of LWD could be a result of the flooding that took place in the early spring. It appeared that the flooding that occurred had moved a lot of the LWD up into the floodplain and out of bankfull, thus making uncountable as LWD. With the return of full flows and a change in the bankfull more wood is likely to be available in the channel.

Reach by Reach Comparison

Table 7. Reach characteristic summaries for the entire survey 2005.

Reach	Total Length (mi)	Gradient (%)	Rosgen Channel Type	Pool Habitat (%)	Riffle Habitat (%)	Side Channel Habitat (%)	Dominant Substrate in Pools	Dominant Substrate in Riffles	LWD Per Mile	Bankfull Width to Depth	Unstable Banks (%)
IX	1.3	3.8	B2	35.5	59.2	3.8	Bedrock	Boulder	0.0	29:1	1.4
X	2.3	1.9	B2	25.0	61.0	3.8	Bedrock	Boulder	3.9	19:1	1.0
XI	0.4	2.1	B3	25.5	44.6	29.9	Cobble	Cobble	9.2	13:1	0
Total	**4.0**	**2.5**	**-**	**28.4**	**58.0**	**12.8**	**Bedrock**	**Boulder**	**3.2**	**-**	**1.3**

Fossil Creek was broken into three reaches as laid out by the 2002 survey. The reaches start upstream from Irving Power Plant and end at the change in flow regime at Fossil Springs. Reach IX had the highest gradient and the highest amount of pool habitat. The high pool count could be due to the higher gradient which causes greater surface agitation. Travertine deposition is higher under these conditions which in turn increases pool formation.

Photo 5. Reach IX, NSO 50, F5. Travertine pool and fall (12 April 05).

Bedrock was the dominant substrate in pools and was the main pool forming feature in the survey. Historic travertine deposition onto bedrock substrate has enhanced pool formation. Boulder was the dominant substrate in riffles which might also be due to the large flows that may have cleaned out the system leaving behind large substrate. The lack of smaller substrate below the dam may also be attributed to the dam collecting and storing fine sediments behind it. Once above the dam, less travertine and bedrock was observed and cobble became the dominant substrate.

Stability was low throughout the entire survey with only 1.3% of the banks being unstable. The B2/B3 channel types have a low sensitivity to disturbance and a low streambank erosion potential (Rosgen 1996) which explains the small percentage of unstable banks even after flooding and high amounts of localized recreation use in the watershed.

Tributaries

Thirty-five (35) tributaries contributed surface flow to Fossil Creek in the form of springs, seeps, and stream habitats (Appendix B). Of the 35 tributaries, four (4) are considered significant, contributing an estimated 10% or more flow to Fossil Creek (see Table 8). Majority of tributaries are found in Reach XI at Fossil Springs.

Photo 6. Reach XI, NSO 156, T3. One of the Fossil Springs entering on the north bank (15 April 05).

Fossil Springs provides the perennial flows to Fossil Creek. According to the Fossil Creek Lower Verde Watershed Condition Assessment (USDA 2003): "Fossil Springs consists of a series of at least 7 major springs that emerge from the north bank along approximately 900 feet in length." These springs provide a constant base flow of 43 cfs. During the 2005 survey, 12 springs and 6 seeps were observed in the Fossil Springs area (see Photo 6). All springs and 4 of the 6 seeps were entering on the north bank. Each south bank seep was adding less than 1% flow (visually estimated). The average temperature observed in Fossil Springs (north bank springs and seeps) was 69.4º F.

Table 8. Summary of tributaries contributing ≥10% surface flow to Fossil Creek during the 2005 Stream Inventory.

Location		Bank	Habitat Type	Name	% Flow*	Time	Tributary Temp (°F)	Stream Temp Below (°F)	Stream Temp Above (°F)	Comments
Reach	Tributary Number									
XI	18	Left	Spring	Fossil Springs	20%	15:45	70	68	-	15% gradient
XI	30	Left	Spring	Fossil Springs	10%	10:40	70	71	-	70% gradient
XI	31	Left	Seep	Fossil Springs	20%	-	-	-	-	70% gradient
XI	34	Left	Spring	Fossil Springs	50%	12:15	69	-	69	4% gradient

* Percent flow is a visual estimate by the surveyors and therefore should not be considered an exact measurement

Stream Flow

Stream flow is best described by the Fossil Creek Lower Verde Watershed Condition Assessment (USDA 2003):

> Fossil Springs consists of a series of at least 7 major springs that emerge from the north bank along a reach approximately 900 feet in length (Monroe 2000 in USDI 2002). This spring outflow contributes a constant base flow of 43 cfs. Storm runoff and snowmelt from surrounding mountains contribute to flows in excess of base flow. Intense, but brief and localized summer monsoon rainstorms produce large volumes of runoff within the watershed that generates flashy flows and flooding. Significant floods that overflow the low flow channel and transport substantial quantities of sediment occur about every other year (Arizona Public Service 1998 in USDI 2002). Floods in excess of a 5-year recurrence have high peak flow velocities capable of transporting cobbles, small boulders and considerable debris. Under current watershed conditions, the estimated peak flow of the 100-year flood event is approximately 13,530 cfs (Loomis 1994 in USDI 2002).
>
> Most of the base flow is currently diverted by the Childs-Irving Hydroelectric Project at the Fossil Springs diversion dam, approximately 14 miles upstream of the Fossil Creek / Verde River confluence. The diversion dam (a 25-foot high concrete structure) removes most of the base flow discharged from Fossil Springs, leaving only approximately 1.5 cfs of seepage flow in the 3.8-mile stream reach between the dam and the Irving Power Plant. After passing through the Irving Power Plant, approximately 5.5 cfs of water is returned to the Fossil Creek stream channel, while an estimated 36 cfs of the spring discharge is diverted through another series of flumes and pipes to Stehr Lake, a regulating reservoir for the Childs Power Plant (pers. comm. Jack Norman, Red Rock Ranger District). From Stehr Lake, the spring water is piped down to and through the Childs Power Plant, where the water is discharged into the Verde River. The Childs Power Plant is situated adjacent to the Verde River approximately 3.5 miles upstream of the Fossil Creek / Verde River confluence. Flume and power plant maintenance allows the periodic return of full flows (~43 cfs) to the stream channel for short periods of time.
>
> Under natural conditions, the ~43 cfs of baseflow emitted from Fossil Springs would account for an estimated 77% of the annual flow volume in Fossil Creek. If the ~43 cfs of baseflow flowed within the Fossil Creek stream channel, then flood flows would not be considered to provide a significant percentage of the annual flow volume. However, given that the baseflow has been diverted from the Fossil Creek stream channel for the past 86 years, flood flows account for the greater majority of the annual flow volume. If floods represented 23% of the natural annual flow volume, under the modified baseflow hydrograph they currently represent 98.5% of the annual volume in the upper reach and 86.6% in the lower reaches (below Irving Power Plant). In terms of annual flow

> volumes, Fossil Creek has shifted from a baseflow-dominated system to a flood flow dominated system. In terms of flow energies, the system has shifted from a predominantly stable flow regime, to an unstable flow regime characterized by extremely low flows followed by erosive and destructive high flows (from a paper by T. Cain, former CNF Fisheries Biologist).

Flow was measured in Fossil Creek utilizing a Swoffer 3000 Flow Meter on April 4, 2005, in Reach IX (NSO 4, R2). Flow was measured at the beginning of the survey in a straight section of riffle with as few flow-restricting obstacles (boulders, logs, etc.) as possible. A transect was created and divided into 26 equally spaced sections. At each section, flow was taken at 60% of the depth in twenty-second intervals. The average flow was recorded from each section and related to area to calculate the stream flow. Fossil Creek flow measured on April 4th was 7.4 cfs.

Water Quality

Fossil Creek is very unique due to Fossil Springs which provides a consistent base flow of 43 cfs at a constant temperature of 72ºF making it the largest spring water discharge in the Mogollon Rim region (NAU 2005). Fossil Springs is also unique for its high amount of calcium and bicarbonate which leads to travertine formations throughout the stream below the springs. A description of water quality from the Specialist Report for the Fossil Creek Management Plan Amendment EIS is given below (Norman 2003):

> Fossil Springs contributes about 72 percent of the total volume of water yielded by the watershed and provides the majority of the water in the creek about 77 percent of the time. Consequently the chemical quality of the spring water dominates the water quality characteristics of the stream during much of the year. The chemical quality of the spring water is conducive to the formation of travertine, which is composed of calcium and bicarbonate; these constituents dominate the water quality of the entire stream system.
>
> The Arizona Department of Health Services collected water quality samples from Fossil Creek near the Irving powerhouse during 1990 and 1991. The large increase in pH recorded at the Irving powerhouse (8.3) compared to the pH at the springs (7.0) can be attributed to the conversion of bicarbonate ions (an acid) to calcium carbonate, carbon dioxide, and water during the travertine deposition process.
>
> The State's 2002 305(b) report indicates that as result of lack of samples it is inconclusive if water quality standards are being met for Fossil Creek. However previous sampling results for specific constituents complied with applicable state standards designed to protect its designated uses.
>
> Dissolved oxygen, water temperatures, fecal coliform, and pH samples were collected by Dames and Moore (1990, cited in APS 1992) at four locations in November 1989 and May 1990 for Arizona Public Service: (1) in Fossil Springs, (2) at the flume inlet at Stehr Lake, (3) at the flume outlet at Stehr Lake, and (4) at the Childs tailrace. Water temperatures ranged from 20 degrees C in the Childs tailrace to 21 degrees C in Fossil Springs. Dissolved oxygen levels ranged from 7.9 mg/l in Fossil Springs to 9.5 mg/l in the Childs tailrace. Fecal coliform levels ranged from 8 colonies/ml at Stehr Lake inlet to 140 colonies/ml at the Childs tailrace, while pH ranged from 7.53 in Fossil Springs to 8.19 in the Childs tailrace.

Riparian and Upland Vegetation

Riparian vegetation is located on both banks. Riparian areas serve many important functions including water purification and storage, erosion reduction and more. Riparian vegetation removes toxins from the water column and improves water quality; stores water in the stream banks, increasing available water and stream flow duration; and improves stream bank stability, reducing erosion and its associated fine sediment inputs (Brodie 1996). Riparian vegetation is important in maintaining a healthy fish population in Fossil Creek.

The riparian zones along Fossil Creek are best described by the Fossil Creek State of the Watershed Report (NAU 2005):

> The riparian zone along Fossil Creek is dominated by deciduous trees. Tree diversity is good throughout but there are differences in overstory dominance between the reach above the Fossil Springs Diversion Dam to the reach below the dam (Sayers 1998). Seedlings are the most common age class among riparian trees at Fossil Creek, generally found in a narrow band along the creek. The number of riparian species decreases with horizontal distance away from the stream bank in direct proportion to decreasing soil moisture availability (APS 1992).
>
> The Fossil Creek riparian area has been divided into 5 different sections for management purposes (USDA Forest Service 2003a). Zone 1 is located above Fossil Springs where stream flow is intermittent. In this area riparian vegetation is sparse and low in diversity with scattered Arizona sycamores (*Platanus wrightii*) dominating the riparian trees. Riparian trees generally show a good age class distribution. The understory is comprised mostly of upland species and is very sparse. Zone 2 consists of the intact riparian corridor from Fossil Springs to the Diversion Dam. Species diversity of riparian tree species is high and with a good age class representation. Fossil Springs Botanical Area is located within this zone. Ash (*Fraxinus velutina*), alder (*Alnus oblongifolia*) and Arizona walnut (*Juglans major*) dominate the riparian areas above the dam (Sayers 1998). Other tree species occurring throughout the riparian area are boxelder (*Acer negundo*), Arizona sycamore, willow (*Salix* sp.) and netleaf hackberry (*Celtis reticulata*). Grasses and ferns are the second most prominent group of plants in this zone, followed by shrubs and other herbaceous vegetation. The understory above the Fossil Springs Diversion Dam also contains a variety of shrubs, including chokecherry (*Prunus virginiana*), New Mexico locust (*Robinia neomexicana*) and smooth sumac (*Rhus glabra*). Introduced and invasive blackberry is increasing and becoming more dominant, especially at several of the spring sources (pers. comm. Cecelia Overby to Michele James).
>
> Below the Fossil Springs Diversion Dam begins the compromised riparian zone, impacted by water diversion from the streambed since the construction of the dam in 1916. Zone 3 begins below the Fossil Springs Diversion Dam, where the substrate type shifts to a higher percentage of bedrock and although there is some deposition of alluvium, there is little soil to support understory vegetation (Sayers 1998). In this zone overstory dominance shifts to Arizona sycamore (Goodwin 1980; see Photo 7). Other dominant tree species below the dam are velvet ash, Arizona alder and cottonwood *(Populus fremontii*) (Sayers 1998). Of lesser dominance are boxelder (*Acer negundo*), willow (*Salix* sp.) and netleaf hackberry (*Celtis reticulata*). Tree cover is higher than above the dam and mature trees represent the majority in the age class distribution (Goodwin 1980; Sayers 1998). The reach contains no shrubs. Grasses and ferns comprise the majority of the understory while herbaceous vegetation is the least dominant life form (Sayers 1998).

Photo 7. Reach X, NSO 75, R24. Large sycamore tree in channel (13 April 05).

Vegetation upland (or outside of the riparian zone) above Irving Power Plant includes mixed conifer, ponderosa pine, Gambel oak, piñon-juniper, and inclusions of chaparral. Below Irving, the vegetation changes to more of a mixed grassland/desert shrub type.

Fisheries

As with most rivers, extensive stocking and the introduction of non-native species has led to drastic changes in the species assemblages. Non-native fish that had invaded Fossil Creek include green sunfish (*Lepomis cyanellus*), smallmouth bass (*Micropterus dolomieu*), flathead catfish (*Pylodictis olivaris)*, and yellow bullhead (*Ameiurus natalis*). Native fish in Fossil Creek include headwater chub (*Gila nigra*), roundtail chub (*Gila robusta*), speckled dace (*Rhinichthys osculus*), Sonora sucker (*Catostomus insignis)*, longfin dace (*Agosia chrysogaster*), and desert sucker (*Catostomus clarki*; USDA 2003). No fish sampling was done as part of the 2005 Fossil Creek Stream Inventory.

In 2004 an effort to restore the native fish assemblage took place. Native fish present in the creek were collected by electrofishing, baited hoopnets, trammel nets, seines and minnow traps, and contained in holding tanks while non-native fish were removed using a piscicide. Once the non-natives were removed the native fish (listed above) were reintroduced into the system. A barrier was constructed in the Mazatzal Wilderness to prevent non-native fish from repopulating Fossil Creek upstream from its confluence with the Verde River.

Wildlife Species

Wildlife species within the watershed are best described by the Fossil Creek State of the Watershed Report (Northern Arizona University, 2005):

> The Fossil Creek Watershed supports over 175 known species of mammals, birds, reptiles, amphibians, and terrestrial invertebrates…The number of known species in the watershed is based on actual sightings of species. There are many more species that potentially, and likely, occur in the area but have not yet been documented. The Forest Service has compiled a database of actual species documented in the area as well as species that various sources have listed as hypothetically occurring there. A query of this database shows that 298 species of mammals, birds, reptiles and frogs may occur but have not yet been documented in the Fossil Creek area..

During the 2005 survey the surveyors did see numerous common black hawks, a kingfisher, great blue heron, and a javelina (see Appendix C for a list of Threatened, Endangered, Sensitive, and Management Indicator Species (MIS) for the Fossil Creek area).

Previous Surveys

In 2002 the Coconino National Forest conducted a stream habitat inventory and fish survey. The habitat study appears to be a modified R6 Hankins/Reeves habitat inventory. The 2005 survey also uses a modified R6 Hankins/Reeves habitat inventory, but different parameters were measured. The 2002 survey began at the Irving Power Plant (T12N, R7E, Sec. 28, elev. 3,760’) and ended 3.3 miles upstream at the diversion dam (T12N, R22E, Sec 14, elev. 4,242’). The stream was divided into two reaches; while the 2005 survey picked up one more reach from the diversion dam to Fossil Springs.

The 2002 survey had broken their main channel habitats into pools, riffles, run, bedrock riffles, bedrock runs, complex (riffles, runs, and pools), and dry. The 2005 survey contained main channel units broken into riffles, falls, and pools. A review of the 2002 survey revealed inconsistency between the two surveys leaving little to compare between the two. Also, even if the two surveys were consistent, the flows were likely quite different; the 2002 survey had dry channels where the 2005 survey had good flows related to a wet winter and spring.

Table 9. Comparative look at 2005 survey and 2002 survey

Reach	Total Length (mi)		Total Bank Instability		Dominant/Subdominant Riffle Substrate				Pieces LWD	
	2002	2005	2002	2005	2002 Ocular	2002 WPC	2005 Ocular	2005 WPC	2002	2005
IX	0.9	1.3	88.6	180.0	Bedrock/ Cobble	Cobble/ Bedrock	Boulder/ Cobble	Bedrock/ Boulder	7	0
X	2.5	2.3	36.1	356.0	Cobble/ Boulder	Cobble/ Gravel	Bedrock/ Boulder	Cobble/ Boulder	11	9
Total	**3.4**	**3.6**	**124.7**	**536.0**	**-**		**-**		**18**	**9**

Bank instability, substrate, and LWD were the only attributes that were comparable. The 2002 survey found the total amount of bank instability (both banks for reaches IX and X) to be 124.7 feet where the 2005 survey found 536 feet (see Table 9). 2002 had 18 pieces of LWD while 2005 only had 9. Differences in LWD may be due to changes in bankfull indicators, differences in methodology, or movement during flooding that had taken place before the 2005 survey.

In comparing ocular estimations of substrate, larger substrates begin to dominate Reach X in 2005. Differences may be due to the flooding that took place in 2005 which may have caused more travertine development as well as washed smaller substrates downstream. In addition to ocular estimates, Wolman Pebble Counts (WPC) were conducted. The 2005 survey had a higher frequency of WPC per reach. The 2002 survey conducted 1 WPC per reach; whereas the 2005 performed 2 counts in Reach IX and 4 in Reach X. The 2002 survey also appeared to stop their pebble counts when they reached 100 samples; whereas the 2005 survey reached 100 samples and continued sampling until reaching the opposite wetted edge from the start completing a full transect of the channel perpendicular to the flow. While the pebble count information is interesting, it is not comparable since they were not conducted in the same location.

Stream Alterations

In December 1992, APS filed an application with the Federal Energy Regulatory Commission (FERC) to relicense the Childs-Irving Hydroelectric Project for 30 years. On August 14th, 1997, FERC issued an EA on the relicensing proposal and invited public comment. After a period of negotiation with a coalition of groups including American Rivers, The Nature Conservancy, the Yavapai-Apache Tribe, the Northern Arizona Audubon Society, the Sierra Club, and the Center for Biological Diversity, APS signed an Agreement in Principle in 1999 to decommission the facilities and return full flows to Fossil Creek. FERC issued a final EA on March 26, 2004, and the Commission issued an order to approve the surrender of license and removal of project works on October 8, 2004. Full flows were returned to Fossil Creek on June 18, 2005, and deconstruction activities are ongoing.

Photo 8. Fossil Creek diversion dam slated for partial removal (14 April 05).

LAND USE

Land use prior to Forest Service Management can best be described in the Environmental Assessment for Native Fish Restoration in Fossil Creek (USDA 2004):

> **Paleo-Indian Period**
> Little archaeological evidence of Paleo-Indian (12,000–8,000 B.C.) use of the Verde Valley has been recorded; however, Pleistocene megafauna, including horse, mastodon, and mammoth, have been found along the Verde (Tagg 1986). Given the recent alluvial deposition in the valley, evidence of Paleo-Indian use of the area is most likely deeply buried.
>
> **Archaic–Dry Creek Phase**
> Evidence of Archaic period (8,000 B.C.–A.D. 1) occupation of the Verde Valley is more abundant. The Dry Creek Site, believed to date to the late Archaic, is located just west of Sedona (Pilles and Stein 1981:608, Shutler 1950). Dry Creek phase sites have been identified along Dry Creek, Spring Creek, Oak Creek and Coffee Creek; most of them reflect hunting and plant gathering activities. Artifact assemblages include ground stone, scrapers, choppers, knives, and hammer stones. Oval one-hand manos and basin metates, as well as small less formal ground stone implements, are ubiquitous on these late Archaic sites. No Archaic-period structures have been identified.
>
> **Squaw Creek Phase**
> Breternitz (1960) has suggested that shallow pit houses and surface dwellings were first built in the Verde Valley during the Squaw Peak phase (A.D. 1–800). Associated material culture resembles artifacts from San Pedro Cochise and Basketmaker II sites. Ceramics, which appear for the first time in this area at the end of the Squaw Peak phase, include Snaketown and Gila Butte Red-on-buff, Lino Gray, and Lino Black-on-gray. The shift from small basin metates and one-hand manos to larger manos and trough metates near the end of the phase has been attributed to a shift to a more sedentary life style and a greater reliance on agricultural products (Pilles 1981a:8). Immigration into the region by Hohokam people, may have contributed to dramatic cultural changes that occurred in the Verde Valley around A.D. 700 (Pilles and Stein 1981:8–12). Hohokam Buff Ware and Pimeria Brown Ware ceramics, shell bracelets, clay figurines and stone palettes, as well as Hohokam-style ballcourts, houses, cremation burials, and irrigation technology have been identified. Other studies suggest that the presence of Hohokam material culture should be attributed to intensive trade rather than immigration (Fish and others 1980).
>
> **Camp Verde Phase**
> Many sites dating to the Camp Verde phase (A.D. 800–1125) have been located in the Upper and Middle Verde Valley. These sites are generally thought to have been occupied by the Southern Sinagua, an extension of the Sinagua cultural tradition identified in the area around Flagstaff. The Southern Sinagua were sedentary farmers of corn, bean, squash, and cotton. Pottery manufactured by the Southern Sinagua was primarily undecorated Alameda Brown Ware, constructed with a paddle and anvil technique. Two site types have been identified for this period: 1) small sites at elevations between 4,500–5,000 ft and 2) larger sites on the floodplain (Macnider and others 1991:5). The floodplain sites are often very large and include ballcourts, mounds and other public architecture. The early Camp Verde phase is characterized by Kana'a Black-on-white, Santa Cruz Red-on-buff, and Deadmans Black-on-red ceramics. The late Camp Verde phase (A.D. 1000–1125) is marked by continued Hohokam influence in the Middle Verde Valley including red-on-buff ceramics, shell and stone ornaments, and clay figurines. Larger sites also often include Hohokam style houses, ball courts, cremation burials and adobe-capped mounds (Fish and Fish 1977; Pilles 1976). In the Upper Verde Valley,

Hohokam influence seems to have ended by this period. Imported ceramics include mainly Winslow and Kayenta types, while plain wares are almost entirely Alameda Brown Ware (Fish and Fish 1977).

Honanki Phase

The Honanki phase (A.D. 1125–1300) is marked by changes in settlement patterns, architecture, and material culture. Sites dating to the Honanki phase tend to be located at higher elevations than sites from earlier phases and consist of small pueblos and cliff dwellings, pit houses, and contiguous masonry rooms. Hilltop sites, often with thick outer walls, also occur during the Honanki Phase, and some researchers believe them to be defensive sites or forts (Fish and Fish 1977; Wilcox and others 2001). Hohokam ceramics do not appear in assemblages from Honanki-phase sites.

Tuzigoot Phase

During the Tuzigoot phase (A.D. 1300–1425) the previously dispersed population aggregated; as many as 40 pueblos with at least 35 rooms each have been recorded. Tuzigoot, Montezuma Castle, and Hatalacva are the three largest sites attributed to this phase (Jackson and Van Valkenburgh 1954; Spicer and Caywood 1936; Spicer and Caywood 1934). Trade and influence in the Verde Valley seems to be mainly from the Flagstaff, Kayenta, and Winslow areas. Trade wares include Tusayan Black-on-white, Jeddito Black-on-yellow, and later proto-Hopi and Hopi wares. Wilcox (2001:158) has posited a Verde Confederacy, an alliance of large sites that stretched from Perkinsville to Davenport Wash along the Verde River, which was formed to protect the region against potential aggression by inhabitants of Perry Mesa. Wilcox (2001) includes three pueblo sites located along Fossil Creek in the Verde Confederacy. Fossil Creek Ruin (NA 3515) a 26-room, Pueblo IV pueblo, is approximately 20 km south of the project area at the confluence of the Verde River and Fossil Creek. Salome Ruin (NA 19,286), a 29-room defensive site, and Verde 10-12, a 30+ room defensive site, both are upstream from the project area.

Protohistoric Yavapai

Until recently, the Verde Valley was thought to have been abandoned about A.D. 1425, but the Yavapai obviously entered the Verde Valley prior to A.D. 1540 and perhaps as early as 1300. Five protohistoric Yavapai sites have been reported from the Jacks Canyon area near the Village of Oak Creek (Logan and others 1996:1108–1109). Yavapai sites are likely underrepresented in archaeological site inventories, as they difficult to identify. Yavapai material culture was easily transported and mostly perishable. Structures consisted of brush wickiups with rock placed outside the circle of brush; once the superstructure has disintegrated little would remain other than a small cleared area and possibly an arc or circle of rocks. A single course of rock is easily disguised by erosion, alluviation, or trampling by grazing herbivores. Don Keller and Pat Stein (1995) documented a twentieth-century Yavapai wickiup site near Prescott Arizona. Even with archival data, historic photos, and informant consultations, Keller and Stein (1995:4) had trouble distinguishing the structures: Within the study area at least 17 and perhaps as many as 29 individual wickiup shelter locations were seen (Figure 2). Each wickiup location consists of a vague clearing 10 to 15 feet in diameter relatively free of rocks and vegetation. Ill-defined semicircular clusters of stone, or stone alignments acting as retaining walls, are associated with some of the cleared areas. Agave was a Yavapai staple, and roasting pits were constructed to cook it. Agave was also a staple of the Southern Sinagua, and roasting pits not directly associated with diagnostic artifacts have seldom been the subject of detailed studies that might determine cultural association.

Historic Yavapai and Apache

Historic use of the Middle Verde and Fossil Creek drainages included both Yavapai and Apache groups. Fur trappers observed the Southeastern (Kewevkapaya) and Northeastern (Wipukpaya) Yavapai and Northern Tonto Apache in the Verde Valley (Basso 1983; Khera and Mariella 1983). Both Yavapai and Apache followed a pattern of seasonal encampments located near ripening plant foods, and both groups supplemented their diet with agricultural crops. Agave was a staple for Yavapai and Apache alike, and Fossil Creek was an important food gathering area. Agave was available on the middle slopes around the creek, the mouth of the creek was important for mesquite beans, and the lower portion of the creek was a source of cactus fruit (Aschmann 1963: 24–29, 202–208). Ceramics from this period consist of Tizon Brown Ware, and projectile points are small triangular points referenced as Desert Side-notched (Fish and Fish 1977; Pilles 1981a: 168–170). In 1871, the Camp Verde Indian Reserve was established along the Verde River near present day Camp Verde; in 1875, the Federal government forcefully moved the Yavapai and Apache people then living in the Verde Valley to San Carlos (Stein 1981:23). The original Camp Verde Indian Reserve was simply eliminated, and Anglo settlers and miners laid claim to the lands. In the early 1900s, the Yavapai and Apache were allowed to return to the Verde Valley and in 1910, the Camp Verde Reservation was established (Munson 1981).

Recreation

Exceptional scenery and perennial stream flow have created a demand for recreation in upper and middle portions of Fossil Creek. Forest Plan emphasis for management of visitor use in these areas calls for dispersed recreation. Within the project area, the most popular recreational activities include sightseeing, hiking, primitive camping, wildlife viewing, hunting, and angling. Sightseeing, camping, and angling are most intensively practiced in road accessible areas along a 2.9- mile segment of Fossil Creek south of Irving. Recreational use within wilderness segments of the project area is low due to general remoteness, rugged terrain, and lack of a developed trail system.

Over the past several years, adverse visual impacts along road-accessible streamside areas have resulted from increasing evidence of human activity such as fire rings, soil destabilization, and damage to vegetation. These intruding visual elements locally detract from the overall natural character of the valley landscape.

Grazing

There are seven grazing allotments in the Fossil Creek Watershed on both the Coconino and Tonto National Forests. They can best be described by the Proposed Action for Fossil Creek Planning Area (USDA 2002):

> Several grazing allotments and numerous pastures exist in the planning area. Most of the upland slopes less than 40 percent are classified as unsatisfactory resulting from the loss of ground cover, plant composition changes, bare and compacted soils and increased runoff during storm events. These conditions have damaged upland soils and impaired two tributaries that flow into the middle portion of Fossil Creek. Livestock grazing uses and activities have historically impacted the flat terraces adjacent to the creek and its two tributaries. These same terraces also contain the remains of prehistoric ruins. While recent livestock management has restricted and eliminated livestock use adjacent to the creek and terraces within the middle reach, some grazing impacts are still evident.

Reach Summaries

Photo 9. Reach X, NSO 88, S8. Algal growth in the stream which helps in travertine formation (13 April 05).

Reach IX: Irving Power Plant to Barrier

Reach IX starts at the Irving Power Plant (T12N, R7E, Sec. 28, elev. 3,760') and continues upstream 1.3 miles (6,905') to a natural waterfall barrier (T12N, R22E, Sec. 22, elev. 4,012'). The average gradient was 3.8% with a mapped sinuosity of 1.02. The Rosgen stream type is a B2 with a boulder dominated substrate. Reach IX was surveyed on April 11th and 12th, 2005.

Photo 10. Reach IX, NSO 27, P11 and NSO 28 R11. Typical riffle/pool habitat (11 April 05).

Reach IX starts at the upstream side of a ford crossing leading to Irving Power Plant. The reach consists of left and right bank (looking upstream) bedrock confinements alternating with open floodplains on the right bank. Travertine formations are abundant throughout Reach IX. Forest Road 708 parallels the right bank of Fossil Creek for the first third of this reach. Fossil Creek Trailhead parking lot is approximately 150 feet away from the creek on the right bank. Trails and dispersed camping areas are intermittently found on both banks.

Reach IX mainly consists little to no overstory shade. However, the streamside woody vegetation that does provide shade consists of alder, cottonwood, sycamore, and willow. Juniper is present intermittently on the both banks above the creek. Algae are also present throughout Reach IX along the creek bottom as well as in tributaries.

No LWD was observed Reach IX. A high flow event occurred in February 2005 as a result of atypical amounts of rain and snow runoff. Impact is evident all along Reach IX. Debris could be found overhead in trees. It is very apparent that water came ripping through this reach. A majority of woody debris had moved over the banks and was not within bankfull; however, five small woody debris pieces were present within bankfull.

Fish were infrequently observed in Reach IX. A couple of suckers were seen as well as dispersed groups of young-of-year less than or equal to one inch. A black hawk was seen flying overhead toward the end of Reach IX.

Water temperatures were measured at random intervals and at tributary confluences during this survey using a handheld thermometer. Main channel temperature readings were taken in the water column. The maximum temperature observed was 63ºF and the minimum was 53ºF. The average of all samples was 58ºF. Reach IX had the coldest recorded temperatures during the survey. Further downstream from Fossil Springs the more it appears that stream temperature is more climatic driven.

Habitat Characteristics

Nearly equal numbers of riffles (18) and pools (19) are evenly distributed throughout Reach IX. This reach has three left bank side channels that contain a very stable island of either cobble and boulder or bedrock. These islands all contain woody vegetation but little to no soil. Twelve tributaries were found in this reach. They are about evenly distributed between both banks and are made up of either springs or seeps with little to no flow. Reach IX also contains five falls/chutes all of which are natural (see Photo 11), do not act as barriers to upstream fish migration, and are in a confined channel (except for NSO 50, F5; see Photo 12).

Table 10. Summary of Reach IX habitat types.

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length¹ (%)	Stream Habitat² (%)
Pool	19	2,456	37.0	35.5
Riffle	18	4,085	61.5	59.2
Culvert	0	-	-	-
Tributary	12	-	-	-
Falls/Chutes	5	103	1.5	1.5
Side Channel	3	261	-	3.8
Total	57	6,905	100	100

[1]percent stream length calculated with only riffle, pool, culvert, and falls habitat types.
[2]percent stream habitat calculated using all stream habitat types except tributary.

Photo 11. Reach IX, NSO 25, F2. Chute habitat (11 April 05).

Table 11. Summary of riffle habitat and substrate composition in Reach IX.

Reach	# Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max Depth	
IX	47	299	28.5* (25.8 est.)	1.6	2.9	
Substrate Summary (%)						
Reach	Sand	Gravel	Cobble	Boulder	Bedrock	Total
IX	5.5	13.2	26.2	31.1	24.0	100

* Average corrected width was calculated with less than the required measured units and may not be statistically valid.
Orange=Dominant Substrate

Riffles contain low amounts of fine sediment with boulder as the dominant substrate. The width-to-depth ratio is functioning properly when related to Rosgen stream classification.

Table 12. Summary of pool habitat and substrate composition in Reach IX.

Pool Habitat Summary											
Reach	# Pool Habitats	Avg. Length (ft)	Avg. Width (ft)	Avg. Max Depth (ft)	Avg. PTC (ft)	Avg. Residual Depth (ft)	Pools per mile	# Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/mi.	# Pools w/ Max Depth >3'	Pools w/ Max Depth >3'/mi.
IX	19	129.3	31.4* (31.4 est.)	6.5	1.0	5.5	15.1	19	15.1	19	15.1

Substrate Summary (%)						
Reach	Sand	Gravel	Cobble	Boulder	Bedrock	Total
IX	9.5	12.1	15.8	21.1	41.6	100.0

* Average corrected width was calculated with less than the required measured units and may not be statistically valid.
Orange=Dominant Substrate

Reach IX contained high quality pools with all having a residual depth average of 5.5 feet (see Photo 12 and Table 12). Reach IX also contained the highest quantity of pool habitat during the survey (35.5%; see Table 10). Active pool enhancement from travertine deposits has been nearly eliminated with the damming and restriction of Fossil Springs. Bedrock was the most common pool forming feature that was encountered in Reach IX with historic travertine deposition enhancing pools. .

Photo 12. Reach IX, NSO 30, P12. C. Dentino (on LB) accentuates the large size of pool habitat (11 April 05).

Photo 13. NSO 57, P19 and NSO 58, F6. Pool marks the end of Reach IX and the falls act as the beginning of Reach X (12 April 05).

Bank instability was low (1.4%) with banks in good condition, even after a large flood event. B2 stream types have been found to be very resilient to disturbances (Rosgen 1996). There is a small section at the beginning of the reach that contains instability related to the trailhead.

Table 13. Habitat characteristics for Reach IX.

Reach	Pool:Riffle Ratio	Avg. Bankfull Width:Depth	Pieces of LWD per mile	Total Unstable Banks (ft)	% Unstable Banks
IX	1:1	29.3:1	0	180	1.4

The lack of LWD could be a result of the February 2005 flooding. It appeared that the flooding that occurred had moved a lot of the LWD out of the channel and into the floodplain outside of bankfull, thus making uncountable. With the return of full flows, there will likely be a change in bankfull and an increased stability, making more wood available in the channel.

Reach X: Barrier to Fossil Springs Diversion Dam

Reach X starts at the waterfall barrier (T12N, R22E, Sec. 22, elev. 4,012') and ends at the Fossil Springs Diversion Dam (T12N, R22E, Sec 14, elev. 4,242'). The flume that runs the length of the creek from the dam to the Irving Power Plant can be seen at times throughout Reach X. The average gradient was 1.9% while the sinuosity was 1.02. The Rosgen Stream type is a B2 with boulder as the dominant substrate. Reach X was surveyed from April 12th to 14th, 2005.

Photo 14. Reach X, NSO 98, R34. Narrow channel with bedrock confinement (13 April 05).

The valley floor consists of left and right bank bedrock confinements alternating with open floodplains on both banks. Within the bedrock confinements there is little to no vegetation, while the floodplains contain woody and low growing vegetation. Travertine formations are abundant throughout Reach X (see Photo 3). A very unique narrow channel exists in part of Reach X (see Photo 14). Both banks consist of bedrock confinements.

The overstory of Reach X consists of alder, willow, sycamore and cottonwood. Very large cottonwoods and sycamores can be found in Reach X. Algae can be seen throughout this reach. The creek bottom, at times, looks to be covered in a carpet of algae making it difficult to differentiate substrate. Clumps of algae helping travertine formation were also found.

Black hawks were observed. Assortments of fish were noted (suckers, chubs, young-of-the-year, and some unknown fish).

Water temperatures were measured at random intervals and at tributary confluences during this survey using a handheld thermometer. Main channel temperature readings were taken in the water column. The maximum temperature observed was 69ºF and the minimum was 60ºF. The average of all samples was 66ºF. Further downstream from Fossil Springs the more it appears that stream temperature is more climatic driven.

Habitat Characteristics

Table 14. Summary of Reach X habitat types.

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length¹ (%)	Stream Habitat² (%)
Pool	27	3,582	29.0	25.5
Riffle	26	8,513	70.0	60.5
Culvert	0	-	-	-
Tributary	5	-	-	-
Falls/Chutes	4	91	1.0	0.7
Side Channel	11	1,874	-	13.3,
Total	65	14,060	100	100

¹percent stream length calculated with only riffle, pool, culvert, and falls habitat types.
²percent stream habitat calculated using all stream habitat types except tributary.

Habitat units consisted of 11 side channels that were about evenly split between both banks (see Photo 15). Three of the five tributaries enter the main channel from the left bank. Reach X contains 4 falls and the diversion dam. Two of these are barriers to fish migration. Some of the channels within this reach appear to have been blown out by the high flow event (see Photo 17).

Reach X contains 26 riffles which made up the dominant habitat. These riffles are relatively long with an average length of 327 feet (see Table 15). Dominant substrate was boulder followed by cobble. The width-to-depth ratio was well within the range of what you expect for a properly functioning system.

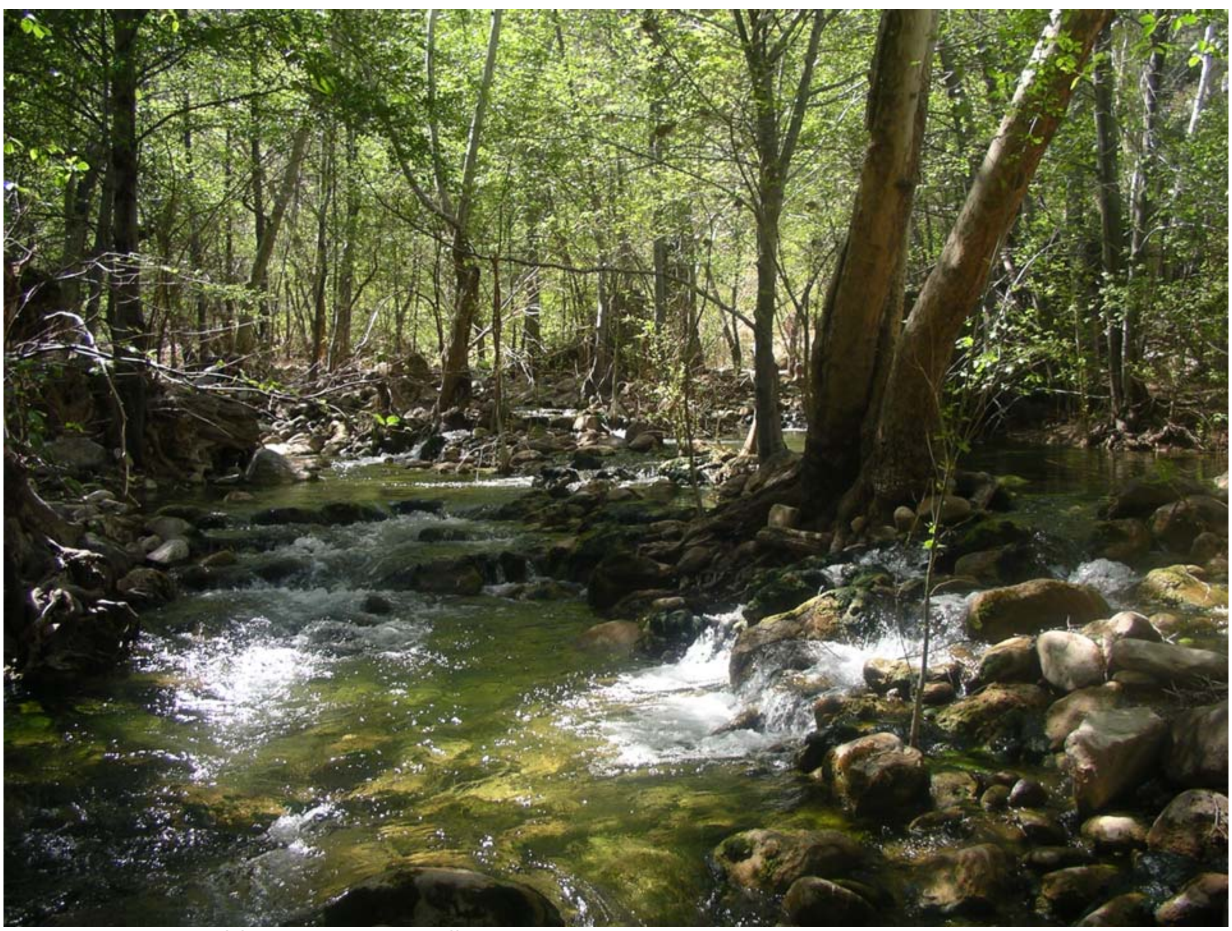

Photo 15. Reach X, NSO 108, R37. Typical riffle habitat with side channels entering on the right (14 April 05).

Table 15. Summary of riffle habitat and substrate composition for Reach X.

Riffle Habitat Summary (ft)						
Reach	# Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max Depth	
X	26	327	20.5 (22 est.)	2.8	1.9	
Substrate Summary (%)						
Reach	Sand	Gravel	Cobble	Boulder	Bedrock	Total
X	6.5	14.6	28.8	33.5	16.5	100.0

* Average corrected width was calculated with less than the required measured units and may not be statistically valid.
Orange =Dominant Substrate

Reach X had 27 pools with some instances where two or more pools were lumped together. Pool quality was high in this reach with an average residual depth of 6.2 feet (see Table 16). Pool quantity was 25% (see Table 14). Pool habitat should increase in Reach X with the return of full flows and increased travertine formation. Bedrock continued to be the most common pool forming feature with historic travertine deposition enhancing pools.

Table 16. Summary of pool habitat and substrate composition in Reach X.

Pool Habitat Summary											
Reach	# Pool Habitats	Avg. Length (ft)	Avg. Width (ft)	Avg. Max Depth (ft)	Avg. PTC (ft)	Avg. Residual Depth (ft)	Pools per mile	# Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/mi.	# Pools w/ Max Depth >3'	Pools w/ Max Depth >3'/mi.
X	27	133	28* (28.3 est.)	7.1	0.9	6.2	11.7	27	6.2	26	11.3

Substrate Summary (%)						
Reach	Sand	Gravel	Cobble	Boulder	Bedrock	Total
X	5.9	11.5	25.2	27.8	29.6	100.0

* Average corrected width was calculated with less than the required measured units and may not be statistically valid.
Orange =Dominant Substrate

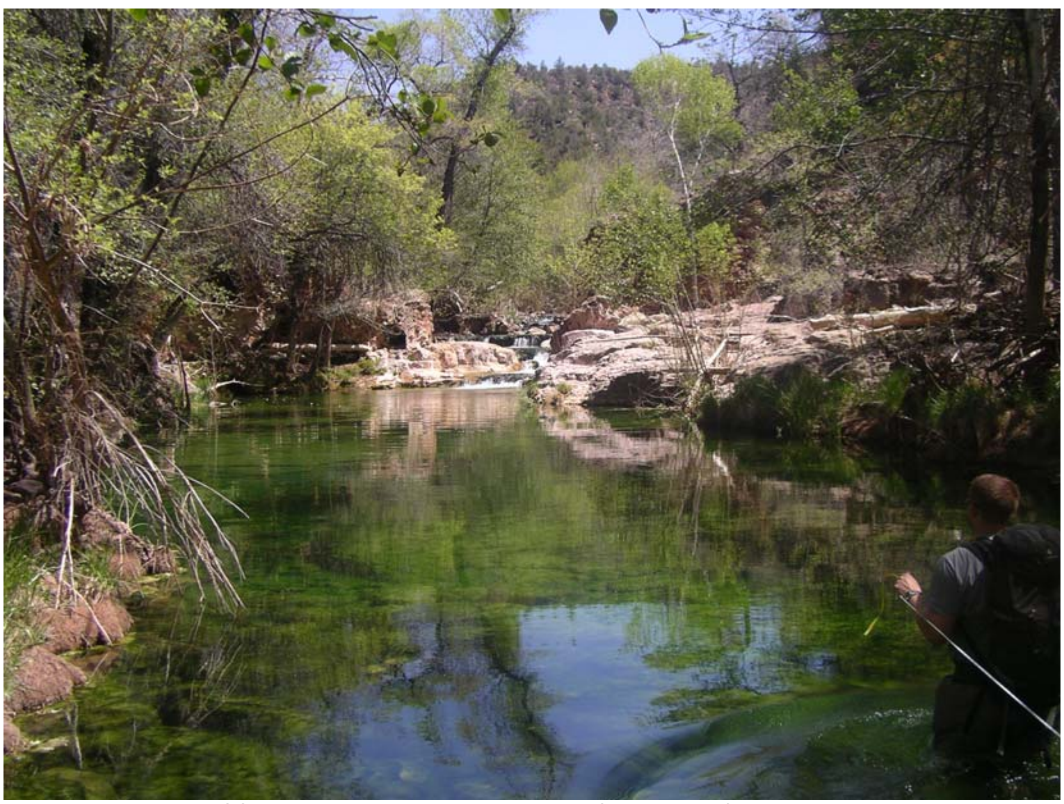

Photo 16. Reach X, NSO 120, P42. Typical pool habitat with C. Dentino in foreground (14 April 05).

LWD was uncommon in Reach X. Evidence of the high flow event that occurred in February 2005 can be seen throughout. Woody debris can be found on both banks within and out of bankfull. Reach X has a total of 9 pieces of LWD. There is good LWD recruitment possibility within Reach X. A flume washout is also evident. Metal debris can be found at times along the left bank with other floodwater carnage.

Table 17. Habitat characteristics for Reach X.

Reach	Pool:Riffle Ratio	Avg. Bankfull Width:Depth	Pieces of LWD per mile	Total Unstable Banks (ft)	% Unstable Banks
X	1:1	18.6:1	3.9	356	1.0

Instability is very low in Reach X (1.0%), likely due to large substrate armoring the banks. Trails and dispersed camping areas are intermittently found on both banks.

Photo 17. Reach X, NSO 64, R20. Debris deposition from February 2005 flood event (12 April 05).

Reach XI: Diversion Dam to Source

Reach XI begins at the Fossil Springs Dam (T12N, R22E, Sec 14, elev. 4,242') and ends 0.43 miles upstream at the start of uppermost perennial flow from Fossil Springs (T12N, R22E, Sec. 12, elev., 4,290'). The source of Fossil Creek's perennial flow is very evident in Reach XI with numerous springs and seep complexes. The average gradient was 2.1% while the sinuosity was 1.20. The Rosgen Stream type is a B3. Reach XI was surveyed on April14thand April 15th, 2005.

Photo 18. Reach XI, NSO 151, T30. T. Webb sits next to seeping wall with thick vegetation (14 April 05).

Reach XI contains 3 riffles, 3 pools, 4 side channels, and 18 tributaries. All of the side channels were located on the right bank. Of the 18 tributaries, only 2 enter the main channel on the right bank. All tributaries had water temperatures around 70ºF. They included springs and seeps that were providing all the perennial flow to Fossil Creek (see Photo 18). Above the last spring, water in the channel disappeared and riparian vegetation was drastically reduced (Photo 21).

The overstory consisted of alder, willow, cottonwood, ash, maple and sycamore. Grasses, mats of Himalayan Blackberry, and unknown shrubs are also present. At times steep walls of vegetation, mainly Himalayan Blackberry, confine the channel on the left bank. Algae are less present at the beginning of Reach XI, but 0.2 miles into the reach the algae returns in mass.

A kingfisher and great blue heron were observed in this reach. Assortments of fish were noted (suckers, chubs, and young-of-year).

Water temperatures were measured at random intervals and at tributary confluences during this survey using a handheld thermometer. Main channel temperature readings were taken in the water column. The maximum temperature observed was 70ºF and the minimum was 67ºF. The average of all samples was 69ºF. Reach XI had the warmest recorded temperatures at this time of year. Further downstream from Fossil Springs the more it appears that stream temperature is more climatic driven.

Habitat Characteristics

Table 18. Summary of Reach XI habitat types.

Habitat Type	Number of Habitats	Total Stream Habitat (ft)	Stream Length[1] (%)	Stream Habitat[2] (%)
Pool	3	835	36.4	25.5
Riffle	3	1459	63.6	44.6
Culvert	0	-	-	-
Tributary	18	-	-	-
Falls	0	-	-	-
Side Channel	4	977	-	29.9
Total	65	3,271	100	100

[1]percent stream length calculated with only riffle, pool, culvert, and falls habitat types.
[2]percent stream habitat calculated using all stream habitat types except tributary.

Reach XI is dominated by smaller substrate (see Photo 19) with much less travertine (though it is still present). Bedrock substrate turns into reddish plates above the springs, and vegetation and water becomes scarce. The banks are dominated with thick woody and low growing vegetation at the beginning of Reach XI. Both banks at Reach XI's conclusion convert to cobble and boulder bars with less vegetation and exposed tree roots.

Photo 19. Reach XI, NSO 134, R46. Riffle habitat below Fossil Springs, notice small substrate (14 April 05).

Table 19. Summary of riffle habitat and substrate composition in Reach XI.

Reach	# Riffles	Avg. Length	Avg. Width	Avg. Depth	Avg. Max Depth	
XI	3	486	22.3 est.*	1.9	2.7	
Substrate Summary (%)						
Reach	Sand	Gravel	Cobble	Boulder	Bedrock	Total
XI	3.3	23.3	40.0	33.3	0.0	100

* Average corrected width could not be calculated so the estimated width is given.
Orange =Dominant Substrate

Reach XI riffles were long (486 feet) and contained smaller substrate (cobble) associated with higher mean flows. The first two (of the 3) riffles in this reach are in narrow channels with fast moving water and undercut banks on both banks (see Photo 19). Both banks of the last riffle are cobble and boulder bars.

Table 20. Summary of pool habitat and substrate composition in Reach XI.

Pool Habitat Summary											
Reach	# Pool Habitats	Avg. Length (ft)	Avg. Width (ft)	Avg. Max Depth (ft)	Avg. PTC (ft)	Avg. Residual Depth (ft)	Pools per mile	# Pools w/ Residual Depth >1'	Pools w/ Residual Depth >1'/mi.	# Pools w/ Max Depth >3'	Pools w/ Max Depth >3'/mi.
XI	3	278	54.6* (50.0 est.)	6.7	1.4	5.3	7.0	3	7.0	3	7.0

Substrate Summary (%)						
Reach	Sand	Gravel	Cobble	Boulder	Bedrock	Total
XI	16.7	23.3	30.0	16.7	13.3	100

Average corrected width was calculated with less than the required measured units and may not be statistically valid.
Orange =Dominant Substrate

Photo 20. Reach XI, Deep pool habitat associated with springs is popular for recreating. In this case, HS students are conducting a fish survey (15 April 05).

All pools in Reach XI were high quality pools (average residual depth 5.3'; see Photo 20). Forming features varied from the dam, bedrock, and boulders. Travertine was not a pool forming feature in Reach XI. Dam deconstruction and the return of flows won't likely have an effect on travertine formation and pool development in Reach XI. Limestone layers could be seen at the upper part of the reach and are responsible for forming one of the pools.

Table 21. Habitat characteristics for Reach XI.

Reach	Pool:Riffle Ratio	Avg. Bankfull Width:Depth	Pieces of LWD per mile	Total Unstable Banks (ft)	% Unstable Banks
XI	1:1	12.8	9.2	0	0.0

Trails run the length of Reach XI on both the floodplain and slopes. Dispersed campsites are also present on both sides. All of the trails and campsites were far enough away from the water's edge and banks (mostly due to Himalayan Blackberry) and were not causing any bank instability.

Photo 21. Above springs and end of survey where flows are intermittent. Notice limestone bedrock with less riparian vegetation (15 April 05).

APPENDIX A

Supporting Information

Table 1. Summary of measurements and estimations used in the Region 3 Hankins/Reeves stream survey protocol (Stream Inventory Handbook April 2003).

Measurements	Estimations
Maximum depth of pools, riffles, and side channels	Average depth of riffles
Depth of pool tail crest	Substrate percentages in bankfull width
One bankfull width depth transect per reach	Average wetted width of riffles and pools*
Number of large woody debris within bankfull	Length of bank instability
Surveyor collected main channel and tributary water temperature and time	Total length, wetted width, and maximum depth of side channels
Thermograph collected water temperature (Recorded every four hours)	Length of first habitat unit of tributaries and percent stream flow contribution

**Width estimations were corrected by the comparison of a minimum of 10% measured habitats in each reach to the related estimates. This technique was used to produce correction factor for each reach, which was then applied to analysis of the widths of that reach and the entire stream analysis.*

Table 2. Feature types collected by Trimble Geo Explorer 3 GPS units.

Reach Breaks	Tributary Mouth
Woody Debris Jams (of 3 or More Pieces)	Barriers to Fish Passage
Areas of Concern (Major Erosion, Road Crossings, Etc…)	Side Channels (only longer than 10 times the wetted width of the main channel)
Beaver Dams (If Active and over 1’ in Height)	Thermograph Stations
Snorkel Survey Transect Locations	Culverts
Flow Stations	Water Temperature Monitoring Stations

APPENDIX B

Tributaries

Table 1. Summary of tributaries contributing surface flow to Fossil Creek during the 2005 Stream Inventory.

Location		Bank	Habitat Type	Name	% Flow*	Time	Tributary Temp (°F)	Stream Temp Below (°F)	Stream Temp Above (°F)	Comments
Reach	Tributary Number									
IX	1	Left	Stream	-	-	11:10	59	56	56	5-10% gradient
IX	2	Left	Stream	-	-	12:00	74	57	57	15% gradient
IX	3	Right	Seep	-	<5%	12:46	58	59	-	20-30% gradient
IX	4	Right	Seep	-	-	12:46	67	59	-	-
IX	5	Right	Seep	-	-	14:08	65	63	-	-
IX	6	Right	Stream	-	-	-	-	-	-	Dry
IX	7	Left	Seep	-	-	-	-	-	-	Seeps out of Bedrock
IX	8	Left	Stream	-	<5%	17:21	61	62	62	80% gradient
IX	9	Left	Seep	-	<5%	17:36	64	62	-	-
IX	10	Right	Seep	-	<5%	9:55	53	56	-	6-8% gradient
IX	11	Right	Spring	-	-	10:35	55	57	-	Starts about 200' from pool
IX	12	Right	Spring	-	≈5%	11:35	62	58	-	4% gradient
X	13	Left	Seep	-	-	-	-	63	-	-
X	14	Left	Stream	-	-	-	-	-	-	A lot of H2o went through
X	15	Left	Seep	-	<1%	15:40	77	68	-	75% gradient
X	16	Right	Seep	-	-	-	-	-	-	-
X	17	Right	-	-	<1%	14:10	56	-	69	12-15% gradient
XI	18	Left	Spring	Fossil Springs	20%	15:45	70	68	-	15% gradient
XI	19	Left	Spring	Fossil Springs	5%	9:52	70	71	-	15% gradient
XI	20	Left	Spring	Fossil Springs	5%	9:52	70	71	-	15% gradient
XI	21	Left	Spring	Fossil Springs	5%	10:00	70	71	-	15% gradient
XI	22	Left	Spring	Fossil Springs	<1%	10:05	70	71	-	20% gradient
XI	23	Left	Seep	Fossil Springs	<5%	10:10	69	71	-	10% gradient
XI	24	Left	Seep	Fossil Springs	<5%	10:15	69	71	-	8% gradient
XI	25	Left	Spring	Fossil Springs	<1%	10:20	68	71	-	4% gradient
XI	26	Left	Spring	Fossil Springs	<5%	10:25	69	71	-	8% gradient
XI	27	Left	Spring	Fossil Springs	<1%	10:30	69	71	-	4% gradient
XI	28	Left	Spring	Fossil Springs	5%	10:35	70	71	-	6% gradient
XI	29	Left	Spring	Fossil Springs	5%	-	-	71	-	80% gradient
XI	30	Left	Spring	Fossil Springs	≈10%	10:40	70	71	-	70% gradient
XI	31	Left	Seep	Fossil Springs	20%	-	-	-	-	70% gradient
XI	32	Right	Seep	Fossil Springs	<1%	11:50	63	-	-	20% gradient
XI	33	Right	Seep	Fossil Springs	<1%	12:00	65	-	-	20% gradient
XI	34	Left	Spring	Fossil Springs	50%	12:15	69	-	69	4% gradient
XI	35	Left	Seep	Fossil Springs	-	12:50	69	67	63	-

*-Percent flow is a visual estimate by the surveyors and therefore should not be considered an exact measurement

APPENDIX C

Wildlife

Table 1. Threatened, endangered, sensitive, and management indicator species (MIS) for the Fossil Creek area (terrestrial species; Northern Arizona University 2005).

Common Name	Scientific Name	Status
Federally Listed (Endangered, Threatened, Proposed) (5)		
Bald Eagle	*Haliaetus leucocephalus*	T, WC, Sen, MIS
Mexican Spotted Owl	*Strix occidentalis lucida*	T, WC, Sen, MIS
Southwestern Willow Flycatcher	*Empidonax traillii extimus*	E, WC, Sen
Yuma Clapper Rail	*Rallus longirostris yumanensis*	E, WC, Sen
Chiricahua Leopard Frog	*Rana chiricahuensis*	T, WC, Sen
Sensitive Mammals (6)		
Southwestern River Otter	*Lutra canadensis sonora*	SC, WC,Sen
Western Red Bat	*Lasiurus blossevillii*	WC, HP
Spotted Bat	*Euderma maculatum*	WC, HP
California Leaf-nosed Bat	*Macrotus californicus*	WC, HP
Allen's Big-eared Bat	*Idionycteris phyllotis*	HP
Townsend's Big-eared Bat	*Corynorhinus townsendii* (formerly *Plecotus)*	HP
Sensitive Birds (6)		
American Peregrine Falcon	*Falco peregrinus anatum*	WC, Sen
Common Black Hawk WC,	*Buteogallus anthracinus*	Sen, MIS
Western Yellow-billed Cuckoo	*Coccyzus americanus occidentalis*	C, WC, Sen
Bell's Vireo	*Vireo bellii*	Sen, MIS
Sensitive Amphibians (2)		
Lowland Leopard Frog	*Rana yavapaiensis*	SC, WC, Sen
Arizona Toad	*Bufo microscaphus microscaphus*	SC, Sen
Sensitive Reptiles (3)		
Narrow-headed Garter Snake	*Thamnophis rufipunctatus*	SC, WC, Sen
Mexican Garter Snake	*Thamnophis eques megalops*	SC, WC, Sen
Arizona Night Lizard	*Xantusia vigilis arizonae*	Sen
Sensitive Snails (1)		
Fossil Springsnail	*Pyrgulopsis simplex*	SC, Sen
Sensitive Invertebrates (14)		
Maricopa Tiger Beetle	*Cicindela oregona maricopa*	SC, Sen
Tiger Beetle	*Cicindela hirticollis corpuscular*	Sen
Freeman's Agave Borer	*Agathymus baueri freemani*	Sen
Neumogen's Giant Skipper	*Agathymus neumoegeni*	Sen
Aryxna Giant Skipper	*Agathymus aryxna*	Sen
Blue-black Silverspot Butterfly	*Speyeria nokomis nokomis*	SC, Sen
Mountain Silverspot Butterfly	*Speyeria nokomis nitocris*	Sen

Obsolete Viceroy Butterfly	*Limenitis archippus obsolete*	Sen
Early Elfin	*Incisalia fotis*	Sen
Comstock's Hairstreak	*Callophrys comstocki*	Sen
Spotted Skipperling	*Piruna polingii*	Sen
Netwing Midge	*Agathon arizonicus*	Sen
Hoary Skimmer	*Libelula nodisticta*	Sen
Arizona Snaketail	*Ophiogomphus arizonicus*	Sen
Other Management Indicator Species (10)		
Yellow-breasted Chat	*Icteria virens*	MIS
Cinnamon Teal	*Anas cyanoptera*	MIS
Lucy's Warbler	*Vermivora luciae*	MIS
Lincoln's Sparrow	*Melospiza lincolnii*	MIS
Summer Tanager	*Piranga rubra*	MIS
Hooded Oriole	*Icterus cucullatus*	MIS
Hairy Woodpecker	*Picoides pubescens*	MIS
Warbling Vireo	*Vireo gilvus*	MIS
Western Wood Pewee	*Contopus sordidulus*	MIS
Arizona Gray Squirrel	*Sciurus arizonensis*	MIS

E = Federally listed as Endangered under Endangered Species Act (ESA)
EXNE = Federally Endangered, Experimental, Non-essential
T = Federally listed as Threatened under ESA
P = Federally Proposed for listing under the ESA
C = Federally designated as Candidate for listing
WC = Wildlife of Special Concern in Arizona (AGFD in prep. 1996)
Sen = On Regional Forester's Sensitive Species List (7/21/99)
HP = High Priority Species; "at high risk of imperilment" (Western Bat Species Regional Priority Matrix (1998)
MIS = Tonto and Coconino Management Indicator Species from the Respective Forest Plans
SC = Federal Species of Concern (former C2 species)

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