# Improvement Plan for the Oak Creek Watershed, Arizona

Prepared by the Oak Creek Watershed Council
For Arizona Department of Environmental Quality
In partial fulfillment of
CWA § 319H contract no. EV09-0035, Project 11T03

August 31, 2012

## Acknowledgements

The development of this plan was funded by the **Arizona Department of Environmental Quality** (ADEQ) Water Quality Improvement Grant (WQIG) program. The WQIG program awards funding to water quality projects focused on nonpoint source pollution throughout the state. Funding for this program is provided by the US EPA pursuant to Section 319(h) of the Clean Water Act.

**Oak Creek Watershed Council**
Plan development oversight was provided by Oak Creek Watershed Council in conjunction with the Oak Creek Watershed Improvement Commission (WIC). Oak Creek Watershed Council is a 501(c)(3) nonprofit organization that exists to protect the Oak Creek Watershed environment as well as the integrity of Oak Creek and its tributaries.

**Oak Creek Watershed Improvement Commission**
The WIC is a voluntary group of watershed stakeholders including local and state government and land management agencies, as well as local residents and community groups. Individuals and organizations represented on the WIC include:

Amina Sena, USDA Forest Service
Josh Myers, Yavapai County
Steve Pawlowski, Sierra Club
Charles Mosley, City of Sedona
Ken Beller, Cathedral Vista POA
Cindy Dunn, Arizona Game and Fish Dept.
Lee Luedeker, Arizona Game and Fish Dept.
Paul Lindberg, Consulting Geologist
Ryan Matson, Slow Water Team
Jeanmarie Haney, The Nature Conservancy
Steve Estes, Verde Valley Land Preservation
Sharon Masek Lopez, Northern Arizona University
Gail Clement, Consulting Geologist

**Technical support**

Arizona Department of Environmental Quality (ADEQ)
Non-point Education for Municipal Officials (NEMO)
University of Arizona Soil, Water, and Environmental Science Department
Master Watershed Stewards (MWS)
Arizona Cooperative Extension
Oak Creek Watershed Council (OCWC)

## Abstract

Previous research and monitoring in Oak Creek have found *Escherichia coli* (*E. coli)* bacteria concentrations exceeding Arizona Water Quality Standard for full body contact of 235 colony forming units per 100 ml water. Efforts have been made to try to reduce human-caused sources of *E. coli*, yet *E. coli* exceedances remain a problem especially where there is concentrated recreation in the creek, such as at Slide Rock State Park, and during storm events that deliver additional *E. coli* to the creek. The Oak Creek Watershed Council conducted a field investigation during summer 2011 to try to identify *E. coli* source areas. Water samples were collected repeatedly before and during summer monsoon at several locations along the entire stream length, from tributary flow, and from springs that discharge to Oak Creek. All samples were tested for *E. coli* bacteria. Some of these samples were also tested for turbidity and nutrient concentrations. A limited number of samples were tested to determine the presence of human, bovine and dog DNA. Results showed that *E. coli* exceedances were greatest in and below the City of Sedona with very few exceedances in Oak Creek Canyon. Exceedances often corresponded with storm flow events, were strongly related to turbidity, and may sometimes be associated with septic leakage, especially from larger commercial systems, that may be intercepted by groundwater and transported through spring discharge to the creek. The findings of the 2011 investigation support earlier studies some of which call for investigation of sediment *E. coli* reservoirs because they appear to be a primary means by which *E. coli* causes exceedances when reservoirs are disturbed either by recreation activity or turbulence caused by storm events. A series of best management practices projects regarding recreational, agricultural, residential and commercial activities in the watershed is recommended, as are continued investigations into potential contaminant pathways including septic system leakage, dog feces concentrations, and sediment reservoir development and disturbance with emphasis on tracking and reducing sediment sources as a means of reducing the *E. coli* bacteria that are harbored in sediment.

# Table of Contents

## Appendices

## List of Figures

## List of Tables

## Abbreviations

| | |
|---|---|
| 303(d) | Arizona's Impaired Waters List |
| 319(h) | Clean Water Act Section 319(h), a source of funding for nonpoint source pollution prevention |
| A&W | Aquatic and wildlife – a designated use for water quality standards |
| ADEQ | Arizona Department of Environmental Quality |
| AGFD | Arizona Game and Fish Department |
| AIS | Anthropogenicly Influenced Site |
| AUW | Arizona Unique Waters |
| AZPDES | Arizona Pollution Discharge Elimination System |
| BMP | Best Management Practices |
| cfu/100ml | colony forming units per 100 milliliters, a measure of *E. coli* concentration |
| CNF | Coconino National Forest |
| *E. coli* | *Escherichia coli* |
| EPA | United States Environmental Protection Agency |
| FBC | Full body contact – a designated use for water quality standards |
| HUC | Hydrologic Unit Code |
| NAU | Northern Arizona University |
| NEMO | Nonpoint Education for Municipal Officials |
| NPDES | National Pollution Discharge Elimination System |
| OAW | Outstanding Arizona Waters |
| OCCTF | Oak Creek Canyon Task Force |
| OCWC | Oak Creek Watershed Council |
| OCWIC | Oak Creek Watershed Improvement Commission |
| PBC | Partial body contact – a designated use for water quality standards |

| | |
|---|---|
| SAP | Sampling and Analysis Plan |
| SRSP | Slide Rock State Park |
| TDS | Total Dissolved Solids |
| TSS | Total Suspended Solids |
| TMDL | Total Maximum Daily Load |
| WIP | Watershed Improvement Plan |
| YCFCD | Yavapai County Flood Control District |

# Chapter 1 – Background

## Pollutant of Concern

Oak Creek is not attaining water quality standards for *E. coli* because for many years water samples have repeatedly exceeded the state water quality standard single sample maximum of 235 colony-forming units per 100 milliliters (235 cfu/100ml) for full body contact. The purpose of the Oak Creek Watershed Improvement Plan is to identify sources that contribute to *E. coli* impairment/standards exceedances and recommend actions to reduce human- and wildlife-related contamination so that the creek may attain the water quality standard.

Since 1973, *Escherichia coli* (*E. coli*) bacteria in the water of Oak Creek have been a concern. Previous DNA testing of water and sediment from Oak Creek has indicated that wild sources of *E. coli* bacteria include raccoon, skunk, elk, beaver, white tail deer, mule deer, bear, and mountain lion, antelope in descending order (Southam et al. 2000, OCCTF 2002) **(**Figure 1). Southam collected scat for genotyping standards and water and sediment samples and conducted genetic analysis using Amplified Fragment Length Polymorphism (AFLP). Samples were collected midweek during baseflow conditions at Pumphouse Wash, Pine Flats, West Fork, upstream and downstream of Slide Rock State Park and Grasshopper Point in Oak Creek Canyon on 11 dates in 1998 and 1999.

Southam et al. (2000) found that human-related sources [ie. from human waste and that of their pets and livestock, including human (16%), dog (6%), horse (5%), cow (4%), and llama (2%)] accounted for about 33% of *E. coli* found in waters of Oak Creek on average. It is important to note that Southam's 33% attributed to human activity is an average; human contribution to *E. coli* in Oak Creek water on individual days ranged from 0 to 70%. It is also important to note that Southam (2000) found single fecal release events, indicated by low *E. coli* diversity index, suggest that a single animal (or human) can cause a direct impact to *E. coli* reservoirs in stream sediments, which in turn may contaminate water when sediment is disturbed. The highest amount of *E. coli* concentration attributed to human source in a sediment reservoir was 125,020 cfu/100ml downstream of Slide Rock State Park on September 6, 1999.

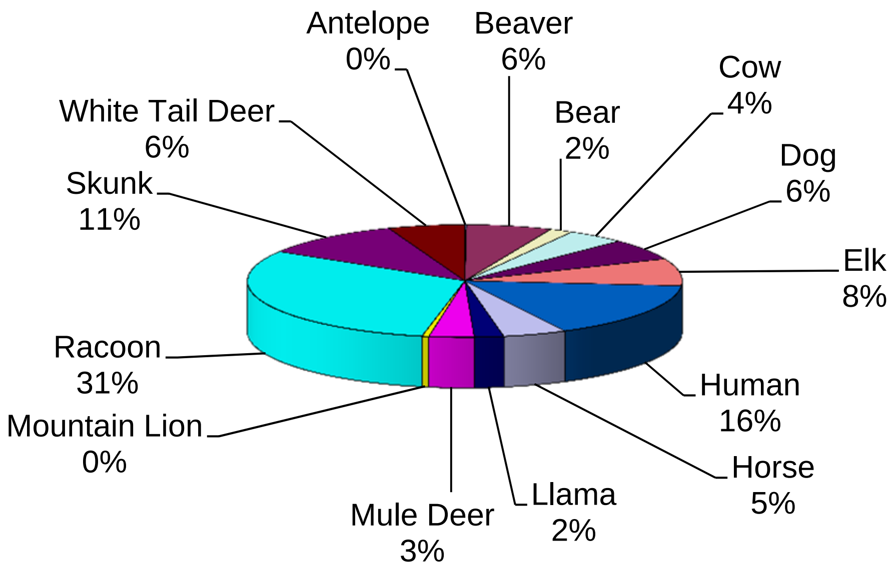



Figure 1. Distribution of *E. coli* by species compiled from Oak Creek Canyon as a whole (OCCTF 2002).

Most strains of *E. coli* are harmless and live in the intestines of warm-blooded mammals, but some strains produce a powerful toxin and can cause severe illness (EPA 2011a). These strains are called pathogens *E. coli* O157:H7 is an example of a pathogenic strain that can cause serious illness and even death, but it is uncommon. While not generally a health threat in itself, *E. coli* is used to indicate the possible presence of potentially harmful bacteria and viruses (EPA 2011b). Testing for *E. coli* is an inexpensive and practical way of monitoring potential fecal pollution. Other fecal contaminants include fecal streptococci, enterococci, *Cryptosporidium spp.*, *Giardia spp.*, *Shigella spp.*, norovirus, total coliforms, fecal coliforms and *E. coli* 0517:H7, which may cause human health problems that include skin, ear, eye, gastrointestinal, urinary tract, respiratory, neurologic and wound infections (EPA 2011c).

## Watershed Description

Oak Creek watershed is a sub-watershed of the Verde River Watershed in north central Arizona at the northern edge of the Transition Zone between the Basin and Range Province and the Colorado Plateau (Figure 2). The headwaters are in ponderosa pine forest of the Coconino National Forest at a maximum elevation of 7,629 feet, and the stream flows 50 miles in a southwesterly direction to the confluence with the Verde River at 3,180 feet elevation while passing through pinyon-juniper, high desert and riparian vegetation types. Annual precipitation in the headwaters is about 18 inches, whereas Sedona receives 12 inches per year (YCFCD 2011). Tributary ephemeral washes descend from the pine forest to Oak Creek Canyon providing streamflow primarily during snowmelt and summer monsoon storms. Oak Creek Canyon is a narrow (1 to 3 miles breadth) canyon extending from the Mogollon Rim thirteen miles downstream to the northern limit of the City of Sedona.

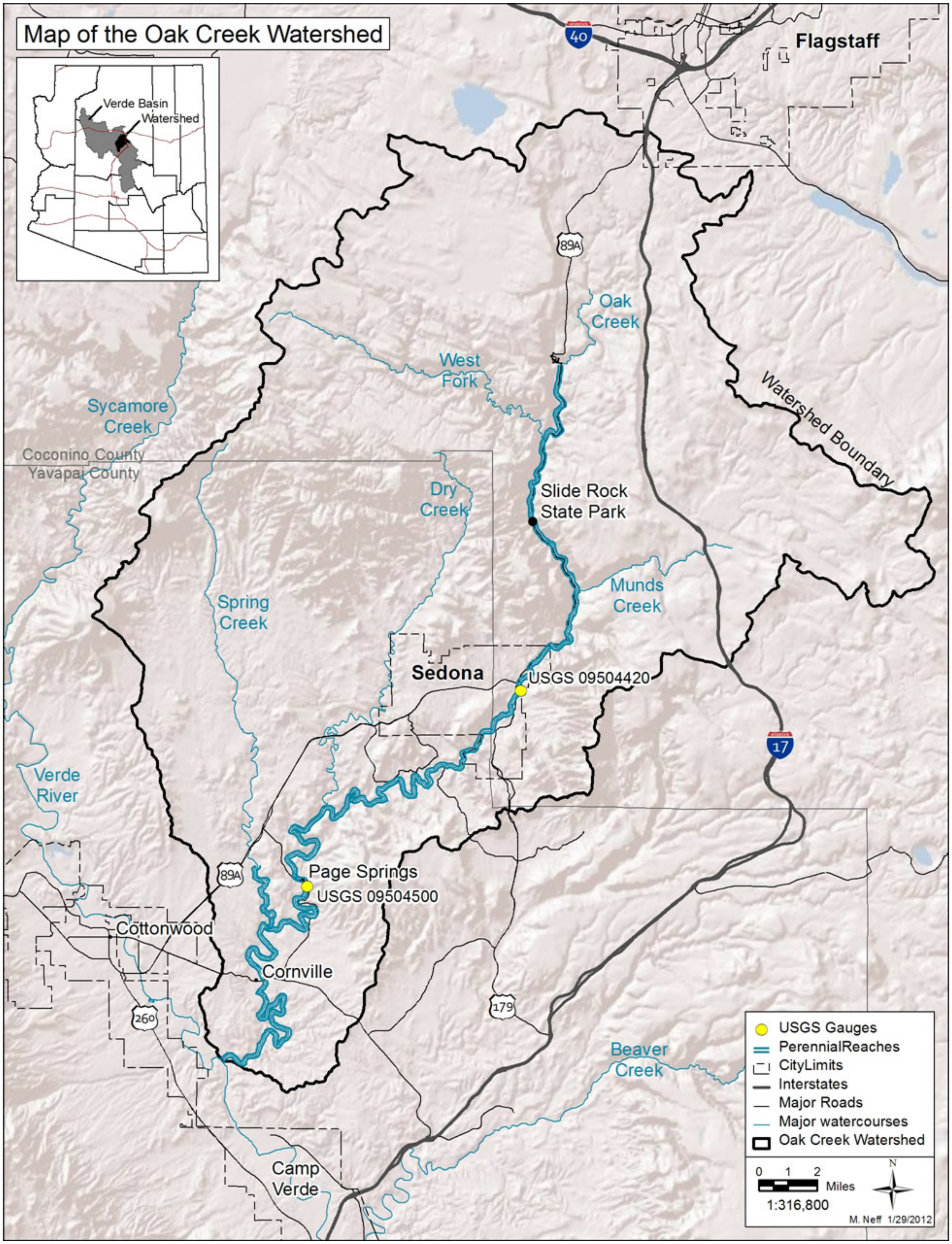



Figure 2. Oak Creek Watershed.

Springs provide perennial flow to Oak Creek. Perennial streamflow begins in Oak Creek Canyon from springs just above Sterling Springs Fish Hatchery. Numerous springs within Oak Creek Canyon issuing from the Coconino Aquifer, which includes the Coconino Sandstone, Supai Formation, and Redwall Limestone (Dryden 1998), provide base flow that increases from ~3-5 cfs near the headwaters, to 18 cfs at Slide Rock State Park and 24 cfs at the Sedona gage (OCCTF 2002). In the Page Springs area springs issuing from the Verde Formation add approximately 20 cfs to streamflow, as measured by Arizona Game and Fish Department at the Page Spring Fish Hatchery (Cindy Dunn, personal communication). Oak Creek is characterized by gaining reaches where springs are located and losing reaches between each major set of springs (Pool 2011). Baseflow at the USGS Oak Creek near Cornville gage is about 21 cfs (OCCTF 2002). Major tributaries include West Fork Oak Creek, Munds Canyon and Spring Creek which all have perennial stream flow in their lower reaches and Pumphouse Wash and Dry Creek which flow only during snowmelt and storm events. Where spring discharge sites correspond with residential development, potential exists for contamination of shallow groundwater by improperly installed or maintained septic systems, which may allow fecal contaminants to be carried to Oak Creek via spring flow (Keswick et al. 1982, Bitton and Harvey 1992).

Oak Creek watershed is situated in Coconino and Yavapai Counties. Land use within the watershed includes forestry, grazing, recreation, agriculture, residential and commercial. In Oak Creek Canyon, 54.5 acres are used by Scenic Highway 89A; 123 acres are developed as campgrounds, parking lots, picnic areas, and scenic views. Houses and homes account for 245 acres (OCCTF 2002). In 1996, 304 permanent residents were reported to live along Oak Creek (Snelling 1996). The largest land owners are public, including national forest and Arizona state lands, parks, and fish hatcheries (Figure 3). The uppermost part of Oak Creek watershed in the Pumphouse Wash subwatershed hosts a population of about 4,000 in the communities of Forest Highlands, Kachina Village and Mountainaire adjacent to Flagstaff and 630 at Munds Park (2010 Census). Numerous small residential lots are situated in the valley floor of Oak Creek canyon, some of which have full time residents and many of which are vacation homes. The city of Sedona and surrounding areas within the watershed have the largest concentration of population with 10,192 residents (U.S. Census 2010). This population swells during periods of high tourism. In Sedona a generous availability of national forest land within the developed area combined with stunning vistas translates into heavy recreational use in this reach also. Going downstream from Sedona agricultural land use is found on acreages adjacent to Oak Creek in the Red Rock Loop, Page Springs and Cornville areas. The population in the Pages Springs and Cornville area is about 3,335. Impaired reaches of Oak Creek include Oak Creek Canyon down to Spring Creek confluence and the perennial reach of Spring Creek.

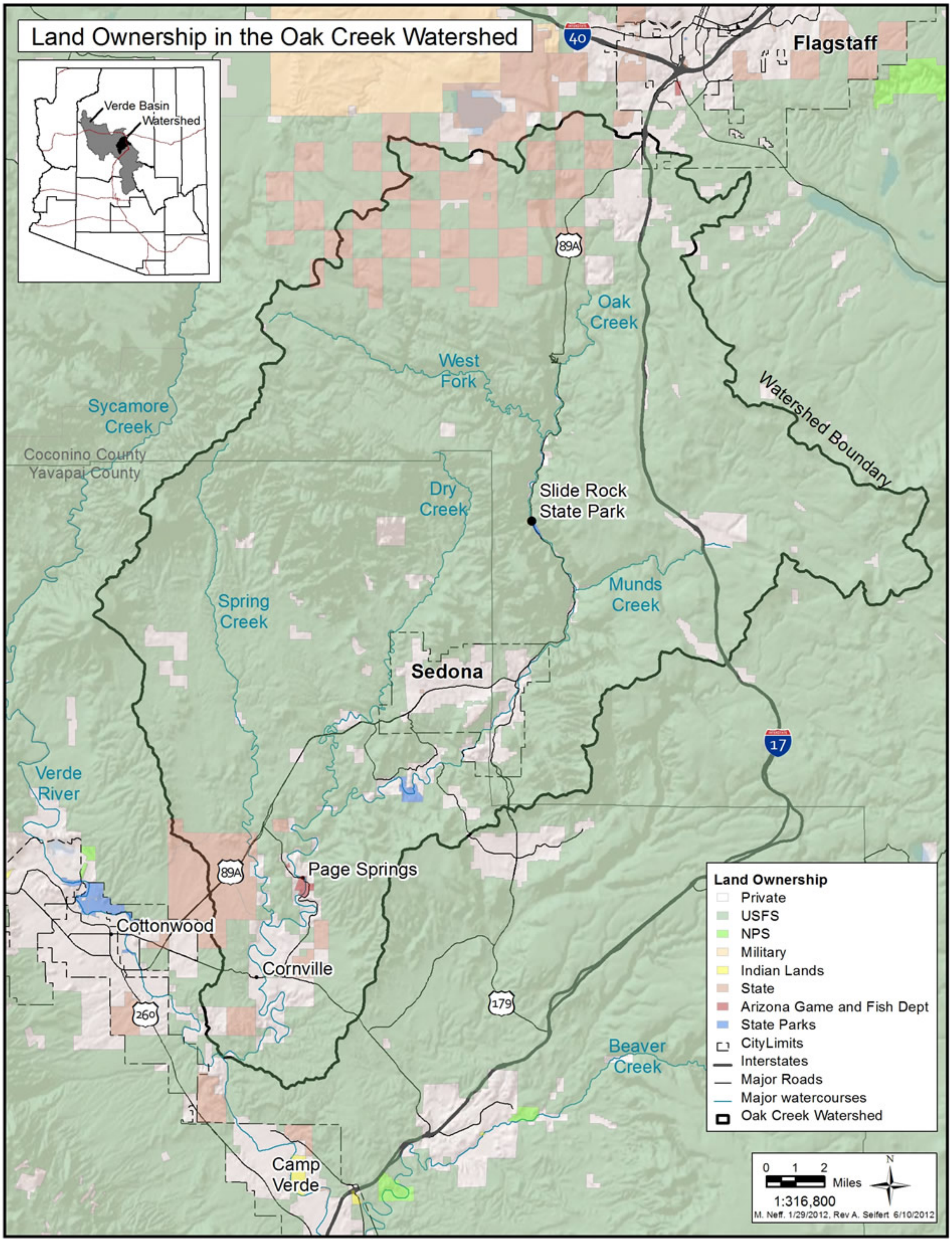



Figure 3. Land ownership in Oak Creek Watershed

## Water Quality Concerns

### Evidence of Impairment

Repeated exceedance of the *E. coli* standard in Oak Creek lead Arizona Department of Environmental Quality (ADEQ) to list Oak Creek as an impaired water and to develop a Total Maximum Daily Load (TMDL) as described below (ADEQ 2010). Seasonal deterioration in bacteriological water quality, due to impacts attributed to fecal pollution, has been observed in Oak Creek since 1973 (Obr et al. 1978). Subsequently, numerous studies and monitoring efforts have confirmed the results of the initial study and discovered the predominant mechanisms by which *E. coli* enters the water column (Jackson 1981, Rose et al. 1987, Hansen and White 1992, Southam et al. 2000) (Table 1). Water quality is impaired during periods of peak recreational use (summer months and especially holiday weekends) (Figure 4), which is to say that concentrations of *E. coli* exceed the water quality standard for the designated uses of full body contact (swimming). This is partly due to recreationalists as a source of fecal bacteria, but largely due to the disturbance of stream sediments by swimmers and waders as well by increased streamflow during storm events.

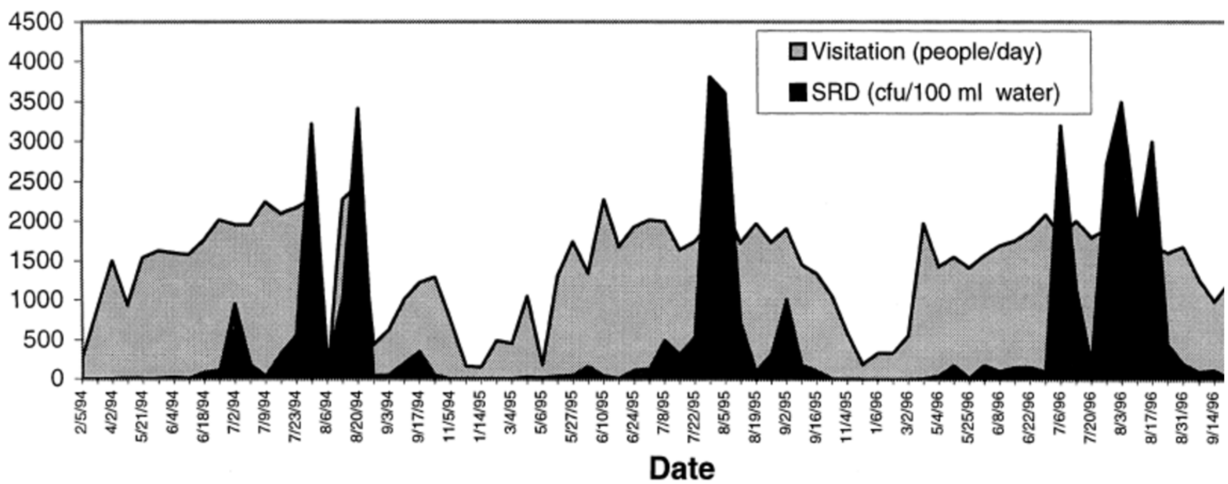



Figure 4. Visitors at site Slide Rock State Park from 1994 to 1996 compared to fecal coliform counts of cfu/100 ml at the Slide Rock downstream (SRD) site. Note the convergence of visitors and fecal coliform during the late summer months during all 3 years. Also, note the improvement of water quality after site closure due to a forest fire (early August, 1994) (Crabill et al. 1999). The largest exceedances occurred during late July and early August when there were not any stormflow events to stir the sediment, so the effect is seen to be due to sediments being disturbed by recreators.

Table 1. Summary of relevant water quality studies and monitoring in Oak Creek Watershed.

| Years | Location tested | Parameters | Timing | Findings | Source |
|---|---|---|---|---|---|
| late 1960s | Banjo Bill, Slide Rock, Indian Gardens, Chavez Crossing, Page Springs | fecal coliform | | | cited in ADEQ 1999 |
| 1967-1978 | Oak Creek near Cornville | biological data, nutrient, organic, inorganic, physical properties, stream flow, sediment | | | USGS (per TMDL 2010) |
| 1970s | | fecal coliform | summer; after heavy runoff | | Obr et al. 1978, Segall 1976 |
| 1975-1979 | 31 sites along Oak Creek | Fecal coliform, fecal streptococci | | Four sites above 235 cfu/100 ml. Concluded that creek has ability to recover from bacterial loading. Wastewater sources present, but system capable of self-mitigation. | cited in ADEQ 1999 |
| 1978-1980 | Oak Creek near Sedona | biological data, nutrient, organic, inorganic, physical properties, stream flow, sediment | | | USGS (per TMDL 2010) |
| 1978-2002 | Oak Creek at Red Rock Crossing | biological data, nutrient, organic, inorganic, physical properties, stream flow, sediment | | | USGS (per TMDL 2010) |
| 1980 | Slide Rock and Grasshopper Point swim areas | water quality | Summer | Fecal coliform not correlated with swimmers or rain events. | Jackson 1981 |

| | | | | | |
|---|---|---|---|---|---|
| 1982 | Slide Rock, sampled by US Forest Service | fecal coliform | | Two samples above 800 cfu/100 ml; Five samples above 150 cfu/100 ml. General trend of increasing coliforms with increasing visitors. | cited in ADEQ 1999 |
| 1982-1984 | Pine Flat, Slide Rock, Indian Gardens, Grasshopper Point, Red Rock, Tlaquepaque, Chavez Crossing, Page Springs | physical and chemical parameters , total coliform, fecal coliform, fecal streptococci, rotavirus, enterovirus, visitor numbers | June – August | Fecal coliform not correlated with swimmers. | Rose et al. 1987 |
| 1985 + 1988 | 31-38 sites along the creek | Fecal coliform, fecal streptococci, chemical parameters | | Higher values at storm water sites & locations below Sedona. Westview Motel: 6,000 cfu/100 ml, Dry Creek blw Hwy. 89A: 30,000 cfu/100 ml Hwy. 179: 12,000 cfu/100 ml, Red Rock Crossing: 11,000 cfu/100 ml, Chipmunk Lodge: 500 cfu/100 ml; 3/15 sites Slide Rock sites blw 120 cfu/100 ml, above Slide Rock: >200 cfu/100 ml, Cave Springs: 260 cfu/100 ml, abv West Fork: 208 cfu/100 ml | cited in ADEQ 1999 |
| 1987-1988 | Seven alluvial wells, 15 deep regional wells | Fecal coliform | | Detected low levels of *E. coli* (10 cfu/100 ml) in two shallow wells in Canyon and one resort well in Sedona | cited in ADEQ 1999 |
| 1987-1988 | Oak Creek Near Sedona | biological data, nutrient, organic, inorganic, physical properties, stream | | | USGS (per TMDL 2010) |

| | | | | | |
|---|---|---|---|---|---|
| | | flow, sediment | | | |
| 1993 | Pine Flats | physical and chemical parameters , fecal coliform | December | | Lightner 1994 |
| 1993 | Three alluvial wells | Fecal coliform | | One well showed 300 total coliform (~60 fecal coliform). Ground water at 10 feet below land surface; aquifer connected to stream | cited in ADEQ 1999 |
| 1994-1998 | Pine Flats campground, Pine Flats residence area, SRSP, Manzanita campground, Trailer Park residence area, Grasshopper point | physical and chemical parameters, fecal coliform | throughout the year | Slide Rock had highest values and showed 14 exceedances; Grasshopper Point showed two exceedances; campgrounds relatively low. Pine Flats Subdivision (1994 MS Thesis). Pattern corroborated earlier results. Sediment reservoir builds at Slide Rock over summer months. No significant difference after 1996 BMPs | Dryden 1998 |
| 1994-1996 | Four upstream, four downstream locations | physical and chemical parameters, fecal coliform | throughout the year | Sediment agitation by recreational activity and storm surges associated with the summer storm season are responsible for the impact to water quality and not recreational users directly. | Crabill et al 1999 |
| Since 1996 | 5 sites: Upstream, Midslide, Large Pool, Foot Bridge, Highway Bridge | *E. coli* | Weekly Oct-Apr, 5 times per week May-Sept., twice daily during water quality exceedances | | Slide Rock State Park (per TMDL 2010) |

| | | | | | |
|---|---|---|---|---|---|
| 1997-1999 | various locations | *E. coli* | throughout the year | | Keys 2001 |
| 1998-1999 | Pump House Wash, West Fork, upstream and downstream of SRSP, Grasshopper Point | *E. coli*, DNA | throughout the year | Water fecal pollution is a sum of the material transported from upstream. Most of the fecal pollutions comes from natural animal populations with sporadic and seasonal impacts from human, cattle, horse and llama sources. Fecal pollutions in Oak Creek is not a regrowth phenomenon. | Southam et al. 2000 |
| Since April 1998 | Above SRSP, Grasshopper Point, Ladders, Mormon Crossing, Crescent Moon, Spring Creek | *E. coli*, air and water temperature | weekly (usually Wednesday) April - September | Frequent elevated *E. coli* concentrations at high recreational use areas. | Friends of the Forest for Coconino National Forest |
| 1998 | 18 sites | fecal coliform, *E. coli*, inorganics, nutrients, physical parameters, turbidity | | | ADEQ TMDL Unit |
| 2003-2008 | | TMDL Phase II monitoring | | | ADEQ |
| July 1, 2008- June 30, 2009 | | *E. coli*, physical parameters, metals, nutrients, and stream flow | Quarterly | | ADEQ Monitoring Unit |
| 2011 | 14 sites on Oak Creek from Pine Flats to Verde confluence, 2 perennial and 5 ephemeral tributaries, 22 springs in Oak Creek Canyon and 4 springs at Page Springs | *E. coli*, streamflow, pH, conductivity, dissolved oxygen, turbidity, nutrients, DNA – human, bovine and dog | July 5 to September 22, baseflow and stormflow | *E. coli* and turbidity were related. *E. coli* was greater during/after storm events, especially from Sedona down. Large amounts of sediment and *E. coli* enter Oak Creek from Sedona-area washes. Some springs appeared to be affected by septic leakage based on *E. coli* and human DNA results. | Oak Creek Watershed Council – the study reported here |

Sediment in Oak Creek supports 10 to 17,000 times more *E. coli* than creek water, acting as a bacteriological reservoir (Southam 2000). In 1995, Crabill et al. (1999) found that water quality violations in Oak Creek only occurred when sediments were found to have high fecal coliform counts (a sediment reservoir in place).When sediment is disturbed, either by recreation or by turbulent, higher-velocity storm flows, the sediment is lifted into the water column where increased contact between sediment particles and water causes entrainment of *E. coli* in the water, thereby increasing aqueous *E. coli* concentrations. Southam et al. (2000) used DNA fingerprinting to identify the relative contributions of *E. coli* from source mammals (Figure 1). Human-related sources (from humans, pets, livestock, septic system effluent) accounted for only about 33% of all *E. coli* found in Oak Creek, with perhaps a few more percentages attributable to wild animals that are present near the creek foraging on human food waste. The remainder of *E. coli* in Oak Creek was attributed to wildlife including: raccoons (31%), skunks (11%), elk (8%), white-tailed deer (6%), beaver (6%), and other mammals. Because 2/3 of *E. coli* in Oak Creek appears to be attributed to something other than human influence, it is challenging to address dispersed nonpoint source pollution with comprehensive and complete measures that could reduce *E. coli* loads below the TMDL. Stakeholders may have to settle for "improvement, rather than perfection", i.e. reducing the risk of human contact with fecal pathogens in Oak Creek water with the understanding that under certain conditions, such as storm events or heavy recreational visitation, exceedances are likely to occur. The Oak Creek Watershed Improvement Plan and future Best Management Practices should result in water quality improvement as well as prevention of fecal contamination and protection of the watershed from future degradation.

Crabill (1999) found that the correlation between the summer rains and the fecal coliform buildup upstream of Pine Flats, near where Oak Creek perennial flow begins, suggested fecal material from the abundant elk, deer and cattle populations on the surrounding plateau impact the creek and are transported there with the runoff. In contrast, downstream at Slide Rock State Park (SRSP) the occurrence of fecal pollution in the sediments prior to the summer rain season suggested that the source of fecal pollution must be close to the creek because a long-distance transport mechanism, i.e. summer storms, is not in place; this implicated a human (recreational and/or residential) source of fecal pollution near SRSP. Crabill's conclusions were largely supported by DNA analysis conducted by Southam et al. (2000), although higher concentrations of human DNA were not found at SRSP as Crabill suspected. Southam had the following conclusions:

1. Oak Creek fecal pollution came from multiple sources based on high temporal and spatial variability of *E. coli* in water and sediment,
2. Fecal pollution in Oak Creek is not a regrowth phenomenon,
3. Most of the fecal pollution in Oak Creek Canyon comes from natural animal populations with sporadic impacts from human, dog, cattle, horse and llama sources,

4. *E. coli* concentrations in water generally do not reflect the sediment profile at the sample sampling site but rather demonstrate that pollution is a sum of material transported from upstream,
5. Single animals (or humans) can cause pollution events in sediment and water, for example Southam's results indicated contamination at Pine Flats by a single raccoon (This is an important message for the outreach program; a single diaper, human waste pile, or dog waste pile could cause water pollution that could affect human health),
6. *E. coli* populations can overwinter but winter populations did not contribute to fecal pollution measured during the following season. (This indicates that there may be a renewal of the creek's water quality each winter.)

To reduce *E. coli* pollution in Oak Creek Southam recommended the following:

1. Increase toilet facilities,
2. Educate the public about dog droppings, provide signage and baggies/disposal containers on critical trails,
3. Implement locally approved grazing modifications that decrease the inflow of sediment carrying fecal material, and
4. Continued water quality monitoring.

In addition to the issues mentioned above, septic effluent contamination is particularly a concern in Oak Creek Canyon where soils may not be sufficient for onsite sewage treatment. Percolation rates in Oak Creek Canyon vary from adequate to exceedingly rapid (50 to 4 minute per inch) (Segall 1976). In 1993, about 150 homes in Oak Creek Canyon utilized septic leach field systems (Stafford 1993) some of them likely on lots with rapid percolation. According to long-time Oak Creek Canyon resident Morgan Stine, prior to the the use of backhoes, septic drainfield leachlines were usually hand dug and shallow, which allowed for adequate separation between effluent and underlying "spring beds" for soil organisms to treat septage and eliminate pathogens. However, from about 1965 to 2001 septic drainfields tended to be installed using backhoes, placing leachlines too close to "spring beds" and unsuitable soils (coarse gravels and sands) to allow for treatment. One of the objectives of the current study has been to identify such places where untreated septic effluent may be intercepted by spring flow. New data will be presented in this report indicating possible contamination of springs by septic effluent. (See the following sections: Water Quality Monitoring Methods and Focus, Preliminary Monitoring Survey Findings and Findings Unique to this Study.

## Application of Water Quality Standards

The presence of *E. coli* in stream water is a concern because it is an indicator of the likely presence of fecal contamination. When surface waters contain fecal contaminants, people can come in contact with pathogens such as *Cryptosporidium spp.*, *Giardia spp.*, *Shigella spp.*, norovirus and *E. coli* 0517:H7 when recreating in the stream, which may cause human health problems that include skin, ear, eye, gastrointestinal, urinary tract, respiratory, neurologic and wound infections. Because of this risk and *E. coli* concentrations found at Slide Rock State Park, a one-mile segment of Oak Creek was designated as "impaired" in 1998 by ADEQ. Based on Arizona Unique Waters status (AUW), specific water quality standards were designated for Oak Creek , including an *E. coli* standard of 580 colony forming units per 100 milliliters (cfu/100ml) to meet the Total Maximum Daily Load (TMDL, see TMDL Findings section below) (ADEQ 1999a). In 2003 the statewide *E. coli* standard for full body contact was lowered to 235 cfu/100 ml, including Oak Creek (ADEQ 2010). Subsequently, The ADEQ 2006/08 305(b) Assessment Report listed five segments of Oak Creek and one segment of Spring Creek as impaired for exceeding the *Escherichia coli* (*E. coli*) water quality standard for a total of 47.4 stream miles (Table 2 and Figure 5). Since a TMDL was approved in 2010 these reaches are no longer considered impaired, but are instead considered "non-attaining".

Table 2. Reaches in Oak Creek watershed impaired in 2008 due to *E. coli*, now considered nonattaining.

| **Reach** | **HUC** | **Length (miles)** | **Year designated** |
|---|---|---|---|
| Oak Creek from headwaters to West Fork Oak Creek | 15060202-019 | 7.4 | 2006 |
| From West fork Oak Creek to tributary | 15060202-018A | 5 | 2006 |
| Oak Creek from tributary to boundary of Slide Rock State Park | 15060202-018B | 1 | 1992 |
| Oak Creek from Slide Rock State Park to Dry Creek | 15060202-018C | 20 | 2006 |
| Oak Creek from Dry Creek to Spring Creek | 15060202-017 | 10 | 2006 |
| Spring Creek | 15060292-22 | 4 | 2006 |

Oak Creek and the West Fork of Oak Creek were renamed from Arizona Unique Waters (AUW) to "Outstanding Arizona Waters" (OAW) during the 2009 Triennial Review of the Arizona Surface Water Quality Standards (ADEQ 2010). However, this was simply a name change and did not affect the standards. Site-specific numeric nitrate and phosphate standards still apply to Oak Creek (Arizona Administrative Code R18-111-9(F)). As an OAW, Oak Creek and West Fork are classified as a Tier 3 waters under the antidegradation language included in the Water Quality Standards (A.A.C. R18-11-106 and 107), which calls for maintaining and protecting the existing water quality and no new or expanded point source discharge directly to an OAW. Any upstream discharge or discharge to a tributary needs to demonstrate that it will not degrade water quality.  Temporary discharges are allowed under the 401/404 program which is administered by the U.S. Army Corp of Engineers and allows for limited "dredge and fill" disturbance of stream channels.  Under a grandfather clause, some excavation of irrigation diversion works in Oak Creek by irrigation associations is allowed without a 404 permit.

ADEQ has recently adopted new biocriteria standards (Jan 2009) and has drafted an associated bioassessment implementation guidance document (ADEQ draft, 2008.  However, because the final guidance document is not complete, implementation procedures have not been adopted and the standard cannot be used for assessment purposes.  Once the new biocriteria standards are implemented, they will be used to assess biological integrity of perennial wadeable streams across Arizona. See the link to ADEQ's webpage: http://www.azdeq.gov/environ/water/standards/index.html.

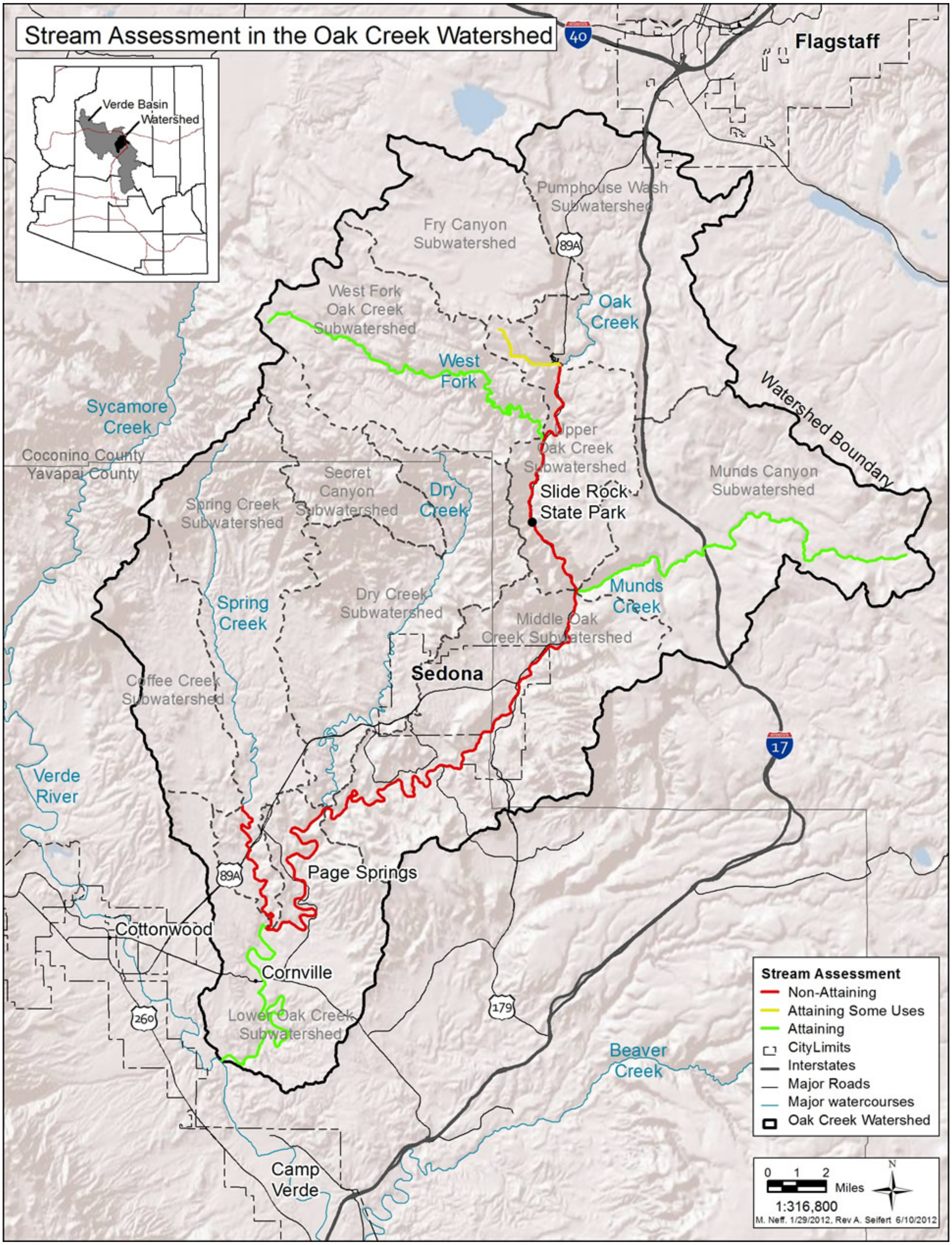



Figure 5. Nonattaining reaches in Oak Creek Watershed

## Critical Conditions

Exceedances of *E. coli* are likely in Oak Creek under the following conditions:

1. Multiple sources from wildlife, livestock, pets and humans provide *E. coli* to Oak Creek, especially during storm events.
2. Temperatures are conducive to persistence of *E. coli* in sediment reservoirs, generally from late spring through early fall.
3. Concentrated recreational activity disturbs sediment reservoirs of *E. coli*, whereby sediment particles mix with the water column and *E. coli* is released into the water column.
4. Storm events deliver fecal material to Oak Creek from surrounding uplands and increase streamflow causing *E. coli* in sediment reservoirs to mix with the water column.
5. Springs intercepting inadequate septic systems deliver *E. coli* to Oak Creek in concentrations greater than creek water
6. In rare circumstances, inadequate and/or overloaded commercial septic systems discharge seepage water to Oak Creek that exceeds the *E. coli* standard.
7. Inappropriate animal waste management (eg. horse manure) may introduce *E. coli* to Oak Creek.

## TMDL Findings

A Total Maximum Daily Load (TMDL) is defined by the EPA as "a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards" (EPA 2011). Since a TMDL determination for Oak Creek and Spring Creek has been completed and approved, both ADEQ and EPA consider the Oak Creek and Spring Creek segments to be "not attaining", rather than "impaired", and were removed from the 303(d) impaired waters list (ADEQ 2010). This means a TMDL has been completed but water quality standards are still not being attained. Prior to TMDL completion, a water may be considered "impaired" that does not meet water quality standards. The Slide Rock State Park segment was first designated as impaired in 1999, whereas the other segments were designated in 2006. In the 1999 TMDL, probable *E. coli* pollution sources causing impairment in the Slide Rock State Park (SRSP) segment of Oak Creek were previously listed as sediment, wildlife, recreational uses and rangeland grazing.

In 1999, ADEQ's pathogen TMDL recommended a 30% reduction of the summer's recreational season to achieve a reduction in fecal coliform loads to Oak Creek at SRSP to attain the standard of 580 cfu/100ml. The TMDL identified the following strategies to be implemented, which were meant to improve water quality at SRSP but are applicable to the watershed as whole:

- Reduce sediment loading to Oak Creek, as bacteria were associated with the sediment;
- Identify failing septic systems and repair or replace these systems;
- Reduce recreation impacts on water quality (e.g., improved public restroom and shower facilities, improved trash management); and

- Reduce animal waste impacts on water quality (e.g., control drainage from pastures and trails, control litter and other wastes that attract skunk and raccoons).

Water quality standards changed in 2003; the previous single sample maximum for fecal coliform bacteria of 580 cfu/100 ml was reduced to 235 cfu/100 ml *E. coli*. Also in 2003, ADEQ started a revision of the 1999 TMDL due to continuing exceedances of *E. coli* water quality standards and because *E. coli* had become the standard, rather than fecal coliform. ADEQ initiated an investigation in 2004 to measure the effectiveness of the implemented strategies, further delineate the extent of the contamination, and identify sources and loadings.

In 1999, ADEQ completed a nutrient TMDL for Oak Creek. The single sample maximum standard for total nitrogen and total phosphorus are 1.5 and 0.25 mg/L respectively and the annual mean values are 1.00 and 0.10 mg/L respectively (ADEQ 1999c). Nutrient concentrations (phosphorous and nitrogen) were found to be low and only a few nutrient standard violations were predicted. Improvements to wastewater treatment systems on Munds Canyon were effective in eliminating nutrient exceedances; no new nutrient limits were needed for septic system loadings on Oak Creek. ADEQ determined that Oak Creek's status as an Outstanding Arizona Water and the existing discharge limits were sufficient protection against nutrient contamination. In 2002, fecal coliform bacteria, nitrogen and phosphorus were removed from the 303(d) impaired waters list (first listed in 1994) for the 17 mile stretch of Munds Creek to Oak Creek. Wastewater effluent reaching Munds Creek no longer led to impairments.

The 2010 TMDL for *E. coli* in Oak Creek uses Load Duration Curves that display the relationship between stream flow, loading capacity, and water quality data to determine if a reduction in pollutant concentration is needed under a certain flow condition. Table 3 represents the findings of this assessment and defines the stream segments that need reductions in *E. coli* loads. For the purposes of the TMDL, hydrograph separation techniques are used to identify storm flows. Flow frequency zones correspond to the percentage of time that flow exceeds a given level as follows:

High flows: 0-10 percent of flows exceed (ie. rare flow event)

Moist conditions: 10-40 percent of flows exceed

Midrange flows: 40-60 percent of flows exceed

Dry conditions: 60-90 percent of flows exceed

Low flows: >90 percent of flows exceed (ie. common flow volume)

Table 3. Summary of percent E. coli load reductions for Oak Creek.

“meets” = existing load meets TMDL, SRSP = Slide Rock State Park (ADEQ 2010 TMDL).

| Segment | High Flows | Moist Conditions | Midrange flows | Dry Conditions | Low Flows |
|---|---|---|---|---|---|
| Headwaters to West Fork | 96% | Meets | 42% | meets | Meets |
| West Fork to Slide Rock | meets | 21% | meets | meets | Meets |
| SRSP | meets | 62% | meets | 2% | 12% |
| SRSP to Dry Creek | 93% | 5% | 68% | meets | 9% |
| Dry Creek to Spring Creek | 94% | Meets | 51% | 34% | 25% |

Figure 6 from the 2010 TMDL report demonstrates how *E. coli* concentrations can be strongly related to streamflow, with the higher concentrations corresponding with high flow events, (although the example is from a stream not in Arizona). This is consistent with studies in the Oak Creek watershed which have found that high flows create turbulence that disturbs sediment on the stream floor and increases contact between sediment particles and water so that *E. coli* is released from the sediment into the water (Southam 2000, Crabill 1999). Some increased *E. coli* during high flow events may also be due to flushing of fecal matter from upland surfaces through overland flow. Figure 6, which is used as an example, is a load duration curve from another state. The solid red line on the graph in Figure 6 is the geometric mean of fecal coliform concentrations while the dashed red is the single daily maximum allowed by Arizona water quality standards (Arizona has a geometric mean *E. coli* standard [126 cfu/100 ml] but it is not exceeded enough to cause impairment). Figure 7 is a load duration curve for the reach Slide Rock to Dry Creek in which *E. coli* concentrations that plot above the curve indicate exceedances of the water quality standard.

Table 3 shows that the relationship between flow magnitude and *E. coli* concentration is not static but varies by stream segment (eg. Slide Rock State Park has greater *E. coli* loading at low flow than most reaches and greater loading during moist conditions than at high flows; this is because exceedances at Slide Rock are correlated more with recreation than with streamflow, which is not the case in most segments of Oak Creek.). This indicates that, while some BMPs are applicable throughout the watershed, in some stream segments BMPs to reduce *E. coli* loading must be tailored to address the particular bacterial sources and processes. According to the 2010 TMDL, the critical conditions when exceedances are likely to occur are as follows: 1. during the summer months, 2. in places where recreational activity is concentrated and 3. when storm events rapidly increase streamflow.

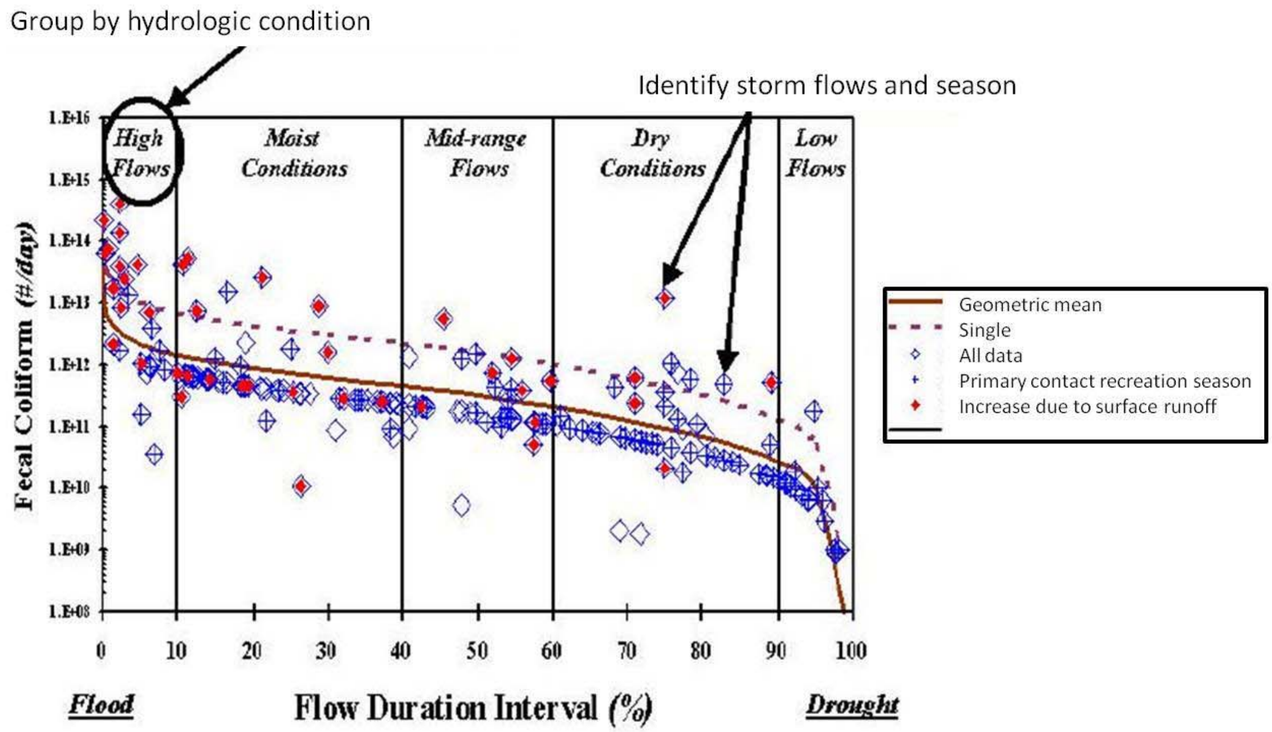



Figure 6. Sample load duration curve (Cleland 2003).

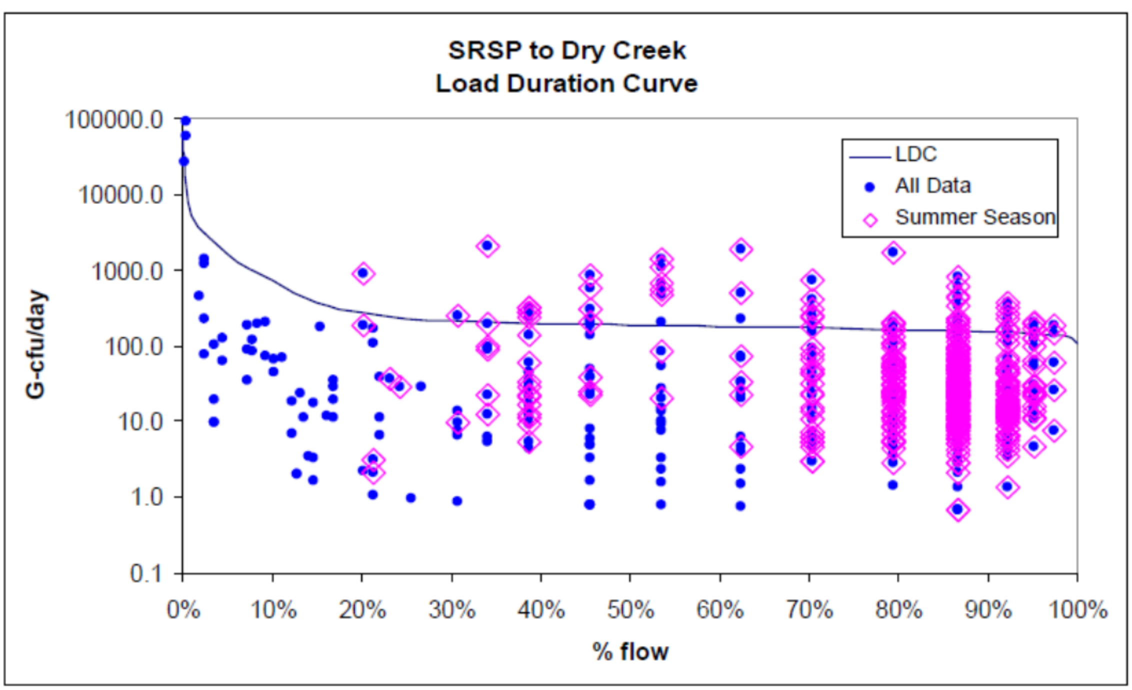



Figure 7. *E. coli* load duration curve, Slide Rock Sate Park to Dry Creek (ADEQ 2010)

Point sources are regulated by ADEQ, but non-point sources are not regulated in the same way and rely on voluntary efforts to control their pollution potential. ADEQ (2010) identified water treatment facilities, fish hatcheries, and storm water related discharges as the main point sources in the Oak Creek watershed. The main non-point sources were identified as wildlife, domesticated animals, humans, and urban development.

## Past Efforts to Reduce *E. coli* Loading

Based on strategies recommended in ADEQ's 1999 TMDL, the Oak Creek Canyon Task Force and other organizations implemented several projects that were funded by Clean Water Act §319(h) Water Quality Improvement Grants and other funding sources. Table 4 and the map in Figure 8 summarize these projects that implemented Best Management Practices (BMPs) in an attempt to reduce *E. coli* loading in Oak Creek. General permit BMPs normally applied in the Oak Creek watershed include: public education, public involvement, illicit discharge detection and elimination, pollution prevention and good housekeeping (EPA 2012). It has been difficult to determine the effectiveness of these measures, since a continuous monitoring program is not in place in the watershed, except at Slide Rock State Park (SRSP). Southam (2000) reported that there were 19 *E. coli* exceedances at SRSP from 1994 to 1997, or an average of 4.75 per year. In 2011 SRSP had 4 exceedances, so perhaps there has been a slight improvement, but evaluation of SRSP's *E. coli* records shows no significant trend. While past BMP projects have all been appropriate and admirable efforts, they probably have not been extensive enough to significantly decrease nonpoint source *E. coli* contamination in Oak Creek. Later in this document we will discuss our investigation results and priority BMPs that could help to reduce *E. coli.*

## Plan Development

The goal of the Oak Creek Watershed Improvement Plan (OCWIP) is to define practical projects whose implementation will reduce *E. coli* and related fecal contamination in Oak Creek. The general methods used to develop this plan were:

1. Review past studies,
2. Conduct a field investigation to collect *E. coli* data, other water quality parameters, and DNA evidence in Oak Creek, its tributaries, and springs that supply Oak Creek to try to identify potential sources of fecal contamination,
3. Conduct a social survey to determine watershed residents' knowledge and attitudes about fecal contamination of Oak Creek, and
4. Based on field investigation and social survey findings, propose BMPs to reduce fecal contamination, including on-the-ground projects and a significant education and outreach component, and
5. Provide projections of reduced *E. coli* loading due to implementation of recommended BMPs.

Past efforts to reduce *E. coli* loading in Oak Creek have not succeeded in attainment of the water quality standard. Our approach differs from previous projects in that we used baseline, anthropogenicly influenced sites (AIS), stormwater and focused sampling to target locations in the watershed where *E. coli* contamination is problematic and identify management measures that are technically appropriate as well as fitting within the local culture.  Chapter 2 will describe the methods by which we collected and analyzed relevant data and the conclusions drawn from our results.  Chapter 3 and Appendix B will lay out in detail the management practices and projects that we propose to reduce *E. coli* contamination in Oak Creek.

Table 4. Historic water quality improvement projects in Oak Creek Watershed.

| Funding Source | Year completed | Organization | Location | Completed Activities |
|---|---|---|---|---|
| 319(h) – 2 related grants | 2001 | Oak Creek Canyon Task Force and Coconino County Environmental Health | Oak Creek Canyon | Installation of 14 residential waste system upgrades along Oak Creek. |
| 319(h) | 2002 | Coconino Nat'l Forest & Slide Rock State Park | West Fork Oak Cr., upstream of SRSP, SRSP, other locations? | Installation of three restroom facilities at popular trailheads to eliminate potential for fecal coliform contamination. Stabilization and restoration of a total of 10 acres of bare ground at 5 sites to reduce erosion and improve soil stability. Sediment traps were installed at SRSP just upstream of the swim area, just north of SRSP and at Encinosa Day Use Area. The sediment traps filled rapidly and were not maintained. |
| ADEQ Water Quality Improvement Grant | 2004 | Oak Creek Canyon Task Force | Oak Creek Canyon | Designed, constructed and installed four trailhead signs that conveyed the concept of reducing litter and promoted using restrooms instead of the forest and creek area. |
| ADEQ Water Quality Improvement Grant | 2004 | Oak Creek Canyon Task Force | Indian Gardens Oak Creek Canyon | Installation of toilets and a wastewater treatment system at Indian Gardens Visitor Center. Providing sediment control structures throughout Oak Creek Canyon. As of 2012 these sediment traps are filled. Sediment traps at Half Way CG, a borrow pit upstream of SRSP on the east side of the Hwy 89, Manzanita CG. Expansion of the campaign to increase waste disposal by summer holiday visitors.<br>Installation of showers waste system at Cave Springs Campground.<br>Keep Oak Creek Canyon Beautiful - volunteers visited campgrounds and day use areas giving away trash bags to visitors. A ten-ton dumpster was placed at Indian Gardens to encourage visitors to drop off their trash rather than leave it behind in the Canyon |

| Funding Source | Year completed | Organization | Location | Completed Activities |
|---|---|---|---|---|
| | 2004 | AZ Game & Fish Dept. | where?<br>where? | Exclusion of livestock from riparian areas<br>Control of off-road vehicle travel to reduce sediment loads and enhance bank stability. |
| 319h | 2002 | AZ State Parks | Slide Rock State Park | |
| 319h | 2009 | Pender Engineering & Oak Creek Canyon Task Force | Oak Creek Canyon, Sedona | Education grant to teach high school students from Sedona how to be Trailhead Ambassadors and pass along their knowledge to Oak Creek Canyon visitors. |
| University of Arizona Cooperative Extension | 2011 | University of Arizona & Oak Creek Watershed Council | Oak Creek Watershed, Sedona | Master Watershed Steward program - volunteers are taught how to become stewards of a watershed. The first course began in March 2011. 12 Master Watershed Steward Associates graduated in June, 2011 |

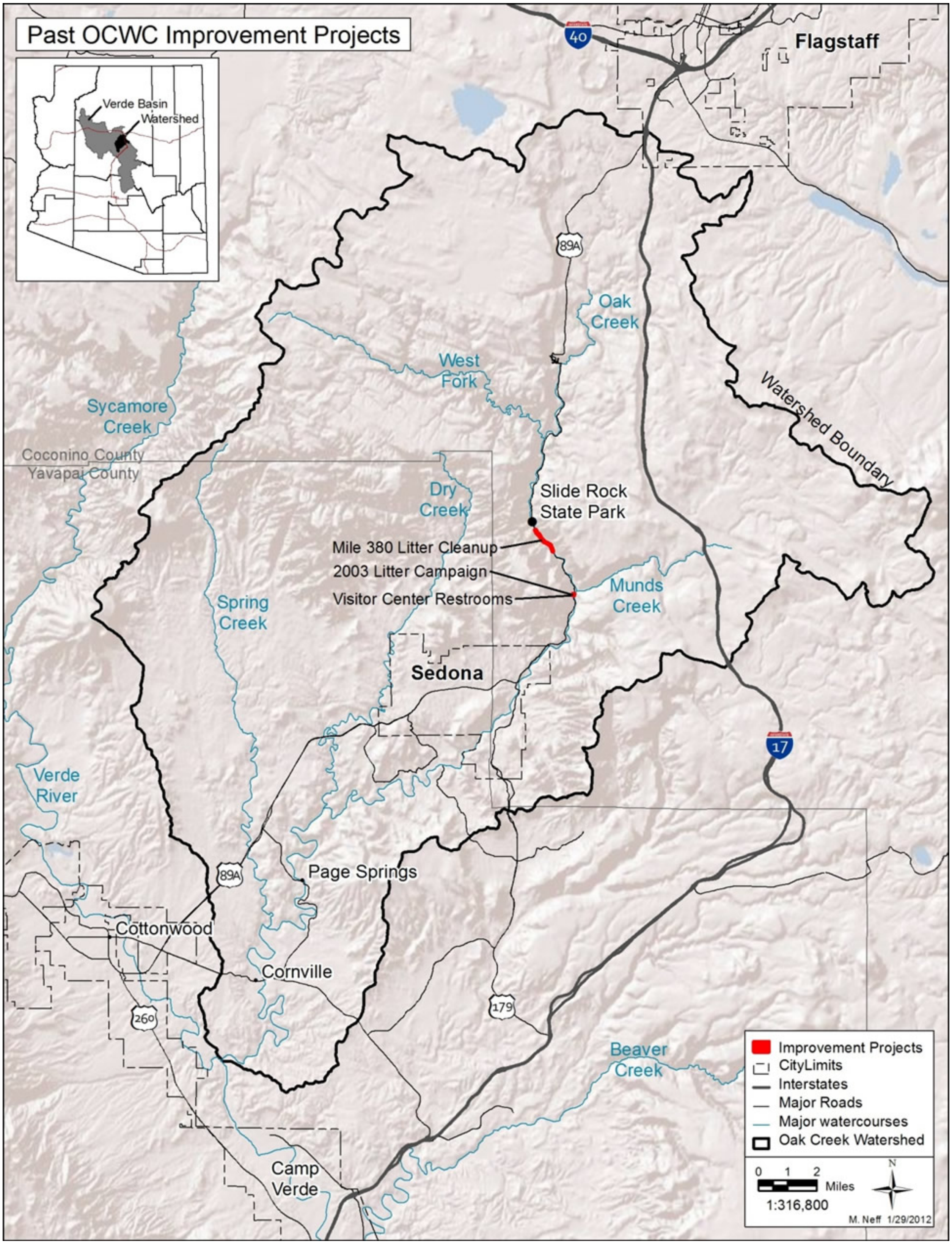



Figure 8. Best Management Practices (BMP) projects in the Oak Creek Watershed

# Chapter 2 – Watershed Investigation

## Field survey methods & findings

### Water Quality Monitoring methods and focus

Water quality was assessed at 56 sites in the watershed including 5 baseline, 11 anthropogenicly influenced (AI), 7 stormwater and 33 focus sites, of which 27 were springs (Figure 9, Table 5). These sites were selected by the monitoring team leaders in consultation with the Oak Creek Watershed Improvement Commission (OCWIC), a technical advisory group with extensive knowledge of current and historic watershed conditions. Baseline sites were selected to reflect more or less natural conditions within Oak Creek. AI sites were places with suspected effects from human influences such as human waste, dog waste, livestock waste, trash, and sediment disturbance during recreation. Stormwater sites were selected in the Sedona urban area to evaluate the degree to which stormwater delivers *E. coli* to Oak Creek. These sites were sampled during one storm event August 1, and on two other occasions (September 6 and 11) pools in the washes were sampled the morning after storm events, since for safety reasons the washes were not sampled during nighttime storm events and by morning flow had ceased. Oak Creek was sampled on mornings following storm events to further characterize impacts. An attempt was made to sample tributary washes outside of the urban area, but due to a shortage of time and confusion about the location of access points, no washes outside of Sedona were sampled during storm events. Focus sites are those where specific impacts on Oak Creek water quality were suspected, such springs that discharge from underneath developed land with septic systems, perennial flow adjacent to waste treatment ponds, or where a concentration of dogs or livestock may impact water quality.

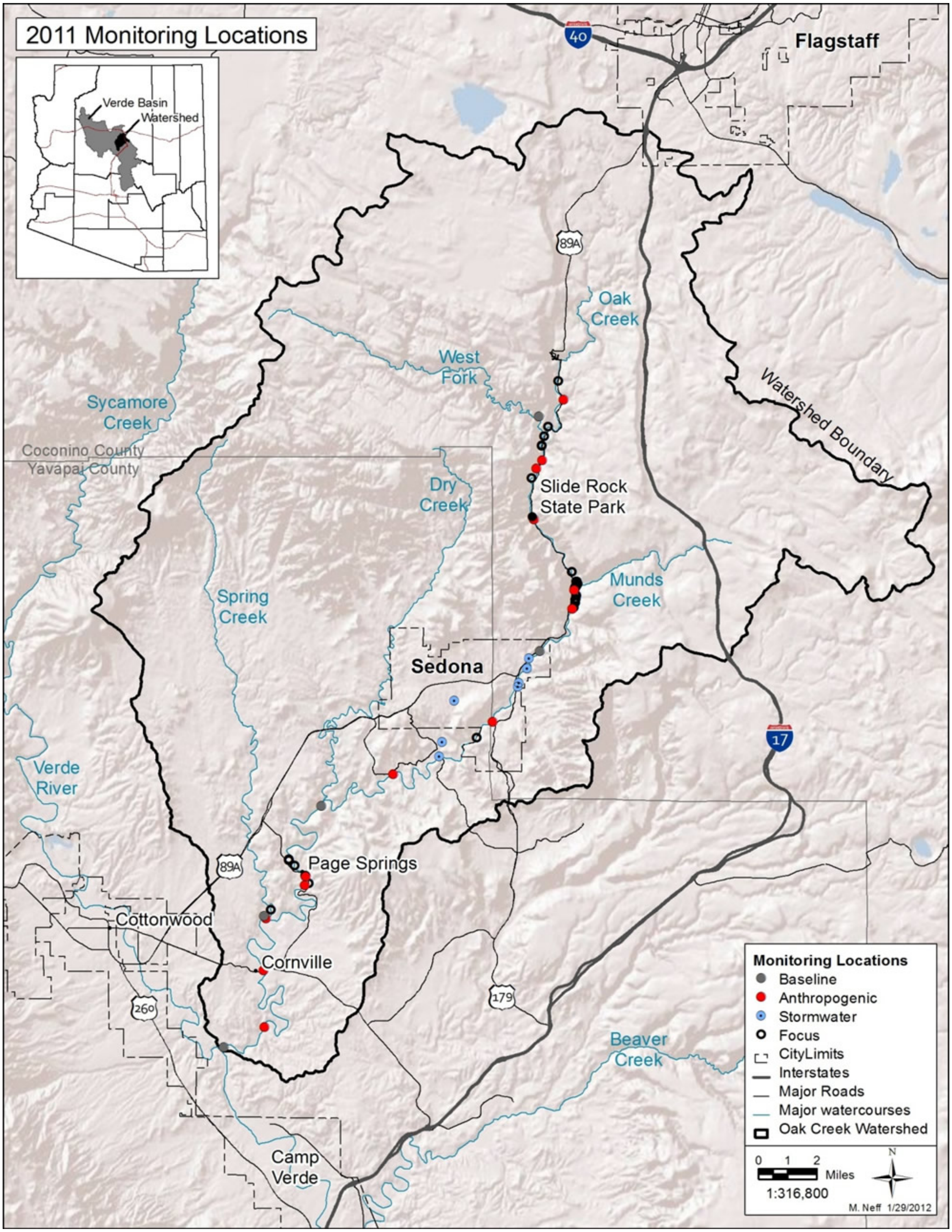



Figure 9. OCWIP monitoring locations, 2011

Table 5. OCWIP sampling location types and locations, 2011

| Site | Testing Rationale | Testing Parameters | # times tested |
|---|---|---|---|
| **Baseline Data** | | | |
| M13 - West Fork, one mile upstream from mouth | Baseline/Reference/ control site | pH, DO, temp, conductivity, TDS, *E. coli*, turbidity, flow, nitrate (field test), nitrogen suite and phosphate (lab analysis) | 8 samples total; 2-3 background samples prior to monsoon stormflow; 5-6 samples during stormflow |
| M45 - Lomacasi, ADEQ site 36.97, control site | Baseline | | |
| M32 - Dry Creek confluence | Baseline | | |
| M39A - below Spring Creek confluence | Baseline | | |
| M43 - above Verde River confluence | Baseline | | |
| **Anthropogenicly Influenced Sites(AIS)** | | | |
| M08 - below Pine Flat subdivision | Septics concentration | All of the above, but nitrogen suite only if field test is >0.8 mg/L | 8 samples total; 2-3 background samples prior to monsoon stormflow; 5-6 samples during stormflow |
| M09, M09A - below Forest Houses | Septics concentration | | |
| M44 - Slide Rock State Park (below bridge) | Recreation | | |
| M17 - Indian Gardens | Septics concentration | | |
| M18 - below Living Springs | Septics concentration | | |
| M25 - Chavez Ranch | Urban runoff | | |
| M29 - – below Red Rock State Park | Ag, septics & recreation | | |
| M36 - Page Springs (below bridge) | Septics and agriculture | | |
| M39 - Spring Creek | Sewage treatment ponds | | |
| M40 - Cornville Bridge | Septics and agriculture | | |
| M41 - below Cornville Estates | Septics and agriculture | | |
| **Stormwater** | | | |
| M49 - Jordan Pump | Urban runoff | Turbidity, *E. coli*, DNA, virus | Washes sampled at first flush (August 1, 2011) and mornings after 2 other storm events. |
| M48 - Arroyo Roble | Urban runoff | | |
| M47 - Tlaquepaque Bridge | Urban runoff | | |
| M46 - Soldier Wash | Urban runoff | | |
| M26 - Carol Canyon, Shelby Road | Urban runoff | | |
| M27 - Carol Canyon, Chavez Ranch Road | Urban runoff | | |
| M51 - Carol Canyon, confluence | Septics concentration | | |

| Site | Testing Rationale | Testing Parameters | # times tested |
|---|---|---|---|
| **Focus** | | | |
| S1, S3, S9, S16, S35, S36, S39, S41, S42, S45, S45A, S45B, S48, S49, S49A, S52, S58, S67, S70, S71, S75, S77, S78, S98, S100, S107, S109, F5, F6, F7 | Spring beds may intercept septic effluent due to mounding and/or soil saturation | Nitrogen suite, basic water quality, TDS, DNA, *E. coli*, phosphate | Once, unless *E. coli* or nutrients were elevated, then repeat sampling |
| F1 | Concentrated dog-walking area | | |
| F3 | sewage treatment ponds | | |
| F4 | Spring outfall with wildlife concentration | | |

At all sites *E. coli*, geographic coordinates and photographs were collected. In addition, at baseline and AI sites the following parameters were measured or noted in the field using methods and equipment described in table 6:

- date, start and stop time of data collection
- time of sample collection
- current weather and weather in past 7 days
- signs of flushing
- air and water temperature
- dissolved oxygen (mg/L) and oxygen saturation (%)
- conductivity (µS)
- total dissolved solids (mg/L)
- pH
- streamflow (cfs)
- crew initials
- designated water uses (eg. FBC, A&W, PBC, Ag)
- samples collected (*E. coli*, nutrients, DNA)
- notes

Table 6. Field data collections methods

| **Parameters** | **method/equipment** |
|---|---|
| Total dissolved solids, conductivity, pH and water temperature | ExTech pH/Conductivity meter - model EC500 |
| Dissolved oxygen, percent dissolved oxygen and water temperature | ExTech dissolved oxygen meter - model DO600 |
| Air temperature | a glass and alcohol thermometer in a protective metal case |
| Streamflow | Rapid method - Channel width and maximum depth where measured. A float was timed as it flowed a distance of 10 feet along the channel thalweg. For channels with a rectangular profile the resulting velocity was multiplied by the width and depth, whereas for most channels the flow was divided by 2 to account for the channel shape. |

*E. coli* samples were collected in sterile 100ml bottles using gloves by lowering the bottle into the stream inverted, removing the lid, turning the bottle upright under water and capping it under water. Over the course of the study 144 samples, including six duplicate samples, were collected. No blank samples were collected. Of the 5 duplicate samples that had *E. coli* concentrations greater than 10 cfu/100 ml, the average log difference from the original sample was +/- 10.8%, with values greater than 200 cfu/100 ml being more consistent (+/- 1.7%) than values between 10 and 200 cfu/ml (+/- 16.8%). Samples were transported in coolers to the laboratory within a 6 hour hold time window. In the laboratory samples were handled using nitrile gloves and analyzed using a IDEXX Colilert® system and QuantiTrays® using a 24-hour incubation period. *E. coli* in samples was analyzed according to manufacturer instructions. Both the *E. coli* lab at Slide Rock State Park and a lab set up at NAU with equipment borrowed from ADEQ were used to test *E. coli*.

Many, but not all, sites were sampled for nutrients including phosphate, nitrite, nitrate, and ammonium (see data summary table in Appendix A). In the latter half of the sampling season we tested nutrient concentrations as personnel was available and if samples were not too sediment laden. Nutrient samples were collected in Nalgene bottles that were previously washed in the laboratory and rinsed with distilled water. Because the bottles were not acid washed to destroy any residual nutrients, in the field at each site the bottles were filled and emptied 5 times before filling with sample. Samples were transported in a cooler on ice, then kept in a refrigerator and analyzed within 48 hours. A Machery-Nagel Nanocolor ® model 500D photometer (unit N500D 0730) was used to measure phosphate, nitrite, nitrate and ammonium. Samples were first allowed to come to room temperature before analysis.

Turbidity was measured in nephalametric turbidity units (NTUs) in the lab using either a Hach 2100P turbidimeter (SN:010200027859) or a Hach 2100Q portable turbidimeter (SN:10110C005972). Sample was shaken to resuspend sediment particles and poured into glass vials that were inserted into the turbidimeter and results were read according to manufacturer instructions.

DNA testing was used to discriminate between human, bovine and other sources of *E. coli* contamination through Microbial Source Tracking (MST). A total of 43 samples were collected across 29 sites in 2 sterile 1-liter HDPE bottles for MST analysis. Prior to sampling bottles were washed using laboratory soap, rinsed 6 times with tap water and 3 times with distilled water, air dried and heat sterilized in an autoclave for 20 minutes at 140 degrees. Samples were shipped on ice to Dr. Channah Rock's laboratory (hereafter the Water Quality Laboratory) at the Maricopa Agricultural Center in Maricopa, Arizona for DNA analysis. MST performed by the Water Quality Laboratory differentiated among three categories of *bacteroides* bacteria: human, bovine and total. Bacteria belonging to the genus *Bacteroides* have been suggested as alternative fecal indicators to *E. coli* or fecal coliform. This is due to the fact that they make up a significant portion of the fecal bacteria population, have little potential for re-growth in the environment, and have a high degree of host specificity that likely reflects differences in host animal digestive systems. The use of fecal bacteria to determine the host animal source of fecal contamination is based on the assumption that certain strains of fecal bacteria are associated with specific host animals and that strains from different host animals can be differentiated based on genotypic markers. One of the most widely used approaches utilizes a method called polymerase chain reaction (PCR) to amplify a gene target that is specifically found in a host population. PCR enables researchers to produce millions of copies of a specific DNA sequence in relatively short amount of time. *Bacteroides*-based methodologies are designed to target specific diagnostic sequences within the *Bacteroides* 16S rRNA gene (which is vital for protein synthesis and therefore present in all bacteria) present in feces from different animals. Testing used microbial detection methodologies and molecular source tracking, in conjunction with microbial genotyping techniques. See the Oak Creek Watershed Council Sampling Analysis Plan for a complete description of DNA testing methods. Combining two methods (testing DNA of *bacteroides* and bacteriophages) allowed for a better understanding of the system dynamics to identify potential non-point source impacts within impaired watersheds.

## Preliminary Monitoring Survey Findings

The following are some of the early findings and adaptations that were made based on findings:

1. With 3 sampling teams, each including a sampling team leader and one or two volunteers, it was not possible to sample more than about 12 sites in one day. Therefore it took 2 days to complete a background sampling of all baseline and AI sites.
2. In the lowest reach around Cornville, it was difficult to sample more than 3 sites and stay within the 6 hour hold time for *E. coli,* because of travel time. Therefore the daily sampling total was sometimes reduced to 11 sites.
3. Each site takes about 1 hour to sample and take measurements. This does not account for travel time between sites.
4. Streamflow estimates were not improved with greater detail in measurements, so we use the simplest method.
5. We discovered greater *E. coli* concentrations in the middle and lower watershed prior to monsoon, which appeared to be associated with greater non-storm-related turbidity.
6. The difference in *E. coli* concentrations became even more abrupt with the onset of stormflow. Above Sedona in Oak Creek Canyon *E. coli* concentrations elevated very slightly in response to stormflow but did not exceed the standard. However, from Sedona downstream to Page Springs, *E. coli* concentrations increased dramatically in response to stormflow and exceeded the standard greatly following the large storm event on August 1st, which might be considered the first flush.
7. A relatively low *E. coli* count at Cornville on August 2nd may indicate that it takes greater than 19 hours for *E. coli*-laden stormwater to travel downstream from Sedona to Cornville. This may be a kinematic wave effect in which cleaner water is pushed ahead of water that has been mixed with surface pollutants, delaying the arrival of pollutants. The delay might allow for warning recreationalists to not swim in turbid waters that may have elevated fecal contamination.
8. Turbidity during storm events seems directly related to the sediment input that increases going downstream (Figure 10).

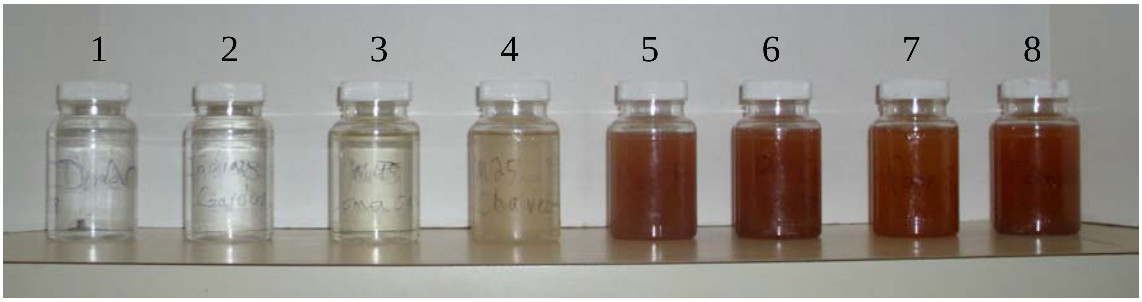



Figure 10. Oak Creek water samples September 15, 2011 following a storm event the night before.

| Site | Stream mile | *E. coli* (cfu/100 ml) |
|---|---|---|
| 1. Pine Flats | 49.0 | 0 |
| 2. Indian Gardens | 40.5 | 65.4 |
| 3. Lomacasi | 37.4 | 426 |
| 4. Chavez Crossing Campground | 33.9 | 1,354 |
| 5. below Red Rock State Park | 27.9 | 2,489 |
| 6. Dry Creek Confluence | 22.7 | 5,794 |
| 7. Page Springs Bridge | 17.2 | 506 |
| 8. Cornville Bridge | 8.9 | 7,270 |

9. We set up a Colilert system (on loan from ADEQ) at the NAU lab to allow for stormwater sampling late in the day, since the Slide Rock Lab was not available after the park closed at 7:00 p.m.
10. Coordinating volunteers for rapid response to sample stormwater flow was challenging. We missed July 4th and July 18th stormwater flow in the Sedona washes. Each event occurred in the late afternoon on a day when we did not have baseline sampling planned and before specific volunteers had made commitments to stormwater sampling. July 5th was our first sampling day, and the *E. coli* results downstream of Sedona were not noticeably different than those on other dates that were not preceded by a storm event. Therefore, although the July 4th and 18th storms did result in stormflow in the Sedona washes, the magnitude might not have been great enough for either to be considered "first flush". See hydrograph in figure 15 (page 55) for magnitude of storm events.
11. We did capture a large storm event on August 1st, which was a 10- to 50-year flow event, ie. there is a 2 to 10 percent chance of a storm of a similar intensity and duration occurring in a given year (Charles Mosley, personal communication). The resulting *E. coli* concentrations were very elevated in Sedona's stormwater runoff and in the creek water downstream of Sedona the following day. The August 1st event might be considered the "first flush". Unfortunately we were only able to grab *E. coli* samples for this event and did not collect DNA samples to determine the relative sources of *E. coli*.
12. September 6th and 11th we collected stormwater the day after rainstorms from pools of water in washes. Although this was not optimal, we felt it was better than no sample. DNA was sampled in the washes on Sept. 6 and analyzed at the Rock Lab for human

and bovine DNA and Real-Time Quantitative Polymerase Chain Reaction (qPCR) DNA Analytical Technology for dog DNA.

13. The strongest single relationship we found was between *E. coli* concentrations and turbidity in Oak Creek on August 2, 2011 following the storm event on August 1st with an $R^2$ of 0.87, n = 10 (Figure 11). For all creek samples that have both *E. coli* and turbidity data the $R^2$ is 0.82, n = 18. Unfortunately we did not have access to a turbidimeter for the first part of the sampling program, but greater turbidity was visually observed at sites where more *E. coli* was found. This was especially true from Page Springs down to the Verde River confluence, even in the absence storm flow. Investigation of turbidity sources is needed in this reach (eg. irrigation return flows, livestock in stream, low water crossings, etc.).

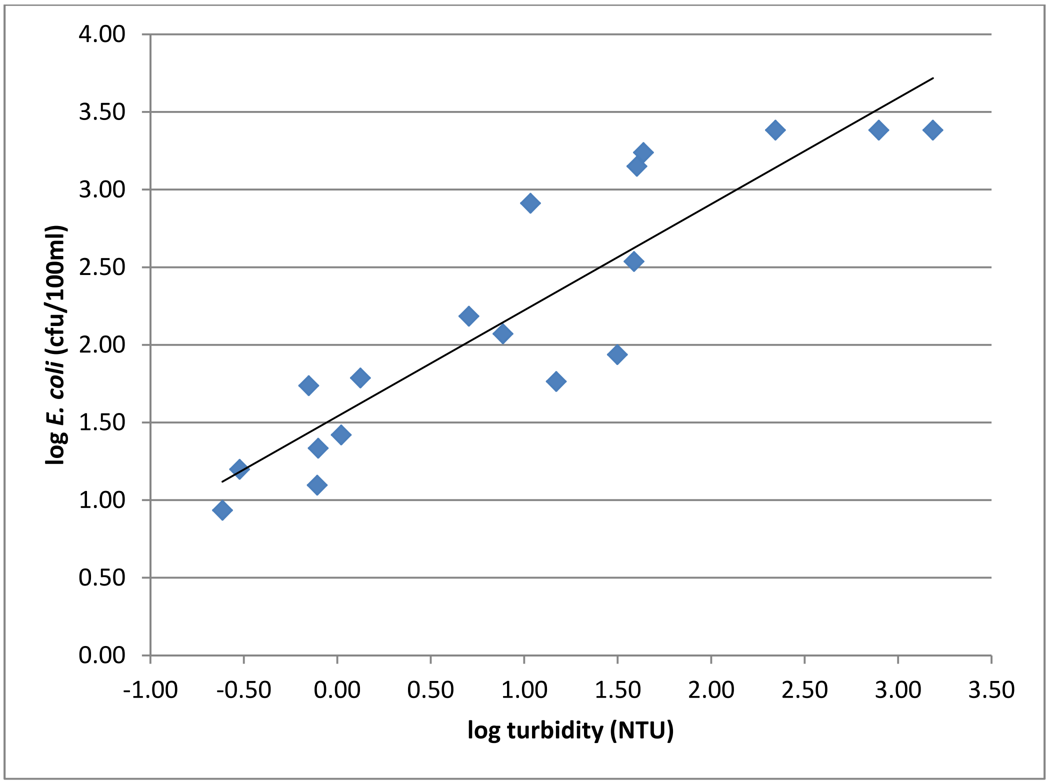



Figure 11. Log *E. coli* concentrations as response to log turbidity, Oak Creek August 2, 2011, $R^2$ = 0.87.

14. Curiously, on August 1st, *E. coli* and turbidity did not seem to be significantly related in Sedona stormwater runoff, though turbidity of stormwater samples was not measured that day. Arroyo Roble which had the highest *E. coli* count (>2,419.2 cfu/100ml) had the lowest turbidity (nearly clear) while Carroll Canyon Wash samples were extremely turbid but had *E. coli* counts ranging from just 222 to 509 cfu/100 ml (Figure 12.). (Sediment in the Carroll Canyon samples clogged the bottom row of small cells, displacing water and probably causing them to not fluoresce. However, when we made an assumption that all those cells would have fluoresced, the result was within 10% of what was reported.) Because *E. coli* is strongly correlated with sediment in the creek but not with sediment in the tributary

washes, it appears that the washes, rather than harboring sediment reservoirs themselves, simply provide the raw materials (sediment & *E. coli*) for the *E. coli* sediment reservoirs in the creek. These reservoirs are then mixed with the water column during storm events or recreational use to elevate the water *E. coli* concentrations.

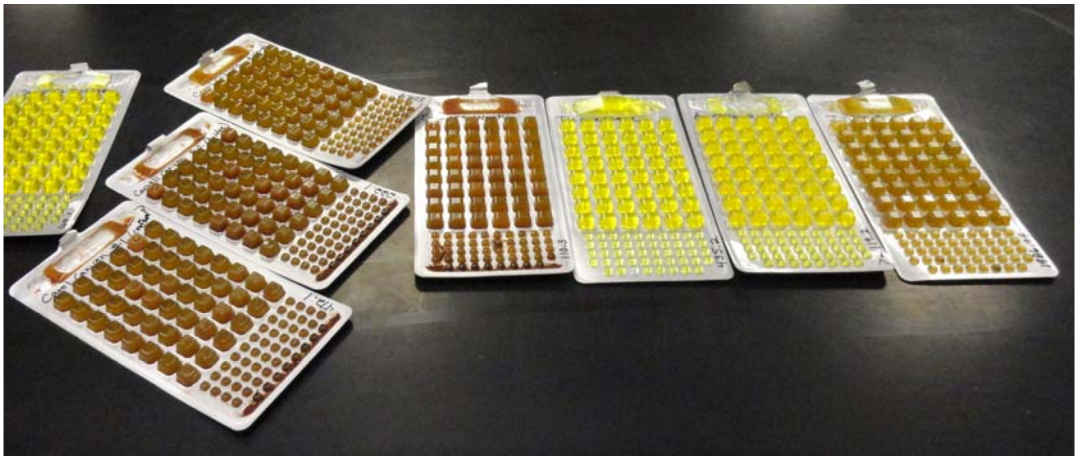


Figure 12. Quanti-trays showing variation in sediment yield among stormwater flow collected from Sedona's washes on August 1. The darker brown the sample is, the more sediment it holds. From left (downstream) to right (upstream) are Carroll Canyon 1, 2, and 3, Soldier's Wash, Tlequepaque, Arroyo Roble and Jordan Wash. (The sample on the far left is from Cornville Bridge, where the storm pulse had not reached yet.)

15. The capacity of the Colilert system was exceeded (>2419.2 cfu/100ml) for one sample from the August 1st stormwater sampling (Arroyo Roble) and 3 of the samples from the followup August 2nd creek sampling (below Red Rock State Park, Dry Creek Confluence and Page Springs bridge). This means we do not know how high the *E. coli* concentration actually was at these locations. In subsequent sampling we analyzed 1/10 dilutions of samples when we suspected we would find very high *E. coli* counts.
16. Monsoon activity in the watershed was sporadic in July and most of August. Some storm events did not generate enough stormwater flow to collect a sample or to elevate creek flow significantly, even though briefly in isolated places rainfall was intense. We were not able to collect samples from as many storm events as we would have liked.
17. Focus site sampling was largely inconclusive. In the first round of spring sampling a few sites appeared to have somewhat elevated *E. coli* counts, but none exceeded the FBC standard. Likewise some sites had very slightly elevated nutrients, but there were no statistically significant relationships between nutrient concentrations and *E. coli* concentrations as we has hoped, so it does not appear that nutrients could be used as a proxy indicator for septic contamination of springs.
18. No nutrients tested (nitrite, nitrate ammonium or phosphate) appear related to *E. coli* concentrations in creek water.
19. Total Dissolved Solids and conductivity are the only other water quality parameters that appear to perhaps have a direct relationship with *E. coli* concentrations in Oak

Creek water. Hypothesizing that they are probably associated with greater turbidity and contact between the water column and *E. coli* in the stream's sediment reservoir, regression analyses were done to see if TDS or conductivity are related to turbidity, but this does not seem to be the case.

20. Dissolved oxygen and pH had no apparent relationship to *E. coli*.
21. Most springs were very low in both nutrients and *E. coli.* with no significant relationships found among nutrients and *E. coli*.
22. Although no focus sites exceeded the *E. coli* FBC standard, except the spring ditch in the Page Springs area (272 cfu/100ml), and most concentrations were less than 100 cfu/ml, some focus sites might merit further monitoring (Table 7), because they had *E. coli* elevated above concentrations in the Oak Creek and/or tested positive for human DNA. [Three replicates for DNA analyses were completed for each sample. A weak positive was one in which one out of three tests was positive for human DNA. A medium positive had two out three tests positive. A strong positive was one in which all three tests were positive for human DNA.] The presence of a strong positive for human DNA, especially along with elevated *E. coli*, indicates a possible septic or sewage source of *E. coli.* Such sources may "charge" sediment reservoirs that produce water quality exceedances when disturbed.
23. Some sites tested positive for human DNA but did not raise concern about septic system influence because they were either far from septic systems (Zane Grey's cabin spring) or they were surface water affected by stormflow that likely delivered human DNA from distal locations (Table 8). It is important to note, however, that several *E. coli* exceedances coincided with human DNA detections in and downstream of Sedona (Chavez Crossing Campground, Carroll Canyon 2, and below Red Rock State Park), so future monitoring should endeavor to pin point sources of human DNA in surface water of the Sedona area in order to locate possible sources of fecal contamination.

Table 7. Three spring locations in Oak Creek Canyon with suspected septic leakage, based on *E. coli* and DNA results.

0 = negative, 1 = weak positive, 2 = medium positive, 3 = strong positive for presence of human DNA.

| **Site, general location** | **Date** | ***E. coli*** cfu/100ml | **Human DNA** | **Notes** |
|---|---|---|---|---|
| S41, stream mile 44.4 | 8/24/11 | 47.1 | 3 | Commercial septic system |
| S49, stream mile 41.0 | 8/24/11 | 202.4 | 1 | Residential septic system(s) |
| S49, stream mile 41.0 | 9/16/11 | 2 | 1 | Residential septic system(s) |
| S49, stream mile 41.0 | 9/20/11 | 15.5 | 3 | Residential septic system(s) |
| S71, stream mile 40.1 | 9/20/11 | 22.8 | 1 | Commercial septic system |
| S70, stream mile 40.1 | 9/20/11 | 18.6 | 3 | Commercial septic system |
| S109, stream mile 40.1 | 9/21/11 | 0 | 3 | Commercial septic system |
| S71, stream mile 40.1 | 9/22/11 | 27.8 | 3 | Commercial septic system |
| S70, stream mile 40.1 | 9/22/11 | 25.6 | 1 | Commercial septic system |
| S109, stream mile 40.1 | 9/22/11 | 8.5 | 2 | Commercial septic system |

Table 8. Other sites that tested positive for human DNA and may warrant further monitoring.

0 = negative, 1 = weak positive, 2 = medium positive, 3= strong positive for presence of human DNA.  Bolded values are *E. coli* exceedances.

| **Site, location** | **Date** | ***E. coli*** cfu/100ml | **Human DNA** | **Note** |
|---|---|---|---|---|
| **Oak Creek Canyon** | | | | |
| M08, Pine Flats | 9/11/11 | 15.8 | 2 | Following storm event |
| S16, Zane Grey's cabin | 8/24/11 | 100.5 | 1 | High recreation area |
| M17, Indian Gardens | 9/11/11 | 152.9 | 3 | Following storm event |
| M45, Lomacasi | 9/11/11 | 117.8 | 2 | Following storm event |
| **Sedona area** | | | | |
| M25, Chavez Crossing CG | 9/11/11 | **1,413.6** | 2 | Following storm event |
| M27, Carroll Canyon 2 | 9/6/11 | **>2,419.2** | 3 | Following storm event |
| M29, below Red Rock SP | 9/11/11 | **2,419.17** | 2 | Following storm event |
| **Downstream of Sedona** | | | | |
| M32, Dry Cr. confluence | 9/11/11 | **344.8** | 1 | Following storm event |
| M36, Page Springs bridge | 9/11/11 | **816.4** | 3 | Following storm event |
| S107, Page Springs | 9/20/11 | 116.9 | 1 | Septic leakage suspected |
| F6, Page Springs | 9/20/11 | **272.3** | 0 | Septic leakage suspected |
| M39, Page Springs | 9/16/11 | **687.7** | 1 | Leaking sewer pond suspected |
| M41, Cornville Estates | 9/11/11 | 58.1 | 1 | Following storm event |

## Summary of Findings

### Findings supportive of past studies

Past studies and past monitoring data show that *E. coli* levels in Oak Creek are usually low but occasionally rise above the single sample maximum of 235 cfu/100ml, the water quality standard set by the Arizona Department of Environmental Quality for full body contact (FBC). Exceedances have usually occurred during periods of high recreational use or during or shortly after stormflow events. Our results are consistent with these past findings. Our sampling data revealed exceedances of the FBC standard only associated with stormwater flow in the washes of Sedona and in Oak Creek downstream of these washes following stormflow events, with the exception of Spring Creek. Spring Creek had an *E. coli* exceedance that coincided with a weak positive human DNA result, which indicates possible leakage from a sewage treatment pond adjacent to Spring Creek. Although we did not find any exceedances apparently associated with recreation, twice daily monitoring at Slide Rock State Park revealed an exceedances on four dates in summer 2011 (Sun. 6/19, Sun. 7/13, Mon. 7/4, Sun. 7/31), wherein all the Sunday dates saw heavy visitation and Monday July 4$^{th}$ the park closed to protect against *E. coli* contact. Because no storm events had occurred around the time of the Slide Rock exceedances, and because the Slide Rock *E. coli* concentrations were much greater (mostly >2,419 cfu/100 ml) than Oak Creek Canyon concentrations associated with storm flow (77 cfu/100 ml average), it may be assumed, as it has been in past studies, these exceedances were associated with heavy recreational use that may have contributed *E. coli* source and/or disturbed sediments sufficiently to mix *E. coli* into the water column from the sediment reservoir.

Recreational use or high streamflow disturb stream sediments and mix them with the water column transferring *E. coli* from sediment particles to the water (Crabill et al. 1999, Southam et al. 2000). Crabill et al. (1999) found that average fecal coliform concentrations (which included *E. coli*) in Oak Creek Canyon were 2200 times greater in the top 10cm of sediment than in the overlying water column. Southam et al. (2000) found sediment *E. coli* concentrations at some sites were >10,000 times greater in than in the water column. The findings are consistent throughout the literature which indicates the majority of enteric bacteria in aquatic systems are associated with sediments and that these associations influence their survival and transport characteristics (Jamieson et al. 2005). Fecal bacteria can persist in the sediment for up to 12 weeks, hence the term "sediment reservoir" of *E. coli* (Lightner 1994). Because *E. coli* concentrations in Oak Creek water appear strongly related to disturbance of sediment reservoirs, more work is needed to identify specific sources of sediment in order to reduce habitat that sustains *E. coli* in the stream system. The University of Arizona may help to determine sediment source areas using sediment loss modeling. Sediment sources might include streambank or upland erosion by recreationalists, construction sites, inappropriately engineered or maintained road crossings, or construction and erosion of irrigation diversion dams, such as this example:

> Considerable sediment was observed at site M39A below the Spring Creek confluence. About ½ mile upstream is an irrigation diversion dam that can be seen on aerial photo with streamflow eroding down through the dam. An irrigation association in the Page Springs area builds up the dam each year to pump water from the pool, sometimes higher than permitted by Army Corp of Engineers and disturbs considerable sediment in the process (Mariann Speare, Oak Creek Valley HOA, personal communication).

Sediment sources such as this need to be investigated and appropriate BMPs implemented to reduce sediment loads that contribute to *E. coli* sediment reservoirs.

Most of the basic water quality parameters or physical stream properties did not yield any significant relationship with *E. coli* concentrations. Table 9 shows some of the possible significant relationships as found through statistical analysis of the 2011 data. $R^2$ is an expression of the goodness of fit of a trend line; $R^2$ ranges from 0 to 1 with higher numbers expressing a closer fit of data points along a trend line. The strongest relationship we found was between turbidity and *E. coli* concentrations, supporting the results of past studies that point to disturbance of stream sediments and contact between sediment particles and the water as the primary means of Oak Creek water becoming contaminated with *E. coli*. Another strong relationship was between ranked streamflow (order from upstream to downstream) and *E. coli* as measured at baseline conditions. What this says is that *E. coli* appears to accumulate going from upstream to downstream. However, lower *E. coli* concentration in the upper reaches (Oak Creek Canyon) may also be due to the creek having better "self cleaning" properties where gradients are higher and aeration is greater. Well-aerated streams, such as in Oak Creek Canyon, have an assimilative capacity that can aerobically treat fecal contamination, essentially through a "fixed-film media system" that has to do with the presence of biofilms and the amount of surface area of rocks (Fitch et al. 1998, Neu and Lawrence 1997). Oak Creek, in Oak Creek Canyon, has demonstrated this aerobic treatment ability, as evidenced in past monitoring, by significantly reducing *E. coli* concentrations from exceedance-level at SRSP to below exceedance-level one mile downstream (Morgan Stine, personal communication).

A possibly significant relationship between *E. coli* in spring samples and the nutrient phosphate merits further investigation to determine if phosphate may be used as indicators of septic effluent impacts on springs. Total dissolved solids (TDS) and conductivity also had a possibly significant relationship to spring *E. coli*. However, given the low $R^2$ on the TDS and conductivity regressions, it appears that it may be necessary to use multiple lines of water quality evidence for inferring septic system influence. The use of monitoring wells and fluorescent dye or other tracers may be necessary to positively identify the effluent contamination of Oak Creek for specific sites.

Table 9. 2011 Oak Creek water quality sampling positive relationships of water quality and physical environment to *E. coli* concentrations according to linear regression

Statistically significant relationships are ranked from strongest to weakest.
Flow rank is the order of the sampling location from headwaters to mouth.
(AI = anthropogenicly-influenced).

| Sample type | Dependent variable | Independent variable | N | $R^2$ | F ratio |
|---|---|---|---|---|---|
| Baseline + AI | *E. coli* | turbidity | 17 | 0.604 | 0.0001 |
| Focus spring | *E. coli* | phosphate | 38 | 0.483 | 0.0001 |
| Baseline + AI | *E. coli* | ammonium | 17 | 0.505 | 0.0010 |
| Baseline + AI | *E. coli* | flow rank | 15 | 0.498 | 0.0022 |
| Focus spring | *E. coli* | total dissolved solids | 42 | 0.247 | 0.0007 |
| Focus spring | *E. coli* | conductivity | 42 | 0.235 | 0.01 |

Statistical results in Table 10 compare and contrast two conditions. The strongest relationship found was that *E. coli* concentrations from Sedona downstream were higher associated with stormflows than with baseflow. The contrast between stormflow and baseflow was also strong for Oak Creek as a whole, but was weak or possibly insignificant in Oak Creek Canyon where *E. coli* concentrations did not elevate much during storm events. There was a significant contrast between *E. coli* concentrations in Oak Creek Canyon and from Sedona downstream, with concentrations being significantly higher from Sedona downstream. In Table 10 statistically significant relationships are ranked from strongest to weakest.

Table 10. T-test significant differences in *E. coli* concentrations by baseflow vs. stormflow and by location.

| Location | condition 1 | condition 2 | F-ratio |
|---|---|---|---|
| Sedona down | Baseflow | Stormflow | <0.0001 |
| all of Oak Creek | baseflow | Stormflow | 0.0002 |
| all of Oak Creek | OC canyon | Sedona down | 0.0082 |
| Oak Creek Canyon | baseflow | Stormflow | 0.0586 |

Given the strong relationship between stream sediments and *E. coli* in the water, the next practical step is to ask where the *E. coli* comes from that resides in the sediments. As discussed in chapter 1, the sources of *E. coli* contamination Oak Creek Canyon's water column have been identified using DNA analysis. The top five contributors to *E. coli* pollution in Oak Creek water accounted for 84% of the pollution, including raccoons (31%), humans (16%), skunks (11%), elk (8%), and beaver, dogs, and white-tailed deer (each 6%) (Southam et al. 2000). In July, prior to flushing monsoon rains, Southam found a greater proportion of *E. coli* was attributed to humans, often around 30% and sometimes nearly 50%. Southam also identified that the top 6 sources of *E. coli* in the Oak Creek Canyon sediment accounted for 88% of sediment *E. coli*; these sources were similar but not the same as water column sources – horse (16%), humans (12%), raccoons and white-tailed deer (both 11%), elk and skunk (10%) and cows and mule deer (both 9%).

Crabill et al. 1999 concluded that the occurrence of fecal pollution in the sediments at Slide Rock State Park (SRSP) prior to the summer rain season suggested that the source of fecal pollution must be close to the creek because a long-distance transport mechanism, i.e. summer storms, was not in place. This implicated a human (recreational and/or residential) source of fecal pollution at SRSP or just upstream.

We sampled a spring (S41) approximately 0.8 miles upstream of SRSP 3 times and found somewhat elevated *E. coli* counts (47.1, 19.5 and 16.4 cfu/100 ml) in comparison to average (non-storm-event) concentrations of *E. coli* in creek water in Oak Creek Canyon (11 cfu/100 ml) and typically low *E. coli* concentrations in Oak Creek Canyon springs (0 to 2 cfu/100 ml). One of two DNA samples of S41 tested positive for human DNA (strong positive), indicating that the resort's leach field might be exceeding its capacity and/or mixing with spring water and contributing fecal contamination that could impact water quality in the park downstream. Another source could be defective sewer pressure or gravity pipes located near springs or Oak Creek. Discharge from this resort and possibly other upstream leaking septic systems may be loading *E. coli* into sediments that are then disturbed by park visitors causing entrainment in the water column. There is also likely direct contribution of fecal matter from swimmers and waders and from feces left near the stream, as has been observed through feces counts in other streams with heavy recreation use (Madigan 1997).

## Findings unique to this study

Many of our monitoring results were supportive of previous studies' conclusions, particularly the correlation between sediment reservoirs and *E. coli* in Oak Creek Water, since turbidity and *E. coli* had the strongest statistical relationship of any two parameters in our study ($p = 0.0001$, $R^2=0.604$). However, we were able to investigate potential sources of *E. coli* more specifically than previous studies. Our findings fit into 2 main focus areas:

1. Septic effluent interception by springs and
2. Stormwater delivery of *E. coli* and sediment to Oak Creek.

### Focus 1: Septic effluent interception by springs

To investigate the possibility that septic systems in residential and commercial sites with shallow groundwater are contaminating springs that provide water to Oak Creek, we collected 25 samples from spring, spring channels and spring ditches in Oak Canyon and the Page Springs area and tested for *E. coli*, nutrients and *Bacteriodes* DNA (Table 11). Sampling sites were selected because they had elevated *E. coli* and/or nutrients levels that indicated possible septic influence due to proximity of septic systems. A spring sample was considered elevated in *E. coli* concentration if the concentration was noticeable higher than typical baseline concentration in nearby Oak Creek. Most natural springs have *E. coli* concentrations (0-2 cfu/100 ml) that are much less than creek water at baseline (~10 cfu/100 ml in Oak Creek Canyon, ~50 cfu/100 ml Sedona down).

DNA samples were analyzed for *Bacteriodes* DNA and bacteriophages at the University of Arizona water quality lab in Maricopa, AZ. The use of fecal bacteria to determine the host animal source of fecal contamination is based on the assumption that certain strains of fecal bacteria are associated with specific host animals and that strains from different host animals can be differentiated based on phenotypic or genotypic markers (Layton 2006). One of the most widely used approaches utilizes polymerase chain reaction (PCR) to amplify a gene target that is specifically found in a host population (Shanks 2010). *Bacteroides*-based methodologies are designed to target specific diagnostic sequences within the *Bacteroides* 16S rRNA gene (which is vital for protein synthesis and therefore present in all bacteria) present in feces from different animals. Katherine Field and colleagues, in particular, have performed extensive research into the use of *Bacteroides* 16S rDNA-based PCR assays for MST (Field and Bernhard 2000, Field et al. 2003, Field and Dick 2004). Bernard and Field developed 16S rRNA gene (rDNA) makers from *Bacteroides* to detect fecal pollution and to distinguish between human and ruminant (e.g., bovine, goat, sheep, deer, and others) sources by PCR (2004). Targeting this gene along with PCR primers will allow differentiating between human- and ruminant-associated *Bacteroides*, therefore identifying the possible source of contamination.

Bacteriophages are viruses that infect bacteria and have also been recommended as alternative indicators to fecal contamination. These organisms are of particular significance due to the fact that they more accurately mimic pathogenic virus survival and fate in the environment. While bacteria may tend to die off or degrade at a rapid rate, viruses tend to be more stable in environmental conditions.

Human DNA results for 43 samples were that nine were a strong positive (3/3), 5 were a medium positive (2/3), 10 were a weak positive (1/3) and 19 were negative. The samples included 25 spring samples for which 14 were positive for human DNA, of which 10 samples had elevated *E. coli* (15.5 - 116.9 cfu/100 ml, average 61.6 9 cfu/100 ml) and 4 samples did not have elevated *E. coli* but could have contained viruses or bacteriophages associated with septic effluent. These results indicate that interception of septic effluent by groundwater flowing to springs is likely a source of *E. coli* in some springs. Figure 13 is a map showing springs that tested positive for human DNA. Some of these are suspected to have septic influence.

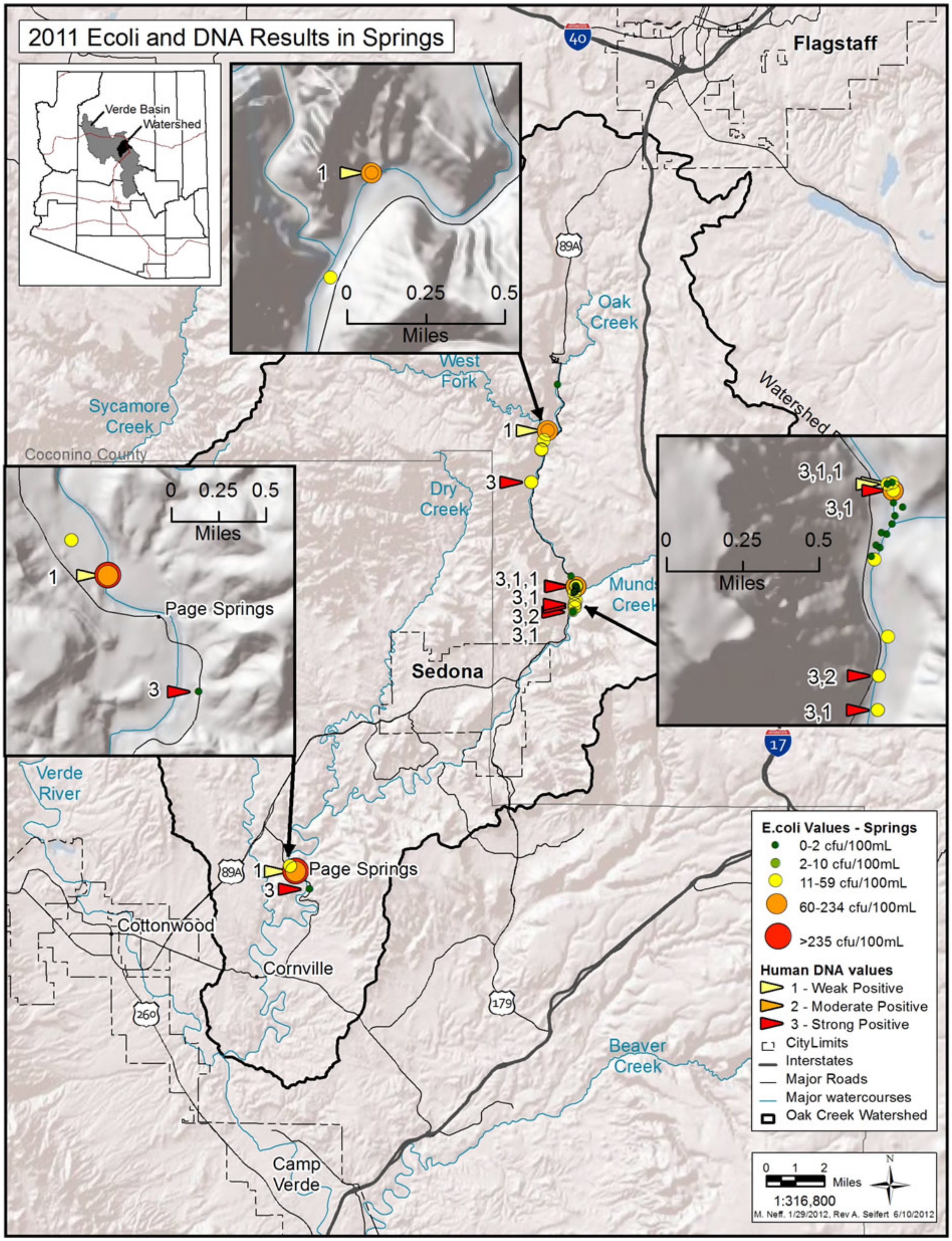



Figure 13. *E. coli* and human DNA test results at springs in Oak Creek watershed. 3= strong positive, 2 = medium positive, 1 = weak positive result for Human DNA.

Identification of contaminated springs is not always straight forward and requires repeat sampling. Whereas *E. coli* concentrations at springs where human DNA was detected are at concentrations below the FBC standard, and the *E. coli* from these source may be quickly diluted by creek water, the more-or-less steady flow of elevated *E. coli* may "charge" sediment reservoirs with *E. coli* that can later be disturbed to cause exceedances in the water column. This concept could possibly be validated by measuring *E. coli* concentrations in sediment below spring discharge points relative to other creek sediment. More sampling is recommended to develop a clearer understanding of the relationship between *E. coli* and human DNA in springs that may be under the influence of septic effluent. With the possible exception of phosphate, nutrient levels showed no obvious relationship with *E. coli* concentrations where human DNA was present (Table 11), so it is not advised to use nutrients as a possible indicator of septic influence, unless further investigations using a large sample size can establish nutrient/*E. coli* relationships with greater confidence.

Table 11. Spring focus site results and interpretation of septic influence.

Grey highlights indicate interpreted background levels. Human DNA: number of detections out 3 tests.

| Date | Description | *E_coli* cfu/100 ml | Phosphate mg/L | Nitrite mg/L | Nitrate mg/L | Ammonia mg/L | Human DNA positive | Suspected Septic Influence |
|---|---|---|---|---|---|---|---|---|
| 8/24/2011 | Spring 16, Zane Grey's cabin | 105 | 0.10 | <0.002 | 0.02 | 0.03 | 1 | No |
| 8/24/2011 | Spring 41, upstream of SRSP | 19.5 | 0.07 | 0.002 | 0.06 | 0.02 | 3 | Yes |
| 8/24/2011 | Spring 52, Indian Gardens | 0 | 0.05 | <0.002 | <0.02 | 0.01 | 1 | Uncertain |
| 8/24/2011 | Spring 49, Indian Gardens | 202.4 | 0.06 | <0.002 | <0.02 | 0.01 | 1 | Yes |
| 8/24/2011 | Page Springs Source | 0 | 0.04 | <0.002 | | 0.02 | 3 | Uncertain |
| 8/24/2011 | Bubbling Ponds Spring | 25.6 | <0.04 | <0.002 | 0.06 | 0.02 | 0 | No |
| 8/24/2011 | Bubbling Ponds Outfall | 14.6 | 1.0 | 0.006 | 0.11 | 0.05 | 0 | No |
| 9/16/2011 | Spring 52, Indian Gardens | 16.1 | Nd | nd | nd | nd | 0 | Uncertain |
| 9/16/2011 | Spring 49, IG, source | 2 | Nd | nd | nd | nd | 1 | Yes |
| 9/16/2011 | spring ditch, AGFD | 2419.17 | Nd | nd | nd | nd | 0 | Uncertain |
| 9/16/2011 | spring ditch, Crawford | >2419.2 | Nd | nd | nd | nd | 0 | Uncertain |
| 9/16/2011 | Bubbling Ponds Spring | 19.9 | Nd | nd | nd | nd | 0 | No |
| 9/16/2011 | Bubbling Ponds outfall | 147 | Nd | nd | nd | nd | 0 | No |
| 9/16/2011 | Page Springs Source | 0 | Nd | nd | nd | nd | 0 | No |
| 9/20/2011 | Spring 41, upstream of SRSP | 16.4 | <0.04 | 0.002 | <0.02 | 0.04 | 0 | Uncertain |
| 9/20/2011 | Spring 49 source | 20.1 | 0.05 | <0.002 | <0.02 | 0.01 | 0 | Uncertain |
| 9/20/2011 | Spring 49 near source | 15.5 | 0.05 | <0.002 | 0.02 | 0.03 | 3 | Yes |
| 9/20/2011 | Lower Indian Gardens, midway | 22.8 | 0.05 | 0.003 | <0.02 | 0.05 | 1 | Yes |
| 9/20/2011 | Lower Indian Gardens, nr runs | 18.5 | 0.08 | 0.010 | 0.08 | 0.15 | 3 | Yes |
| 9/20/2011 | Spring ditch, AGFD | 272.3 | 0.10 | 0.002 | 0.03 | 0.03 | 0 | Uncertain |
| 9/20/2011 | Spring ditch, Crawford | 116.9 | 0.04 | 0.003 | 0.03 | 0.05 | 1 | Yes |
| 9/21/2011 | Lower Indian Gardens, lower | 0 | 0.07 | 0.009 | 0.07 | 0.07 | 3 | Yes |
| 9/22/2011 | Lower Indian Gardens, midway | 27.8 | 0.06 | 0.002 | 0.05 | 0.01 | 3 | Yes |
| 9/22/2011 | Lower Indian Gardens, nr runs | 25.6 | 0.05 | 0.008 | 0.13 | 0.08 | 1 | Yes |
| 9/22/2011 | Lower Indian Garden, lower | 8.5 | 0.08 | 0.009 | 0.15 | 0.08 | 2 | Yes |

It should be noted that not all property owners allowed us to sample springs on their property. One commercial property with a large septic system in proximity to a spring denied access for sampling, but human DNA and elevated *E. coli* were found downstream in the spring ditch samples. Water sampled twice in September 2011 from 2 locations on a ditch downstream of the this spring revealed elevated *E. coli* (116.9 to >2419.2), with the water quality standard greatly exceeded on 9/16/11 and human DNA detected 9/20/11. A commercial property owner in Oak Creek Canyon where septic issues have been a concern in the past was also reticent at first to have springs sampled, but did eventually allow sampling in September. *E. coli* levels were slightly elevated but there were no exceedances. However, a neighbor anonymously reported a sewage smell emanating from the property in August and human DNA was detected in all of the September samples. It is recommended that these and other commercial properties with septic systems is close proximity to springs should be monitored in the future.

Water quality was also sampled in Spring Creek upstream and downstream of a residential area's wastewater treatment plant (WWTP) evaporative ponds adjacent to the spring-fed creek. There were two *E. coli* exceedances on Spring Creek below the WWTP ponds. Water sampled from Spring Creek on 8/24 upstream of the WWTP ponds had an *E. coli* concentration of 46.7 cfu/100 ml, whereas below the WWTP ponds the concentration was 249.5cfu/100 ml, exceeding the water quality standard. On 9/16 Spring Creek samples had *E. coli* concentrations of 579.3 and 686.7 cfu/100ml above and below the WWTP ponds respectively. Human DNA was detected (weak positive) in Spring Creek below but not above the WWTP ponds on 9/16/11. There was clearly some *E. coli* traveling down Spring Creek in perennial flow from above the waste water treatment ponds on 9/16/11, so the *E. coli* below the treatment ponds on that date cannot be fully attributed to the ponds. However, the large difference in *E. coli* concentrations above and below the ponds on 8/24, combined with the positive human DNA result on 9/16 below the ponds, is cause for concern. Inspection of the ponds is recommended to determine if leaks are a problem, as they have been in the past, as reported by the HOA manager.

### Focus 2: Stormwater delivery of *E. coli* to Oak Creek

2011 was a very hot, dry year for Sedona. For the month of August a new record was set for average daily temperature of 83 degrees Farenheit. Perhaps the heat affected the formation of monsoon storms, since there were few that resulted in stormflow during July and August. Figures 14 and 15 show the rainfall record and hydrograph for the Oak Creek near Sedona gage. The first 2 storms of the season caused stormwater flow in the washes and increased streamflow of Oak Creek slightly, but we were not able to grab samples because our volunteer sampling team was not yet organized. Never-the-less the 3$^{rd}$ storm on August 1$^{st}$ which we captured appears to have been the "first flush" of the watersheds with sufficient flow to move fecal material from the uplands.

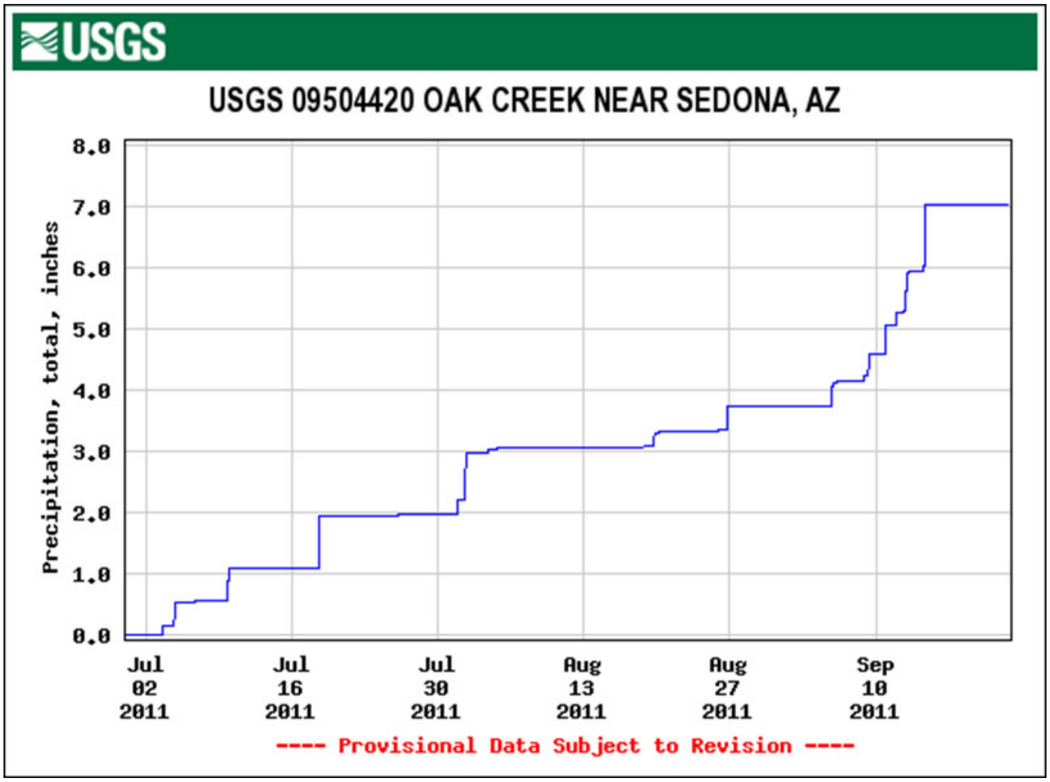



Figure 14. Rainfall July 1 through September 22, 2011 at Oak Creek near Sedona, USGS gage no. 09504420

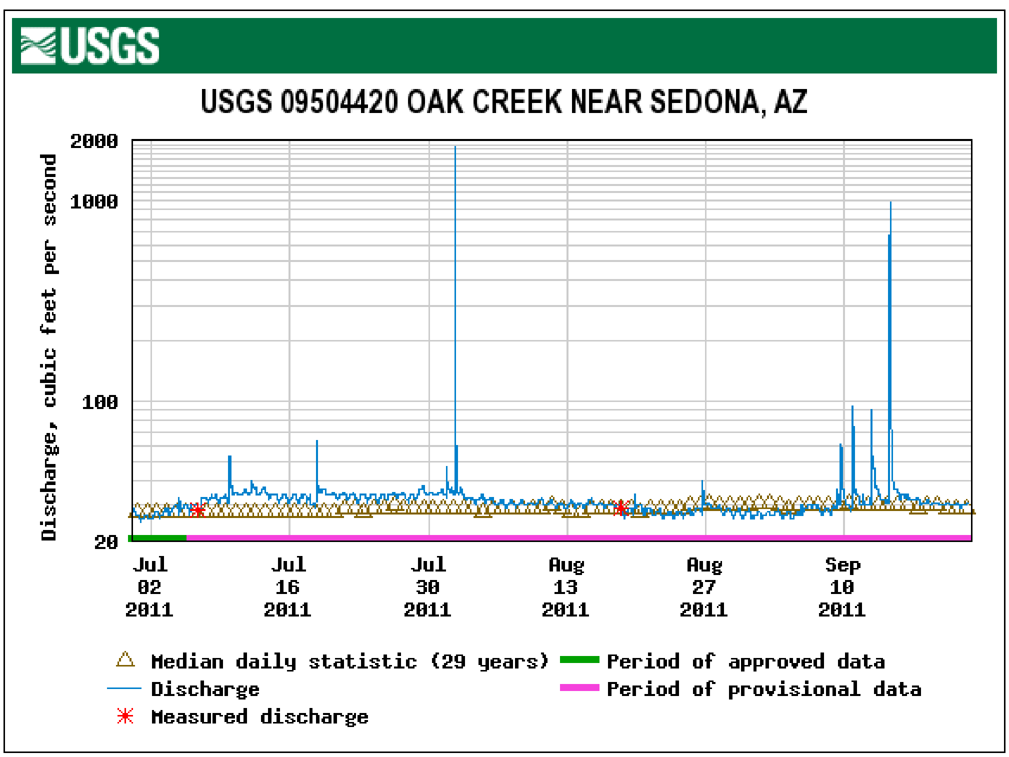



Figure 15. Rainfall July 1 through September 22, 2011 at Oak Creek near Sedona, USGS gage no. 09504420

Stormwater in the Sedona area was sampled on three occasions and found to have very high concentrations of *E. coli*. Sedona washes sampled August 1st had *E. coli* concentrations ranging from 110.3 to >2419.2 cfu/100 ml with an average >879.3 cfu/100 ml. On 9/6/11, with the exception of Jordan Pump (172 cfu/100 ml), all pools in Sedona washes sampled the morning following a storm showed had >2419.2 cfu/100 ml *E. coli*. Dilutions of 9/11/11 samples collected from pools the morning following a storm event were tested for *E. coli* and showed that concentrations in Sedona's stormwater ranged from 1,563.1 to >8,200.7 cfu/100 ml. Sedona's urban runoff is a huge episodic contributor of *E. coli* to Oak Creek. This is evidenced by the high *E. coli* concentrations in stormwater draining from urban areas (>2,157.5 cfu/100 ml average) contrasted with concentrations in Oak Creek upstream of Sedona following storm events (143.1 cfu/100 ml). A concerted effort should be made within Sedona to identify stormwater pollution sources and ameliorate them. OCWC will need to work closely with the City of Sedona, Coconino National Forest and other interested parties to address this concern. A pilot program survey and cleanup of dog and human feces at the urban/recreation interface may assist in affecting a change in habits of hikers in these areas.

Oak Creek was sampled throughout its length on August 2nd to see how stormwater flow impacted the creek. Although the whole watershed received considerable rainfall on August 1st (City of Sedona Engineer Charles Mosley described the 1+ inches of rainfall in Sedona as a 10- to 50-year event), the average *E. coli* concentration the following day upstream of Sedona was only slightly higher than background (28.9 cfu/100ml versus the 10.5 cfu/100ml baseline average for Oak Creek Canyon), while concentrations in Sedona downstream to Page Springs were extremely high (1,733 cfu/100ml to >2,419 cfu/100ml) compared with average background (47.1 cfu/100 ml for this reach). Curiously, the *E. coli* concentration at Cornville Estates (86.5 cfu/100 ml) were comparatively not much higher than previous concentrations (37 and 13.4 cfu/100 ml), leading to the conclusion that the bulk of the *E. coli* pulse from the August 1st event took longer than 19 hours to arrive downstream at Cornville. This type of delay may be useful for warning recreationalists via radio public service announcements to avoid swimming in Oak Creek when water is turbid following storm events, since *E. coli* levels are likely to be high. OCWC could work with Yavapai County Flood Control District, who provides flood warning, to develop a water quality warning system.

## Social Survey Findings

On February 9, 2012 the Oak Creek Watershed Council mailed 1,224 social surveys to randomly selected residences in the Oak Creek watershed. The purpose of this survey was to ascertain resident's knowledge, understanding, attitudes and behaviors with regards to fecal contamination of Oak Creek to inform priorities for the education and outreach programs. The survey recipients represented a 10% random sample of residential property owners, using parcel data provided by Coconino and Yavapai Counties. From 14,802 properties OCWC subtracted those properties with out of state mailing addresses and obvious nonresidential properties (commercial, government, school, church, etc.) for a final "population" of 12, 241 residences. The 10% sample was selected by numbering each entry, generating 1,224 random numbers from 1 to

12,241 and selecting the properties with those numbers. On March 20, 2012 OCWC ended receipt of the surveys and entered response data in a spreadsheet. There were 265 replies or 21.6% of those sent out, which is generally considered a good response rate for a mail survey, meaning that the sample results are representative of the attitudes of the residential population as a whole.

The mailed social survey included a one-page introductory letter and a two-sided page with multiple choice questions on which respondents checked boxes, wrote comments, folded, taped or stapled, and mailed back to OCWC using postage that was pre-affixed. The survey was publically announced in the local newpaper and on a local radio station about one week prior to it being sent out. The social survey and its results may be found in Appendix B. Insights from the survey are presented below.

Highlights of the results from Questions 1 – 14, regarding knowledge, perceptions, behaviors and demographics, include the following through direct answers and extrapolation:

- 95% of property owners have some concern about the health of the Oak Creek Watershed.
- On average each property owner visits/recreates along the Creek between 7 and 10 times per year.
- Hiking is almost 3 times as popular an activity as swimming.
- Personal observation & the newspaper were the choice of 74% as sources of information.
- Human feces, litter, baby diapers & septic systems were thought to be biggest contributors to creek contamination.
- Half of watershed property owners have pets & 90% of the pets go outside.
- 90% of watershed property owners with pets clean their yard of pet waste.
- 45% own a dog therefore there are at least 5400 dogs in the watershed.
- 45% of those who own a dog walk it (them) in the watershed, extrapolating to almost 2500 dogs walked in the watershed annually.
- 64% of dog owners who walk their dog(s) always pick up their dog's waste. Approximate quantification of dog feces left behind in the watershed is around 500 feces per day, just from dogs owned by residents of the watershed, not counting dogs of visitors. Each gram of dog feces has 20 million *E. coli* bacteria colonies in it.
- 95% of dog owners who pick up the feces throw them into the trash.
- 89% of dog owners would use dog waste stations if provided.
- 93% of respondents were over 45 years old, and 47% were over 65 years old.
- 80% have 1 or 2 people living in the household
- For 62% there property in the watershed is their primary home.

Question 15 on the second page of the Survey had multiple choice answers to several questions regarding how much the respondents think various potential pollution sources threaten Oak Creek's water quality, with the choices being, "not sure", "not a problem", "slight problem" "moderate problem" and "large problem". Percentages below are for responses that included some concern about the problem (slight problem, moderate problem and large problem):

- Responses to recreation problems were the most significant of all categories. Respondents ranked recreation threats to Oak Creek in this order:

  - Trash 84%
  - Lack of public toilets 79%
  - Lack of trash receptacles 79%
  - Baby diapers 75%
  - Human feces 67%
- There seems to be a consistency in these answers to those in Question 6 regarding which sources respondents thought were the biggest contributors to creek contamination that can cause human illness.
- 69% believe that dog feces are a problem to some degree, and 48% wildlife feces.
- Almost 2/3 thought that wildlife attracted to water by human food waste threatens the water quality of Oak Creek.
- More than twice as many people thought Jeep/ORV trails cause erosion and sedimentation which affects water quality of Oak Creek than any other reason.
- 60% thought there was some problem with stormwater runoff: lawn fertilizers & pesticides 71%, pet feces in yards 66%.
- For wastewater, respondents saw the following threats: residential septic systems 68%, and commercial septic systems, 66%, inadequately maintained sewer system 62%.
- 54% saw disturbance of sediment as a threat.
- 51% felt lack of riparian buffers was a threat.

## Potential Future Projects

Based on the findings of the field investigation, especially where we found elevated *E. coli* concentrations, *E. coli* exceeding the water quality standard, and evidence of human sources or *E. coli* (eg. human DNA indicating possible septic contamination of springs), we developed 15 potential Best Management Practices projects to address contamination. Tables 12 and 13 outline these projects. Appendix C provides complete project descriptions and may be used as guide for project planning. The projects in Table 12 are the highest priority projects, based on based on findings from previous studies and our data collection and analysis. Table 13 outlines a second tier of projects that are based on inference through observation and some data collection, but more data is needed to confirm the project need and/or direction. The subject areas are in order of priority. Within each subject the projects are in order of priority based on current and previous findings.

Project prioritization was developed by the principal investigator with advice and approval from the Oak Creek Watershed Improvement Commission. Outreach projects were given the highest priority, because reducing *E. coli* contamination in Oak Creek relies largely on changes in human behavior that will hopefully follow outreach and education. Also, every project has an outreach component, all of which will be coordinated under the umbrella of the Oak Creek Community Outreach Program (OCCOP), which will appeal to various audiences – residents, visitors, hikers, pet owners, jeep users, swimmers, fishermen, commercial property owners, farmers, livestock owners, etc. Within the outreach category, the highest priority projects are those that address critical pollution pathways as identified through observation, past research, and 2011 data collection and analysis.

Commercial septic system issues are the second priority after education and outreach, because there are a number of commercial septic systems that appear to be exceeding their capacity and causing septic effluent to be intercepted by springs that deliver elevated *E. coli* and human DNA to Oak Creek. Effluent mounding during high use periods in the summer may be responsible for this effect. Although the indicator *E. coli* was not always very high in spring discharge, it was often elevated above typical spring levels and the presence of human DNA is of concern, since septic effluent can deliver other pathogens (such as viruses) in which the human DNA is detected. The potential for human health risk to recreators in Oak Creek due to septic discharge makes the commercial septic system project a high priority. Working collaboratively with commercial property owners to evaluate and address this situation is vital. Because there is a less certain connection between residential septic systems and spring contamination, and because the loading from individual systems is small, a project to address residential septic systems is relegated to Tier 2 as displayed in Table 13.

Stormwater issues are the third priority category. Tremendous amounts of sediment and *E. coli* were detected in stormwater in Sedona's washes, and *E. coli* concentrations in Oak Creek indicate the Sedona washes are probably the biggest sources of sediment and *E. coli* to the creek during storm events. To what extent these pollutants arise due to natural geology and wildlife fecal sources or are due to recreational activities and the feces of pets and humans is uncertain. Observation of heavy deposits of dog feces along trails in and around Sedona suggests that pet feces are a significant source, but DNA testing of stormflow was inconclusive, probably due to lack of sensitivity of the test or due to sampling or analysis error, since all test results were negative. The projects in this category are aimed at continued and expanded monitoring of *E. coli*, human DNA, erosion and sedimentation in the catchment areas of Sedona's washes both in and outside city limits. Monitoring findings will guide focused efforts to decrease *E. coli* and sediment sources. Working with neighborhood groups such as the Elf Neighborhood Association, will help facilitate community involvement and proactive solutions. Physical improvements will include erosion control work, and the installation and maintenance of dog waste stations to the extent that funding allows. Partners will work together with the U.S. Forest Service to seek permits and cooperative agreements for these activities.

Recreation is a major activity in the watershed and a potential source of water pollution. This has been evidenced by the cleanup days where volunteers have picked up huge amounts of litter (which may draw scavenging wildlife to the creek and often includes used baby diapers) and observed prodigious dog waste. Projects in the recreation category will address tangible infrastructure needed to facilitate changes in human behavior that can improve water quality. The placement of toilets, trash receptacles, and signage will aid visitors in keeping Oak Creek beautiful and reduce fecal matter in Oak Creek. Also, evaluating the impact of specific recreation activities is needed, such as erosion along jeep trails or social trails to the creek.

Second tier projects include those that would benefit from further data collection and analysis to support the project need and to focus the activities. Outreach related to stormwater can be informed by results from additional stormwater monitoring described above. Outreach related to animal waste dumping from farmlands in the lower watershed may be informed by a survey of current animal waste management practices that was outside the scope of the 2011 investigation. Projects to address erosion in the lower watershed due to road crossings and irrigation diversion structures also require inventory of such sites to determine the extent of the problem, before developing workable solutions.

Table 12. Oak Creek WIP top priority project recommendations.

The need for these projects is supported by finding from this and/or previous investigations as well as observations.

| Project Number | Reach | Findings | Recommendations | Potential Collaborators |
|---|---|---|---|---|
| | | **Education and Outreach** | | |
| EO-2 | Oak Creek Canyon | High recreation use of Oak Creek Canyon in the Summer contributes to *E. coli* contamination through several pathways: 1. dog feces, 2. used baby diapers, 3. human feces, 4. food waste that attract wildlife that defecates near the stream, 5. soil disturbance and erosion that contributes sediment to *E. coli* sediment reservoirs, and 6. disturbance of sediment reservoirs by swimmers and waders causing *E. coli* to enter the water column. | Conduct a pre-summer and early summer media campaign that is tiered to both residents and visitors with a public health awareness focus that includes public service announcements, kiosks, and volunteer contact with recreators at campground and day use areas to get the message out. The message should include health effects of fecal contamination, symptoms of infection due to fecal contamination, pictures of dirty diapers in the woods and blown up pictures of the germs that cause illness. Involve local businesses in an incentives/reward programs such as free frozen yogurt certificates or Red Rock day passes that volunteers hand out to visitors who pick up dog waste. | Coconino County Health Department, OCWC |
| EO-5 | Throughout the watershed | Recreators often do not grasp the consequences of their actions. Even one fece (dog, diaper or dump) can cause contamination of Oak Creek. | Conduct a public outreach program to get the "Even one" message across that even one deposit of human or pet feces can cause contamination that threatens human health. | Coconino and Yavapai County Health Departments, OCWC |
| EO-6 | Throughout the watershed | An umbrella outreach coordination is needed | Oak Creek Community Outreach Program (OCCOP) | OCWC, Verde River Basin Partnership? |

| | | | | |
|---|---|---|---|---|
| | | **Septic System Issues** | | |
| SS-1 | Oak Creek Canyon and Page Springs commercial sites | Some commercial property owners are resistant to water quality monitoring, but anecdotal evidence as well as *E. coli* testing and human DNA analysis results point to possible contamination from commercial septic systems. Because these systems have large loads, mounding is possible that increases the potential for septic effluent to be intercepted by springs and carried to the creek. | Use soil surveys and county environmental health records for septic system installation to identify areas of high potential for septic leakage to groundwater. Consider use of fluorescent dye or other tracers to identify effluent migration to Oak Creek. Monitor the spring channels downstream of commercial septic systems. Work along with county environmental health departments to build a collaborative relationship with property owners. Provide incentives to improve septic system. | Coconino and Yavapai County Health Departments, OCWC |
| | | **Stormwater Issues** | | |
| SW-1 | Sedona as a whole | Washes deliver considerable *E. coli* and sediment to Oak Creek during storm events, which raise *E. coli* levels in Oak Creek and provide source materials for sediment reservoirs of *E. coli* that contribute to later exceedances during storm events or recreation when sediment reservoirs are disturbed. Along with *E. coli* a tremendous amount of sediment is discharged from Carroll Canyon during storm events. This sediment adds to *E. coli* sediment reservoirs in Oak Creek that, when disturbed, are a leading cause of *E. coli* exceedances in the water column. | Establish a monitoring program in city washes for *E. coli* and sediment. Conduct DNA testing to determine what portion of *E. coli* is from humans, dogs and wildlife or livestock as a baseline and repeat sampling after BMPs are in place to see if they are effective at reducing *E. coli*. Test sewer system for leaks at wash crossings and repair any leaks. Establish and maintain dog waste stations. Conduct outreach program. Evaluate erosion problems in the Carroll Canyon watershed through field surveys and modeling to identify critical sites. Implement best management practices to reduce erosion on both private and public lands. These may include riparian area protection, improved rangeland health, and corral maintenance. | City of Sedona, Yavapai County Health Department, ADEQ Stormwater & General Permits Unit, OCWC, Coconino National Forest, Little Elf Neighborhood Group |

| | | | | |
|---|---|---|---|---|
| **Recreation Issues** | | | | |
| RC-1 | Oak Creek Canyon | There is a shortage of public restrooms in the canyon, especially access that does not require a Red Rock Pass, since many people will park along the highway and hike into the creek rather than pay the fee. | Establish restrooms at intervals that will help ensure the public accesses them rather than defecating near the stream. Post signs along the highway indicating public restrooms. Establish collaborative agreements and funding to maintain restrooms. This is a high priority, which was identified in the past and has not had enough action. | Coconino National Forest, business owners, ADOT, OCWC |
| RC-3 | Oak Creek Canyon and national forest access adjacent to Oak Creek in Sedona | Trash receptacles are lacking, leading visitors to litter including used diapers that contribute to *E. coli* pollution and food waste that attracts wildlife whose feces add to *E. coli* in the creek. | Place trash receptacles at convenient locations. Work out collaborative agreements and funding to maintain trash receptacles. | Coconino National Forest, business owners, Arizona State Parks, OCWC |

Table 13. Oak Creek WIP second tier project recommendations.

These projects are supported by some findings of the current and/or past investigations, but more data collection and analysis are needed to determine the scope of these projects and priority locations.

| Project Number | Reach | Findings | Recommendations | Potential Collaborators |
|---|---|---|---|---|
| | | **Education and Outreach** | | |
| EO-1 | Sedona | Stormflow events in Sedona deliver large doses of *E. coli* to Oak Creek. Much of this *E. coli* may come from pet feces, since there are many pet owners and a great deal of dog-walking in these watersheds. Dog owners need to know the seriousness of leaving dog waste along trails and in yards where it can wash into tributaries of Oak Creek during storms. The need to be encouraged to pick up and properly dispose of dog feces. | Implement an outreach program that includes radio and newspaper stories, public service announcements, and presentations to civic groups. Use brief messages that get across 4 points: 1. the danger of *E. coli* and health effects on children, 2. causes of *E. coli* contamination, 3. how to change behaviors that cause *E. coli* contamination, 4. "Deputizing the World", i.e. encouraging residents to speak up when they see others leaving dog waste unattended. | City of Sedona, Yavapai County Health Department, OCWC |
| EO-3 | Page Springs and Cornville | Dumping of animal waste into ditches or the creek may be increasing *E. coli.* Annual reconstruction of irrigation diversion dams may cause sediment deposition that contributes to *E. coli* sediment reservoirs. | Educate land owners about the impacts of animal waste dumping and provide technical assistance for implementing best management practices for animal waste management. Work with RV park owners to inform customers of the health effects of dumping waste and assure that they know where to properly dispose of waste according to pertinent waste management ordinances. Provide assistance with design, permitting, finances and construction for hardened irrigation diversion structures that will simultaneously reduce annual streambed disturbance and maintenance efforts by water users. | Cooperative Extension Service, Yavapai County Health Department, OCWC |

| | | | | |
|---|---|---|---|---|
| EO-4 | Throughout watershed | RV owners may be dumping "black water" an/or gray water into ditches or the creek, based on past observations and sewage odor observed near a creek-side RV park. | Work with RV park owners and the Forest Service to inform campers of the health effects of dumping waste and assure that they know where to properly dispose of waste. Evaluate the spacing and availability of waste dumping stations and determine if more stations or improved information about stations is needed. Provide information on website and pamphlets for distribution. | RV park owners and managers, Coconino National Forest, Arizona State Parks, OCWC |
| | | **Septic System Issues** | | |
| SS-2 | Oak Creek Canyon residential sites | Two springs we tested appeared to indicate that residential septic systems contributed 0 to 202.5 (average = 42.7) cfu/100 ml *E. coli* at various times to Oak Creek by way of spring discharge. Although not exceeding the FBC standard, these supplies of *E. coli* during the summer months might inoculate sediment reservoirs that are later disturbed by recreation or storm events to cause exceedances of *E. coli* in the water column. | Continue to monitor springs that have shown elevated *E. coli* or/or DNA indication of septic influence. Using higher-density *E. coli* sampling of creek water and sediment in areas with springs and septic systems, identify neighborhoods where septic effluent interception by springs may be an issue and use targeted sampling to zoom in on possible sources. Conduct tracer dye or other tracer studies as practical to pinpoint improperly functioning septic systems. Establish an incentive program to upgrade septic systems where needed. Complete a hydrogeologic characterization by of springs in the vicinity of residential and commercial septic systems. | Coconino County Health Department, volunteer scientists, Northern Arizona University, neighborhood groups, OCWC |

| | | | | |
|---|---|---|---|---|
| | | **Recreation Issues** | | |
| RC-2 | Slide Rock and Oak Creek Canyon | Past studies have noted that sediment reservoirs of *E. coli* build up at Slide Rock throughout the summer. This may be in part due to soil disturbance from people hiking into the park from upstream. | Evaluate erosion problems upstream of Slide Rock S.P., within the park, and throughout Oak Creek Canyon. Implement best management practices to reduce erosion. Post signs regarding importance of avoiding erosion to reduce *E. coli* problems that can close the park and/or contribute to illness. | Slide Rock State Park, Coconino County Rural Environmental Corp., Coconino National Forest, OCWC |
| RC-4 | Throughout the watershed | Dog feces contribute to *E. coli* contamination. | Establish dog waste stations at ALL trailheads within 3 miles of Oak Creek. Conduct a public outreach program to encourage social pressure to pick up dog waste. Work collaboratively to secure funding for establishment and maintenance of dog waste stations. | Arizona State Parks, City of Sedona, Coconino National Forest, OCWC |
| | | **Agricultural Issues** | | |
| AG-1 | Throughout the watershed but especially downstream from Chavez Crossing. | Some livestock owners have reportedly dumped animal waste into irrigation ditches or Oak Creek. Also, a horse rehabilitation center uses as large pond adjacent to Oak Creek for physical therapy. Method of disposal of waste from this pond is unknown. | The location of all livestock owners should be determined and a focused outreach effort made to educate livestock owners on the water quality impacts of dumping animal waste into water. Distributed information should include local ordinances regulating setbacks from water for animal waste. A manure management brochure developed by Prescott Creeks may be modified for Oak Creek. Assistance should be provided to implement best management practices alternatives to dumping. | Cooperative Extension Service, livestock organizations in the watershed, OCWC |

| | | | | |
|---|---|---|---|---|
| AG-2 | Throughout the watershed but especially downstream from Chavez Crossing. | Annual earth moving activities to build or restore irrigation diversion structures may be introducing large quantities of sediment to creek and contributing to *E. coli* sediment reservoirs. Also, if irrigation tailwater is entering ditches, it may deliver sediment and/or *E. coli* to the creek. | Map all irrigation diversions and ditches. Have volunteers float/wade the creek with a GPS unit, camera, and notebook to inventory irrigation infrastructure. Engage local ditch associations. Identify problem areas and provide incentives to implement best management practices. | Cooperative Extension, ditch associations, Yavapai County GIS, ADWR, OCWC |
| AG-3 | Cornville area | Reportedly there is a least one low water ford across Oak Creek downstream of Cornville that may be contributing sediment to the creek. | Investigate and map all fords, especially those that are not cement fords (can be combined with mapping effort above). Work collaboratively with property owners to explore implementation of improvements to reduce sediment inputs. | Yavapai County GIS, property owners, OCWC |

# Chapter 3 – Watershed Improvement Strategy

## Best Management Practices Projects

As the result of the field investigation, social survey and review of past studies, OCWC is proposing 15 projects to reduce sources of *E. coli* and related fecal contamination in Oak Creek. These projects are outlined in detail in Appendix B. The project descriptions are intended to serve as a foundation for future funding proposals and project work plans. Table 14 provides the titles of the 15 projects. They are arranged by topic in order of priority, ie. Education and Outreach is the highest priority. The topics include Education and Outreach, Septic Systems, Stormwater, Recreation, and Agriculture. Priority ranking is based on knowledge from investigation results, past studies, observation, and anecdotal evidence. These priority rankings are subject to change following further review by the OCWC and OCWIC.

Table 14. Oak Creek WIP proposed BMP projects in order of priority

| Project ID | Project Name |
|---|---|
| ***Top Priority Projects*** | |
| EO-2 | Oak Creek Canyon Public Outreach Program |
| EO-5 | "Even One" *E. Coli* Outreach Project |
| EO-6 | Oak Creek Community Outreach Program (OCCOP) |
| SS-1 | Oak Creek Commercial Septic System Improvement Incentive Project |
| SW-1 | Sedona Area Stormwater Improvement Project |
| RC-1 | Oak Creek Canyon Public Toilet Access Project |
| RC-3 | Keeping Oak Creek Beautiful – Trash Receptacle Access Project |
| ***Second Tier Projects*** | |
| EO-1 | Sedona Dog Waste Reduction Outreach Project |
| EO-3 | Lower Oak Creek Watershed Outreach Project |
| EO-4 | Recreational Vehicle Proper Waste Disposal Outreach Project |
| SS-2 | Oak Creek Residential Septic System Improvement Project |
| RC-2 | Oak Creek Canyon Sediment Source Reduction Project |
| RC-4 | Oak Creek Watershed Dog Waste Station Installation Project |
| AG-1 | Animal Waste BMPs for Oak Creek Watershed |
| AG-2 | Oak Creek Irrigation Diversion Erosion Reduction Project |
| AG-3 | Lower Oak Creek Erosion Reduction Project |

## Load Reduction

Through the implementation of Best Management Practices, over the course of several years, *E. coli* loading in Oak Creek may be expected to decrease considerably and the incidence of WQS exceedances should also decrease. However, evidence shows that it unlikely that exceedances can be completely eliminated, because storm events deliver large loads of *E. coli* to Oak Creek, much of which comes from wildlife sources. This loading, along with turbulent resuspension of *E. coli* from sediment reservoirs, causes *E. coli* counts in Oak Creek that far exceed the water quality standard but attenuate to background levels over 2 to 3 days following the storm event.

The University of Arizona estimated load reductions for each of the BMP projects using modeling techniques, pollutant loading values from the literature, and Oak Creek monitoring data. Table 15 is a summary of the estimated pollutant load reductions. The BMP project descriptions include explanations of UA's methods and findings.

Table 15. Pollution load reduction estimations for each Oak Creek BMP project

| Project # | Project Title | Estimated Load Reduction | source |
|---|---|---|---|
| EO-1 | Sedona Dog Waste Reduction Outreach Project | 5.1 x $10^{13}$ CFU *E. coli* bacteria/year | dog feces |
| EO-2 | Oak Creek Canyon Public Outreach Program | 5.6 x $10^{12}$ CFU *E. coli* bacteria/year | human feces |
| | | 3 x $10^{10}$ CFU *E. coli* bacteria/year | diapers |
| | | 5.1 x $10^{13}$ CFU *E. coli* bacteria/year | dog feces |
| | | 7.02 tons of sediment/year | erosion |
| EO-3 | Lower Oak Creek Watershed Outreach Project – Animal Waste Dumping | 5.1 x $10^{11}$ CFU *E. coli* bacteria/year | horse feces |
| | | 9.7 x $10^{12}$ CFU *E. coli* bacteria/year | cow feces |
| EO-4 | Recreational Vehicle Proper Waste Disposal Outreach Project | 8.7 x $10^{11}$ CFU *E. coli* bacteria/year | human feces |
| EO-5 | "Even One" *E. Coli* Outreach Project | 5.6 x $10^{12}$ CFU *E. coli* bacteria/year | human feces |
| SS-1 | Oak Creek Commercial Septic System Improvement Incentive Project | 77.9 tons sediment/year | septics |
| | | 3,506.5 lbs nitrogen/year | septics |
| | | 601.6 lbs phosphorus/year | septics |
| SS-2 | Oak Creek Residential Septic System Improvement Project | 77.9 tons sediment/year | septics |
| | | 3,506.5 lbs nitrogen/year | septics |
| | | 601.6 lbs phosphorus/year | septics |
| SW-1 | Sedona Area Stormwater Improvement Project | 17 x $10^{12}$ CFU *E. coli* bacteria/year | dog feces |
| | | 4.75 x $10^{10}$ CFU *E. coli* bacteria/year | human feces |
| RC-1 | Oak Creek Canyon Public Toilet Access Project | 5.6 x $10^{12}$ CFU *E. coli* bacteria/year | human feces |

| | | | |
|---|---|---|---|
| RC-2 | Oak Creek Canyon Sediment Source Reduction Project | 7.02 tons per year | erosion |
| RC-3 | Keeping Oak Creek Beautiful – Trash Receptacle Access Project | 3 x $10^{10}$ CFU *E. coli* bacteria/year | diapers |
| RC-4 | Oak Creek Watershed Dog Waste Station Installation Project | 5.1 x $10^{13}$ CFU *E. coli* bacteria/year | dog feces |
| AG-1 | Animal Waste BMPs for Oak Creek Watershed | 5.1 x $10^{11}$ CFU *E. coli* bacteria/year<br>9.7 x $10^{12}$ CFU *E. coli* bacteria/year | horse feces<br>cow feces |
| AG-2 | Oak Creek Irrigation Diversion Erosion Reduction Project | 10.2 tons sediment/year<br>267.6 lbs nitrogen/year<br>30.2 lbs phosphorus/year | erosion |
| AG-3 | Lower Oak Creek Erosion Reduction Project | none; This project would provide information for development of future BMPs | |

Reducing loads to meet standards is one of the objectives of the WIP. Reducing loads to meet standards necessarily entails eliminating human-related sources as much as possible to try to meet the TMDL reduction recommendation. Because eliminating all human sources would be extremely challenging, priorities should be set to reduce those sources that most affect *E. coli* exceedances during the summer months when there is high level of human contact with Oak Creek water. It is the finding of the OCWC that the greatest effort should be spent where the greatest opportunity exists to reduce human contact with pathogens, in other words where the greatest concentration of recreational water use occurs, with the acknowledgement that recreation in Oak Creek occurs throughout its entire length.

All of the proposed projects provide needed *E. coli* load reduction, but the largest reductions would most likely come from identifying sediment and *E. coli* sources in tributary wash watersheds in and around Sedona. Also the Oak Creek Canyon Public Toilet Campaign and the Commercial Septic System Improvement Demonstration Program would be important. Some reduction would occur immediately upon implementation, but total reduction is not likely to occur until there is comprehensive control of nonpoint source fecal pollution in the Oak Creek Watershed.

## Cost-effectiveness comparison

Although an in-depth cost analysis was not completed for this report, generally the education and outreach projects are probably the most cost effective, since change in human behavior is necessary to reduce fecal contamination in Oak Creek. Also, outreach does not require permitting or pose technical challenges for the most part. Projects that physically support behavior changes, such as installation and maintenance of public toilets, trash receptacles and dog waste stations, are all expected to be cost effective in addressing pollution. Mitigation measures for septic systems may be very expensive, but should not be ruled out, since where needed these projects could have a significant effect on human health. Projects for some of the agricultural impacts in the lower watershed were ranked lower because the causation is not as directly attributable, fewer recreators may be impacted, and the cost in time and effort to address these concerns is considerable for an uncertain outcome.

## Other resources and barriers considered

Several funding opportunities and potential collaborations exist to support proposed projects, including:

- Arizona Community Foundation
- Arizona Department of Environmental Quality
- Arizona Department of Water Resources/Arizona Water Protection Fund
- Arizona Public Service
- Bureau of Land Management
- Bureau of Reclamation
- Coconino County
- Coconino National Forest
- Clean Water Act Section 319(h) grants
- City of Sedona
- EQIP
- Kling Family Foundation
- Nina Mason Pulliam Charitable Trust
- National Science Foundation research grant related to *E. coli* in sediments
- Red Rock State Park
- Salt River Project
- Sedona Community Foundation
- Sedona New Frontiers
- Slide Rock State Park
- Udall Foundation
- United States Environmental Protection Agency
- Yavapai County
- The Walton Family Foundation
- Watershed Management Group
- WIFA

Land owners' desire and commitment to maintain improvements are important for project success. Considerations include the following:

- Agricultural land owners need to be engaged.
- Firm commitments are needed for maintaining dog waste collection stations.
- Septic system owners need to be approached in a non-threatening way, encourage collaboration and provide assistance.
- City of Sedona continued commitment to stormwater monitoring and public outreach.
- Elf Neighborhood desires to resolve flooding problems that may impact water quality

The Oak Creek Watershed is fortunate to have technical support available from several sources. Technical support may involve loaning monitoring equipment, providing technical advice, reviewing documents and outreach materials, providing student workers for assessment tasks, sharing historic data, providing technical expertise, collaborating on funding proposals, assisting with permitting processes, contributing to any needed environmental assessments prior to project implementation, entering into cost share agreements, and linking project activities to larger regional water management objectives. Sources of technical support may include:

- ADEQ
- City of Sedona
- Arizona State Parks
- Northern Arizona University
- University of Arizona
- OCWC volunteer experts
- The Nature Conservancy
- Sierra Club
- Verde Watershed Association
- Yavapai County Water Advisory Committee
- Coconino National Forest
- Bureau of Reclamation
- ADWR

Training and educational support available from:

- Northern Arizona University
- University of Arizona, Cooperative Extension Service
- NEMO
- OCWC volunteer experts

Several organizations may provide community involvement in implementation and maintenance, including:

- Home Owners Associations
- Friends of the Forest
- OCWC
- Master Watershed Stewards
- Spring Stewards

Some potential barriers to implementation include the following

- Absentee landowners
- It could be difficult to reach recreation users with information during the brief window they are in the watershed.

## Other Recommendations

### Water Quality Monitoring

Oak Creek Watershed Council should continue to monitor water quality in Oak Creek and perhaps enter into a collaborative relationship with Friends of the Forest who does regular *E. coli* monitoring. Beyond water quality monitoring, systematic testing of Oak Creek sediment should be conducted to see were *E. coli* sediment reservoir hot spots exists and to try to trace upgradient sources of *E. coli*. Coordinated sampling at various points along Sedona washes would be very beneficial to locate source areas of *E. coli* that is washed into Oak Creek during storm events. Turbidity testing may be another very useful way to locate erosion problems and sediment sources that contribute to *E. coli* sediment reservoirs.

### Scientific investigations

Since Crabill published his results in 1999, we have known that a primary mode of *E. coli* contamination in Oak Creek is disturbance of *E. coli* sediment reservoirs by recreation or storm events. Southam (2000) repeated this finding and urged further investigation of Oak Creek sediment. Yet, only limited sediment testing (by ADEQ in 2004 and 2005) has been conducted in the past 12 years, and the methods and results differed from Southam's, so a both methods should be employed simultaneously to test the efficacy of each for monitoring *E. coli* sediment reservoirs. Also, testing of sediment up- and downstream of suspected *E. coli* sources should be done to determine the extent to which sources may "charge" reservoirs with bacteria. While many of the efforts to reduce *E. coli* have been well intentioned, none have proven effective. BMPs are not likely to be fully effective until sediment reservoir hot spots are identified and the *E. coli* stored in these reservoirs is traced back to its source. If Oak Creek contains more fine sediment than would naturally occur without human activity in the watershed, then identification of priority sediment reduction projects is in order. A geomorphic study of the bedload and bank deposits may be able to determine if sediment load in Oak Creek has changed over the past approximately 140 years since settlement by non-Indians. Forest restoration work in the upper watershed over the next 10 to 20 years is likely to generate additional sediment. Working with the Coconino National Forest, sediment and dissolved organic carbon discharge from the upper watershed should be monitored both because of potential to generate *E. coli* sediment reservoir and because of potential impacts on aquatic life.

The very obvious loading of *E. coli* into Oak Creek from washes in the Sedona area begs for a study of the washes in and around Sedona. Perhaps, as a City of Sedona's engineer asserts, a concentration of wildlife around the perimeter of Sedona is the primary source of *E. coli*. Or perhaps pet waste and human waste are also significant sources. Human DNA appeared in only 1 of 4 stormwater DNA samples (Carroll Canyon), but it was a strong positive (3 of 3). Dog DNA was negative in all 4 stormwater samples and 2 stormflow creek samples, which seem to be erroneous results due to a fairly high detection limit or perhaps degraded sample, since Southam's results regularly showed dog DNA is Oak Creek. A stratified stormwater sampling scheme should be devised with 1. high density *E. coli* and DNA sampling, 2. follow-up DNA testing where *E. coli* levels are high, and 3. systematic isolation of areas that appear as sources of *E. coli*, especially from human and dogs. This would require a high level of coordination and sufficient volunteer or paid personnel to accomplish, because storm events that produce stormwater flow are infrequent and unpredictable. Alternatively, automated samplers with cooling systems to preserve samples and cellular text messaging to alert investigators that a sample is available for pickup could be used, but such systems are expensive. In either case, ground surveys of fecal matter should be conducted throughout the tributary wash watersheds to determine where there are concentrations of human, pet or wildlife feces that may contribute to *E. coli* loading. Plots may be established along transects and feces found within a plot would be tossed outside the plot so that on subsequent outings only new feces are counted, to obtain an estimate of the human, pet or wildlife defecation rates in the area.

### NPDES and MS4 Compliance Monitoring

Although tracking water discharge permits in the watershed would not necessarily rise to the level of a project, some sort of communication is needed between watershed advocates and the NPDES and MS4 Permit Units of ADEQ to see if resources can be pooled to facilitate regular compliance monitoring of wastewater treatment systems and stormwater systems in the watershed. These systems are self-monitoring and there is little independent monitoring of downstream water quality. Ongoing monitoring of *E. coli* concentrations in Oak Creek might be useful to identify wastewater discharges of concern. Discharge Monitoring Reports for the Sedona Ventures WWTP that discharges to Dry Creek and Pinewood Sanitary District that discharge to Munds Creek were viewed at ADEQ. No exceedances were found in Sedona Ventures records and in fact discharge effects flow down Dry Creek that reaches Oak Creek. Pinewood Sanitary District (Pinewood) reported one exceedance during January of 2011. During the period 2005-2011, Pinewood listed several emergency discharges, which are allowed under their permit (with monitoring) to avoid pond levels becoming too high on their dam. The most reasonable monitoring would be to keep tabs on when Munds Creek flows in the spring or during monsoon season and sample flow to see if any *E. coli* may be coming down from Munds Park.

## Conclusion

The same actions recommended in 1999 by ADEQ's first TMDL report and by Southam in 2000 (see Chapter 1) are needed yet today to reduce *E. coli* and related fecal contamination in Oak Creek. Some have been implemented on a limited basis, but a more comprehensive effort is needed to educate the public and provide the means for healthy behaviors (eg. dog waste collection stations and adequate toilet access). The fact that our findings echo those of previous studies that were completed more than 10 years ago underscores the importance of translating science to the public through effective public outreach efforts. Science is not meant to sit on a shelf moldering in a forgotten professional journal or agency report. Scientific findings must be transformed into public knowledge that has the power to affect human behavior to improve the environment. That is why 5 out of 15 of the proposed projects are education and outreach projects, and the remaining 10 projects each have a key education and outreach element, all of which would fall under the umbrella of the Oak Creek Community Outreach Program (OCCOP). Although actions of the Oak Creek Watershed Council (previously Oak Creek Canyon Task Force), ADEQ, Coconino National Forest, Slide Rock State Park and others have tried to reduce *E. coli*, records of *E. coli* exceedances at SRSP show no trend in either frequency or severity. This lack of response may be because some key science-based recommendations of the past have not been acted upon. Our hope is that this WIP and the projects created from it will remedy this situation.

## Literature cited


ADEQ. 1999a. Total Maximum Daily Loads for Oak Creek – Slide Rock State Park. Parameters: *Escherichia coliform*. Arizona Department of Environmental Quality. 54 p.

ADEQ. 1999b. Pathogen Total Maximum Daily Loads for Oak Creek – Slide Rock State Park Oak Creek Canyon, AZ. Arizona Department of Environmental Quality. 69 p.

ADEQ. 1999c. Total Maximum Daily Load for Oak Creek - Headwaters to the Verde River - Parameters: Total Phosphorous and Total Nitrogen. Open File Report 09-05. 48 p.

ADEQ. 2008. Draft Biocriteria Implementation Procedures. Arizona Department of Environmental Quality, Phoenix, AZ. 25 p.

ADEQ. 2010. Oak Creek and Spring Creek Verde River Watershed Total Maximum Daily Loads for *Escherichia coliform.* Arizona Department of Environmental Quality. 39 p.

Bitton, Gabriel and Ronald W. Harvey. Transport of pathogens through soils and aquifers. Environmental microbiology, 103-124.

Cleland, Bruce. 2003. TMDL Development from the "Bottom Up"– Part III: Duration Curves and Wet-Weather Assessments. TMDL 2003 Conf. Proc. 27 p.

EPA. 2011a. Basic Information about *E. coli* 0157:H7 in Drinking Water. http://water.epa.gov/drink/contaminants/basicinformation/ecoli.cfm Website accessed July 18, 2011.

EPA. 2011b. Drinking Water Contaminants: National Primary Drinking Water Regulations. http://water.epa.gov/drink/contaminants/index.cfm website accessed July 18, 2011.

EPA. 2011c. Water: Monitoring and Assessment: 5.11 Fecal Bacteria. Online document only, http://water.epa.gov/type/rsl/monitoring/vms511.cfm,Website accessed June 26, 2011.

EPA. 2011d. Impaired Waters and Total Maximum Daily Loads. http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/, Website accessed June 25, 2011.

EPA. 2012. National Menu of Stormwater Best Management Practices. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/. Website accessed March 31, 2012.

Dryden, J.E. 1998. Relationships between nutrient concentrations and fecal coliform levels at Pine Flats in Oak Creek, Arizona. MS thesis, Department of Chemistry, NAU. p.13

Field, K. G. and A.E. Bernhard. 2000 Identification of nonpoint sources of fecal pollution in coastal waters by using host-specific 16s ribosomal DNA genetic markers from fecal anaerobes. Appl. Environ. Microbiol. 66 (4) 1587-1594.

Field, K. G., A. E. Bernhard T.J. and Brodeur. 2003. Molecular approaches to microbiological monitoring: fecal source detection. Environ. Monitoring and Assessment 81: 313–326.

Field, K. G. and L.K. Dick. 2004 Rapid estimation of numbers of fecal bacteroides by use of a quantitative PCR assay for 16S rRNA genes. Appl. Environ. Microbiol. 70 (9) 5695-5697.

Fitch, Mark W., Natalie Pearson, Gene Richards and Joel G. Burken. 1998. Biological Fixed-Film Systems. Water Environment Research, 70 (4) 495-518.

Hansen, O. and R. White. 1992. STORET documentation for menu-driven user interface. U.S. Environmental Protection Agency, Region IX, Water Quality Branch, San Francisco, CA.

Jackson, P.D. 1981. Water Quality Report, Slide Rock and Grasshopper Point swim areas in Oak Creek Canyon. Summer 1980. U.S. Forest Service, Coconino National Forest, Arizona.

Jamieson, Rob, Doug M. Joy, Hung Lee, Ray Kostaschuk and Robert Gordon. 2005. Transport and deposition of sediment-associated *Escherichia coli* in natural streams. Water Research 39: 2665–2675

Keswick, Bruce H., De-Shin Wang and Charles P. Gerba. 1982. The use of microorganisms as ground-water tracers: A review. Groundwater, 20 (2) 142-149.

Layton, A., L. McKay, D. Williams, V. Garrett, R. Gentry and G. Sayler. 2006. Development of bacteroides 16S rRNA gene TaqMan-based real-time PCR assays for estimation of total, human, and bovine fecal pollution in water. Appl. Environ. Microbiol. 72 (6) 4214-4224.

Madigan, M.T., J.M. Martinko and J. Parker. 1997. Brock: Biology of Microorganisms. Prentice Hall Pub., 986 p.

Neu, Thomas R. and John R. Lawrence. 1997. Development and structure of microbial biofilms in river water studied by confocal laser scanning microscopy. FEMS Microbiology Ecology, 24 (1) 11–25.

Obr, J.E., R.H. Follett and J.K.Kracht. 1978. Oak Creek Water Quality Report. Arizona Department of Health Services in NADCOG-ADHS, Phoenix, AZ.

OCCTF. 2002. Watershed Based Plan. Oak Creek Canyon Task Force. Available on the Oak Creek Watershed Council website, http://www.oakcreekwatershed.org/2011-12-24-10-32-55/library/2011-12-25-12-34-35/watershed-based-plan. Website accessed March 31, 2012.

Pool, D.R., K.W. Blasch, J.B.Callegary, S.A. Leake and L.F. Graser. 2011. Regional groundwater-flow model of the Redwall-Muav, Coconino, and alluvial basin aquifer systems of northern and central Arizona: U.S. Geological Survey Scientific Investigations Report 2010-5180, 101 p.

Rose, J.B. R.L. Mullinax, S.N. Singh, M.V.Yates AND C.P. Gerba, C.P. 1987. Occurrence of rotaviruses and enteroviruses in recreational waters of Oak Creek, Arizona. Water Research 21(11):1375-1381.

Shanks, O. C., et al. 2010 Performance assessment PCR-based assays targeting bacteroidales genetic markers of bovine fecal pollution. Appl. Environ. Microbiol., 76 (5):1359-1366.

Southam, Gordon, Paul Keim and Christine Keys. 2000. The Oak Creek Canyon *Escherichia coli* Genotyping Project. Submitted to ADEQ Nonpoint Source Unit by Northern Arizona University Dept. of Biological Sciences. 40 p.

Snelling, Julie. 1996. Variation of water chemistry from non-point source pollution at Pine Flats in Oak Creek. MS Thesis, Dept. of Chemistry, Northern Arizona University. 146 p.

Stafford, W.E. 1993. Arizona Forest Service Publication

YCFCD. 2011. Rainfall Sensor Date - Yavapai County Flood Control District. website http://hydrolynx.co.yavapai.az.us/histdata.html. Website accessed February 21, 2012.

**Additional References (not cited)**

Keys, Christine. E. 2001. The identification and characterization of watershed fecal pollution sources affecting Oak Creek, Arizona. MS Thesis, Dept. of Biological Sciences, Northern Arizona University. 139 p.

Lightner, Roger L. 1994. Fecal coliform survival times in sediments of a segment of Oak Creek, Arizona. MS Thesis, Dept. of Biological Sciences, Northern Arizona University. 35 p.

Segall, Burton. A. 1976. The impact of vacation homes on National Forest water resources. Eisenhower Consortium Bulletin 3, Fort Collins, Colorado. 19 p.

## Appendices

Appendix A. Oak Creek W.I.P. watershed investigation data

Appendix B. Oak Creek watershed social survey results

Appendix C. OCWIP Best Management Practices (BMP) Project Descriptions

## Appendices

Appendix A. Oak Creek W.I.P. watershed investigation data

Appendix B. Oak Creek watershed social survey results

Appendix C. OCWIP Best Management Practices (BMP) Project Descriptions

**Table A.1. *E. coli* and DNA results for samples collected in Oak Creek, adjacent springs and tributary washes Summer 2011.**

| | | | | | | | | | | | | | | DNA Results | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| strm_mi | Site_ID | Type | Date | Descript | East* | North* | Elev_m | Elev_ft | Accuracy | Hold_time | E_coli | E_co_dup | E_co_dil | MS** | S*** | all296 | human | bovine | dog |
| *0.5* | M13 | Baseline | 7/5/2011 | West Fork | 431602 | 3872890 | 1702 | 5584 | 18ft | 2:41 | 9.7 | | | | | | | | |
| 49.0 | M08 | Hot Spot | 7/5/2011 | Pine Flats | 432976 | 3873836 | 1691 | 5549 | 7ft | 5:00 | 10.5 | | | | | | | | |
| 46.0 | M09A | Hot Spot | 7/5/2011 | 1/4 mi ds of Forest Houses | 431432 | 3870005 | 1597 | 5241 | 18ft | 0:28 | 8.5 | | | | | | | | |
| 37.4 | M45 | Baseline | 7/5/2011 | Lomacasi | 431532 | 3359813 | 1305 | 4280 | | 1:04 | 5.2 | | | | | | | | |
| 22.7 | M32 | Baseline | 7/5/2011 | Dry Creek Confluence | 419367 | 3851286 | 1121 | 3678 | 4m | 2:49 | 5.1 | | | | | | | | |
| 17.0 | M36 | Hot Spot | 7/5/2011 | Page Springs Bridge | 418422 | 3846869 | 1051 | 3448 | 6m | 3:25 | 33.6 | | | | | | | | |
| 8.9 | M40 | Baseline | 7/5/2011 | Cornville Bridge | 416097 | 3842142 | 1009 | 3310 | 5m | 2:53 | 74.9 | | | | | | | | |
| 2.2 | M41 | Hot Spot | 7/5/2011 | Cornville Estates | 416122 | 3838990 | 1012 | 3320 | 9m | 4:54 | 37.9 | | | | | | | | |
| 46.3 | M09 | Hot Spot | 7/11/2011 | Hoel's Wash/Forest Houses | -111.74748 | 34.97442 | | | 9m | 1:50 | 19.5 | | | | | | | | |
| 43.7 | M44 | Hot Spot | 7/11/2011 | Slide Rock | -111.75261 | 34.94470 | 1362 | 4469 | 9m | 0:23 | 16.8 | | | | | | | | |
| 40.5 | M17 | Hot Spot | 7/11/2011 | Indian Gardens | -111.72820 | 34.90914 | 1397 | 4584 | 5m | 3:10 | 4.1 | | | | | | | | |
| 40.0 | M18 | Hot Spot | 7/11/2011 | Living Springs | -111.72954 | 34.89975 | 1367 | 4485 | 6m | 4:38 | 6.3 | | | | | | | | |
| 34.0 | M25 | Hot Spot | 7/11/2011 | Chavez Crossing Campground | 428890 | 3855894 | 1247 | 4092 | 11ft | 1:14 | 44.1 | | | | | | | | |
| 17.2 | M36 | Hot Spot | 7/11/2011 | Page Springs Bridge | 418475 | 3847364 | 1065 | 3494 | 13ft | 2:25 | 62.0 | | | | | | | | |
| 12.6 | M39A | Baseline | 7/11/2011 | below Spring Creek Confluence | 416142 | 3845177 | 1007 | 3304 | 6m | 1:29 | 70.8 | | | | | | | | |
| 8.9 | M40 | Hot Spot | 7/11/2011 | Cornville Bridge | 416102 | 3842149 | 1005 | 3297 | 6m | 6:34 | 76.8 | | | | | | | | |
| 0.4 | M43 | Baseline | 7/11/2011 | above Verde Confluence | 413855 | 3837885 | 970 | 3182 | 3m | 4:20 | 35.9 | | | | | | | | |
| *0.1* | M39 | Hot Spot | 7/11/2011 | Spring Creek | -111.91485 | 34.74421 | 1023 | 3355 | 15 ft | 1:13 | 32.8 | | | | | | | | |
| 49.0 | M08 | Hot Spot | 7/14/2011 | Pine Flats | -111.73462 | 35.00505 | 1497 | 4911 | 7m | 0:59 | 1.0 | | | | | | | | |
| 37.4 | M45 | Baseline | 7/14/2011 | Lomacasi | -111.74924 | 34.87843 | 1305 | 4280 | | 2:18 | 0.0 | | | | | | | | |
| 22.7 | M32 | Baseline | 7/14/2011 | Dry Creek Confluence | -111.88151 | 34.80063 | 1121 | 3678 | | 3:38 | 2.0 | | | | | | | | |
| 2.2 | M41 | Hot Spot | 7/14/2011 | Cornville Estates | -111.91344 | 34.69084 | 1012 | 3320 | 4m | 5:02 | 13.4 | | | | | | | | |
| 40.5 | M17 | Hot Spot | 7/19/2011 | Indian Gardens | -111.72823 | 34.90922 | 1397 | 4584 | 13 ft | 1:11 | 24.0 | | | | | | | | |
| 22.7 | M32 | Baseline | 7/19/2011 | Dry Creek Confluence | -111.88151 | 34. 80063 | 1121 | 3678 | | 2:36 | 54.7 | | | | | | | | |
| 8.9 | M40 | Baseline | 7/19/2011 | Cornville Bridge | -111.91600 | 34.71806 | 1005 | 3297 | 6m | 3:55 | 149.7 | | | | | | | | |
| *0.5* | M13 | Baseline | 7/28/2011 | West Fork | -111.74952 | 34.99648 | 1625 | | 6m | 1:36 | 6.2 | | | | | | | | |
| 43.7 | M44 | Hot Spot | 7/28/2011 | Slide Rock | -111.75210 | 34.94548 | 1362 | 4469 | 11m | 3:29 | 21.8 | 11.0 | | | | | | | |
| 40.0 | M18 | Hot Spot | 7/28/2011 | Living Springs | -111.72955 | 34.89981 | 1367 | 4485 | 6m | 4:56 | 13.4 | 22.8 | | | | | | | |
| 34.0 | M25 | Hot Spot | 7/28/2011 | Chavez Crossing Campground | -111.77778 | 34.84285 | 1247 | 4092 | 11ft | 5:54 | 18.7 | | | | | | | | |
| 17.2 | M36 | Hot Spot | 7/28/2011 | Page Springs Bridge | -111.89086 | 34. 76523 | 1060 | 3478 | 11 ft | 2:14 | 63.7 | | | | | | | | |
| 12.6 | M39A | Baseline | 7/28/2011 | below Spring Creek Confluence | -111.91587 | 34. 74511 | 1021 | 3350 | 11 ft | 2:46 | 48.8 | | | | | | | | |
| 0.4 | M43 | Baseline | 7/28/2011 | above Verde Confluence | -111.94041 | 34.67934 | 973 | 3193 | 17 ft | 4:33 | 9.4 | | | | | | | | |
| *0.1* | M39 | Hot Spot | 7/28/2011 | Spring Creek | -111.91485 | 34.74421 | 1023 | 3355 | 15 ft | 3:27 | 72.3 | | | | | | | | |
| | M49 | Stormwater | 8/1/2011 | Jordan Pump | -111.75561 | 34.87486 | 1300 | 4264 | 20ft | 2:08 | 1986.28 | | | | | | | | |
| | M48 | Stormwater | 8/1/2011 | Arroyo Roble | -111.75704 | 34.86974 | 1289 | 4229 | 20ft | 3:51 | **2419.2** | | | | | | | | |
| | M47 | Stormwater | 8/1/2011 | Tlaquepaque | -111.76189 | 34.86247 | 1273 | 4176 | 16ft | 4:21 | 435.2 | | | | | | | | |
| | M46 | Stormwater | 8/1/2011 | Soldier's Wash | -111.76265 | 34.86061 | 1270 | 4168 | 16ft | 4:09 | 110.3 | | | | | | | | |
| *2.6* | M26 | Stormwater | 8/1/2011 | Carroll Canyon 3, trail (@Shelby) | -111.80097 | 34.85351 | 1299 | 4263 | 13ft | 4:04 | 509.9 | | | | | | | | |
| *0.6* | M27 | Stormwater | 8/1/2011 | Carroll Canyon 2, bridge | -111.80837 | 34.83286 | 1214 | 3983 | 15ft | 4:23 | 222.1 | | | | | | | | |
| *0.0* | M51 | Stormwater | 8/1/2011 | Carroll Canyon 1, mouth | -111.81006 | 34.82558 | 1206 | 3957 | 16ft | 4:13 | 472.1 | | | | | | | | |
| 8.9 | M40 | Baseline | 8/1/2011 | Cornville Bridge | 416102 | 3842149 | 1005 | 3297 | 6m | 3:04 | 49.6 | | | | | | | | |
| *0.5* | M13 | Baseline | 8/2/2011 | West Fork | -111.74968 | 34.99650 | 1630 | | | 3:27 | 17.5 | | | | | | | | |
| 49.0 | M08 | Hot Spot | 8/2/2011 | Pine Flats | -111.73493 | 35.00590 | 1707 | | 6m | 1:51 | 8.6 | | | | | | | | |
| 46.3 | M09 | Hot Spot | 8/2/2011 | Hoel's Wash/Forest Houses | -111.74785 | 34.97377 | | | 4m | 4:47 | 54.6 | | | | | | | | |

| strm_mi | Site_ID | Type | Date | Descript | East* | North* | Elev_m | Elev_ft | Accuracy | Hold_time | E_coli | E_co_dup | E_co_dil | DNA Results | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | MS** | S*** | all296 | human | bovine | dog |
| 43.7 | M44 | Hot Spot | 8/2/2011 | Slide Rock | -111.75248 | 34.94530 | 1483 | | 4m | 5:58 | 21.6 | | | | | | | | |
| 40.5 | M17 | Hot Spot | 8/2/2011 | Indian Gardens | -111.72832 | 34.90918 | 1394 | 4573 | 17 ft | 2:12 | 12.5 | | | | | | | | |
| 40.0 | M18 | Hot Spot | 8/2/2011 | Living Springs | -111.72956 | 34.89974 | 1365 | 4478 | 18 ft | 2:54 | 26.3 | | | | | | | | |
| 37.4 | M45 | Baseline | 8/2/2011 | Lomacasi | -111.74920 | 34.87845 | 1307 | 4288 | 13 ft | 3:47 | 61.3 | | | | | | | | |
| 34.0 | M25 | Hot Spot | 8/2/2011 | Chavez Crossing Campground | -111.77779 | 34.84282 | 1246 | 4087 | 10 ft | 4:54 | 1732.87 | | | | | | | | |
| 27.9 | M29 | Hot Spot | 8/2/2011 | below Red Rock State Park | -111.83756 | 34.81677 | 1159 | 3802 | 6m | 2:10 | **2419.2** | | | | | | | | |
| 22.7 | M32 | Baseline | 8/2/2011 | Dry Creek Confluence | -111.88068 | 34.80209 | 1121 | 3678 | 4m | 3:12 | **2419.2** | | | | | | | | |
| 17.2 | M36 | Hot Spot | 8/2/2011 | Page Springs Bridge | -111.89099 | 34.76459 | 1060 | 3478 | 5m | 4:11 | **2419.2** | | | | | | | | |
| 2.2 | M41 | Hot Spot | 8/2/2011 | Cornville Estates | -111.91575 | 34.68953 | 1012 | 3320 | 4m | 5:20 | 86.5 | | | | | | | | |
| | S41 | Focus | 8/10/2011 | Spring 41, upstream of SRSP | -111.75408 | 34.96543 | 1549 | 5081 | 16 ft | 5:37 | 47.1 | | | | | | | | |
| | S52 | Focus | 8/10/2011 | Spring 52, Indian Gardens | -111.72732 | 34.91336 | 1411 | 4629 | 16 ft | 4:41 | 1.0 | | | | | | | | |
| | S49 | Focus | 8/10/2011 | Spring 49 near source | -111.72690 | 34.91309 | 1391 | 4565 | 18 ft | 4:28 | 86.0 | | | | | | | | |
| | S48 | Focus | 8/10/2011 | Spring 48, Indian Gardens | -111.72687 | 34.91257 | 1384 | 4540 | 16 ft | 4:16 | 0.0 | | | | | | | | |
| | S45 | Focus | 8/10/2011 | Spring 45 waterfall | -111.72680 | 34.91192 | 1399 | 4589 | 16 ft | 4:05 | 2.0 | | | | | | | | |
| | S42 | Focus | 8/10/2011 | Spring 42, Munds Creek | -111.72667 | 34.91174 | 1400 | 4592 | 17 ft | 3:56 | 0.0 | | | | | | | | |
| | S2 | Focus | 8/10/2011 | Spring 2, South of IG bridge | -111.72786 | 34.91053 | 1390 | 4559 | 16 ft | 3:23 | 0.0 | | | | | | | | |
| | S16 | Focus | 8/10/2011 | Spring 16, Zane Grey's cabin | -111.74415 | 34.99123 | 1636 | 5369 | 16 ft | 2:19 | 20.7 | | | | | | | | |
| | S16 | Focus | 8/24/2011 | Spring 16, Zane Grey's cabin | -111.74419 | 34.99126 | 1631 | 5351 | 13 ft | 5:19 | 105.0 | | | *1* | *1* | 3 | 1 | 0 | na |
| | S41 | Focus | 8/24/2011 | Spring 41, upstream of SRSP | -111.75405 | 34.96542 | 1551 | 5088 | 15 ft | 4:40 | 19.5 | | | *1* | 3 | 3 | 3 | 0 | na |
| | S52 | Focus | 8/24/2011 | Spring 52, Indian Gardens | -111.72729 | 34.91330 | 1452 | 4763 | 16 ft | 3:55 | 0 | | | *1* | *1* | 3 | 1 | 0 | na |
| | S49 | Focus | 8/24/2011 | Spring 49 near source | -111.72690 | 34.91310 | 1396 | 4580 | 15 ft | 3:29 | 202.4 | 186.0 | | *1* | *1* | 3 | 1 | 0 | na |
| | S100 | Focus | 8/24/2011 | Page Springs Source | -111.88918 | 34.76175 | 1069 | 3507 | 6m | 2:55 | 0.0 | | | 6 | *1* | 3 | 3 | 0 | na |
| | F3 | Focus | 8/24/2011 | Spring Creek above WWT pond | -111.91182 | 34.74839 | 1024 | 3360 | 5m | 5:40 | 46.7 | | | *1* | *1* | 3 | 0 | 0 | na |
| | M39 | Hot Spot | 8/24/2011 | Spring Creek | -111.91481 | 34.74415 | 1018 | 3340 | 8m | 5:03 | 249.5 | | | 12 | 4 | 3 | 0 | 0 | na |
| | S98 | Focus | 8/24/2011 | Bubbling Ponds Spring | -111.90100 | 34.77334 | | | 6m | 3:58 | 25.6 | | | *1* | 2 | 3 | 0 | 0 | na |
| | F4 | Focus | 8/24/2011 | Bubbling Ponds outfall | -111.89695 | 34.76559 | 1048 | 3438 | 6m | 3:28 | 14.6 | | | *1* | 4 | 3 | 0 | 0 | na |
| | S35 | Spring | 9/1/2011 | Spring 35, West Fork | -111.74804 | 34.98176 | 1633 | 5358 | 5m | 1:58 | 20.3 | | | | | | | | |
| | S36 | Spring | 9/1/2011 | Spring 36, West Fork | -111.74792 | 34.98204 | | | | 1:52 | 56.9 | | | | | | | | |
| | S39 | Spring | 9/1/2011 | Walnut Spring, West Fork | -111.74649 | 34.98646 | 1619 | 5312 | 4 m | 3:22 | 12.0 | | | | | | | | |
| | S1 | Spring | 9/1/2011 | Spring 1, Indian Gardens | -111.72790 | 34.90980 | 1431 | 4695 | 8m | 4:31 | 0.0 | | | | | | | | |
| | S3 | Spring | 9/1/2011 | Spring 3, Indian Gardens | -111.72752 | 34.91114 | | | | 4:51 | 0.0 | | | | | | | | |
| | F5 | Focus | 9/1/2011 | Creek from Spring 59, Indian Gardens | -111.72728 | 34.90637 | | | | 6:43 | 29.5 | | | | | | | | |
| | S58 | Spring | 9/1/2011 | Spring 58 Pool, Indian Gardens | -111.72804 | 34.90982 | 1384 | 4541 | 6m | 6:00 | 35.9 | | | | | | | | |
| | S67 | Spring | 9/1/2011 | Spring 67, Indian Gardens | -111.72711 | 34.90614 | | | | 6:31 | 18.1 | | | | | | | | |
| | S75 | Spring | 9/1/2011 | Spring 75 Pool, Indian Gardens | -111.72769 | 34.91044 | 1382 | 4534 | 4m | 5:44 | 0.0 | | | | | | | | |
| | S77 | Spring | 9/1/2011 | Spring 77 Pool, Indian Gardens | -111.72741 | 34.91112 | 1398 | 4587 | 5m | 5:20 | 0.0 | | | | | | | | |
| | S78 | Spring | 9/1/2011 | Spring 78, Indian Gardens | -111.72987 | 34.91822 | 1420 | 4659 | 5m | 3:52 | 0.0 | | | | | | | | |
| | M49 | Stormwater | 9/6/2011 | Jordan Pump | -111.75561 | 34.87486 | 1300 | 4264 | 20ft | 4:13 | 172.0 | | | *1* | *1* | 3 | 0 | 0 | 0 |
| | M48 | Stormwater | 9/6/2011 | Arroyo Roble | -111.75704 | 34.86974 | 1289 | 4229 | 20ft | 4:40 | **2419.2** | | | *1* | 2110 | 3 | 0 | 0 | 0 |
| | M46 | Stormwater | 9/6/2011 | Soldier's Wash | -111.76265 | 34.86061 | 1270 | 4168 | 16ft | 5:08 | **2419.2** | | | *1* | 19 | 3 | 0 | 0 | 0 |
| | F1 | Focus | 9/6/2011 | Chavez Ranch Day Use Area | | | | | | 2:44 | 727.0 | | | 19 | 35 | 3 | 0 | 0 | na |
| | M26 | Stormwater | 9/6/2011 | Carroll Canyon 3, trail (@Shelby) | -111.80097 | 34.85351 | 1299 | 4263 | 13ft | 2:04 | **2419.2** | | | *1* | 610 | 3 | 0 | 0 | na |
| | M27 | Stormwater | 9/6/2011 | Carroll Canyon 2, bridge | -111.80837 | 34.83286 | 1214 | 3983 | 15ft | 3:17 | **2419.2** | | | *1* | *1* | 3 | 3 | 0 | 0 |
| 37.4 | M45 | Baseline | 9/7/2011 | Lomacasi | -111.74920 | 34.87845 | 1307 | 4288 | 13 ft | 1:31 | 18.1 | | | | | | | | |

| | | | | | | | | | | | | | | DNA Results | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| strm_mi | Site_ID | Type | Date | Descript | East* | North* | Elev_m | Elev_ft | Accuracy | Hold_time | E_coli | E_co_dup | E_co_dil | MS** | S*** | all296 | human | bovine | dog |
| 34.0 | M25 | Hot Spot | 9/7/2011 | Chavez Crossing Campground | 428890 | 3855894 | 1247 | 4092 | 11ft | 1:56 | 57.1 | | | | | | | | |
| 27.9 | M29 | Hot Spot | 9/7/2011 | below Red Rock State Park | -111.83798 | 34.81655 | 1165 | 3821 | 17 ft | 2:35 | 30.5 | 40.2 | | | | | | | |
| 17.2 | M36 | Hot Spot | 9/7/2011 | Page Springs Bridge | 418475 | 3847364 | 1065 | 3494 | 13ft | 3:45 | 39.7 | | | | | | | | |
| 8.9 | M40 | Hot Spot | 9/7/2011 | Cornville Bridge | 416102 | 3842149 | 1005 | 3297 | 6m | 4:25 | 25.3 | | | | | | | | |
| | M49 | Stormwater | 9/11/2011 | Jordan Pump | -111.75561 | 34.87486 | 1300 | 4264 | 20ft | 2:57 | **2419.2** | | **8200.7** | | | | | | |
| | M48 | Stormwater | 9/11/2011 | Arroyo Roble | -111.75704 | 34.86974 | 1289 | 4229 | 20ft | 2:54 | 1986.2 | | 1563.1 | | | | | | |
| | M46 | Stormwater | 9/11/2011 | Soldier's Wash | -111.76265 | 34.86061 | 1270 | 4168 | 16ft | 6:11 | 2419.2 | | 2625.5 | | | | | | |
| | M26 | Stormwater | 9/11/2011 | Carroll Canyon 3, trail (@Shelby) | -111.80097 | 34.85351 | 1299 | 4263 | 13ft | 6:24 | **2419.2** | | 6019.0 | | | | | | |
| | M27 | Stormwater | 9/11/2011 | Carroll Canyon 2, bridge | -111.80837 | 34.83286 | 1214 | 3983 | 15ft | 6:40 | **2419.2** | | 3695.9 | | | | | | |
| 49.0 | M08 | Hot Spot | 9/11/2011 | Pine Flats | 432976 | 3873836 | 1691 | 5549 | 7ft | 2:15 | 15.8 | | 1101.7 | *1* | 2 | 3 | 2 | 0 | na |
| 40.5 | M17 | Hot Spot | 9/11/2011 | Indian Gardens | -111.72832 | 34.90918 | 1394 | 4573 | 17 ft | 2:35 | 152.9 | | 179.7 | *1* | 2 | 3 | 3 | 0 | na |
| 37.4 | M45 | Baseline | 9/11/2011 | Lomacasi | -111.74920 | 34.87845 | 1307 | 4288 | 13 ft | 2:50 | 117.8 | | 599.2 | *1* | 7 | 3 | 2 | 0 | 0 |
| 34.0 | M25 | Hot Spot | 9/11/2011 | Chavez Crossing Campground | 428890 | 3855894 | 1247 | 4092 | 11ft | 3:12 | 1413.6 | | 8202.4 | *1* | 18 | 3 | 2 | 0 | na |
| 27.9 | M29 | Hot Spot | 9/11/2011 | below Red Rock State Park | -111.83798 | 34.81655 | 1165 | 3821 | 17 ft | 3:49 | 2419.17 | | 3170.4 | *1* | 81 | 3 | 2 | 0 | 0 |
| 22.7 | M32 | Baseline | 9/11/2011 | Dry Creek Confluence | -111.88068 | 34.80209 | 1121 | 3678 | 4m | 4:24 | 344.8 | | 354.2 | *1* | 15 | 3 | 1 | 0 | na |
| 17.2 | M36 | Hot Spot | 9/11/2011 | Page Springs Bridge | 418475 | 3847364 | 1065 | 3494 | 13ft | 4:21 | 816.4 | 727.0 | 459.1 | *1* | 14 | 3 | 3 | 0 | na |
| 2.2 | M41 | Hot Spot | 9/11/2011 | Cornville Estates | 416122 | 3838990 | 1012 | 3320 | 9m | 4:46 | 58.1 | | 90.3 | *1* | 12 | 3 | 1 | 0 | na |
| | F4 | Focus | 9/11/2011 | Bubbling Ponds outfall | -111.89695 | 34.76559 | 1048 | 3438 | 6m | 4:51 | 23.3 | | 19.1 | | | | | | |
| 49.0 | M08 | Hot Spot | 9/15/2011 | Pine Flats | 432976 | 3873836 | 1691 | 5549 | 7ft | 3:01 | 0.0 | | n/a | | | | | | |
| 40.5 | M17 | Hot Spot | 9/15/2011 | Indian Gardens | -111.72832 | 34.90918 | 1394 | 4573 | 17 ft | 3:32 | 54.7 | | 65.4 | | | | | | |
| 37.4 | M45 | Baseline | 9/15/2011 | Lomacasi | -111.74920 | 34.87845 | 1307 | 4288 | 13 ft | 3:16 | 517.2 | | 426.0 | | | | | | |
| 34.0 | M25 | Hot Spot | 9/15/2011 | Chavez Crossing Campground | 428890 | 3855894 | 1247 | 4092 | 11ft | 3:35 | **2419.2** | | 1354.0 | | | | | | |
| 27.9 | M29 | Hot Spot | 9/15/2011 | below Red Rock State Park | -111.83798 | 34.81655 | 1165 | 3821 | 17 ft | 4:26 | **2419.2** | | 2489.0 | | | | | | |
| 22.7 | M32 | Baseline | 9/15/2011 | Dry Creek Confluence | -111.88068 | 34.80209 | 1121 | 3678 | 4m | 5:10 | **2419.2** | | 5794.0 | | | | | | |
| 17.2 | M36 | Hot Spot | 9/15/2011 | Page Springs Bridge | 418475 | 3847364 | 1065 | 3494 | 13ft | 5:49 | n/a | | 506.0 | | | | | | |
| 8.9 | M40 | Baseline | 9/15/2011 | Cornville Bridge | 416102 | 3842149 | 1005 | 3297 | 6m | 6:22 | **2419.2** | | 7270.0 | | | | | | |
| | S52 | Focus | 9/16/2011 | Spring 52, Indian Gardens | -111.72729 | 34.91330 | 1452 | 4763 | 16 ft | 2:05 | 16.1 | | | *1* | *1* | 3 | 0 | 0 | na |
| | S49A | Focus | 9/16/2011 | Spring 49 source | -111.72700 | 34.91347 | 1394 | 4574 | 17 ft | 2:35 | 2.0 | 4.1 | | 6 | *1* | 3 | 1 | 0 | na |
| | F6 | Focus | 9/16/2011 | Spring ditch, AGFD | -111.90091 | 34.77384 | 1083 | 3552 | 18 ft | 3:39 | 2419.17 | | | *1* | *1* | 3 | 0 | 0 | na |
| | S107 | Focus | 9/16/2011 | Spring ditch | -111.89752 | 34.77061 | 1063 | 3488 | 19 ft | 4:07 | **2419.2** | | | *1* | 82 | 3 | 0 | 0 | na |
| | S98 | Focus | 9/16/2011 | Bubbling Ponds Spring | -111.90100 | 34.77334 | | | 6m | 4:17 | 19.9 | | | *1* | *1* | 3 | 0 | 0 | na |
| | F4 | Focus | 9/16/2011 | Bubbling Ponds outfall | -111.89695 | 34.76559 | 1048 | 3438 | 6m | 3:31 | 147.0 | | | *1* | 17 | 2 | 0 | 0 | na |
| | S100 | Focus | 9/16/2011 | Page Springs source | -111.88918 | 34.76175 | 1069 | 3507 | 6m | 5:55 | 0.0 | | | 1 | *1* | 3 | 0 | 0 | na |
| | F3 | Focus | 9/16/2011 | Spring Creek above WWT pond | -111.91182 | 34.74839 | 1024 | 3360 | 5m | 6:32 | 579.3 | | | *1* | *1* | 3 | 0 | 0 | na |
| | M39 | Hot Spot | 9/16/2011 | Spring Creek | -111.91482 | 34.74411 | 1025 | 3363 | 20 ft | 7:03 | 686.7 | | | 2 | 39 | 3 | 1 | 0 | na |
| | S9 | Focus | 9/20/2011 | Pine Flat spring @ road | | | | | | 1:43 | 0.0 | | | | | | | | |
| | S41 | Focus | 9/20/2011 | Spring 41, upstream of SRSP | -111.75408 | 34.96543 | 1549 | 5081 | 16 ft | 2:30 | 16.4 | | | 4 | 3 | 3 | 0 | 0 | na |
| | S49A | Focus | 9/20/2011 | Spring 49 source | -111.72700 | 34.91347 | 1394 | 4574 | 17 ft | 2:57 | 20.1 | | | 2 | *1* | 3 | 0 | 0 | na |
| | S49 | Focus | 9/20/2011 | Spring 49 near source | -111.72690 | 34.91309 | 1391 | 4565 | 18 ft | 3:10 | 15.5 | | | 6 | *1* | 3 | 3 | 0 | na |
| | F7 | Focus | 9/20/2011 | Lower Indian Gardens spring, upper end | | | | | | 3:40 | 27.8 | | | | | | | | |
| | S71 | Focus | 9/20/2011 | Lower Indian Gardens spring, midway | -111.727733 | 34.90435 | | | | 3:57 | 22.8 | | | *1* | *1* | 3 | 1 | 0 | na |
| | S70 | Focus | 9/20/2011 | Lower Indian Gardens spring, near fish runs | -111.727806 | 34.90273 | | | | 4:13 | 18.5 | | | *1* | 3 | 3 | 3 | 0 | na |

| strm_mi | Site_ID | Type | Date | Descript | East* | North* | Elev_m | Elev_ft | Accuracy | Hold_time | E_coli | E_co_dup | E_co_dil | DNA Results<br>MS** | S*** | all296 | human | bovine | dog |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F6 | Focus | 9/20/2011 | Spring ditch, AGFD | -111.900909 | 34.77382 | | | | 5:52 | 272.3 | | 187.0 | *1* | 33 | 3 | 0 | 0 | na |
| | S107 | Focus | 9/20/2011 | Spring ditch | -111.897561 | 34.77068 | | | | 5:25 | 116.9 | | 86.0 | *1* | 19 | 3 | 1 | 0 | na |
| | S109 | Focus | 9/21/2011 | Lower Indian Gardens spring, down channel | -111.72854 | 34.90035 | 1373 | 4506 | 4m | 1:21 | 0.0 | | 0.0 | *1* | *1* | 3 | 3 | 0 | na |
| | S45A | Focus | 9/22/2011 | Spring 45 source | -111.726331 | 34.91233 | | | | 1:23 | 0.0 | | | | | | | | |
| | S45B | Focus | 9/22/2011 | Spring 45 water fountain on side of house | | | | | | 1:13 | 0.0 | | | | | | | | |
| | S71 | Focus | 9/22/2011 | Lower Indian Gardens spring, midway | -111.727733 | 34.90435 | | | | 2:14 | 27.8 | | | *1* | 4 | 3 | 3 | 0 | na |
| | S70 | Focus | 9/22/2011 | Lower Indian Gardens spring, near runs | -111.727806 | 34.90273 | | | | 2:37 | 25.6 | | | *1* | 4 | 3 | 1 | 0 | na |
| | S109 | Focus | 9/22/2011 | Lower Indian Gardens spring, down channel | -111.72854 | 34.90035 | 1373 | 4506 | 4m | 3:07 | 8.5 | | | *1* | *1* | 3 | 2 | 0 | na |

gray highlight denotessamples from tributary streams
green highlight denotes samples from springs
no highlighting denotes Oak Creek samples

**bold numbers** mean "greater than"
*italic numbers* mean "less than"
red font means "out of hold time" or other attention

* Eastings and northings are either in WGS 84 Decimal Degrees (eg. -111.727733 degrees E, 34.904349 degrees N) or in NAD 83 UTM zone 12N (eg. 418375 meters E, 3847364 meters N).
**MS = Male Specific Phage
***S = Somatic Phage

**Table A.2. Basic water quality for sampling locations in Oak Creek, adjacent springs and tributary washes Summer 2011.**

| strm_mi | Site_ID | Date | Descript | turbid | PO4-P | NO2- | NO3-N | NH4+ | Air_T_C | H2O_T_C | DO_mg/L** | DO_%sat | Cond*** | TDS | pH | pH_T_C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 | M13 | 7/5/2011 | West Fork | | | | | | 32.0 | 26 | n/a | n/a | 326 | 228 | 8.73 | 26 |
| 49.0 | M08 | 7/5/2011 | Pine Flats | | | | | | 24.0 | 14.5 | n/a | n/a | 270 | 195 | 8.1 | 14.5 |
| 46.0 | M09A | 7/5/2011 | 1/4 mi ds of Forest Houses | | | | | | 28.5 | 21.1 | n/a | n/a | 303 | 212 | 8.66 | 21.1 |
| 37.4 | M45 | 7/5/2011 | Lomacasi | | | | | | 28.0 | 22.1 | 6.14 | 94.4 | 276 | 192 | 9.41 | |
| 22.7 | M32 | 7/5/2011 | Dry Creek Confluence | | | | | | 32.0 | 28.4 | 5.62 | 96.6 | 314 | 214 | 9.05 | |
| 17.0 | M36 | 7/5/2011 | Page Springs Bridge | | | | | | 25.0 | 22.5 | 6.17 | 94.9 | 374 | 266 | 8.41 | 22.8 |
| 8.9 | M40 | 7/5/2011 | Cornville Bridge | | | | | | 34.0 | 27.8 | 9.16 | 133.1 | 451 | 314 | 7.86 | 27.8 |
| 2.2 | M41 | 7/5/2011 | Cornville Estates | | | | | | 34.0 | 27 | 7.54 | 115.3 | 462 | 320 | 8.3 | 27 |
| 46.3 | M09 | 7/11/2011 | Hoel's Wash/Forest Houses | | | | | | 32.0 | 19.1 | 10 | 118 | 286 | 203 | 8.54 | 19.1 |
| 43.7 | M44 | 7/11/2011 | Slide Rock | | | | | | 29.0 | 20.7 | 8.8 | 119.1 | 298 | 210 | 8.3 | 20.7 |
| 40.5 | M17 | 7/11/2011 | Indian Gardens | | | | | | 25.5 | 18.8 | 9.65 | 124 | 272 | 186 | 8.33 | 18.8 |
| 40.0 | M18 | 7/11/2011 | Living Springs | | | | | | 23.0 | 17.7 | 9.2 | 120 | 269 | 188 | 8.06 | 17.7 |
| 34.0 | M25 | 7/11/2011 | Chavez Crossing Campground | | | | | | 27.0 | 22.3 | n/a | n/a | n/a | n/a | 8.37 | 22.3 |
| 17.2 | M36 | 7/11/2011 | Page Springs Bridge | | | | | | 28.1 | 24.4 | n/a | n/a | n/a | n/a | 7.98 | 24.4 |
| 12.6 | M39A | 7/11/2011 | below Spring Creek Confluence | | | | | | 30.5 | 26.3 | 6.22 | 103.38 | 394 | 270 | 9.32 | 26.2 |
| 8.9 | M40 | 7/11/2011 | Cornville Bridge | | | | | | 24.0 | 23.9 | 6.23 | 98.7 | 458 | 319 | 8.22 | 23.9 |
| 0.4 | M43 | 7/11/2011 | above Verde Confluence | | | | | | 29.0 | 27.2 | 6.47 | 110 | 456 | 320 | 9.23 | 27.2 |
| 0.1 | M39 | 7/11/2011 | Spring Creek | | | | | | | | | | | | | |
| 49.0 | M08 | 7/14/2011 | Pine Flats | | | | | | 24.0 | 15.3 | 9.25 | 109.2 | 266 | 185 | 7.97 | 15.3 |
| 37.4 | M45 | 7/14/2011 | Lomacasi | | | | | | 28.9 | 17.9 | 9.12 | 116.6 | 283 | 193 | 8.47 | 17.9 |
| 22.7 | M32 | 7/14/2011 | Dry Creek Confluence | | | | | | 30.0 | 22.3 | 8.01 | 111.7 | 308 | 212 | 7.96 | 22.3 |
| 2.2 | M41 | 7/14/2011 | Cornville Estates | | | | | | 27.5 | 21.3 | 7.21 | 99.8 | 453 | 324 | 7.84 | 21.3 |
| 40.5 | M17 | 7/19/2011 | Indian Gardens | | | | | | 25.4 | 18.9 | n/a | n/a | 279 | 196 | 8.3 | 18.9 |
| 22.7 | M32 | 7/19/2011 | Dry Creek Confluence | | | | | | 33.0 | 24.7 | n/a | n/a | 310 | 216 | 8.21 | 24.7 |
| 8.9 | M40 | 7/19/2011 | Cornville Bridge | | | | | | 23.5 | 23 | n/a | n/a | 468 | 325 | 7.7 | 23 |
| 0.5 | M13 | 7/28/2011 | West Fork | | | | | | 26.0 | 23.6 | n/a | n/a | 315 | 219 | 8.68 | 23.6 |
| 43.7 | M44 | 7/28/2011 | Slide Rock | | | | | | 30.0 | 18.7 | n/a | n/a | 297 | 205 | 8.52 | 18.7 |
| 40.0 | M18 | 7/28/2011 | Living Springs | | | | | | 25.0 | 18.2 | n/a | n/a | 276 | 186 | 8.22 | 18.2 |
| 34.0 | M25 | 7/28/2011 | Chavez Crossing Campground | | | | | | 29.0 | 21.1 | n/a | n/a | 282 | 189 | 8.54 | 21.1 |
| 17.2 | M36 | 7/28/2011 | Page Springs Bridge | | | | | | 30.1 | 25.6 | n/a | n/a | 408 | 293 | 7.92 | 25.6 |
| 12.6 | M39A | 7/28/2011 | below Spring Creek Confluence | | | | | | 32.0 | 23.3 | n/a | n/a | 476 | 333 | 7.88 | 23.3 |
| 0.4 | M43 | 7/28/2011 | above Verde Confluence | | | | | | 29.0 | 24.6 | n/a | n/a | 467 | 324 | 8.16 | 24.6 |
| 0.1 | M39 | 7/28/2011 | Spring Creek | | | | | | 28.0 | 21.9 | n/a | n/a | 653 | 455 | 7.62 | 21.9 |
| | M49 | 8/1/2011 | Jordan Pump | | | | | | | | | | | | | |
| | M48 | 8/1/2011 | Arroyo Roble | | | | | | | | | | | | | |
| | M47 | 8/1/2011 | Tlaquepaque | | | | | | | | | | | | | |
| | M46 | 8/1/2011 | Soldier's Wash | | | | | | | | | | | | | |
| 2.6 | M26 | 8/1/2011 | Carroll Canyon 3, trail (@Shelby) | | | | | | | | | | | | | |
| 0.6 | M27 | 8/1/2011 | Carroll Canyon 2, bridge | | | | | | | | | | | | | |
| 0.0 | M51 | 8/1/2011 | Carroll Canyon 1, mouth | | | | | | | | | | | | | |
| 8.9 | M40 | 8/1/2011 | Cornville Bridge | | | | | | | | | | | | | |
| 0.5 | M13 | 8/2/2011 | West Fork | 0.83 | 0.04 | 0.002 | 0.05 | 0.01 | 28.0 | 24.5 | 7.24 | 116.6 | 337 | 235 | 9.64 | 24.5 |
| 49.0 | M08 | 8/2/2011 | Pine Flats | 0.24 | 0.04 | 0.002 | 0.02 | 0.01 | 23.0 | 15.3 | 11.73 | 160.2 | 290 | 202 | 8.56 | 14.7 |
| 46.3 | M09 | 8/2/2011 | Hoel's Wash/Forest Houses | 0.70 | 0.04 | 0.002 | 0.03 | 0.01 | 24.5 | 18.3 | 7.46 | 105.9 | 311 | 221 | 8.05 | 18.3 |

| strm_mi | Site_ID | Date | Descript | turbid | PO4-P | NO2- | NO3-N | NH4+ | Air_T_C | H2O_T_C | DO_mg/L** | DO_%sat | Cond*** | TDS | pH | pH_T_C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 43.7 | M44 | 8/2/2011 | Slide Rock | 0.79 | *0.04* | *0.002* | 0.03 | *0.01* | 21.0 | 17.5 | 7.77 | 104.7 | 317 | 219 | 8.01 | 17.5 |
| 40.5 | M17 | 8/2/2011 | Indian Gardens | 0.78 | 0.07 | *0.002* | 0.02 | *0.01* | 29.0 | 18.7 | n/a | n/a | 293 | 206 | 6.52? | 18.7 |
| 40.0 | M18 | 8/2/2011 | Living Springs | 1.05 | 0.04 | *0.002* | 0.03 | 0.01 | 30.0 | 19.3 | n/a | n/a | 279 | 193 | 8.38 | 19.3 |
| 37.4 | M45 | 8/2/2011 | Lomacasi | 1.33 | 0.05 | *0.002* | 0.03 | *0.01* | 33.0 | 19.5 | n/a | n/a | 278 | 195 | 8.11 | 19.5 |
| 34.0 | M25 | 8/2/2011 | Chavez Crossing Campground | 43.43 | 0.18 | 0.012 | 0.14 | 0.03 | 31.0 | 20.2 | n/a | n/a | 291 | 203 | 7.95 | 20.2 |
| 27.9 | M29 | 8/2/2011 | below Red Rock State Park | 1537.00 | *0.04* | *0.002* | *0.02* | 0.17 | 34.0 | 24.4 | n/a | n/a | 200 | 140 | 7.64 | 24.4 |
| 22.7 | M32 | 8/2/2011 | Dry Creek Confluence | | | | | | 35.0 | 25.5 | n/a | n/a | 210 | 147 | 7.64 | 25.5 |
| 17.2 | M36 | 8/2/2011 | Page Springs Bridge | 788.70 | *0.04* | *0.002* | *0.02* | 0.06 | 34.0 | 28 | n/a | n/a | 306 | 213 | 7.91 | 28 |
| 2.2 | M41 | 8/2/2011 | Cornville Estates | 31.50 | 0.10 | 0.006 | 0.09 | 0.03 | 33.0 | 24.2 | n/a | n/a | 487 | 315 | 8.1 | 24.2 |
| | S41 | 8/10/2011 | Spring 41, upstream of SRSP | 8.43 | 0.06 | 0.003 | 0.06 | 0.03 | 27.0 | 14.6 | n/a | n/a | 373 | 264 | 6.5 | 14.6 |
| | S52 | 8/10/2011 | Spring 52, Indian Gardens | 0.74 | 0.12 | *0.002* | 0.07 | 0.06 | 23.6 | 15.7 | n/a | n/a | n/a | n/a | n/a | n/a |
| | S49 | 8/10/2011 | Spring 49 near source | 0.62 | 0.07 | *0.002* | 0.05 | 0.01 | 25.0 | 13.3 | n/a | n/a | 255 | 188 | 7.4 | 13.3 |
| | S48 | 8/10/2011 | Spring 48, Indian Gardens | 0.51 | 0.05 | *0.002* | 0.06 | 0.01 | 24.0 | 14.9 | n/a | n/a | 131 | 186 | 7.1 | 14.9 |
| | S45 | 8/10/2011 | Spring 45 waterfall | 0.20 | *0.04* | *0.002* | 0.04 | 0.01 | 23.8 | 13.1 | n/a | n/a | 129 | 175 | 7.54 | 13.1 |
| | S42 | 8/10/2011 | Spring 42, Munds Creek | 0.68 | 0.20 | *0.002* | 0.03 | 0.02 | 25.2 | 15.2 | n/a | n/a | 246 | 178 | 7.63 | 15.2 |
| | S2 | 8/10/2011 | Spring 2, South of IG bridge | 0.27 | *0.04* | *0.002* | 0.10 | 0.03 | 28.0 | 13.8 | n/a | n/a | 259 | 191 | 7.95 | 13.8 |
| | S16 | 8/10/2011 | Spring 16, Zane Grey's cabin | 2.58 | 0.04 | 0.002 | 0.04 | 0.04 | 29.0 | 12.7 | n/a | n/a | 432 | 301 | 7.34 | 12.7 |
| | S16 | 8/24/2011 | Spring 16, Zane Grey's cabin | 2.09 | 0.10 | *0.002* | 0.02 | 0.03 | 23.8 | 13.2 | n/a | n/a | 422 | 294 | 8.06 | 13.2 |
| | S41 | 8/24/2011 | Spring 41, upstream of SRSP | 2.81 | 0.07 | 0.002 | 0.06 | 0.02 | 23.0 | 17.6 | n/a | n/a | 346 | 247 | 7.41 | 17.6 |
| | S52 | 8/24/2011 | Spring 52, Indian Gardens | 0.31 | 0.05 | *0.002* | *0.02* | 0.01 | 28.0 | 18.6 | n/a | n/a | 477 | 331 | 7.37 | 19 |
| | S49 | 8/24/2011 | Spring 49 near source | 0.67 | 0.06 | *0.002* | *0.02* | 0.01 | 30.0 | 16 | n/a | n/a | 252 | 177 | 7.72 | 16.1 |
| | S100 | 8/24/2011 | Page Springs Source | 0.21 | 0.04 | *0.002* | 0.02 | 0.02 | | 20.3 | n/a | n/a | 333 | 228 | 7.37 | 20.3 |
| | F3 | 8/24/2011 | Spring Creek above WWT pond | n/a | n/a | n/a | n/a | n/a | 33.0 | 22.4 | n/a | n/a | 525 | 362 | 8.45 | 22.4 |
| | M39 | 8/24/2011 | Spring Creek | 10.45 | 0.14 | 0.006 | 0.09 | 0.05 | 33.5 | 23.3 | n/a | n/a | 626 | 429 | 7.77 | 23.3 |
| | S98 | 8/24/2011 | Bubbling Ponds Spring | 0.24 | *0.04* | *0.002* | 0.06 | 0.02 | 33.0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | F4 | 8/24/2011 | Bubbling Ponds outfall | 5.69 | 0.10 | 0.006 | 0.11 | 0.05 | 33.0 | 26.3 | n/a | n/a | 435 | 303 | 7.87 | 26.3 |
| | S35 | 9/1/2011 | Spring 35, West Fork | 0.50 | *0.04* | n/a | *0.02* | 0.01 | | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | S36 | 9/1/2011 | Spring 36, West Fork | 0.46 | 0.04 | n/a | *0.02* | 0.02 | | 15.7 | n/a | n/a | 330 | 227 | 8.01 | 15.7 |
| | S39 | 9/1/2011 | Walnut Spring, West Fork | 1.76 | 0.07 | n/a | 0.02 | 0.02 | 28.0 | 14.5 | n/a | n/a | 305 | 208 | 7.88 | 14.5 |
| | S1 | 9/1/2011 | Spring 1, Indian Gardens | 2.97 | 0.06 | n/a | *0.02* | 0.02 | 29.0 | 15.3 | n/a | n/a | 298 | 206 | 6.94 | 15.3 |
| | S3 | 9/1/2011 | Spring 3, Indian Gardens | 1.06 | 0.05 | n/a | *0.02* | 0.01 | 29.0 | 15.8 | n/a | n/a | 287 | 196 | 7.48 | 15.8 |
| | F5 | 9/1/2011 | Creek from Spring 59, Indian Gardens | 1.01 | 0.05 | n/a | *0.02* | 0.02 | 28.5 | 16.7 | n/a | n/a | 260 | 182 | 7.81 | 16.7 |
| | S58 | 9/1/2011 | Spring 58 Pool, Indian Gardens | 1.88 | 0.05 | n/a | *0.02* | 0.01 | 29.0 | 16.4 | n/a | n/a | 294 | 208 | 7.05 | 16.4 |
| | S67 | 9/1/2011 | Spring 67, Indian Gardens | 59.30 | 0.09 | n/a | 0.03 | 0.01 | 29.0 | 16.7 | n/a | n/a | 260 | 183 | 7.38 | 16.7 |
| | S75 | 9/1/2011 | Spring 75 Pool, Indian Gardens | 21.37 | 0.05 | n/a | *0.02* | 0.01 | 28.5 | 15.2 | n/a | n/a | 268 | 185 | 7.11 | 15.2 |
| | S77 | 9/1/2011 | Spring 77 Pool, Indian Gardens | 0.84 | *0.04* | n/a | *0.02* | 0.01 | | 14.9 | n/a | n/a | 274 | 182 | 6.33 | 14.9 |
| | S78 | 9/1/2011 | Spring 78, Indian Gardens | 0.18 | 0.05 | n/a | *0.02* | 0.01 | | 15.4 | n/a | n/a | 266 | 188 | 7.65 | 15.4 |
| | M49 | 9/6/2011 | Jordan Pump | 597.00 | >1.70 | n/a | n/a | n/a | | | | | | | | |
| | M48 | 9/6/2011 | Arroyo Roble | 51.60 | 0.84 | n/a | n/a | n/a | | | | | | | | |
| | M46 | 9/6/2011 | Soldier's Wash | 345.00 | >1.70 | n/a | n/a | n/a | | | | | | | | |
| | F1 | 9/6/2011 | Chavez Ranch Day Use Area | 34.30 | 0.27 | n/a | n/a | n/a | | | | | | | | |
| | M26 | 9/6/2011 | Carroll Canyon 3, trail (@Shelby) | 22.30 | 0.35 | n/a | n/a | n/a | | | | | | | | |
| | M27 | 9/6/2011 | Carroll Canyon 2, bridge | 358.00 | 1.55 | n/a | n/a | n/a | | | | | | | | |
| 37.4 | M45 | 9/7/2011 | Lomacasi | | | | | | 20.9 | 26.6 | n/a | n/a | 271 | 186 | 8.49 | 20.9 |
| 34.0 | M25 | 9/7/2011 | Chavez Crossing Campground | | | | | | 35.1 | 23.7 | n/a | n/a | 283 | 198 | 8.41 | 23.7 |
| 27.9 | M29 | 9/7/2011 | below Red Rock State Park | | | | | | 31.9 | 24.8 | n/a | n/a | 293 | 201 | 8.19 | 25.8 |

| strm_mi | Site_ID | Date | Descript | turbid | PO4-P | NO2- | NO3-N | NH4+ | Air_T_C | H2O_T_C | DO_mg/L** | DO_%sat | Cond*** | TDS | pH | pH_T_C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17.2 | M36 | 9/7/2011 | Page Springs Bridge | | | | | | n/a | 24.3 | n/a | n/a | 424 | 277 | 8.06 | 24.3 |
| 8.9 | M40 | 9/7/2011 | Cornville Bridge | | | | | | n/a | 24.9 | n/a | n/a | 455 | 314 | 8.16 | 24.6 |
| | M49 | 9/11/2011 | Jordan Pump | | | | | | | | | | | | | |
| | M48 | 9/11/2011 | Arroyo Roble | | | | | | | | | | | | | |
| | M46 | 9/11/2011 | Soldier's Wash | | | | | | | | | | | | | |
| | M26 | 9/11/2011 | Carroll Canyon 3, trail (@Shelby) | | | | | | | | | | | | | |
| | M27 | 9/11/2011 | Carroll Canyon 2, bridge | | | | | | | | | | | | | |
| 49.0 | M08 | 9/11/2011 | Pine Flats | 0.30 | 0.07 | *0.002* | *0.02* | *0.01* | | | | | | | | |
| 40.5 | M17 | 9/11/2011 | Indian Gardens | 5.06 | 0.08 | 0.004 | *0.02* | 0.03 | | | | | | | | |
| 37.4 | M45 | 9/11/2011 | Lomacasi | 7.69 | 0.11 | 0.004 | *0.02* | 0.02 | | | | | | | | |
| 34.0 | M25 | 9/11/2011 | Chavez Crossing Campground | 40.07 | *0.04* | 0.002 | *0.02* | 0.02 | | | | | | | | |
| 27.9 | M29 | 9/11/2011 | below Red Rock State Park | 221.00 | 0.11 | 0.022 | 0.18 | 0.01 | | | | | | | | |
| 22.7 | M32 | 9/11/2011 | Dry Creek Confluence | 38.70 | 0.04 | 0.002 | *0.02* | 0.01 | | | | | | | | |
| 17.2 | M36 | 9/11/2011 | Page Springs Bridge | 10.80 | 0.09 | 0.006 | 0.04 | 0.01 | | | | | | | | |
| 2.2 | M41 | 9/11/2011 | Cornville Estates | 14.83 | 0.15 | 0.008 | 0.12 | 0.04 | | | | | | | | |
| | F4 | 9/11/2011 | Bubbling Ponds outfall | | | | | | | | | | | | | |
| 49.0 | M08 | 9/15/2011 | Pine Flats | | | | | | | | | | | | | |
| 40.5 | M17 | 9/15/2011 | Indian Gardens | | | | | | | | | | | | | |
| 37.4 | M45 | 9/15/2011 | Lomacasi | | | | | | | | | | | | | |
| 34.0 | M25 | 9/15/2011 | Chavez Crossing Campground | | | | | | | | | | | | | |
| 27.9 | M29 | 9/15/2011 | below Red Rock State Park | | | | | | | | | | | | | |
| 22.7 | M32 | 9/15/2011 | Dry Creek Confluence | | | | | | | | | | | | | |
| 17.2 | M36 | 9/15/2011 | Page Springs Bridge | | | | | | | | | | | | | |
| 8.9 | M40 | 9/15/2011 | Cornville Bridge | | | | | | | | | | | | | |
| | S52 | 9/16/2011 | Spring 52, Indian Gardens | | | | | | 22.0 | 16.1 | n/a | n/a | 254 | 177 | 7.39 | 16.1 |
| | S49A | 9/16/2011 | Spring 49 source | | | | | | 24.0 | 15.8 | n/a | n/a | 260 | 179 | 7.69 | 15.8 |
| | F6 | 9/16/2011 | Spring ditch, AGFD | | | | | | 24.0 | 19.9 | n/a | n/a | 536 | 368 | 7.61 | 19.9 |
| | S107 | 9/16/2011 | Spring ditch | | | | | | 23.0 | 19.5 | n/a | n/a | 495 | 343 | 7.84 | 20.4 |
| | S98 | 9/16/2011 | Bubbling Ponds Spring | | | | | | 25.0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | F4 | 9/16/2011 | Bubbling Ponds outfall | | | | | | 26.0 | 21.0 | n/a | n/a | 452 | 308 | 7.8 | 21 |
| | S100 | 9/16/2011 | Page Springs source | | | | | | 23.0 | 20.1 | n/a | n/a | 349 | 240 | 7.42 | 20.1 |
| | F3 | 9/16/2011 | Spring Creek above WWT pond | | | | | | 22.5 | 19.1 | n/a | n/a | 585 | 406 | 8.27 | 19.1 |
| | M39 | 9/16/2011 | Spring Creek | | | | | | 20.0 | 18.9 | n/a | n/a | 677 | 470 | 7.8 | 18.9 |
| | S9 | 9/20/2011 | Pine Flat spring @ road | | | | | | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | S41 | 9/20/2011 | Spring 41, upstream of SRSP | 5.46 | *0.04* | 0.002 | *0.02* | 0.04 | 21.0 | 16.6 | n/a | n/a | 326 | 234 | 7.76 | 16.6 |
| | S49A | 9/20/2011 | Spring 49 source | 0.25 | 0.05 | *0.002* | *0.02* | *0.01* | 22.0 | 15.6 | n/a | n/a | 256 | 176 | 7.62 | 15.6 |
| | S49 | 9/20/2011 | Spring 49 near source | 0.46 | 0.05 | *0.002* | 0.02 | 0.03 | 23.0 | 15.5 | n/a | n/a | 256 | 179 | 7.76 | 15.5 |
| | F7 | 9/20/2011 | Lower Indian Gardens spring, upper end | | | | | | 24.0 | 16.5 | n/a | n/a | 239 | 172 | 7.99 | 16.5 |
| | S71 | 9/20/2011 | Lower Indian Gardens spring, midway | 5.12 | 0.05 | 0.003 | *0.02* | 0.05 | 28.5 | 17.1 | n/a | n/a | 253 | 175 | 8 | 17.1 |
| | S70 | 9/20/2011 | Lower Indian Gardens spring, near fish runs | 0.69 | 0.08 | 0.010 | 0.08 | 0.15 | 27.0 | 17.5 | n/a | n/a | 248 | 159 | 7.91 | 17.5 |
| | F6 | 9/20/2011 | Spring ditch, AGFD | 1.37 | 0.10 | 0.002 | 0.03 | 0.03 | 28.0 | 21.1 | n/a | n/a | 518 | 361 | 7.73 | 21.1 |
| | S107 | 9/20/2011 | Spring ditch | 1.34 | 0.04 | 0.003 | 0.03 | 0.05 | 25.5 | 20.7 | n/a | n/a | 485 | 343 | 7.95 | 20.7 |
| | S109 | 9/21/2011 | Lower Indian Gardens spring, down channel | 0.61 | 0.07 | 0.009 | 0.07 | 0.07 | n/a | 17.1 | n/a | n/a | 170 | 245 | 8.22 | 17.1 |
| | S45A | 9/22/2011 | Spring 45 source | 0.22 | *0.04* | *0.002* | 0.07 | 0.01 | | | | | | | | |
| | S45B | 9/22/2011 | Spring 45 water fountain on side of house | | | | | | | | | | | | | |
| | S71 | 9/22/2011 | Lower Indian Gardens spring, midway | 2.15 | 0.06 | *0.002* | 0.05 | 0.01 | n/a | 17.4 | n/a | n/a | 237 | 172 | 8.03 | 17.4 |

| strm_mi | Site_ID | Date | Descript | turbid | PO4-P | NO2- | NO3-N | NH4+ | Air_T_C | H2O_T_C | DO_mg/L** | DO_%sat | Cond*** | TDS | pH | pH_T_C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S70 | 9/22/2011 | Lower Indian Gardens spring, near fish runs | 1.17 | 0.05 | 0.008 | 0.13 | 0.08 | n/a | 17.4 | n/a | n/a | 253 | 175 | 7.83 | 17.4 |
| | S109 | 9/22/2011 | Lower Indian Gardens spring, down channel | 0.58 | 0.08 | 0.009 | 0.15 | 0.08 | 24.7 | 17.2 | n/a | n/a | 244 | 164 | 8 | 17.2 |

gray highlight denotessamples from tributary streams
green highlight denotes samples from springs
no highlighting denotes Oak Creek samples

**bold numbers** mean "greater than"
*italic numbers* mean "less than"
red font means "out of hold time" or other attention

** The instrument used for measuring dissolved oxygen and temperature was the Extik DO600. Measurements of DO were discontinued after no noticeable trend was seen and two out three meters ceased to function properly.
*** The intrument used for measuring pH, conductivity, total dissolved solids and temperature was the Extik EC500.

**Table A.3. Environmental conditions and streamflow during sampling of Oak Creek, adjacent springs and tributary washes Summer 2011.**

| strm_mi | Site_ID | Date | Descript | Weather | 7-day weather | Flushing | Stream width | Depth (ft) | Velocity ft/s | ChanArea | Flow_cfs | Crew | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *0.5* | M13 | 7/5/2011 | West Fork | Partly cloudy | Rain | N | 10.1 | 0.75 | 0.58 | 3.79 | 2.2 | CW, KK, JL | Highly used recreation area downstream of sampling site, DO meter not properly functioning |
| 49.0 | M08 | 7/5/2011 | Pine Flats | overcast | Rain | N | 37.5 | 1.23 | 0.31 | 23.06 | 7.08 | CW, KK, JL | DO meter not properly functioning |
| 46.0 | M09A | 7/5/2011 | 1/4 mi ds of Forest Houses | overcast/rain | Rain | N | 45.5 | 2.54 | 0.46 | 57.79 | 26.7 | CW, KK | Random site; site will be moved 1/4 mile upstream, DO meter not properly functioning |
| 37.4 | M45 | 7/5/2011 | Lomacasi | partly cloudy | rain | N | | | | | | SML, LMP | |
| 22.7 | M32 | 7/5/2011 | Dry Creek Confluence | clear | rain | N | 23.0 | 1.7 | 0.7 | 19.6 | 13.7 | SML, LMP | Abundant white bubbles on water surface. Occassional funky (dead animal) odor. No shade at cross-section |
| 17.0 | M36 | 7/5/2011 | Page Springs Bridge | overcast | rain | N | 45.5 | 1.8 | 0.75 | 41.0 | 30.7 | SML, LMP | Diversion dam takes considerable flow at outfall into an irrigation ditch above this cross-section |
| 8.9 | M40 | 7/5/2011 | Cornville Bridge | clear | rain | N | 49.9 | 0.63 | 1.11 | 31.4 | 43.5 | KJA, CJ | Semi turbid water, DO |
| 2.2 | M41 | 7/5/2011 | Cornville Estates | Partly cloudy | rain | N | 51.3 | 2.4 | 0.11 | 116.3 | 11.4 | KJA, CJ | turbid appearance to water |
| 46.3 | M09 | 7/11/2011 | Hoel's Wash/Forest Houses | clear | rain | N | 29.5 | 1.23 | 0.32 | 36.5 | 10.9 | KJA, LP | No biofilm, clear water |
| 43.7 | M44 | 7/11/2011 | Slide Rock | clear | rain | N | 51.5 | 1.94 | 0.11 | 100.7 | 14.04 | KJA, CW | clear water, layer of loose brown colored algae |
| 40.5 | M17 | 7/11/2011 | Indian Gardens | partly cloudy | rain | N | 51.5 | 1.18 | 0.46 | 59.4 | 25.5 | KJA, LP | Thin Layer diatoms, clear water |
| 40.0 | M18 | 7/11/2011 | Living Springs | partly cloudy | rain | N | 52.2 | 2.02 | 0.33 | 101.4 | 35.2 | KJA, LP | White bubbles on water surface. Clear water. Thin layer diatoms |
| 34.0 | M25 | 7/11/2011 | Chavez Crossing Campground | Partly cloudy | Rain | N | 31 | 2.94 | 0.62 | 45.57 | 28.25 | CW, KD | |
| 17.2 | M36 | 7/11/2011 | Page Springs Bridge | overcast | Rain | N | 48 | 3.24 | 0.54 | 77.76 | 41.99 | CW, KD | |
| 12.6 | M39A | 7/11/2011 | below Spring Creek Confluence | clear | showers | N | 74.7 | 2.85 | 0.4 | 106.4 | 42.6 | SML, CTA | A lot of silt settled on bottom. Fairly turbid, but less than at Verde onfluence. |
| 8.9 | M40 | 7/11/2011 | Cornville Bridge | partly cloudy | showers | | 40.0 | 1.9 | 1.66 | 38.0 | 63.1 | SML, CTA | |
| 0.4 | M43 | 7/11/2011 | above Verde Confluence | clear | showers | N | 42.2 | 1.7 | 1.66 | 35.9 | 59.5 | SML, CTA | Bottom is 1.6-1.7 for about 20 feet, starting 11.4' from LEW and going toward REW. Many dragonflies & damselflies. Water is turbid. Was also turbid on July 1, 2011 during recon. |
| *0.1* | M39 | 7/11/2011 | Spring Creek | | | | | | | | | | Collected *E coli* sample only in Spring Creek above path bridge. Sewer odor at Spring Creek. |
| 49.0 | M08 | 7/14/2011 | Pine Flats | clear | partly cloudy | | 37.1 | 2.51 | 0.39 | 91.9 | 33.3 | KJA,CW | No biofilm, clear water; Possible error in reading *E. coli* result. Overhead light not turned off. Disregard result. |
| 37.4 | M45 | 7/14/2011 | Lomacasi | clear | partly cloudy | | 44.3 | 2.39 | 0.34 | 102.1 | 32.13 | KJA,CW | No biofilm, clear water; Possible error in reading *E. coli* result. Overhead light not turned off. Disregard result. |
| 22.7 | M32 | 7/14/2011 | Dry Creek Confluence | clear | clear | | 24.4 | 1.09 | 0.68 | 25.9 | 16.19 | KJA, CJ,CW | No biofilm, clear water; Possible error in reading *E. coli* result. Overhead light not turned off. Disregard result. |
| 2.2 | M41 | 7/14/2011 | Cornville Estates | clear | clear | | 50.9 | 2.28 | 0.31 | 108.7 | 34.71 | KJA, CJ,CW | Possible error in reading *E. coli* result. Overhead light not turned off. Disregard result. |
| 40.5 | M17 | 7/19/2011 | Indian Gardens | Clear | Rain | Y? | 43 | 1.5 | 0.99 | 32.25 | 31.83 | CW, CJ | Discharge was increased due to Rain on 7/18/11 afternoon |
| 22.7 | M32 | 7/19/2011 | Dry Creek Confluence | Partly cloudy | Rain | Y? | 30.2 | 1.16 | 0.94 | 17.51 | 16.41 | CW, CJ | Discharge was increased due to Rain on 7/18/11 afternoon |

| strm_mi | Site_ID | Date | Descript | Weather | 7-day weather | Flushing | Stream width | Depth (ft) | Velocity ft/s | ChanArea | Flow_cfs | Crew | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8.9 | M40 | 7/19/2011 | Cornville Bridge | Cloudy | Rain | Y? | 54.3 | 2.36 | 1.47 | 64.07 | 94.18 | CW, CJ | Discharge was increased due to Rain on 7/18/11 afternoon |
| *0.5* | M13 | 7/28/2011 | West Fork | Partly cloudy | partly cloudy | | 7.41 | 0.52 | 0.04 | 3.42 | 0.25 | KJA, KM | clear water |
| 43.7 | M44 | 7/28/2011 | Slide Rock | raining | partly cloudy | | 51.9 | 1.97 | 0.06 | 99.48 | 6.13 | KJA, KM | clear water, benthic algal coverage, duplicate e.coli |
| 40.0 | M18 | 7/28/2011 | Living Springs | cloudy | partly cloudy | | 52.3 | 1.66 | 0.29 | 84.16 | 32.02 | KJA, KM | clear water |
| 34.0 | M25 | 7/28/2011 | Chavez Crossing Campground | Partly cloudy | partly cloudy | | 35 | 2.07 | 0.39 | 70 | 30.39 | KJA, KM | clear water |
| 17.2 | M36 | 7/28/2011 | Page Springs Bridge | partly cloudy | showers | N | 65.6 | 3.2 | 1.03 | 104.96 | 108.11 | CW, CJ | |
| 12.6 | M39A | 7/28/2011 | below Spring Creek Confluence | partly cloudy | showers | N | 63.5 | 3.41 | 0.36 | 108.27 | 38.49 | CW, CJ | |
| 0.4 | M43 | 7/28/2011 | above Verde Confluence | clear | showers | N | 38.6 | 1.43 | 0.94 | 27.6 | 25.86 | CW, CJ | |
| *0.1* | M39 | 7/28/2011 | Spring Creek | partly cloudy | showers | N | 13.1 | 1.42 | n/a | 9.3 | n/a | CW, CJ | No discharge assessment method because flow was very inconsistent along a small area of channel |
| | M49 | 8/1/2011 | Jordan Pump | | | | | | | | | CTA | |
| | M48 | 8/1/2011 | Arroyo Roble | | | | | | | | | KHD | |
| | M47 | 8/1/2011 | Tlaquepaque | | | | | | | | | KHD | |
| | M46 | 8/1/2011 | Soldier's Wash | | | | | | | | | KHD | |
| *2.6* | M26 | 8/1/2011 | Carroll Canyon 3, trail (@Shelby) | | | | | | | | | SH | Likely *E. coli* underestimation. Sample contained a great deal of sediment which filled the bottom row of small cells that consequently did not fluoresce. |
| *0.6* | M27 | 8/1/2011 | Carroll Canyon 2, bridge | | | | | | | | | SH | Likely *E. coli* underestimation. Sample contained a great deal of sediment which filled the bottom row of small cells that consequently did not fluoresce. |
| *0.0* | M51 | 8/1/2011 | Carroll Canyon 1, mouth | | | | | | | | | SH | Likely *E. coli* underestimation. Sample contained a great deal of sediment which filled the bottom row of small cells that consequently did not fluoresce. |
| 8.9 | M40 | 8/1/2011 | Cornville Bridge | | | | | | | | | CJ | |
| *0.5* | M13 | 8/2/2011 | West Fork | partly cloudy | rain | | 10 | 0.82 | 1.14 | 8.2 | 9.35 | SML, JVS | |
| 49.0 | M08 | 8/2/2011 | Pine Flats | partly cloudy | showers | | 40.7 | 1.16 | 1.03 | 47.21 | 48.63 | SML, JVS | |
| 46.3 | M09 | 8/2/2011 | Hoel's Wash/Forest Houses | clear | rain | | 33.2 | 1.88 | n/a | 62.42 | n/a | SML, JVS | |
| 43.7 | M44 | 8/2/2011 | Slide Rock | clear | rain | | 39.6 | 1.7 | 1.18 | 46.73 | 55.14 | SML, JVS | |
| 40.5 | M17 | 8/2/2011 | Indian Gardens | partly cloudy | Rain/Showers | N | 45.6 | 2.21 | n/a | 50.39 | n/a | CW, JL | Velocity (orange peel method) not done because of injured volunteer (recovering from knee surgery) |
| 40.0 | M18 | 8/2/2011 | Living Springs | partly cloudy | Rain/Showers | N | 44.2 | 3.42 | n/a | 75.58 | n/a | CW, JL | Velocity (orange peel method) not done because of injured volunteer (recovering from knee surgery) |
| 37.4 | M45 | 8/2/2011 | Lomacasi | partly cloudy | Storm/Rain | Y | 41.9 | 3.27 | 0.68 | 68.51 | 46.65 | CW, JL, JM | Some debris in water. Water was mostly clear. |
| 34.0 | M25 | 8/2/2011 | Chavez Crossing Campground | clear | Storm | Y | 35.7 | 3.08 | 1.18 | 54.98 | 64.87 | CW, JL, JM | A lot of debris in water. Water was reddish-brown, opaque, and muddy. |
| 27.9 | M29 | 8/2/2011 | below Red Rock State Park | clear | storm | | 21.2 | 1.45 | 1.25 | 30.74 | 38.43 | KJA, KK, WJ | |
| 22.7 | M32 | 8/2/2011 | Dry Creek Confluence | clear | storm | | 28.8 | 1.42 | 1.13 | 40.9 | 46.22 | KJA, KK, WJ | |
| 17.2 | M36 | 8/2/2011 | Page Springs Bridge | clear | storm | | 48 | 2.28 | 0.52 | 109.44 | 56.91 | KJA, KK, WJ | Water was a medium brown color |
| 2.2 | M41 | 8/2/2011 | Cornville Estates | clear | storm | | 52.1 | 2.91 | 0.8 | 151.61 | 121.29 | KJA, KK, WJ | |

| strm_mi | Site_ID | Date | Descript | Weather | 7-day weather | Flushing | Stream width | Depth (ft) | Velocity ft/s | ChanArea | Flow_cfs | Crew | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S41 | 8/10/2011 | Spring 41, upstream of SRSP | partly cloudy | overcast | N | | | | | | CW, AB | Forgot to take pictures |
| | S52 | 8/10/2011 | Spring 52, Indian Gardens | clear | overcast | N | | | | | | CW, AB | Forgot to take pictures; Flow was too small to take pH, cond, and TDS measurements |
| | S49 | 8/10/2011 | Spring 49 near source | clear | overcast | N | | | | | | CW, AB | Forgot to take pictures |
| | S48 | 8/10/2011 | Spring 48, Indian Gardens | clear | overcast | N | | | | | | CW, AB | Forgot to take pictures; Forgot to write down bacterial collection time, so I estimated |
| | S45 | 8/10/2011 | Spring 45 waterfall | clear | overcast | N | | | | | | CW, AB | Forgot to take pictures |
| | S42 | 8/10/2011 | Spring 42, Munds Creek | clear | overcast | N | | | | | | CW, AB | Forgot to take pictures |
| | S2 | 8/10/2011 | Spring 2, South of IG bridge | clear | overcast | N | | | | | | CW, AB | Forgot to take pictures |
| | S16 | 8/10/2011 | Spring 16, Zane Grey's cabin | clear | overcast | N | | | | | | CW, AB | Forgot to take pictures |
| | S16 | 8/24/2011 | Spring 16, Zane Grey's cabin | clear | showers | N | | | | | | CW, KK | Wasn't able to fill sample bottles to top because of shallow water |
| | S41 | 8/24/2011 | Spring 41, upstream of SRSP | clear | showers | N | | | | | | CW, KK | Compared to 8/10/2011, air temp is 4˚C cooler, but water temp is 3˚C warmer |
| | S52 | 8/24/2011 | Spring 52, Indian Gardens | clear | showers | N | | | | | | CW, KK | Took pH, cond, TDS, and temp measurements with water in sample bottle; compared to 8/10/2011 air and water temp are about 3-4˚C warmer |
| | S49 | 8/24/2011 | Spring 49 near source | clear | showers | N | | | | | | CW, KK | Compared to 8/10/2011, elevation difference is 134 ft higher?, air and water temp are about 3-5˚C warmer |
| | S100 | 8/24/2011 | Page Springs Source | clear | showers | N | | | | | | KA, MN | DO meter not working; DNA sample may haven been switched with Spring Creek M39A? |
| | F3 | 8/24/2011 | Spring Creek above WWT pond | clear | showers | N | | | | | | KA, MN | DO meter not working |
| | M39 | 8/24/2011 | Spring Creek | clear | showers | N | | | | | | KA, MN | DO meter not working. Exceeds *E. coli* standard. DNA sample may haven been switched with Page Springs S100. |
| | S98 | 8/24/2011 | Bubbling Ponds Spring | clear | showers | N | | | | | | KA, MN | DO meter not working. Not allowed to collect pH, conductivity, TDS at Bubbling Ponds Spring. |
| | F4 | 8/24/2011 | Bubbling Ponds outfall | clear | showers | N | | | | | | KA, MN | DO meter not working |
| | S35 | 9/1/2011 | Spring 35, West Fork | | | | | | | | | KJA, MN | |
| | S36 | 9/1/2011 | Spring 36, West Fork | | | | | | | | | KJA, MN | |
| | S39 | 9/1/2011 | Walnut Spring, West Fork | | | | | | | | | KJA, MN | |
| | S1 | 9/1/2011 | Spring 1, Indian Gardens | | | | | | | | | KJA, MN | |
| | S3 | 9/1/2011 | Spring 3, Indian Gardens | | | | | | | | | KJA, MN | |
| | F5 | 9/1/2011 | Creek from Spring 59, Indian Gardens | | | | | | | | | KJA, MN | |
| | S58 | 9/1/2011 | Spring 58 Pool, Indian Gardens | | | | | | | | | KJA, MN | |

| strm_mi | Site_ID | Date | Descript | Weather | 7-day weather | Flushing | Stream width | Depth (ft) | Velocity ft/s | ChanArea | Flow_cfs | Crew | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S67 | 9/1/2011 | Spring 67, Indian Gardens | | | | | | | | | KJA, MN | |
| | S75 | 9/1/2011 | Spring 75 Pool, Indian Gardens | | | | | | | | | KJA, MN | |
| | S77 | 9/1/2011 | Spring 77 Pool, Indian Gardens | | | | | | | | | KJA, MN | |
| | S78 | 9/1/2011 | Spring 78, Indian Gardens | | | | | | | | | KJA, MN | |
| | M49 | 9/6/2011 | Jordan Pump | | | | | | | | | SML, KJA | |
| | M48 | 9/6/2011 | Arroyo Roble | | | | | | | | | SML, KJA | |
| | M46 | 9/6/2011 | Soldier's Wash | | | | | | | | | SML, KJA | |
| | F1 | 9/6/2011 | Chavez Ranch Day Use Area | | | | | | | | | SML, KJA | |
| | M26 | 9/6/2011 | Carroll Canyon 3, trail (@Shelby) | | | | | | | | | SML, KJA | |
| | M27 | 9/6/2011 | Carroll Canyon 2, bridge | | | | | | | | | SML, KJA | |
| 37.4 | M45 | 9/7/2011 | Lomacasi | | | | | | | | | CW | Normal clarity conditions |
| 34.0 | M25 | 9/7/2011 | Chavez Crossing Campground | | | | | | | | | CW | Fairly clear, small amount of debris on waters surface |
| 27.9 | M29 | 9/7/2011 | below Red Rock State Park | | | | | | | | | CW | E.coli Duplicate sample taken here; Muddy, partially opaque water, could barely see bottom of creek |
| 17.2 | M36 | 9/7/2011 | Page Springs Bridge | | | | | | | | | CW | I smelled sewage at the sampling site |
| 8.9 | M40 | 9/7/2011 | Cornville Bridge | | | | | | | | | CW | |
| | M49 | 9/11/2011 | Jordan Pump | | | | | | | | | KJA | |
| | M48 | 9/11/2011 | Arroyo Roble | | | | | | | | | KJA | |
| | M46 | 9/11/2011 | Soldier's Wash | | | | | | | | | KHD | |
| | M26 | 9/11/2011 | Carroll Canyon 3, trail (@Shelby) | | | | | | | | | KHD | |
| | M27 | 9/11/2011 | Carroll Canyon 2, bridge | | | | | | | | | KHD | |
| 49.0 | M08 | 9/11/2011 | Pine Flats | | | | | | | | | KJA | |
| 40.5 | M17 | 9/11/2011 | Indian Gardens | | | | | | | | | KJA | |
| 37.4 | M45 | 9/11/2011 | Lomacasi | | | | | | | | | KJA | |
| 34.0 | M25 | 9/11/2011 | Chavez Crossing Campground | | | | | | | | | KJA | |
| 27.9 | M29 | 9/11/2011 | below Red Rock State Park | | | | | | | | | SML, KHD | |
| 22.7 | M32 | 9/11/2011 | Dry Creek Confluence | | | | | | | | | SML, KHD | |
| 17.2 | M36 | 9/11/2011 | Page Springs Bridge | | | | | | | | | SML, KHD | |
| 2.2 | M41 | 9/11/2011 | Cornville Estates | | | | | | | | | SML, KHD | |
| | F4 | 9/11/2011 | Bubbling Ponds outfall | | | | | | | | | SML, KHD | |
| 49.0 | M08 | 9/15/2011 | Pine Flats | | | | | | | | | KJA | Samples were too turbid to analyze for nutrients without filtering. Could not filter within the hold time, so nutrients were not analyzed. |

| strm_mi | Site_ID | Date | Descript | Weather | 7-day weather | Flushing | Stream width | Depth (ft) | Velocity ft/s | ChanArea | Flow_cfs | Crew | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40.5 | M17 | 9/15/2011 | Indian Gardens | | | | | | | | | KJA | Samples were too turbid to analyze for nutrients without filtering. Could not filter within the hold time, so nutrients were not analyzed. |
| 37.4 | M45 | 9/15/2011 | Lomacasi | | | | | | | | | KJA | Samples were too turbid to analyze for nutrients without filtering. Could not filter within the hold time, so nutrients were not analyzed. |
| 34.0 | M25 | 9/15/2011 | Chavez Crossing Campground | | | | | | | | | KJA | Samples were too turbid to analyze for nutrients without filtering. Could not filter within the hold time, so nutrients were not analyzed. |
| 27.9 | M29 | 9/15/2011 | below Red Rock State Park | | | | | | | | | KJA | Samples were too turbid to analyze for nutrients without filtering. Could not filter within the hold time, so nutrients were not analyzed. |
| 22.7 | M32 | 9/15/2011 | Dry Creek Confluence | | | | | | | | | KJA | Samples were too turbid to analyze for nutrients without filtering. Could not filter within the hold time, so nutrients were not analyzed. |
| 17.2 | M36 | 9/15/2011 | Page Springs Bridge | | | | | | | | | KJA | Samples were too turbid to analyze for nutrients without filtering. Could not filter within the hold time, so nutrients were not analyzed. |
| 8.9 | M40 | 9/15/2011 | Cornville Bridge | | | | | | | | | KJA | Samples were too turbid to analyze for nutrients without filtering. Could not filter within the hold time, so nutrients were not analyzed. |
| | S52 | 9/16/2011 | Spring 52, Indian Gardens | overcast | storm | N | | | | | | CW, MN | |
| | S49A | 9/16/2011 | Spring 49 source | overcast | storm | N | | | | | | CW, MN | E.coli Duplicate sample taken |
| | F6 | 9/16/2011 | Spring ditch, AGFD | overcast | storm | Y | | | | | | CW, MN | Across from Bubbling Ponds source site |
| | S107 | 9/16/2011 | Spring ditch | overcast | storm | Y | | | | | | CW, MN | Oak Creek had a heavy sediment load at the ditch outfall, but ditch itself did not |
| | S98 | 9/16/2011 | Bubbling Ponds Spring | overcast | stotrm | Y | | | | | | CW, MN | Instruments not allowed in water |
| | F4 | 9/16/2011 | Bubbling Ponds outfall | overcast | storm | N | | | | | | CW, MN | |
| | S100 | 9/16/2011 | Page Springs source | clear | storm | N | | | | | | CW, MN | Sampled about 1-2 feet below metal gate |
| | F3 | 9/16/2011 | Spring Creek above WWT pond | clear | storm | Y | | | | | | CW, MN | Evidence of a recent large storm |
| | M39 | 9/16/2011 | Spring Creek | clear | storm | Y | | | | | | CW, MN | Evidence of a recent large storm |
| | S9 | 9/20/2011 | Pine Flat spring @ road | clear | storm | N | | | | | | CW, MN | |
| | S41 | 9/20/2011 | Spring 41, upstream of SRSP | clear | storm | N | | | | | | CW, MN | |
| | S49A | 9/20/2011 | Spring 49 source | clear | storm | N | | | | | | CW, MN | |
| | S49 | 9/20/2011 | Spring 49 near source | clear | storm | N | | | | | | CW, MN | |
| | F7 | 9/20/2011 | Lower Indian Gardens spring, upper end | clear | storm | N | | | | | | CW, MN | |
| | S71 | 9/20/2011 | Lower Indian Gardens spring, midway | clear | storm | N | | | | | | CW, MN | |
| | S70 | 9/20/2011 | Lower Indian Gardens spring, near fish runs | clear | storm | N | | | | | | CW, MN | Water has a definite blue color in sample bottles |

| strm_mi | Site_ID | Date | Descript | Weather | 7-day weather | Flushing | Stream width | Depth (ft) | Velocity ft/s | ChanArea | Flow_cfs | Crew | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F6 | 9/20/2011 | Spring ditch, AGFD | clear | storm | N | | | | | | CW, MN | |
| | S107 | 9/20/2011 | Spring ditch | clear | storm | N | | | | | | CW, MN | |
| | S109 | 9/21/2011 | Lower Indian Gardens spring, down channel | | | | | | | | | KJA, MS | |
| | S45A | 9/22/2011 | Spring 45 source | | | | | | | | | CW, MN | |
| | S45B | 9/22/2011 | Spring 45 water fountain on side of house | | | | | | | | | CW, MN | |
| | S71 | 9/22/2011 | Lower Indian Gardens spring, midway | overcast | overcast | N | | | | | | CW, MN | |
| | S70 | 9/22/2011 | Lower Indian Gardens spring, near runs | overcast | overcast | N | | | | | | CW, MN | Water has a definite blue color in sample bottles |
| | S109 | 9/22/2011 | Lower Indian Garden spring, down channel | overcast | overcast | N | | | | | | CW, MN | |

gray highlight denotessamples from tributary streams
green highlight denotes samples from springs
no highlighting denotes Oak Creek samples

**bold numbers** mean "greater than"
*italic numbers* mean "less than"
red font means "out of hold time" or other attention

March 24, 2012

Oak Creek Watershed
COUNCIL

To: Members of the Oak Creek Watershed Improvement Commission (WIC)

From: Barry Allan, OCWIP Grant Administrator

Re: Oak Creek Watershed Social Survey Results

In late December, 2011 we sent the Oak Creek Watershed Residents' Survey to you all for review and final comments. We also asked if you had the time, to fill out the Survey and let us know how long it took you to complete. Your feedback was invaluable and confirmed we needed to allow 15 minutes for residents to fill it out.

On February 9, 2012 we mailed 1,224 copies of the Oak Creek Watershed Residents' Survey through our distributor Hansen Light Works in Sedona. On March 20, 2012 we ended receipt of the Surveys from residents after entering the data from 265 replies or 21.6% of those sent out.

Methods used to create 10% random sample of addresses within the Oak Creek Watershed:

We used the parcel data provided by Coconino and Yavapai counties earlier in the project, and selected all parcels within the watershed boundary using a spatial intersection between the outline of the watershed and the map of parcel boundaries. There were 14,802 properties.

From the parcels within the watershed, we removed all parcels that did not contain information about the owner, and then removed all banks, credit unions, city properties, county properties, fire district properties, mortgage companies, and churches. We did not remove LLCs, trusts, or associations, but took a subset of all the owner addresses within Arizona, removing all international and out-of-state owners. The net total was 12, 241 addresses.

We then randomized the entries using Excel's RAND() function, generating random numbers and then removing the formula to convert the random numbers to values. The random numbers were sorted, smallest to largest, and the first 1224 entries selected to provide a 10% sample.

Prior to sending the list for distribution, we edited the names of owners to remove legal terminology such as the dates trusts were created. (Eg: An owner name listed as "Evans Jack Mercer & Marcia Anne Trustees ; Evans Jm & Ma Rvcbl Liv Trust Dtd 2/2/07" was reduced to "Evans Trust" for mailer purposes.)

The letter accompanying the Survey:

January 31, 2012

From: Barry Allan, Executive Director

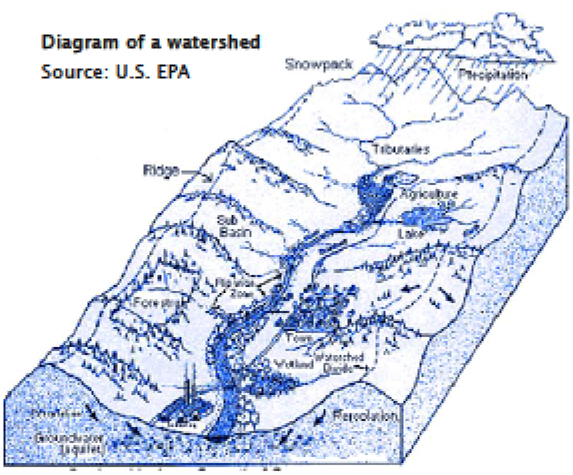
Oak Creek Watershed COUNCIL

Dear Oak Creek Watershed Resident...

Oak Creek is the 50 mile thread that weaves together the fabric of our watershed community, as well as being vital to its economic, recreational and natural future. The Oak Creek Watershed Council is committed to preserving the integrity of Oak Creek and recognizes that its stewardship must be a part of the watershed community culture.

Funded by a grant from the Arizona Department of Environmental Quality (ADEQ) and the United States Environmental Protection Agency (EPA) our group has submitted a draft of the Oak Creek Watershed Improvement Plan, which will be ready for public review very soon. The Plan identifies problems associated with the impairment of Oak Creek by the fecal coliform *Escherichia coli (E. coli)*, as well as solutions to those problems.

Diagram of a watershed
Source: U.S. EPA




*We need your help discovering how best to inform other members of the public on ways to protect Oak Creek, and the health of people who recreate in it.* Your household has been randomly selected to represent the view of Oak Creek watershed residents. This survey is designed to obtain residents' opinions on human behaviors that affect water quality. It will be used to guide projects to improve water quality in Oak Creek, and its five tributaries.

The enclosed survey takes approximately 15 minutes to fill out. Please take the time complete it, then fold and staple or tape, and return to the Oak Creek Watershed Council.

**We highly value your opinion, and it matters a lot to us! Your time is very much appreciated, and every survey we receive back helps Oak Creek. *Thank you for your participation!***

For more information about how you can help protect Oak Creek please visit our website at www.oakcreekwatershed.org. We also sponsor a website for visitors to Oak Creek Canyon at www.oakcreekcanyonaz.org in which we promote good stewardship and outdoor protocols.

Look for information on safe-guarding the water quality in Oak Creek through the Oak Creek Community Outreach Program in the spring of 2012 through radio, television, newspapers, as well as community groups. Your ideas at work along with hundreds of other watershed survey residents. *Together, we ARE making a difference!*

P.O. Box 732, Sedona, AZ 86339 • Tel: (928) 554-5460 • www.oakcreekwatershed.org

The Oak Creek Watershed Residents' Survey (2 pages) and Map of Watershed Zip Codes follows:

# Oak Creek Watershed Residents' Survey

**1) Of the following, which best fits your definition of what a watershed is?**

- □ Area that retains water like a swamp or a marsh
- □ Water intake area that feeds a water treatment plant
- □ The area of land where all of the water that drains off of it goes into a single creek, river or other water body
- □ None of the above
- □ Don't know

**2) How concerned are you with the health of the Oak Creek Watershed?**

□ Not concerned □ Somewhat
□ Concerned □ Very concerned

**3) How many times a year do you visit/recreate along Oak Creek?**

□ Never □ 1-5 □ 6-10
□ 11-15 □ 16-20 □ 20+

**4) What activities do you undertake while visiting Oak Creek? Please mark all that apply.**

□ Hiking □ Camping □ Fishing
□ Swimming □ Biking □ Dog walks
□ Equestrian □ Other:

**5) Which is the most important source of information affecting your perception of the Oak Creek Watershed's health?**

□ Personal observation
□ Newspaper □ Radio □ Internet
□ State or federal reports
□ Local environmental groups

**6) What sources do you think are the biggest contributors to creek contamination that can cause human illness?** Please number 1, 2 and 3 for your top choices.

__ Litter __ Dog feces
__ Baby diapers __ Human feces
__ Wildlife feces __ Livestock waste
__ Septic systems __ Don't know
__ Waste water treatment plants
__ Other (specify)

| | | Yes | No |
|---|---|---|---|
| 7) | Are you a pet owner? **If no please go to question 10.** | | |
| 8a) | *If so*, does/do your pet(s) go outside? | | |
| 8b) | Do you clean your yard of pet waste? | | |
| 9a) | Do you own a dog? If **no please go to question 10.** | | |
| 9b) | Do you walk your dog in the Oak Creek Watershed? | | |

9c) How often do you pick up your dog's waste when on a walk?

□ Never □ Rarely □ Sometimes
□ Most of the time □ Always

9d) If you pick up dog waste, how do you dispose of it?

□ Bag and leave it □ Trash
□ Toilet □ Compost □ Toss in ditch

9e) Would you use dog waste stations (plastic bag dispensers with or without trash can), if more were made available at parks and trails?

□ Yes □ No

10) Would you be willing to volunteer your time to help preserve Oak Creek and/or educate others about Oak Creek? (*If yes, provide contact information on next page.*)

□ Yes □ No

11) How old is the head of the household?

□ <34 □ 35-44 □ 45-54 □ 55-64
□ 65-74 □ 75+

12) How many people live in this household?

□ 1 □ 2 □ 3 □ 4 □ 5+

13) Is this residence a second home?

□ Yes □ No

14) What is your approximate annual household income in thousands of dollars?

□ 0-20 □ 20-50 □ 50-100
□ 100-200 □ >200

***Please complete the reverse side, then fold and staple or tape survey closed and mail to the Oak Creek Watershed Council.***
For more information, please visit our website at www.oakcreekwatershed.org

15) **In your opinion, how much do the following threaten Oak Creek water quality?**

0 = not sure  1 = not a problem  2 = slight problem
3 = moderate problem  4 = large problem  **Please mark with an X**

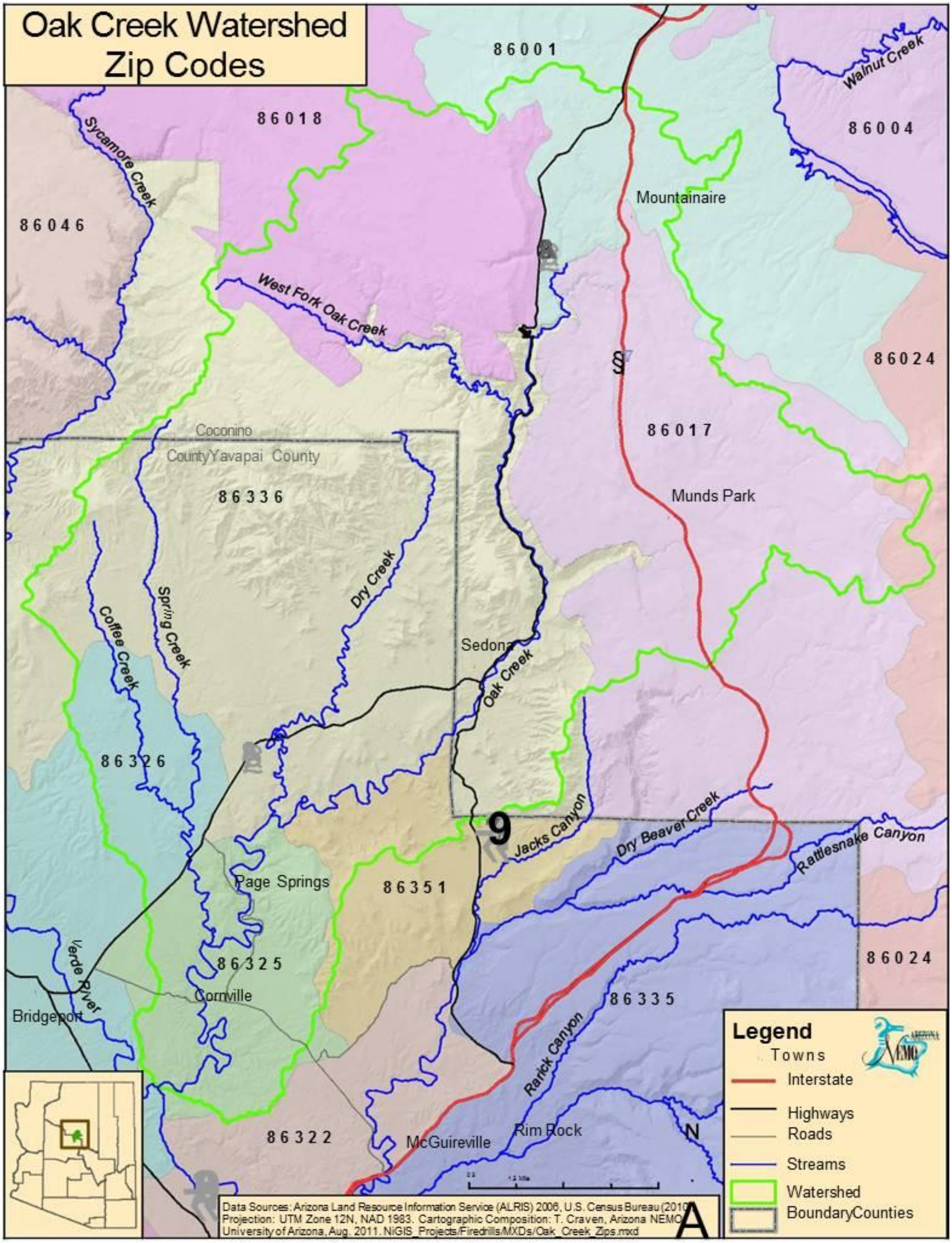
| | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| **Agricultural runoff** | | | | | |
| Livestock manure | | | | | |
| Fertilizers and pesticides | | | | | |
| **Animals** | | | | | |
| Dog feces that are not picked up and disposed properly | | | | | |
| Wildlife feces | | | | | |
| Wildlife attracted to water by discarded human food waste | | | | | |
| **Erosion and sedimentation due to the following:** | | | | | |
| Construction and maintenance of irrigation diversions | | | | | |
| Building and road construction | | | | | |
| Road maintenance | | | | | |
| Low water creek crossings | | | | | |
| Unmaintained "social" trails | | | | | |
| Jeep/ORV trails | | | | | |
| Other sources (specify) | | | | | |
| **Recreation** | | | | | |
| Human feces deposited outdoors | | | | | |
| Trash | | | | | |
| Used and improperly discarded baby diapers | | | | | |
| Lack of public toilet facilities near creek and at trailheads | | | | | |
| Lack of trash receptacles at recreation sites and trailheads | | | | | |
| **Urban areas** | | | | | |
| Stormwater runoff | | | | | |
| Lawn fertilizers and pesticides | | | | | |
| Pet feces not collected from yards | | | | | |
| **Wastewater** | | | | | |
| Inadequately maintained sewer system | | | | | |
| Improperly built or maintained residential septic systems | | | | | |
| Improperly built or maintained commercial septic systems | | | | | |
| **Other** | | | | | |
| Lack of riparian buffers (natural vegetation next to the water) | | | | | |
| Disturbance of "sediment reservoirs" on the bottom of Oak Creek that hold bacteria and viruses that can cause human illness | | | | | |
| Other (specify) | | | | | |

**Please, write any comments here:**

Fold here

Oak Creek Watershed Council
P.O. Box 732, Sedona, AZ 86339

Oak Creek Watershed Council
P.O. Box 732
Sedona, AZ 86339


Oak Creek Watershed
Zip Codes
86001
86018
86004
Walnut Creek
Sycamore Creek
86046
Mountainaire
West Fork Oak Creek
86024
86017
Coconino
County Yavapai County
86336
Munds Park
Dry Creek
Spring Creek
Coffee Creek
Sedona
Oak Creek
86326
9
Jacks Canyon
Dry Beaver Creek
Rattlesnake Canyon
Page Springs
86351
Verde River
86325
86024
Cornville
86335
Bridgeport
Rarick Canyon
86322
McGuireville
Rim Rock
N
Legend
Towns
Interstate
Highways
Roads
Streams
Watershed
BoundaryCounties
Data Sources: Arizona Land Resource Information Service (ALRIS) 2006, U.S. Census Bureau (2010)
Projection: UTM Zone 12N, NAD 1983. Cartographic Composition: T. Craven, Arizona NEMO
University of Arizona, Aug. 2011. NiGIS_Projects/Firedrills/MXDs/Oak_Creek_Zips.mxd
A

The results from the Social Survey are on a separate pdf attachments. Answers to questions 1 – 14 are in one pdf and answers to question 15 on the second. Three pages print out for all.

On the right side of each question's responses and tabulated data are some Take Away Notes that are meant to be summary observations. They assume that the collective answers from the 265 respondents are a fair sampling of all watershed residents and therefore the data can be extrapolated as such.

Our main use of the data and observations will be in developing the Oak Creek Community Outreach Program (OCCOP) as well as support in BMP decisions such as dog waste station installations.

We spent some time gathering some Census 2010 data regarding the ages of people living in watershed zip codes. We were hoping to compare that data with our own, relative to the age of the head of the household. Our reasoning was the low number of respondents under 45 years old (5.3%). Did younger people just not answer the survey or was it because there really are not a lot of younger people living in the watershed? The answer would be helpful in identifying our "audience" in the development of the OCCOP, but as it stands, it appears that middle aged and older watershed residents are in the majority.

<u>Highlights of the results from Questions 1 – 14 through direct answers and extrapolation are as follows</u>:

- 95% of property owners have some concern about the health of the Oak Creek Watershed.
- Each property owner visits/recreates along the Creek between 7 and 10 times a year.
- Hiking is almost 3 times as popular an activity as swimming.
- Personal observation & the newspaper were the choice of 74% as sources of information.
- Human feces, litter, baby diapers & septic systems were thought to be biggest contributors to creek contamination.
- Half of watershed property owners have pets & 90% of the pets go outside.
- 90% of watershed property owners clean their yard of waste
- 45% own a dog therefore there are at least 5400 dogs in the watershed.
- 45% of those who own a dog walk it (them) in the watershed extrapolating to almost 2500 dogs walked in the watershed annually.
- 64% always pick up their dog's waste. Approximate quantification of feces left behind is around 500 feces. Each gram of dog feces has 20 million *e. coli* bacteria colonies in it.
- 95% of dog owners who pick up the feces throw them into the trash.
- 89% of dog owners would use dog waste stations if provided.

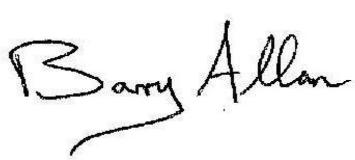
- 93% of respondents were over 45 years old, and 47% were over 65. 80% have 1 or 2 people living in the household, and for 62% it is their primary home.

Question 15 on the second page of the Survey had multiple choice answers to several questions within several categories, but all regarding the threat to Oak Creek water quality. Our percentages shown here are the total of 3 columns (slight problem, moderate problem and large problem):

- 69% believe that dog feces are a problem to some degree, and 48% wildlife feces. Almost 2/3 thought that wildlife attracted to water by human food waste threatens the water quality of Oak Creek.
- More than twice as many people than any other reason thought Jeep/ORV trails cause erosion and sedimentation which affects water quality of Oak Creek.
- The responses to recreation problems were the most significant of all categories: Totals: Human feces 67%; Trash 84%; Baby diapers 75%; Lack of public toilets 79%; Lack of trash receptacles 79%. There seems to be a consistency in these answers to those in Question 6.
- 60% thought there was some problem with stormwater runoff; lawn fertilizers & pesticides 71%; and pet feces in yards 66%.
- For wastewater: 62% inadequately maintained sewer system; 68% residential septic systems and 66% commercial septic systems.
- The lack of riparian buffers was 51% and disturbance of sediment 54%.

Thank you for reviewing this data and if you have any comments or feedback, please feel comfortable in dropping us a note at your earliest convenience. The Social Survey will be inserted into the Oak Creek Watershed Improvement Plan (OCWIP) and we highly value you're your opinion.

Sincerely,



Barry Allan
Grant Administrator/WIC Coordinator

P.O. Box 732, Sedona, AZ 86339 • Tel: (928) 554-5460 • www.oakcreekwatershed.org

# OAK CREEK WATERSHED RESIDENTS' SURVEY

RESULTS FOR QUESTIONS 1 - 14

Prepared by Barry Allan Revised on March 23, 2012 | Today is March 23, 2012

| | # of responses | % of total | hi (1) to low | |
|---|---|---|---|---|
| **1) Of the following, which best fits your definition of what a watershed is?** | | | | |
| a) Area that retains water like a swamp or a marsh | 5 | 1.9% | | |
| b) Water intake area that feeds a water treatment plant | 4 | 1.5% | | |
| c) The area of land where all of the water that drains off of it goes into a single creek, river or other water body | 240 | 90.6% | 1 | |
| d) None of the above | 6 | 2.3% | | |
| e) Don't know | 6 | 2.3% | | |
| NO RESPONSE | 12 | 4.5% | | |

**TAKE AWAY NOTES Question 1**

The survey based its sampling on 12,240 property owners with addresses in Arizona. The sampling of 1224 represents 10%, and the response was 265 or 21.65%. The cover letter sent with the Social Survey included a diagram of a typical watershed. This proved to be an effective education tool given the 90% of correct answers in the first question.

| **2) How concerned are you with the health of the Oak Creek Watershed?** | # of responses | % of total | hi (1) to low | |
|---|---|---|---|---|
| a) Not concerned | 7 | 2.6% | | |
| b) Somewhat | 68 | 25.7% | 3 | |
| c) Concerned | 87 | 32.8% | 2 | |
| d) Very concerned | 98 | 37.0% | 1 | |
| NO RESPONSE | 11 | 4.2% | | |

**TAKE AWAY NOTES Question 2**

While 37% were very concerned then 70% were at least concerned. In total over 95% had concern in varying degrees.

| **3) How many times a year do you visit/recreate along Oak Creek?** | # of responses | % of total | hi (1) to low | minimum # visits | maximum # visits |
|---|---|---|---|---|---|
| a) Never | 31 | 11.7% | | | |
| b) 1-5 | 122 | 46.0% | 2 | 5635 | 28175 |
| c) 6-10 | 33 | 12.5% | 3 | 9145 | 15242 |
| d) 11-15 | 10 | 3.8% | 5 | 5081 | 6928 |
| e) 16-20 | 10 | 3.8% | 4 | 7390 | 9238 |
| f) 20+ | 53 | 20.0% | 1 | 48960 | 48960+ |
| NO RESPONSE | 10 | 3.8% | | | |
| | | 86.0% | Totals>> | 76211 | 108543 |

TAKE AWAY NOTES Question 3

20% (2,448 watershed residents) visit Oak Creek over 20 times in a year which extrapolates to over 48,960 visits.
86% (10,531 watershed residents) collectively make between 76,000 and possibly over 108,000 visits to Oak Creek annually. This averages out to between 7 and 10 visits each a year.

| **4) What activities do you undertake while visiting Oak Creek? Please mark all that apply.** | # of responses | % of total | hi (1) to low | |
|---|---|---|---|---|
| a) Hiking | 187 | 70.6% | 1 | |
| b) Camping | 30 | 11.3% | 6 | |
| c) Fishing | 44 | 16.6% | 5 | |
| d) Swimming | 65 | 24.5% | 2 | |
| e) Biking | 25 | 9.4% | 7 | |
| f) Dog walks | 53 | 20.0% | 4 | |
| g) Equestrian | 7 | 2.6% | 8 | |
| h) Other: | 58 | 21.9% | 3 | |
| NO RESPONSE | | | | |

**TAKE AWAY NOTES Question 4**

Hiking is almost 3 times as popular an activity in the area of Oak Creek as swimming with watershed residents. Other activities are varied and include photography, picnics, walking, kayaking, canoeing, bird watching. 20% of watershed residents chose Dog Walks as an activity. This would extrapolate out to around 2500 a year or 7 every day.

| **5) Which is the most important source of information affecting your perception of the Oak Creek Watershed's health?** | # of responses | % of total | hi (1) to low | |
|---|---|---|---|---|
| a) Personal observation | 113 | 42.6% | 1 | |
| b) Newspaper | 84 | 31.7% | 2 | |
| c) Radio | 21 | 7.9% | 5 | |
| d) Internet | 11 | 4.2% | 6 | |
| e) State or federal reports | 41 | 15.5% | 4 | |
| f) Local environmental groups | 50 | 18.9% | 3 | |
| NO RESPONSE | | | | |

**TAKE AWAY NOTES Question 5**

Personal observation and the newspaper accounted for 74%. The newspaper, radio and internet media totalled 44%.

**TAKE AWAY NOTES Question 6**

Litter and Septic Systems tied at 23.4% followed by Human Feces at 20%, and Baby Diapers at 11.7% were the top 3 in the #1 creek contamination choices of 78.5% of respondees. Tallying all 3 responses for each sources though indicated Human Feces to be prevalent with Litter in second place and Baby Diapers/Septic Systems tied for third.

| **6) What sources do you think are the biggest contributors to creek contamination that can cause human illness? Please number 1, 2 and 3 for your top choices.** | #1 | % of total | hi to low | #2 | % of total | hi to low | #3 | % of total | hi to low | Weighted for all 3 Lowest numbers are most popular |
|---|---|---|---|---|---|---|---|---|---|---|
| a) Litter | 62 | 23.4% | 1 | 23 | 8.7% | 7 | 40 | 15.1% | 1 | 9 =2 |
| b) Baby diapers | 31 | 11.7% | 3 | 38 | 14.3% | 1 | 25 | 9.4% | 6 | 10 =3 |
| c) Wildlife feces | 21 | 7.9% | 6 | 25 | 9.4% | 6 | 7 | 2.6% | 9 | 21 =7 |
| d) Septic systems | 62 | 23.4% | 1 | 35 | 13.2% | 2 | 24 | 9.1% | 7 | 10 =3 |
| e) Waste water treatment plants | 9 | 3.4% | 8 | 12 | 4.5% | 9 | 13 | 4.9% | 8 | 25 =8 |
| f) Dog feces | 19 | 7.2% | 7 | 28 | 10.6% | 4 | 28 | 10.6% | 5 | 16 =5 |
| g) Human feces | 53 | 20.0% | 2 | 34 | 12.8% | 3 | 37 | 14.0% | 2 | 7 =1 |
| h) Livestock waste | 27 | 10.2% | 4 | 27 | 10.2% | 5 | 31 | 11.7% | 3 | 12 =4 |
| i) Don't know | 24 | 9.1% | 5 | 20 | 7.5% | 8 | 30 | 11.3% | 4 | 17 =6 |
| j) Other (specify) | 5 | 1.9% | 9 | 1 | 0.4% | 10 | 4 | 1.5% | 10 | 29 =9 |
| NO RESPONSE | | | | | | | | | | |

| 7) Are you a pet owner? If no please go to question 10. | # of responses | % of total | | | TAKE AWAY NOTES Question 7 |
|---|---|---|---|---|---|
| Yes | 139 | 52.5% | | | Over half of watershed residents have pets. |
| No | 108 | | | | |

| 8a) *If so,* does/do your pet(s) go outside? | # of responses | % of total | | | TAKE AWAY NOTES Question 8a |
|---|---|---|---|---|---|
| Yes | 126 | 90.6% | | | 90% of watershed residents' pets go outside |
| No | 14 | | | | |

| 8b) Do you clean your yard of pet waste? | # of responses | % of total | | | TAKE AWAY NOTES Question 8b |
|---|---|---|---|---|---|
| Yes | 125 | 94.0% | | | 90% of watershed residents whose pets go outside clean their yard of pet waste. |
| No | 8 | | | | |

| 9a) Do you own a dog? If no please go to question 10. | # of responses | % of total | | | TAKE AWAY NOTES Question 9a |
|---|---|---|---|---|---|
| Yes | 118 | 44.5% | | | 45% of watershed residents own a dog. Therefore there are at least 5400 dogs in the watershed. |
| No | 20 | | | | |

| 9b) Do you walk your dog in the Oak Creek Watershed? | # of responses | % responses | | | TAKE AWAY NOTES Question 9b |
|---|---|---|---|---|---|
| Yes | 57 | 45.6% | | | 45% of watershed residents who own a dog walk it in the watershed. That's almost 2500 dogs walked in the watershed annually. (See question 4 for |
| No | 68 | 54.4% | | | |

| 9c) How often do you pick up your dog's waste when on a walk? | # of responses | % responses | | # dog walks | approx # feces unattended | TAKE AWAY NOTES Question 9c |
|---|---|---|---|---|---|---|
| a) Never | 10 | 8.0% | 3 | 200 | 200 | 64% of watershed residents always pickup their dog's waste which accounts for 1600 out of 2500 dog walks. Approximate quantification of those dog walks that feces may be left behind: rarely = 10%; Sometimes = 30%; most of the time = 70% The total is 500 feces (see table) left in the watershed. Each gram of dog feces has 20 million e. coli bacteria colonies in it. |
| b) Rarely | 4 | 3.2% | 5 | 80 | 72 | |
| c) Sometimes | 7 | 5.6% | 4 | 140 | 84 | |
| d) Most of the time | 24 | 19.2% | 2 | 480 | 144 | |
| e) Always | 80 | 64.0% | 1 | 1600 | 0 | |

| 9d) If you pick up dog waste, how do you dispose of it? | # of responses | % dog owners | | | TAKE AWAY NOTES Question 9d |
|---|---|---|---|---|---|
| a) Bag and leave it | 1 | 0.8% | | | 95% of residents throw their dog's waste into the trash. |
| b) Trash | 113 | 91.9% | 1 | | |
| c) Toilet | 2 | 1.6% | | | |
| d) Compost | 5 | 4.1% | | | |
| e) Toss in ditch | 0 | 0.0% | | | |
| NO RESPONSE | 2 | 1.6% | | | |

| 9e) Would you use dog waste stations (plastic bag dispensers with or without trash can), if more were made available at parks and trails? | # of responses | % dog owners | | | TAKE AWAY NOTES Question 9e |
|---|---|---|---|---|---|
| Yes | 106 | 83.5% | | | 89% of dog owners would use dog waste stations. |
| No | 17 | 13.4% | | | |
| NO RESPONSE | 4 | 3.1% | | | |

| 10) Would you be willing to volunteer your time to help preserve Oak Creek and/or educate others about Oak Creek? (*If yes, provide contact information on next page.*) | | | | | TAKE AWAY NOTES Question 10 |
|---|---|---|---|---|---|
| Yes | 30 | 11.3% | | | 11% of respondees would be willing to volunteer their time, and only a few left contact information. |
| No | 204 | 77.0% | | | |
| NO RESPONSE | 15 | 5.7% | | | |

| 11) How old is the head of the household? | | | | | TAKE AWAY NOTES Question 11 |
|---|---|---|---|---|---|
| a) <34 | 2 | 0.8% | 6 | | Over 93% of respondees were over 45 years old, and 47% were over 65. These statistics could be compared with Census 2010 population counts if supplied by zip code or checked against the city of Sedona, for instance. |
| b) 35-44 | 12 | 4.5% | 5 | | |
| c) 45-54 | 43 | 16.2% | 4 | | |
| d) 55-64 | 80 | 30.2% | 1 | | |
| e) 65-74 | 70 | 26.4% | 2 | | |
| f) 75+ | 54 | 20.4% | 3 | | |
| NO RESPONSE | 12 | 4.5% | | | |

| 12) How many people live in this household? | | | | | TAKE AWAY NOTES Question 12 |
|---|---|---|---|---|---|
| 1 | 38 | 14.3% | 2 | | 2/3 of respondees have 2 people living in the household. 80% of respondees have at 1 or 2. |
| 2 | 173 | 65.3% | 1 | | |
| 3 | 16 | 6.0% | 4 | | |
| 4 | 23 | 8.7% | 3 | | |
| 5+ | 6 | 2.3% | 5 | | |
| NO RESPONSE | 7 | 2.6% | | | |

| 13) Is this residence a second home? | | | | | TAKE AWAY NOTES Question 13 |
|---|---|---|---|---|---|
| Yes | 92 | 34.7% | | | 62% of watershed residents are living in their primary home and for over 1/3 it is a second home. |
| No | 163 | 61.5% | | | |
| NO RESPONSE | 6 | 2.3% | | | |

| 14) What is your approximate annual household income in thousands of dollars? | | | | | TAKE AWAY NOTES Question 14 |
|---|---|---|---|---|---|
| a) 0-20 | 10 | 3.8% | 5 | | 62% of watershed residents make over $50,000 a year. A quarter of them earn $100,000 to $200,000. Relativity of age and income were not studied. |
| b) 20-50 | 41 | 15.5% | 3 | | |
| c) 50-100 | 87 | 32.8% | 1 | | |
| d) 100-200 | 65 | 24.5% | 2 | | |
| e) >200 | 14 | 5.3% | 4 | | |
| NO RESPONSE | 32 | 12.1% | | | |

# OAK CREEK WATERSHED RESIDENTS' SURVEY

RESULTS FOR QUESTION 15

Prepared by Barry Allan Revised on March 23, 2012

Today is March 23, 2012

| **15) In your opinion, how much do the following threaten Oak Creek water quality?** **Please mark with an X** | not sure 0 | not a problem 1 | slight problem 2 | moderate problem 3 | large problem 4 |
|---|---|---|---|---|---|
| **Agricultural runoff** | | | | | |
| Livestock manure | 52 | 40 | 58 | 59 | 32 |
| Fertilizers and pesticides | 41 | 24 | 46 | 65 | 50 |
| **Animals** | | | | | |
| Dog feces that are not picked up and disposed properly | 27 | 32 | 74 | 59 | 51 |
| Wildlife feces | 36 | 75 | 58 | 46 | 24 |
| Wildlife attracted to water by discarded human food waste | 36 | 37 | 74 | 56 | 41 |
| **Erosion and sedimentation due to the following:** | | | | | |
| Construction and maintenance of irrigation diversions | 56 | 45 | 74 | 46 | 15 |
| Building and road construction | 44 | 46 | 80 | 51 | 17 |
| Road maintenance | 44 | 54 | 91 | 39 | 8 |
| Low water creek crossings | 45 | 69 | 75 | 38 | 7 |
| Unmaintained “social” trails | 48 | 62 | 83 | 34 | 11 |
| Jeep/ORV trails | 41 | 43 | 57 | 55 | 35 |
| Other sources (specify) | 45 | 9 | 4 | 6 | 6 |
| **Recreation** | | | | | |
| Human feces deposited outdoors | 34 | 34 | 69 | 47 | 61 |
| Trash | 13 | 9 | 53 | 85 | 85 |
| Used and improperly discarded baby diapers | 28 | 17 | 57 | 62 | 80 |
| Lack of public toilet facilities near creek and at trailheads | 21 | 12 | 48 | 76 | 85 |
| Lack of trash receptacles at recreation sites and trailheads | 24 | 11 | 66 | 67 | 78 |
| **Urban areas** | | | | | |
| Stormwater runoff | 30 | 54 | 54 | 68 | 36 |
| Lawn fertilizers and pesticides | 31 | 27 | 69 | 68 | 51 |
| Pet feces not collected from yards | 36 | 35 | 87 | 58 | 29 |
| **Wastewater** | | | | | |
| Inadequately maintained sewer system | 41 | 32 | 46 | 67 | 54 |
| Improperly built or maintained residential septic systems | 34 | 26 | 37 | 78 | 65 |
| Improperly built or maintained commercial septic systems | 34 | 29 | 43 | 66 | 65 |
| **Other** | | | | | |
| Lack of riparian buffers (natural vegetation next to the water) | 55 | 48 | 66 | 41 | 30 |
| Disturbance of “sediment reservoirs” on the bottom of Oak Creek that hold bacteria and viruses that can cause human illness | 55 | 38 | 54 | 57 | 33 |
| Other (specify) | 35 | 4 | 1 | 3 | 6 |

| | not sure 0 | not a problem 1 | slight problem 2 | moderate 3 | large problem 4 |
|---|---|---|---|---|---|
| **Agricultural runoff** | | | | | |
| Livestock manure | 20% | 15% | 22% | 22% | 12% |
| Fertilizers and pesticides | 15% | 9% | 17% | 25% | 19% |
| **Animals** | | | | | |
| Dog feces that are not picked up and disposed properly | 10% | 12% | 28% | 22% | 19% |
| Wildlife feces | 14% | 28% | 22% | 17% | 9% |
| Wildlife attracted to water by discarded human food waste | 14% | 14% | 28% | 21% | 15% |
| **Erosion and sedimentation due to the following:** | | | | | |
| Construction and maintenance of irrigation diversions | 21% | 17% | 28% | 17% | 6% |
| Building and road construction | 17% | 17% | 30% | 19% | 6% |
| Road maintenance | 17% | 20% | 34% | 15% | 3% |
| Low water creek crossings | 17% | 26% | 28% | 14% | 3% |
| Unmaintained “social” trails | 18% | 23% | 31% | 13% | 4% |
| Jeep/ORV trails | 15% | 16% | 22% | 21% | 13% |
| Other sources (specify) | 17% | 3% | 2% | 2% | 2% |
| **Recreation** | | | | | |
| Human feces deposited outdoors | 13% | 13% | 26% | 18% | 23% |
| Trash | 5% | 3% | 20% | 32% | 32% |
| Used and improperly discarded baby diapers | 11% | 6% | 22% | 23% | 30% |
| Lack of public toilet facilities near creek and at trailheads | 8% | 5% | 18% | 29% | 32% |
| Lack of trash receptacles at recreation sites and trailheads | 9% | 4% | 25% | 25% | 29% |
| **Urban areas** | | | | | |
| Stormwater runoff | 11% | 20% | 20% | 26% | 14% |
| Lawn fertilizers and pesticides | 12% | 10% | 26% | 26% | 19% |
| Pet feces not collected from yards | 14% | 13% | 33% | 22% | 11% |
| **Wastewater** | | | | | |
| Inadequately maintained sewer system | 15% | 12% | 17% | 25% | 20% |
| Improperly built or maintained residential septic systems | 13% | 10% | 14% | 29% | 25% |
| Improperly built or maintained commercial septic systems | 13% | 11% | 16% | 25% | 25% |
| **Other** | | | | | |
| Lack of riparian buffers (natural vegetation next to the water) | 21% | 18% | 25% | 15% | 11% |
| Disturbance of “sediment reservoirs” on the bottom of Oak Creek that hold bacteria and viruses that can cause human illness | 21% | 14% | 20% | 22% | 12% |
| Other (specify) | 13% | 2% | 0% | 1% | 2% |

## TAKE AWAY NOTES

**Agricultural runoff:** Several respondees fumbled this section because they filled in the heading.

**Animals:** 69% believe that dog feces are a problem to some degree, and wildlife feces total 48%. Almost 2/3 think that wildlife attracted to water by human food waste threaten water quality to

**Erosion and sedimentation:** More than twice as many people than any other reason thought Jeep/ORV trails cause erosion and sedimentation which affects water quality of Oak Creek.

**Recreation:** The responses to recreation problems were the most significant of all categories. Totals: Human feces 67%; Trash 84%; Baby diapers 75%; lack of public toilets 79%; lack of trash receptacles 79%. There is a consistency in these answers to those in Question 6.

**Urban areas:** Totals: stormwater 60%; lawn fertilizers & pesticides 71%; Pet feces in yards 66%

**Wastewater:** Totals: sewer system 62%; residential septic systems 68%; commercial septic systems 66%

**Other:** Totals: lack of riparian buffers 51%; disturbance of sediment 54%

# Oak Creek Watershed Improvement Plan Appendix C:

# Best Management Practices (BMP) Project Descriptions

## Contents

# Introduction

The following are project descriptions for proposed BMP implementation projects in the Oak Creek Watershed intended to reduce *E. coli* concentrations and related water quality problems, such as erosion and sedimentation. Each is a stand-alone project description that can be used for developing funding proposals and implementing projects. Each has an education and outreach component, but there are also stand- alone education and outreach projects that are supportive of the on-the-ground projects. These projects were developed based on the findings of the 2011 water quality investigation as well the findings of past studies and information provided by watershed residents both formally (through a social survey) and informally (anecdotal information). The projects have been reviewed and approved by the Oak Creek Watershed Improvement Commission. They are shown here in order of priority based on multiple lines of evidence that point to the greatest sources *E. coli* contamination of Oak Creek.

## Project Prioritization

Project prioritization is described in the "Potential Future Projects" section in Chapter 2 of the Oak Creek Watershed Improvement Plan. There are two tiers of project prioritization. Tier 1are top priority projects and Tier 2 are lower priority projects. Within each tier projects priority is also ranked by project type and by project. The table below shows the tier 1 project priorities, with "1" being the top priority.

***OCWIP Top Priority BMP Project***

| Priority | Project number | Project title |
|---|---|---|
| 1 | EO-2 | Oak Creek Canyon Public Outreach Program |
| 2 | EO-5 | "Even One" *E. Coli* Outreach Project |
| 3 | EO-6 | Oak Creek Community Outreach Program (OCCOP) |
| 4 | SS-1 | Oak Creek Commercial Septic System Improvement Incentive Project |
| 5 | SW-1 | SW-1 Sedona Area Stormwater Improvement Project |
| 6 | RC-1 | Oak Creek Canyon Public Toilet Access Project |
| 7 | RC-3 | Keeping Oak Creek Beautiful – Trash Receptacle Access Project |

The table below shows the Tier 2 project priorities:

***OCWIP Second Tier BMP Project Priorities***

| Priority | Project number | Project title |
|---|---|---|
| 8 | EO-1 | Sedona Dog Waste Reduction Outreach Project |
| 9 | EO-3 | Lower Oak Creek Watershed Outreach Project |
| 10 | EO-4 | Recreational Vehicle Proper Waste Disposal Outreach Project |
| 11 | SS-2 | Oak Creek Residential Septic System Improvement Project |
| 12 | RC-2 | Oak Creek Canyon Sediment Source Reduction Project |
| 13 | RC-4 | Oak Creek Watershed Dog Waste Station Installation Project |
| 14 | AG-1 | Animal Waste BMPs for Oak Creek Watershed |
| 15 | AG-2 | Oak Creek Irrigation Diversion Erosion Reduction Project |
| 16 | AG-3 | Lower Oak Creek Erosion Reduction Project |

# Top Priority Projects

## EO-2 Oak Creek Canyon Public Outreach Program

**Need**

High recreation use of Oak Creek Canyon in the summer contributes to *E. coli* contamination of Oak Creek through several pathways: 1. dog feces, 2. used baby diapers, 3. human feces, 4. food waste that attrack wildlife that defecates near the stream, 5. soil disturbance and erosion that contribute sediment to *E. coli* sediment reservoirs, and 6. disturbance of sediment reservoirs by swimmers and waders causing *E. coli* and related fecal contaminants to enter the water column. Bilingual signage and oral communication are needed to reach both English- and Spanish-speaking recreators.

**Description**

Conduct a pre-summer and early summer media campaign with a public health awarement focus that includes public service announcements, kiosks, and volunteer contact with recreators at campground and day use areas to get the message out. The message should include health effects of fecal contamination, symptoms of infection due to fecal contamination, pictures of dirty diapers in the woods and blown up pictures of the germs that cause illness. Emphasize that July has the highest risk of contracting illness due to fecal contamination, because of high recreational use and the fact that flushing rains usually start later than July. Involve local businesses in an incentives/reward programs such as free frozen yogurt certificates or Red Rock day passes that volunteers hand out to visitors who pick up dog waste and/or properly dispose of used diapers. The success of this project relies on a presence of volunteers (preferably wearing official looking polo shirts with OCWC insignias) in the high recreational use areas interfacing with the public to convey information, solicit feedback, encourage the public through praise and incentives and generally promote a culture of caring for Oak Creek.

**Estimated load reduction**

***Human feces***

A University of North Dakota study for the U.S. Department of Agriculture regarding human waste distributions reveals the average stool produced is 95.5 grams per day, and 2066 ml of urine per day (Parker and Gallagher 1988). The average number of bowel movements per day was 2.54 (Parker and Gallagher 1988), but the number times a person urinates is variable based on the volume of fluid they consume, with a range of 4-10 times per day based on an Internet search. An urination rate of 7 per day will be used in this analysis.

The only access to and through the Oak Creek Canyon is Highway 89-A which carries about 7million visitors a year to Oak Creek and Sedona. Approximately one million of these visitors stop and utilize the publicly owned recreational sites, while 300,000 visit Slide Rock State Park (in Poff and Tecle 2002).

Assuming 60% of the potential visitors use the toilets once for urination and 30% of the potential visitors use the toilets for bowel movements, instead of relieving themselves into the environment, the load reductions for urine and fecal material are:

Urine (l) = 1 million visitors/year * 0.6 * 2066 ml/day * day/7 urinations * 1 liter/1000 ml = 177,086 liters

Fecal Material (kg) = 1 million visitors/year * 0.3 * 95.5 g/day * day/2.54 movements * 1 kg/1000 g = 11,280 kg

The Fecal Material estimate is more important in regard to *E. coli*. *E. coli*, as member of the intestinal flora, is part of the digestive process and is excreted in feces. Brandys (2007) found that human stool contained an average of 5 million CFU/gram of *E. coli* bacteria. Consequently, if 10% (11,280 kg) of fecal material that is now captured by the toilet facilities would have reached the river environment it would result in the potential *E. coli* load of $5.6 \times 10^{12}$ CFU per year, representing a 100% load reduction compared to not having the toilet facilities.

In order estimate the actual load reduction a survey of rest room users should be conducted.

References:

Brandys, B. 2007. Quantifying Bacteria Levels in Water Categories 1-3. Occupational and Environmental Health Consulting Services, accessed July 11, 2012. Located at: http://www.bio-reveal.com/AdminWeb/userfiles/image/file/IICRC%20S520%20-%20IICRC%20S500/Quantifying-Levels-02-07.pdf

Parker, D. and S. Gallagher, 1988. Distribution of Human Waste Samples in Relation to Sizing Waste Processing in Space, accessed July 9, 2012. Located at http://www.nss.org/settlement/moon/library/LB2-611-WasteProcessing.pdf

Poff, B. and A. Tecle, 2002. Bacteriological Water Quality Trend Analysis in Oak Creek Canyon, Arizona. In: Ground Water/Surface Water Interactions, 2002 AWRA Summer Specialty Conference Proceedings, July 1-3, 2002, Keystone, CO. pp. 431-436.

### *Diapers*

Peterson (1974) reported that feces-soiled diapers contained an average of 60 grams of feces. Brandys (2007) found that human stool contained an average of 5 million CFU/gram of *E. coli* bacteria. Assuming that the Trash Receptacle Access Project and the Outreach Program changes the behavior of 100 people per year (i.e. 100 diapers). The average annual load reduction would be $3 \times 10^{10}$ CFU per year.

References:

Brandys, B. 2007. Quantifying Bacteria Levels in Water Categories 1-3. Occupational and Environmental Health Consulting Services, accessed July 11, 2012. Located at: http://www.bio-reveal.com/AdminWeb/userfiles/image/file/IICRC%20S520%20-%20IICRC%20S500/Quantifying-Levels-02-07.pdf

Peterson, M.L., 1974. Soiled disposable diapers: a potential source of viruses.. American Journal of Public Health: September 1974, Vol. 64, No. 9, pp. 912-914. doi: 10.2105/AJPH.64.9.912

### *Dog feces*

*E. coli* bacteria are bacteria that are common to the intestinal tracts of humans and animals. Walker and Garfield (2008) found that a gram of fresh dog feces contained an average of 50 million CFU/gram with a range of 2 million to 200 million CFU/gram of *E. coli* bacteria. The average dog excretes 0.75 pounds (340 grams) of waste per day (Clear Choices Clean Water, 2012). That equates to an average 17 billion CFU of *E. coli* bacteria per day per dog. If the Sedona Dog Waste Reduction Outreach/Oak Creek Watershed Dog Waste Station Installation Projects prevents 100 dog/days from contaminating Oak Creek this would result in a load reduction 34 kg of dog feces and $17 \times 10^{12}$ CFU of *E. coli* bacteria.

The goal of the Outreach Project is to improve community awareness on the role of dog waste in water quality impairment of Oak Creek. The Outreach Project should increase the use of the dog waste stations and the rate of dog waste removal. If the Outreach Project increases use of the dog waste stations from 100 to 300 dog/days the result would be a load reduction of 102 kg of dog feces and $5.1 \times 10^{13}$ CFU of *E. coli* bacteria.

The actual load reduction will depend on the number of people that utilize the dog waste stations, before and after the Outreach Project. A monitoring program should be implemented to assess the use of the dog waste stations.

References:

Clear Choices Clean Water Organization, access on June 27, 2012 http://clearchoicescleanwater.org/wp-content/uploads/2011/08/pet-waste-FAQs_final.pdf

Walker, M. and L. Garfield, 2008. Dog wastes and water quality: Evaluating the connection at Lake Tahoe. University of Nevada Cooperative Extension, Fact Sheet-08-18.

### *Sediment*

The project seeks to reduce the amount of erosion and sediment entering Oak Creek as a result of soil disturbance from people hiking into Oak Creek Canyon and Slide Rock State Park on unmaintained social trails.

Without knowing the locations of the BMPs that will be implemented, some assumptions must be made in order to formulate a reasonable estimation of load reduction. The Automated Geospatial Watershed Assessment tool (AGWA) with the SWAT model (ARS, 2012) was first run using land cover data downloaded from the SWReGAP server. Land cover was then modified starting at the bridge just below the public swimming area at Slide Rock S.P. upstream just over 0.5 miles to the Halfway Day Use Area in order to represent disturbed soils due to hiking off-trail. Assuming that twenty percent of the entire area could be considered disturbed by people going off the trails and making their own pathways to the stream, the Land Cover Modification Tool within AGWA allows for a partial change of landcover within an area, and the second model reflects that percentage.

The difference between the SWAT model run with normal landcover, and a model run with landcover that reflects 20% of disturbed soil within an area of approximately 50 acres is the reduction of sediment load as a result of trail engineering and maintenance.

Load Reduction: 7.02 tons of sediment per year

References:

Agricultural Research Service (ARS) Website, Access on June, 2012. Automated Geospatial Watershed Assessment Tool located at http://www.tucson.ars.ag.gov/agwa/.

***Multiple effects***

Because the project is a multi-faceted approach to overall watershed improvement, using different methods and making some assumptions of effectiveness of the BMP when modeling each facet separately is necessary in order to formulate a reasonable estimation of load reduction. The project seeks to reduce the amount of *E. coli* and sediment delivered to Oak Creek during summer stormflow events by first surveying and determining where there are concentrations of human and animal waste, and where erosion problems exist.

If the watershed survey reveals that jeep use is a significant cause of soil disturbance and sediment discharge, then BMP's will be implemented along trails and public outreach will promote practices that will reduce erosion. Each subwatershed with hiking or jeep trails was modeled assuming that the total area of the disturbance by humans was either 10%, 20% or 30% of the total area of subwatersheds with jeep and/or hiking trails, and that BMP's were utilized in the model in those proportions. The Automated Geospatial Watershed Assessment tool (ARS, 2012) with the SWAT model was used to estimate the sediment runoff of the areas of with landcover data that represents normal vegetation, then with landcover data that had been modified to reflect the disturbed areas near jeep and hiking trails within the six subwatersheds. If 10% of the areas were disturbed, recovered normal vegetation would be responsible for the reduction of 19.5 tons of sediment per year.

The STEP L Model (U.S. EPA, 2012) was used to estimate the effectiveness of installing water bars and bioretention ponds to slow runoff and reduce erosion, and the revegetation of areas denuded by erosion in areas near jeep and hiking trails. If humans and jeeps disturbed 10% of the area of subwatersheds with trails, the load reduction as a result of the installation of water bars, bioretention ponds, and native vegetation is 153.9 tons of sediment per year.

Dog waste stations will be installed at all trailheads. Walker and Garfield (2008) found that a gram of dog feces contained an average of 50 million CFU/gram of *E. coli* bacteria. The average dog excretes 340 grams per day (Clear Choices Clean Water, 2012). That equates to 17 billion CFU of *E.coli* bacteria per dog per day. If the project successfully prevents 100 dog/days per year from contaminating Oak Creek, the result would be a reduction of 34 kg of dog feces and 17 x $10^{12}$ CFU of *E. coli* bacteria.

Public outreach efforts aimed at eliminating human waste contributions to the watershed will be implemented. Brandys (2007) found that human stool contained an average of 5 million CFU/gram of *E. coli* bacteria. Parker and Gallagher (1988) found that the mean human waste in over 25,000 subjects was 95 grams per day of solid fecal matter. That equates to 475 million CFU of *E. coli* per person per day. If the project successfully prevents 100 people per day from contaminating Oak Creek, the result would be a reduction of 9.5 kg of human feces and 4.75 x $10^{10}$ CFU of *E. coli* bacteria.

Average annual load reduction:

AGWA SWAT (Soil Disturbance and Normal Vegetation)
19.5 tons of sediment per year

STEP L (Water Bars, Bioretention Ponds, Revegetation)
153.9 tons of sediment per year

Combined Sediment Load Reduction: 173.4 tons of sediment per year

Dog Waste
34 kg (75 lbs) of feces and 17 x $10^{12}$ CFU per year of *E. coli* bacteria

Human Waste
9.5 kg (21 lbs) of feces and 4.75 x $10^{10}$ CFU per year of *E. coli.* bacteria

References:

Agricultural Research Service (ARS) Website, Access on June, 2012. Automated Geospatial Watershed Assessment Tool located at http://www.tucson.ars.ag.gov/agwa/.

Clear Choices Clean Water Organization Website, access June 27, 2012. Located at http://clearchoicescleanwater.org/wp-content/uploads/2011/08/pet-waste-FAQs_final.pdf

Walker, M. and L. Garfield, 2008. Dog Wastes and Water Quality; Evaluating the Connection at Lake Tahoe. University of Nevada Cooperative Extension, Fact Sheet-08-18.

Brandys, B. 2007. Quantifying Bacteria Levels in Water Categories 1-3. Occupational and Environmental Health Consulting Services, accessed July 11, 2012. Located at: http://www.bio-reveal.com/AdminWeb/userfiles/image/file/IICRC%20S520%20-%20IICRC%20S500/Quantifying-Levels-02-07.pdf

Parker, D. and S. Gallagher, 1988. Distribution of Human Waste Samples in Relation to Sizing Waste Processing in Space, accessed July 9, 2012. Located at http://www.nss.org/settlement/moon/library/LB2-611-WasteProcessing.pdf

U.S. EPA Website, Access June, 2012. Welcome to STEPL and Region 5 Model, http://it.tetratech-ffx.com/stepl/

### *Animal Waste*

*E. coli* bacteria are bacteria that are common to the intestinal tracts of humans and animals. A 1000-pound horse will defecate from 4-13 times each day and produce 35 to 50 pounds of wet manure (feces plus urine) daily, or approximately 9.1 tons per year. E. coli concentrations in fresh and dry manure from horses are $6.17 \times 10^4$ CFU per gram and $6.31 \times 10^5$ CFU per gram, respectively (NERA, 2012).

A mature cow weighting 1000 lbs produces an average of 8.7 lbs/day of manure (NRCS, 2012) or approximately 1.5 tons per year. Wang et al. (2004) showed that *E. coli* populations extracted from fresh cow manure ranging from $6.55 \times 10^6$ to $7.6 \times 10^6$ cfu per gram of manure (average of $7.1 \times 10^6$ cfu per gram).

If the fresh waste from one animal was dumped into the stream the potential average annual *E. coli* load would be:

Horse (CFU/year) = 9.1 tons/yr * $6.17 \times 10^4$ CFU per gram * 907,184.74 grams/ton = $5.1 \times 10^{11}$ CFU per year

Cow (CFU/year) = 1.5 tons/yr * $7.1 \times 10^6$ CFU per gram * 907,184.74 gram/ton = $9.7 \times 10^{12}$ CFU per year

The actual load reduction is based on the number of people currently dumping waste into the streams and the resulting number of people that stop dumped after the implementation of the Outreach Programs. A monitoring program would be implemented to assess the current rate of dumping and to evaluate the behavior changes after the implementation of Outreach Programs.

References:

Natural Resource Conservation Service (NRCS), access on June 25, 2012. Wyoming Comprehensive Nutrient Management Plan Workbook located at http://www.wy.nrcs.usda.gov/technical/wycnmp/

NERA Website, Access July 2012. NE1041: Environmental Impacts of Equine Operation located at http://lgu.umd.edu/lgu_v2/homepages/attachs.cfm?trackID=11196.

Wang, L., K.R. Mankin, and G.L. Marchin, 2004. Survival of Fecal Bacteria in Dairy Cow Manure. Transactions of the ASAE 47(4): 1239-1246.

**Project schedule and milestones**

| | |
|---|---|
| *Implementation schedule:*<br>January 2012 through September 2014<br>*Measurable milestones:*<br>~ Outreach planning & coordination complete<br>~ Spring & early summer media campaign complete<br>~ ADOT approval for highway signs<br>~ Signs posted along Hwy 89 for public toilets<br>~ Educational materials posted at #? kiosks<br>~ Volunteers log recreators observed:<br>▪ using dog waste stations & trash receptacles | *Resources and other support commitments:*<br>ADEQ 319(h) grants<br>????<br>*Commitment date(s):*<br><None at this time ><br>*Pending commitments:*<br><Unknown at this time><br>*Estimated commitment date:*<br><None at this time > |

| | |
|---|---|
| ▪ telling others to pick up waste<br>▪ using designated trails to reduce erosion<br>~ Volunteers distribute #? "thank you" gift certificates | |

**Education and Outreach Strategy**

*Findings of education needs survey:*

At least 12% of residents do not think dog feces impact water quality.
At least 6% of residents do not think used baby diapers impact water quality.
At least 13% of residents do not think human feces impact water quality.
At least 23% of residents do not think soil erosion due to unmaintained trails impacts water quality.
At least 14% of residents do not think leaving food waste near the creek can attract wildlife that contribute to fecal contamination of the creek.
At least 14% of residents do not think that disturbing *E. coli* sediment reservoirs can cause water contamination.

*Goals and target audiences:*

~ Target audience is summer recreators in Oak Creek Canyon, both English language speakers and English language learners.
~ Inform them of risks to human health from unsanitary practices such as:
  - not picking up dog feces
  - improperly discarding used baby diapers
  - defecating near Oak Creek
  - causing erosion by accessing creek on unmaintained trails
  - leaving food waste near the creek
~ Inform recreators of risk of swimming/wading when water is turbid
~ Offer incentives to recreators for demonstrating and promoting healthy habits
~ Make information available in Spanish and English both orally and in writing

*Priority education and outreach projects schedule:*

~ Stage campaign to coordinate with completion of public toilets and dog waste station installations.
~ Early summer 2012 - media campaign: Let public know about health risks, expected behavior, availability of toilets, waste receptacles and dog waste stations, future availability of amenities.
~ Early summer 2013 - media campaign: Same as previous year with notice of new amenities.
~ 2013 - success stories coverage

## Monitoring and Evaluating Effectiveness

**Long-term effectiveness criteria:** The number of summer time *E. coli* exceedances at Slide Rock State Park decreases.

**On-the-ground project effectiveness monitoring plan**

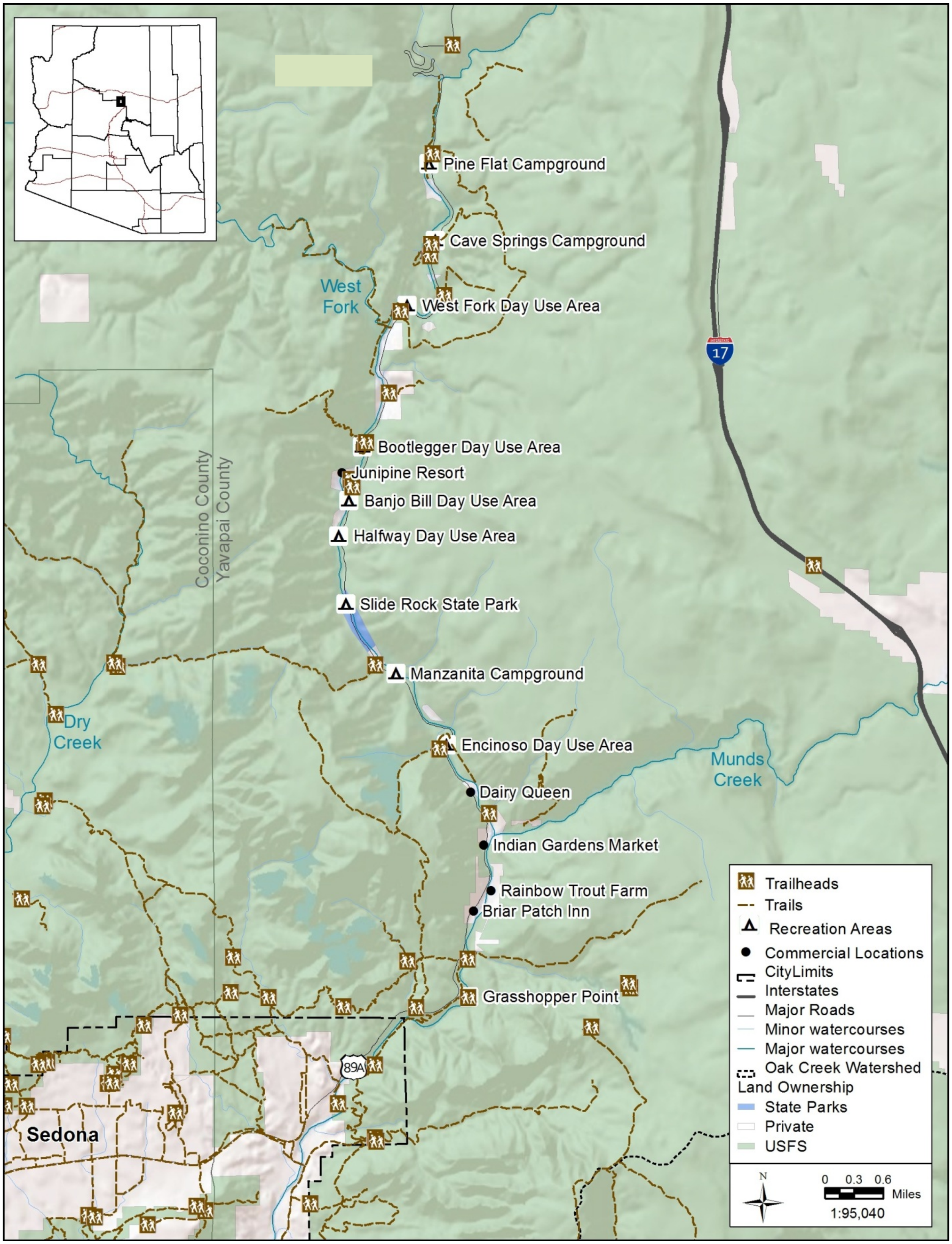
- *Monitoring and reference condition sites*:

Volunteers will observe recreator behavior at Slide Rock State Park and on Coconino National Forest at day use areas, campgrounds, and popular creek access points to determine whether desired behaviors are being exhibited.

- *Parameters & critical conditions:*
    - *E. coli* exceedences at Slide Rock State Park (>235 cfu/100 ml)
    - Observed behaviors
        - picking up dog feces
        - properly discarding used baby diapers
        - using public toilets
        - using maintained trails to avoid erosion
        - removing food waste near the creek
- *Schedule, frequency and duration*:
  Biweekly observations on the weekends throughout the summer, 2012-2014
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan:*
  Annual report in the fall of each year

**Education effectiveness monitoring**

- *Long-term behavior change criteria:*
  Recreators exhibit behaviors conducive to reducing *E. coli* contamination. The incidences of dog feces, used baby diapers, human feces, food waste, and soil erosion near the creek decrease.
- *Generation and implementation of second generation improvement projects:*
  Recreators provide feedback on the best locations for installing additional public toilets, trash receptacles, and dog waste stations.
- *Measurable reductions of pollutant loading:*
  Reduced *E. coli* exceedances at Slide Rock State Park
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan, how findings will be used:*
  Annual report in the fall of each year



Pine Flat Campground
Cave Springs Campground
West Fork
West Fork Day Use Area
17
Bootlegger Day Use Area
Junipine Resort
Banjo Bill Day Use Area
Halfway Day Use Area
Coconino County
Yavapai County
Slide Rock State Park
Manzanita Campground
Dry Creek
Encinoso Day Use Area
Munds Creek
Dairy Queen
Indian Gardens Market
Rainbow Trout Farm
Briar Patch Inn
Grasshopper Point
89A
Sedona
Trailheads
Trails
Recreation Areas
Commercial Locations
CityLimits
Interstates
Major Roads
Minor watercourses
Major watercourses
Oak Creek Watershed
Land Ownership
State Parks
Private
USFS
N
0 0.3 0.6
Miles
1:95,040

## EO-5 "Even One" *E. Coli* Outreach Project

**Need**

Recreators often do not grasp the consequences of their actions. Even one fece (dog, diaper or dump) can cause contamination of Oak Creek. This is known from past bacterial DNA studies in Oak Creek Canyon where it was discovered that a single animal (including human animals) can cause fecal contamination of the creek.

**Description**

Conduct a public outreach program to get the "Even one" message across that even one deposit of human or pet feces can cause contamination that threatens human health. Use fliers, presentations to schools, civic groups and campers, public service announcements and press releases to spread the message about personal responsibility for reducing *E. coli* contamination. Encourage residents and recreators in the watershed to speak up when they see someone polluting with used diapers, human feces, dog feces or food waste that attracts wild animals whose feces also contaminate Oak Creek. Be sure to emphasize that feces do not have to be right next to the creek to have an impact; feces on can be carried miles by stormwater and still cause contamination.

**Estimated load reduction**

A University of North Dakota study for the U.S. Department of Agriculture regarding human waste distributions reveals the average stool produced is 95.5 grams per day, and 2066 ml of urine per day (Parker and Gallagher 1988). The average number of bowel movements per day was 2.54 (Parker and Gallagher 1988), but the number times a person urinates is variable based on the volume of fluid they consume, with a range of 4-10 times per day based on an Internet search. An urination rate of 7 per day will be used in this analysis.

The only access to and through the Oak Creek Canyon is Highway 89-A which carries about 7million visitors a year to Oak Creek and Sedona. Approximately one million of these visitors stop and utilize the publicly owned recreational sites, while 300,000 visit Slide Rock State Park (in Poff and Tecle 2002). Assuming 60% of the potential visitors use the toilets once for urination and 30% of the potential visitors use the toilets for bowel movements, instead of relieving themselves into the environment, the load reductions for urine and fecal material are:

Urine (l) = 1 million visitors/year * 0.6 * 2066 ml/day * day/7 urinations * 1 liter/1000 ml = 177,086 liters

Fecal Material (kg) = 1 million visitors/year * 0.3 * 95.5 g/day * day/2.54 movements * 1 kg/1000 g = 11,280 kg

The Fecal Material estimate is more important in regard to *E. coli*. *E. coli*, as member of the intestinal flora, is part of the digestive process and is excreted in feces. Brandys (2007) found that human stool contained an average of 5 million CFU/gram of *E. coli* bacteria. Consequently, if 10% (11,280 kg) of fecal material that is now captured by the toilet facilities would have reached the river environment it would result in the potential *E. coli* load of 5.6 x $10^{12}$ CFU per year, representing a 100% load reduction compared to not having the toilet facilities.

In order estimate the actual load reduction a survey of rest room users should be conducted.

References:


Brandys, B. 2007. Quantifying Bacteria Levels in Water Categories 1-3. Occupational and Environmental Health Consulting Services, accessed July 11, 2012. Located at: http://www.bio-reveal.com/AdminWeb/userfiles/image/file/IICRC%20S520%20-%20IICRC%20S500/Quantifying-Levels-02-07.pdf

Parker, D. and S. Gallagher, 1988. Distribution of Human Waste Samples in Relation to Sizing Waste Processing in Space, accessed July 9, 2012. Located at http://www.nss.org/settlement/moon/library/LB2-611-WasteProcessing.pdf

Poff, B. and A. Tecle, 2002. Bacteriological Water Quality Trend Analysis in Oak Creek Canyon, Arizona. In: Ground Water/Surface Water Interactions, 2002 AWRA Summer Specialty Conference Proceedings, July 1-3, 2002, Keystone, CO. pp. 431-436.


**Project schedule and milestones**

| | |
|---|---|
| *Implementation schedule:*<br>March 2012 through September 2014<br><br>*Measurable milestones:*<br>~ Design of literature, presentations, PSA scripts, and press releases<br>~ Spring/early summer media campaign completed<br>~ #? presentations to civic groups<br>~ Late summer “Thank you” message in media<br>~ Survey to gage any change in attitudes<br>~ Annual reports on activities and response from public | *Resources and other support commitments:*<br>ADEQ 319(h) grants<br>????<br>*Commitment date(s):*<br><None at this time ><br><br>*Pending commitments:*<br><Unknown at this time><br>*Estimated commitment date:*<br><None at this time > |

**Education and Outreach Strategy**

*Findings of education needs survey:*

The opinions of watershed residents regarding whether feces from various sources pose a threat to the water quality of Oak Creek are as follows:

| source | Not sure | Not a problem | Slight problem |
|---|---|---|---|
| Dog feces | 10% | 12% | 28% |
| Human feces | 13% | 13% | 26% |
| Wildlife feces | 14% | 28% | 22% |

*Goals and target audiences:*

~ Residents, visitors and school children who recreate in Oak Creek watershed.

- ~ Make it common knowledge that a single feces (human, pet or wildlife) can cause fecal contamination of Oak Creek that can cause human illness.
- ~ Affect people’s behavior so that do not defecate outdoors, do not litter with used diapers or food waste, do pick up their dog’s feces and do encourage others to do the same.

*Priority education and outreach projects schedule:*

- ~ Early 2012 - The Oak Creek Community Outreach program collaborative group designs elements of outreach project
- ~ Summers 2012-2014 – Volunteers give “campfire talks” at Coconino National Forest campgrounds; mix natural history with “Even one” message.
- ~ Summers 2012-2014 – PSAs with the “Even one” message.
- ~ School year 2012-2014 – Volunteers/ staff/consultants give presentations to area schools
    - o “Deputize” students to bust people who pollute.
    - o Provide examples of children who have gotten very ill because of fecal contamination of streams, rivers or lakes.
    - o Tie into science learning about microbes and the spread of disease.
    - o Provide English and Spanish literature (comic book/coloring book) to take home so parent might see the message.
    - o Have a poster contest.
    - o Encourage adoption of a reach of Oak Creek
- ~ Year round - Presentations to civic groups, eg. Chamber of Commerce, Rotary Club, etc.; Encourage adoption of a reach of Oak Creek
- ~ 2013-2014 - success stories coverage

## Monitoring and Evaluating Effectiveness

**Long-term effectiveness criteria:**

- Reduced human and pet feces along trails and creek.
- Reduced *E. coli* concentrations in Oak Creek.
- Reduced percentage of human- and dog-sourced bacterial DNA.
- Survey results indicate a change in attitude about the importance of picking up dog waste, properly disposing of used diapers, not defecating outside (especially near water), and not littering in the riparian area with food waste that attracts wild animals whose feces can contaminate water.

**On-the-ground project effectiveness monitoring plan**

- *Monitoring and reference condition sites*:

    Fecal counts will be conducted once per month May through September along popular trails and at popular swim areas (sites to be determined by collaborative group). *E. coli* and bacterial DNA will be sampled at least 3 times per summer the day after storm events that can wash material into the stream.
- *Parameters & critical conditions:*
    - o number of presentations given to civic groups
    - o number of campfire talks
    - o number of school presentations
    - o number of PSA airings
    - o feces counts (>20 feces per ¼ mile)

- *E. coli* (>90% of baseline average for reach; >235 cfu/100 ml exceedence)
- Bacterial DNA (greater than the historic average percentage of human or dog source.)
- percentage of people reporting desired attitude as determined by survey
- percentage of people exhibiting desired behavior as determined by volunteer observers

- *Schedule, frequency and duration*:
  - Monthly fecal counts, May-September, 2012 -2014
  - Early summer and late summer observations and surveys administered by volunteers in the watershed on busy weekends, 2012 and 2014

- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan:*
  - Annual accomplishments reports
  - Final report

**Education effectiveness monitoring**

- *Long-term behavior change criteria:*
  Residents exhibit an understanding and related behaviors regarding the importance of not depositing human or pet feces in the watershed or attracting wildlife with food litter to riparian areas where they may leave feces that contaminate Oak Creek.
- *Generation and implementation of second generation improvement projects:*
  Civic groups or schools may choose to adopt a reach of Oak Creek to patrol for pollution and carry the "Even one" message to recreators.
- *Measurable reductions of pollutant loading:*
  Fecal counts by volunteer monitors show decreased pollutant loading at recreation sites throughout the watershed. *E. coli* concentrations and the percentage of human- and dog-sourced bacterial DNA are reduced.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan, how findings will be used:*
  - Annual accomplishment reports and final report posted on OCWC website.
  - Feature stories in local media on project implementation and effectiveness.

## EO-6 Oak Creek Community Outreach Program (OCCOP)

The Oak Creek Community Outreach Program (OCCOP) is a comprehensive program designed to promote better stewardship of Oak Creek by the watershed community, and reduce or eliminate trash and fecal contamination. The objective is to raise the awareness level, particularly of those living, working or recreating in the proximity of Oak Creek, regarding the consequences to littering and pollution, as well as changing the outdoor behavior of all visitors to Oak Creek. Framers of the program will coordinate all education and outreach projects described in the watershed improvement plan, with the OCCOP serving as an umbrella for these activities.

## SS-1 Oak Creek Commercial Septic System Improvement Incentive Project

### Need

Some septic systems in Oak Creek Canyon appear to contribute 20 to 200 cfu/100 ml (average = 72) to Oak Creek by way of spring discharge, whereas average *E. coli* concentrations in the creek are about 10 cfu/100ml based on 2011 monitoring. Also, in the Page Springs area discharge from a spring that is in the vicinity of a large commerical septic system has been found to exceed the *E. coli* standard for full body contact. These springs also tested postive for human DNA, indicating possible septic leakage. These more or less steady supplies of *E. coli* during the summer months may innoculate sediment reservoirs that are later disturbed by recreation or storm events to cause exceedences of *E. coli* in the water column. Evaluation and upgrade of septic systems is needed, particularly for commercial septic systems with seasonally large loads.

### Description

Technical assistance will be offered to property owners for septic system evaluation and remediation design, and a subsidy will be offered for system upgrades.

### Estimated load reduction

Approximately 10 springs in the Oak Creek Canyon area contain elevated concentrations of *E. coli*. Some failing septic systems in the watershed produce effluent that is intercepted by the springs and carried to the creek. These septic-influenced springs may provide a steady supply of *E. coli* to Oak Creek that may suffuse sediment reservoirs that can be later disturbed by recreational activity or a storm event causing exceedances of *E. coli* in the water column.

The project seeks to reduce the amount of effluent from failing septic systems by offering property owners technical assistance for septic system evaluation and remediation design. Upgrades to the failing septic systems will reduce contaminants from entering the springs, and improve water quality.

The STEPL model (U.S. EPA, 2012) is a spreadsheet tool that uses data inputs provided by the EPA to estimate nutrient and sediment loads. Best management practices can be incorporated into the model to determine the load reductions that would occur if the BMPs are implemented.

The numbers reflected in the load reduction results represent the remediation of all failing septic systems within the five subwatersheds adjacent to Oak Creek Canyon.

Using nitrogen and phosphorus as indicates for *E. coli* the average annual load reduction is:
Sediment – 77.9 tons per year (14.2%)
Nitrogen (N) – 3,506.5 lbs per year (10.3%)
Phosphorus (P) – 601.6 lbs per year (7.8%)

References:

U.S. EPA Website, Access June, 2012. Welcome to STEPL and Region 5 Model, http://it.tetratech-ffx.com/stepl/

**Project schedule and milestones**

| *Implementation schedule:* | *Resources and other support commitments:* |
|---|---|
| January 2012 through December 2014<br>*Measurable milestones:*<br>~ Baseline springs monitoring complete<br>~ Septic upgrades identified & prioritized<br>~ Upgrade funding secured<br>~ Upgrades implemented<br>~ Implementation report<br>~ Follow-up monitoring complete<br>~ Follow-up report complete | ADEQ 319(h) grants<br>????<br>*Commitment date(s):*<br>None at this time<br>*Pending commitments:*<br>Unknown at this time<br>*Estimated commitment date:*<br>None at this time |

**Education and Outreach Strategy**

*Findings of education needs survey:*

Watershed residents' opinions about whether improperly functioning septic systems threaten water quality are as follows:

| | Not sure | Not a problem | Slight problem | Moderate problem | Large problem |
|---|---|---|---|---|---|
| Improperly built or maintain residential septic systems | 13% | 10% | 14% | 29% | 25% |
| Improperly built or maintain commercial septic systems | 13% | 11% | 16% | 25% | 25% |

Watershed residents rank septic systems as one of the top three biggest contributors to creek contamination that can cause human illness as follows:

#1 – 23.4%

#2 – 13.2%

#3 – 9.1%

There seems to be a pretty high awareness in the general population about the potential impacts of septic system on water quality. Outreach should be focused on owners of septic systems in locations of concern, such as where there is shallow groundwater.

*Goals and target audiences:*

~ Reach commercial septic system owners in Oak Creek Canyon.
~ Inform them of risks to human health from poorly functioning septic systems.
~ Offer incentives (technical assistance, evaluation, subsidy) for upgrading septic systems.
~ Work cooperatively with land owners to assure completion of upgrades.

*Priority education and outreach projects schedule:*

~ Early 2013 - outreach
~ Late 2013 - cooperative agreements
~ 2014 - success stories coverage

## Monitoring and Evaluating Effectiveness

**Long-term effectiveness criteria:** *E. coli* concentrations below 5 cfu/100 ml in spring discharge near septic systems.

### On-the-ground project effectiveness monitoring plan

- *Monitoring and reference condition sites*:
  Five springs in Oak Creek Canyon with a history of elevated *E. coli* and suspected commercial septic system influence will be monitored along with one reference spring in each vicinity (one spring could serve as reference for multiple affected springs in close proximity). Springs to monitor are those that have shown elevated *E. coli* (greater than 2 cfu/100 ml) and tested positive for human DNA, including:
    - S41 upstream of Slide Rock State Park and
    - S70, S71 and S109 at lower Indian Gardens
    - S107 in the Page Springs area

  Other springs may be added to the monitoring list if areas of concern are identified through examination of septic system records, field reconnaissance, and/or sample testing.
- *Parameters & critical conditions:*
    - *E. coli:* >5 cfu/100 ml if sample is collected directly at a spring discharge point. This is a conservative threshold; the presence of any *E. coli* in spring water could be considered elevated *E. coli*, since the bacteria do not naturally occur in groundwater. The critical condition for samples collected away from the spring discharge point is >10 cfu/ml. In this situation it is important to confirm potential septic influence through DNA testing.
    - DNA: presence of human DNA
- *Schedule, frequency and duration*:
  Early and late summer samples for 1 year pretreatment and 2 years post-treatment.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan:*
  Project implementation report, 2-year follow-up monitoring report

### Education effectiveness monitoring

- *Long-term behavior change criteria:*
  Residents exhibit an understanding and willingness to have properly functioning septic systems.
- *Generation and implementation of second generation improvement projects:*
  Residents seek additional assistance with septic system improvements.
- *Measurable reductions of pollutant loading:*
  Reduced *E. coli* concentrations
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan, how findings will be used:*
  Project implementation report, 2-year follow-up monitoring report. Feature stories in local media on project implementation and effectiveness.

## SW-1 Sedona Area Stormwater Improvement Project

### Need

Summer stormflow events in the Sedona area deliver large doses of *E. coli* to Oak Creek. Stormwater samples from Carroll Canyon Wash, Soldier Wash, a storm drain at Tlaquepaque, Arroyo Roble and Jordan Wash have yielded *E. coli* concentrations exceeding the water quality standard of 235 cfu/100 ml for full body contact on multiple occasions, with concentrations often greater than 2,419.2 cfu/100 ml and 2 samples greater than 6,000 cfu/100 ml in summer 2011. Although DNA testing was inconclusive (6 of 6 samples where negative for dog DNA; this is probably erronenous, since previous studies in Oak Creek Canyon reguläry found dog DNA), it is still suspected that much of stormwater *E. coli* comes from dog feces, because there are obvious concentrations of dog feces deposited along trails within and adjacent to the city where residents and visitors walk their dogs. The City of Sedona and neighboring Coconino National Forest have a some dog waste "mitt" and collection stations and provide education/outreach, but these efforts need to be expanded to change dog owners attitudes and behaviors in order to reduce the loading of *E. coli* and other fecal pathogens in the watershed due to dog feces.

Human DNA was found in a water sample from Carroll Canyon Wash collected from a pool of standing water near the Chavez Crossing Road bridge on the morning of September 6, 2012 following a storm event the night before. The *E. coli* count for this sample was > 2,419.2. This results warrants further monitoring and investigation in the Carroll Canyon Wash watershed to determine if there are human fecal sources affecting water quality. Sources might include leaking sewer pipes, sewer overflows and human waste long trails. Whereas Carroll Canyon historically was a location to dump extra sewage in case of an overflow (Amina Sena personal communication), the City of Sedona has significantly reduced the number of overflows within the City over the last five years (Charles Mosely personal communication). Also the city has a sewer pipe inspection program; the City has inspected its gravity sewer pipe system once during the last five years and is preparing to begin the second round of inspections (Charles Mosely personal communication). Watershed stakeholders should stay engaged with City of Sedona and offer support for the sewer inspection program, as well as a potential study that would look at sewer system overflows, sewer lateral work (repair/replacement) on private property, and septic tank failure and repair records versus storm events and *E. coli* concentrations to look for correlations.

Finally, a tremendous amount of sediment is discharge to Oak Creek from Sedona Washes, especially Carroll Canyon. This sediment contributes to *E. coli* sediment reservoirs in Oak Creek which when disturbed cause increased *E. coli* concentrations in the water column. Erosion problems need to be identified and ammeliorated. Continued monitoring of turbidity and *E. coli* in stormwater from Sedona area washes is needed to more accurately identify source areas of sediment and bacteria, so that best management practices can be implemented accordingly. The City of Sedona has implemented a pro-active best management practices program under the MS-4 program relative to sediment. Stakeholders should work with the City to help ensure that BMPs are effective. The monitoring programshould endeavor to differentiate sediment that is part of natural background and sediment that is generated within and adjacent to the city due to human activity.

**Description**

To address the problems of dog feces, human waste, and sediment in Sedona stormwater loading Oak Creek with *E. coli* and promoting *E. coli* sediment reservoirs, the following actions will be taken:

1. Conduct surveys of smaller watersheds (eg. Dry Creek, Carroll Canyon, Soldier's Wash, Arroyo Roble, Jordan Pump) in Sedona to determine where there are concentrations of animal and human waste and where erosion problems exist,
2. To determine where best to focus efforts, sample stormwater at the boundary where washes pass from Yavapai County or national forest land into City of Sedona to determine the relative contributions of fecal contamination from outside and within the City's jurisdiction,
3. Interface with jeep tour companies to determine how they handle situations when customers need to defecate while on a tour. Is this a source of fecal material in the watershed? Encourage the use of ammo boxes or other small portable toilets to reduce loading in the watershed. Appeal to tourists protecting the fragile desert soils.
4. If the watershed survey reveals that jeep use appears to be a significant cause of erosion and sediment discharge, work with tour companies and use outreach to promote practices that reduce erosion,
5. Work collaboratively with City of Sedona to support inspection of sewer lines through pressure testing or other means to determine whether any leaks exist that could introduce untreated sewage to washes,
6. Establish dog waste stations and at all trailheads. Work collaboratively with City of Sedona, Arizona State Parks and Coconino National forest to establish a funding and staff to maintain waste stations,
7. Install erosion control measures such as waterbars on hiking and jeep trails to slow the flow of water and revegetation with native plants in areas that have been denuded,
8. If appropriate, install detention and settling basins to slow runoff for reducing erosion and to intercept fecal matter before it is carried by washes to Oak Creek.
9. Encourage the establishment of a city or regional stormwater utility or similar payment structure to fund upgrades and maintenance of the stormwater system to protect water quality and aquatic habitat of Oak Creek,
10. Monitor *E. coli* and turbidity in Sedona washes during stormflow before, during and after implementing best management practices.

**Estimated load reduction**

Because the project is a multi-faceted approach to overall watershed improvement, using different methods and making some assumptions of effectiveness of the BMP when modeling each facet separately is necessary in order to formulate a reasonable estimation of load reduction. The project seeks to reduce the amount of *E. coli* and sediment delivered to Oak Creek during summer stormflow events by first surveying and determining where there are concentrations of human and animal waste, and where erosion problems exist.

If the watershed survey reveals that jeep use is a significant cause of soil disturbance and sediment discharge, then BMP's will be implemented along trails and public outreach will promote practices that will reduce erosion. Each subwatershed with hiking or jeep trails was modeled assuming that the total area of the disturbance by humans was either 10%, 20% or 30% of the total area of subwatersheds with jeep and/or hiking trails, and that BMP's were utilized in the model in those proportions. The Automated Geospatial Watershed Assessment tool (ARS, 2012) with the SWAT model was used to estimate the sediment runoff of the areas of with landcover data that represents normal vegetation, then with landcover data that had been modified to reflect the disturbed areas near jeep and hiking trails within the six subwatersheds. If 10% of the areas were disturbed, recovered normal vegetation would be responsible for the reduction of 19.5 tons of sediment per year.

The STEP L Model (U.S. EPA, 2012) was used to estimate the effectiveness of installing water bars and bioretention ponds to slow runoff and reduce erosion, and the revegetation of areas denuded by erosion in areas near jeep and hiking trails. If humans and jeeps disturbed 10% of the area of subwatersheds with trails, the load reduction as a result of the installation of water bars, bioretention ponds, and native vegetation is 153.9 tons of sediment per year.

Dog waste stations will be installed at all trailheads. Walker and Garfield (2008) found that a gram of dog feces contained an average of 50 million CFU/gram of *E. coli* bacteria. The average dog excretes 340 grams per day (Clear Choices Clean Water, 2012). That equates to 17 billion CFU of *E.coli* bacteria per dog per day. If the project successfully prevents 100 dog/days per year from contaminating Oak Creek, the result would be a reduction of 34 kg of dog feces and 17 x $10^{12}$ CFU of *E. coli* bacteria.

Public outreach efforts aimed at eliminating human waste contributions to the watershed will be implemented. Brandys (2007) found that human stool contained an average of 5 million CFU/gram of *E. coli* bacteria. Parker and Gallagher (1988) found that the mean human waste in over 25,000 subjects was 95 grams per day of solid fecal matter. That equates to 475 million CFU of *E. coli* per person per day. If the project successfully prevents 100 people per day from contaminating Oak Creek, the result would be a reduction of 9.5 kg of human feces and 4.75 x $10^{10}$ CFU of *E. coli* bacteria.

Average annual load reduction:

AGWA SWAT (Soil Disturbance and Normal Vegetation)
19.5 tons of sediment per year

STEP L (Water Bars, Bioretention Ponds, Revegetation)
153.9 tons of sediment per year

Combined Sediment Load Reduction: 173.4 tons of sediment per year

Dog Waste
34 kg (75 lbs) of feces and 17 x $10^{12}$ CFU per year of *E. coli* bacteria

Human Waste
9.5 kg (21 lbs) of feces and 4.75 x $10^{10}$ CFU per year of *E. coli*. bacteria

References:

Agricultural Research Service (ARS) Website, Access on June, 2012. Automated Geospatial Watershed Assessment Tool located at http://www.tucson.ars.ag.gov/agwa/.

Clear Choices Clean Water Organization Website, access June 27, 2012. Located at http://clearchoicescleanwater.org/wp-content/uploads/2011/08/pet-waste-FAQs_final.pdf

Walker, M. and L. Garfield, 2008. Dog Wastes and Water Quality; Evaluating the Connection at Lake Tahoe. University of Nevada Cooperative Extension, Fact Sheet-08-18.

Brandys, B. 2007. Quantifying Bacteria Levels in Water Categories 1-3. Occupational and Environmental Health Consulting Services, accessed July 11, 2012. Located at: http://www.bio-reveal.com/AdminWeb/userfiles/image/file/IICRC%20S520%20-%20IICRC%20S500/Quantifying-Levels-02-07.pdf

Parker, D. and S. Gallagher, 1988. Distribution of Human Waste Samples in Relation to Sizing Waste Processing in Space, accessed July 9, 2012. Located at http://www.nss.org/settlement/moon/library/LB2-611-WasteProcessing.pdf

U.S. EPA Website, Access June, 2012. Welcome to STEPL and Region 5 Model, http://it.tetratech-ffx.com/stepl/

**Costs**

????

**Project schedule and milestones**

| | |
|---|---|
| *Implementation schedule:*<br>January 2012 through December 2014<br><br>*Measurable milestones:*<br>~ Tributary watershed surveys complete<br>~ Stormwater sampling complete<br>~ Cooperative agreement for funding and maintenance of dog waste stations complete<br>~ Dog waste station installed at all trailheads<br>~ Outreach and education for dog waste stations complete<br>~ Sewer system inspection complete<br>~ Erosion control measures installed<br>~ Retention basins installed<br>~ Follow-up monitoring complete<br>~ Project progress and completion reports | *Resources and other support commitments:*<br>ADEQ 319(h) grants<br>????<br>*Commitment date(s):*<br><None at this time ><br><br>*Pending commitments:*<br>City of Sedona??<br><Unknown at this time><br>*Estimated commitment date:*<br><None at this time > |

## Education and Outreach Strategy

(See also OCWIP Project #EO1 - Sedona Dog Waste Reduction Outreach Project)

*Findings of education needs survey:*

Watershed residents' opinions about potential sources of contamination in stormwater that could affect human health in Oak Creek are as follows:

| | Not sure | Not a problem | Slight problem | Moderate problem | Large problem |
|---|---|---|---|---|---|
| Dog feces that are not picked up and disposed properly | 10% | 12% | 28% | 22% | 19% |
| Human feces deposited outdoors | 13% | 13% | 26% | 18% | 23% |
| **Erosion and sediment due to the following:** | | | | | |
| Building & road construction | 17% | 17% | 28% | 17% | 6% |
| Road maintenance | 17% | 20% | 34% | 19% | 6% |
| Low water creek crossings | 17% | 26% | 28% | 14% | 3% |
| Unmaintained " social" trails | 18% | 23% | 31% | 13% | 4% |
| Jeep/ORV trails | 15% | 16% | 22% | 21% | 13% |

*Goals and target audiences:*

- ~ Reach people who hike and walk dogs on trails in tributary watersheds in the Sedona area.
- ~ Reach home owners who might be prone to tossing dog feces into drainage ways.
- ~ Reach jeep tour company owners and drivers as well as others who use jeep trails for recreation.
- ~ Inform the public of risks to human health from dog and human feces left in the watershed.
- ~ Have volunteers offer incentives (eg. OCWC water bottles, gift certificates for frozen yogurt, etc.) for picking up dog feces and/or encouraging others to do so.
- ~ If increased taxes may be needed to cover the cost of stormwater and/or sewage improvements, work with City of Sedona to develop appropriate outreach campaign.

*Priority education and outreach projects schedule:*

- ~ 2012 - initial outreach;
- ~ 2013-2014 adapt and modify outreach and continue activities
- ~ 2013, 2014 - success stories coverage

## Monitoring and Evaluating Effectiveness

**Long-term effectiveness criteria:** *E. coli* concentrations below <235 cfu/100 ml and turbidity <50 NTU in Sedona washes during storm events.

### On-the-ground project effectiveness monitoring plan

- *Monitoring and reference condition sites*:
  *E. coli* and turbidity should be monitored in Sedona washes during summer storm events before and after implementing best management practices. Process dilutions of *E. coli* samples to quantify concentrations >2,419.2 cfu/100 ml.
- *Parameters & critical conditions:*
  - *E.coli* (>235 cfu/100 ml)
  - Turbidity (>50 NTU)
  - DNA (presence of human DNA; dog DNA >10%)
- *Schedule, frequency and duration*:
  Two to four storm events during monsoon season 2012-2014. Try to capture "first flush" when rainfall is of great enough magnitude and intensity to move fecal material from uplands into washes.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants; City of Sedona; Coconino National Forest
- *Reporting plan:*
  Produce an annual report of summer water quality results and interpretation by November.

### Education effectiveness monitoring

- *Long-term behavior change criteria:*
  Residents, visitors, and tour drivers exhibit an understanding and willingness to reduce fecal contamination and erosion in Oak Creek tributary watersheds in the Sedona area.
- *Generation and implementation of second generation improvement projects:*
  City of Sedona considers establishing a stormwater utility to support ongoing outreach and improvement/maintenance of stormwater infrastructure to reduce pollutant loading in Oak Creek.
- *Measurable reductions of pollutant loading:*
  Reduced *E.coli* concentrations, turbidity and human and canine sources of fecal contamination in stormwater runoff in Sedona
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants; City of Sedona; Coconino National Forest
- *Reporting plan, how findings will be used:*
  Quarterly and final reports to funding agencies. Progress reports on OCWC website. Feature stories in local media on project implementation and effectiveness.

Soldier Wash
Mormon Canyon
Sedona
Dry Creek
89A
Carroll Canyon Wash
Chavez Crossing Campground
179
Crescent Moon Day Use Area
Red Rock Crossing
Red Rock Loop Rd
Red Rock State Park
Oak Creek
Verde Valley School Rd
Exceeding E.coli
Trailheads
Trails
Arterial Road
Residential Road
CityLimits
Recreation Areas
Major Roads
Minor watercourses
Major watercourses
Oak Creek Watershed
Land Ownership
State Parks
Private
State
Fish and Game
USFS
N
0 0.25 0.5
Miles
1:63,360

## RC-1  Oak Creek Canyon Public Toilet Access Project

**Need**

There is a shortage of public restrooms  in Oak Creek Canyon, especially access that does not require a Red Rock Pass.  Many people will park along the highway and hike into the creek rather than pay the fee.  Because toilet and trash amenities on national forest land are associated with fee areas, but many recreators avoid the fee areas, they have limited options for sanitary toilet facilities.  The public rest room at Indian Gardens is one available toilet.  The others are primarily in a limited number of commerical sites, many of which are not available to general public.  This shortage of public toilets sometimes results in people defecating near the stream where feces can wash into the channel during storm events, thereby contributing to fecal contamination of Oak Creek water that threatens human health.  The shortage of public toilets is a long-standing problem that requires priority attention.

**Description**

Work with Coconino N.F., business owners, and ADOT to establish restrooms at intervals that will help ensure the public can conveniently access them rather than defecating near the stream. Post signs along the highway indicating public restrooms.  Establish  collaborative agreements and funding to maintain restrooms.  This is a high priority, which was identified in the past and has not had enough action.

**Estimated load reduction**

A University of North Dakota study for the U.S. Department of Agriculture regarding human waste distributions reveals the average stool produced is 95.5 grams per day, and 2066 ml of urine per day (Parker and Gallagher 1988).   The average number of bowel movements per day was 2.54 (Parker and Gallagher 1988), but the number times a person urinates is variable based on the volume of fluid they consume, with a range of 4-10 times per day based on an Internet search.  An urination rate of 7 per day will be used in this analysis.

The only access to and through the Oak Creek Canyon is Highway 89-A which carries about 7million  visitors a year to Oak Creek and Sedona. Approximately one million of these visitors stop and utilize the publicly owned recreational sites, while 300,000 visit Slide Rock State Park (in Poff and Tecle 2002).  Assuming 60% of the potential visitors use the toilets once for urination and 30% of the potential visitors use the toilets for bowel movements, instead of relieving themselves into the environment, the load reductions for urine and fecal material are:

Urine (l) = 1 million visitors/year * 0.6 * 2066 ml/day * day/7 urinations * 1 liter/1000 ml = 177,086  liters

Fecal Material (kg) = 1 million visitors/year * 0.3 * 95.5 g/day * day/2.54 movements * 1 kg/1000 g = 11,280 kg

The Fecal Material estimate is more important in regard to *E. coli*.  *E. coli*, as member of the intestinal flora, is part of the digestive process and is excreted in feces.  Brandys (2007) found that human stool contained an average of 5 million CFU/gram of *E. coli* bacteria. Consequently, if 10% (11,280 kg) of fecal material that is now captured by the toilet facilities would have reached the river environment it would result in the potential *E. coli* load of 5.6 x $10^{12}$ CFU per year, representing a 100% load reduction compared to not having the toilet facilities.

In order estimate the actual load reduction a survey of rest room users should be conducted.

References:


Brandys, B. 2007. Quantifying Bacteria Levels in Water Categories 1-3. Occupational and Environmental Health Consulting Services, accessed July 11, 2012. Located at: http://www.bio-reveal.com/AdminWeb/userfiles/image/file/IICRC%20S520%20-%20IICRC%20S500/Quantifying-Levels-02-07.pdf

Parker, D. and S. Gallagher, 1988. Distribution of Human Waste Samples in Relation to Sizing Waste Processing in Space, accessed July 9, 2012. Located at http://www.nss.org/settlement/moon/library/LB2-611-WasteProcessing.pdf

Poff, B. and A. Tecle, 2002. Bacteriological Water Quality Trend Analysis in Oak Creek Canyon, Arizona. In: Ground Water/Surface Water Interactions, 2002 AWRA Summer Specialty Conference Proceedings, July 1-3, 2002, Keystone, CO. pp. 431-436.


**Costs**

| **Item** | **units** | **price/unit** | **cost** |
|---|---|---|---|
| full service restrooms with water well and septic system | # | $$ | $$$ |
| vault toilets | # | $$ | $$$ |
| portable toilets | | | |
| Purchased | # | $$ | $$$ |
| rented - # toilet x # months (2012-2014) | # | $$ | $$$ |
| highway pullouts and parking | # | $$ | $$$ |
| easement or purchase of land for toilets on private property | # | $$ | $$$ |
| Annual maintenance costs for first 3 years | # | $$ | $$$ |
| Signage along Hwy 89A | # | $$ | $$$ |
| Legal fees for permit processing, establishment of maintenance agreements, construction contracting, establishment of easements or property purchase contracts, etc. (some if this may count as inkind contribution from participating agencies?) | # | $$ | $$$ |

**Project schedule and milestones**

| | |
|---|---|
| *Implementation schedule:*<br>January 2012 through December 2014 | *Resources and other support commitments:*<br>ADEQ 319(h) grants |

| | |
|---|---|
| *Measurable milestones:*<br>~ Meet with collaborators (USFS, SRSP, local business owners, ADOT) to discuss roles and responsibilities, cost-sharing, necessary permits and clearances, etc.<br>~ Make a complete inventory of available toilets, distance between toilets, ownership and accessibility; identify gaps that must be filled.<br>~ Select sites for additional toilets and types of toilets to be installed.<br>~ Complete all permits, clearances, construction contracting and maintenance agreements.<br>~ Construct flush toilets (including water wells and septic systems where needed) and necessary pull outs and parking<br>~ Place portable or vault toilets with adequate pull outs and parking<br>~ Signage installed along Hwy 89A.<br>~ Outreach activities complete<br>~ Monitoring complete<br>~ Reporting complete | ????<br>*Commitment date(s):*<br><None at this time ><br><br>*Pending commitments:*<br><Unknown at this time><br>*Estimated commitment date:*<br><None at this time > |

**Education and Outreach Strategy**

*Findings of education needs survey:*

At least 13 % of watershed residents do not think human feces are a source of water contamination in Oak Creek.

Watershed residents think the lack of toilet facilities threatens Oak Creek water quality as follows:

| | Not sure | Not a problem | Slight problem | Moderate problem | Large problem |
|---|---|---|---|---|---|
| Lack of public toilet facilities near creek and trailheads | 8% | 5% | 18% | 29% | 32% |

*Goals and target audiences:*

~ Swimmers, waders, hikers and fishermen in Oak Creek Canyon who need public access toilets
~ Stress how important it is for human and environmental health that they not defecate near the creek
~ Inform them of collaborators' efforts to increase public toilet access
~ Let them know where toilets are now and where they will be in the near future
~ Encourage them to tell others where to access toilets

- ~ Explain the health risks of discarded used diapers and encourage them to dispose of used diapers in trash receptacles at public toilets.
- ~ Have volunteers offer incentive items to people observed using public toilets
- ~ Have workers or volunteers (in uniform – polo shirt or T shirt) conducting fecal counts on the weekend to show a presence along the creek and interface with the curious public to offer information about reducing pollution, including directing them to available public toilets.

*Priority education and outreach projects schedule:*

- ~ Summer 2012 - radio PSA (including on the Slide Rock S.P. park information frequency) about available public toilets, the importance of using them, and upcoming additional toilets. Try to come up with something fun and catchy (eg. if not too distasteful or outdated, use a spin-off of the Cheech and Chong "What's that?" skit) or come up with a good catch phrase. Encourage public participation in siting of new toilets. Advertise public meeting.
- ~ Public meeting(s) July/August 2012 soliciting comment on siting of public toilets.
- ~ Feature stories in local media lauding the collaborative effort to increase toilet access in Oak Creek Canyon and soliciting input from the public.
- ~ 2014 - success stories coverage

## Monitoring and Evaluating Effectiveness

**Long-term effectiveness criteria:** Increased use of public toilets. Reduced human feces observed along Oak Creek in Oak Creek Canyon. Human-sourced DNA in fecal bacteria of Oak Creek reduced from an average of 16% in 1998-1999 samples.

### On-the-ground project effectiveness monitoring plan

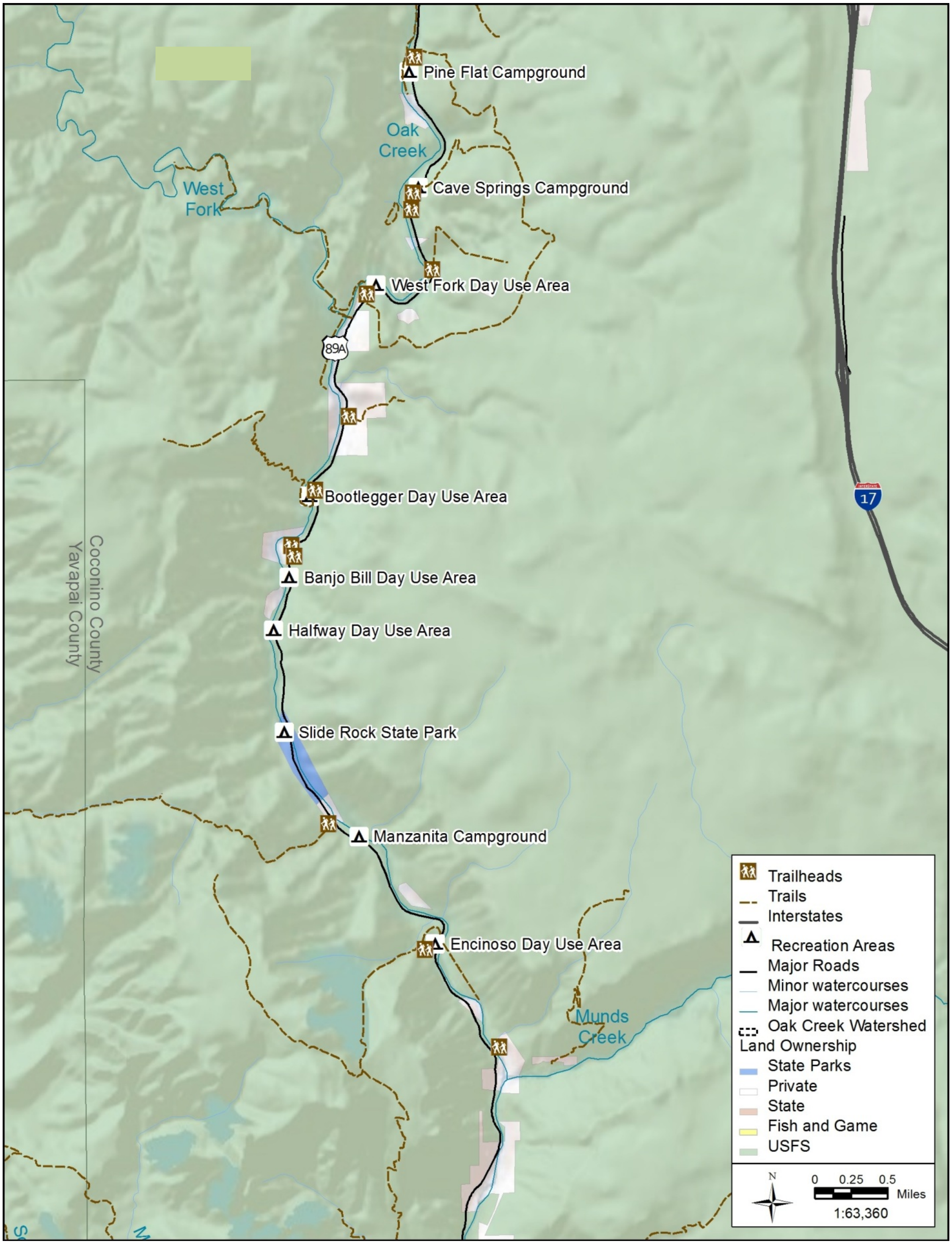
- *Monitoring and reference condition sites*:
  Volunteers will monitor the number of people utilizing public toilets. Approximately ## sites along the creek in Oak Creek Canyon will be monitored for *E. coli* and human-sourced bacterial DNA in proximity to new toilet installations and new signage for toilet access.
- *Parameters & critical conditions:*
  - Fecal counts along popular stretches of Oak Creek (>X human feces per ¼ mile); feces will be picked up and bagged so they are not double counted [Research degradation time for feces; if practical, space fecal count intervals so that previous feces would have decomposed, if volunteers are not wanting to pick up feces.]
  - *E.coli* (>10 cfu/100 ml for elevated values, >235 cfu/100 ml for exceedence)
  - DNA (average >15% human-sourced DNA in fecal bacteria)
- *Schedule, frequency and duration*:
  Public toilet use counts and fecal counts will be conducted twice per month May through September. *E. coli* and DNA sampling during high-use weekends in the early-, mid- and late summer and the day of or the day following a storm event that increases streamflow. Baseline monitoring will be accomplished in 2012 and effectiveness monitoring will be conducted in 2013-2014.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants; Coconino National Forest; Coconino County Rural Environmental Corp [contract for services to conduct fecal counts and *E. coli* sampling? Require at least one Spanish speaking crew member to interface with the

public. Try to have crews along creek on the weekend for a presence to make visitors aware of the ramifications of their actions.]

- *Reporting plan:*
  Annual report on summer monitoring results and interpretation by November of each year. Final analysis report in Fall 2014.

**Education effectiveness monitoring**

- *Long-term behavior change criteria:*
  Recreators exhibit an understanding and willingness to use public toilets rather than defecating near the creek in order to reduce *E. coli* and other fecal contaminants that threaten human health.
- *Generation and implementation of second generation improvement projects:*
  The public may identify additional sites where portable or vault toilets may be appropriate, initiating future projects.
- *Measurable reductions of pollutant loading:*
  Reduced *E.coli* concentrations and human-sourced bacterial DNA
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants; Slide Rock State Park; Coconino National Forest
- *Reporting plan, how findings will be used:*
  Annual accomplishments and monitoring report in the fall each year will be posted to OCWC website. Feature stories in local media will describe project implementation and effectiveness.



Pine Flat Campground
Oak Creek
Cave Springs Campground
West Fork
West Fork Day Use Area
89A
Bootlegger Day Use Area
Banjo Bill Day Use Area
Halfway Day Use Area
Coconino County
Yavapai County
17
Slide Rock State Park
Manzanita Campground
Encinoso Day Use Area
Munds Creek
Trailheads
Trails
Interstates
Recreation Areas
Major Roads
Minor watercourses
Major watercourses
Oak Creek Watershed
Land Ownership
State Parks
Private
State
Fish and Game
USFS
N
0 0.25 0.5
Miles
1:63,360

## RC-3 Keeping Oak Creek Beautiful – Trash Receptacle Access Project

**Need**

Trash receptacles are lacking in many places along Oak Creek that are popular recreation sites, leading visitors to litter. Used diapers that are dumped contribute to *E. coli* pollution as does food waste that attracts wildlife whose feces add to *E. coli* concentrations.

**Description**

Work with Coconino N.F., business owners, and the state parks to place trash receptacles at convenient locations. Work out collaborative agreements and funding to maintain trash receptacles. Investigate the cost/value of bear-proof receptacles and install as appropriate.

**Estimated load reduction**

***Diapers***

Peterson (1974) reported that feces-soiled diapers contained an average of 60 grams of feces. Brandys (2007) found that human stool contained an average of 5 million CFU/gram of *E. coli* bacteria. Assuming that the Trash Receptacle Access Project and the Outreach Program changes the behavior of 100 people per year (i.e. 100 diapers). The average annual load reduction would be $3 \times 10^{10}$ CFU per year.

References:


Brandys, B. 2007. Quantifying Bacteria Levels in Water Categories 1-3. Occupational and Environmental Health Consulting Services, accessed July 11, 2012. Located at: http://www.bio-reveal.com/AdminWeb/userfiles/image/file/IICRC%20S520%20-%20IICRC%20S500/Quantifying-Levels-02-07.pdf

Peterson, M.L., 1974. Soiled disposable diapers: a potential source of viruses.. American Journal of Public Health: September 1974, Vol. 64, No. 9, pp. 912-914. doi: 10.2105/AJPH.64.9.912


**Costs** ????

**Project schedule and milestones**

<table>
<tr>
<td rowspan="2">Implementation schedule:<br>January 2012 through December 2014<br><br>Measurable milestones:<br>~ Survey of popular recreation sites without trash receptacles<br>~ Coordination meetings with collaborators (USFS, services vendor for USFS, state parks, businesses, City of Sedona, OCWC, etc.) to discuss funding, permits, clearances, and maintenance<br>~ MOA regarding trash receptacle placement and maintenance</td>
<td>Resources and other support commitments:<br>ADEQ 319(h) grants<br>????<br>Commitment date(s):<br><None at this time></td>
</tr>
<tr>
<td>Pending commitments:<br><Unknown at this time><br>Estimated commitment date:<br><None at this time ></td>
</tr>
</table>

| | |
|---|---|
| ~ Purchase and installation of trash receptacles<br>~ Litter surveys before and after receptacle placement<br>~ Quarterly and final reports | |

**Education and Outreach Strategy**

*Findings of education needs survey:*

Watershed residents reported the following opinions about litter and baby diapers as the biggest contributors to creek contamination that can cause human illness:

| | #1 contributor | #2 contributor | #3 contributor |
|---|---|---|---|
| litter | 23.4% | 8.7% | 15.1% |
| Baby diapers | 11.7% | 14.3% | 9.4% |

At least 14% of watershed residents did not think that leaving food waste at campgrounds or picnic sites attracts wild animals whose feces can contaminate Oak Creek.

*Goals and target audiences:*

~ Swimmers, waders, hikers and fishermen in Oak Creek Canyon.
~ Use signs next to trash receptacles and PSAs to inform recreators of the risks to human health from *E. coli* and how increased *E. coli* in water can be caused by littering food waste and used diapers
~ Have volunteers offer incentive items to people observed using waste receptacles rather than littering.

*Priority education and outreach projects schedule:*

~ Early summer 2012 - trash receptacles and signs in place
~ Summer 2012-2014 - radio PSA about risks of elevated *E. coli* and what people can do to reduce the risk, including reducing using trash receptacles rather than littering food waste and used diapers. Include PSA on Spanish language radio stations.
~ 2013 - success stories coverage

## Monitoring and Evaluating Effectiveness

**Long-term effectiveness criteria:** Reduced incidence of food waste and used diapers in recreation areas. Reduced *E. coli* concentrations in Oak Creek.

**On-the-ground project effectiveness monitoring plan**

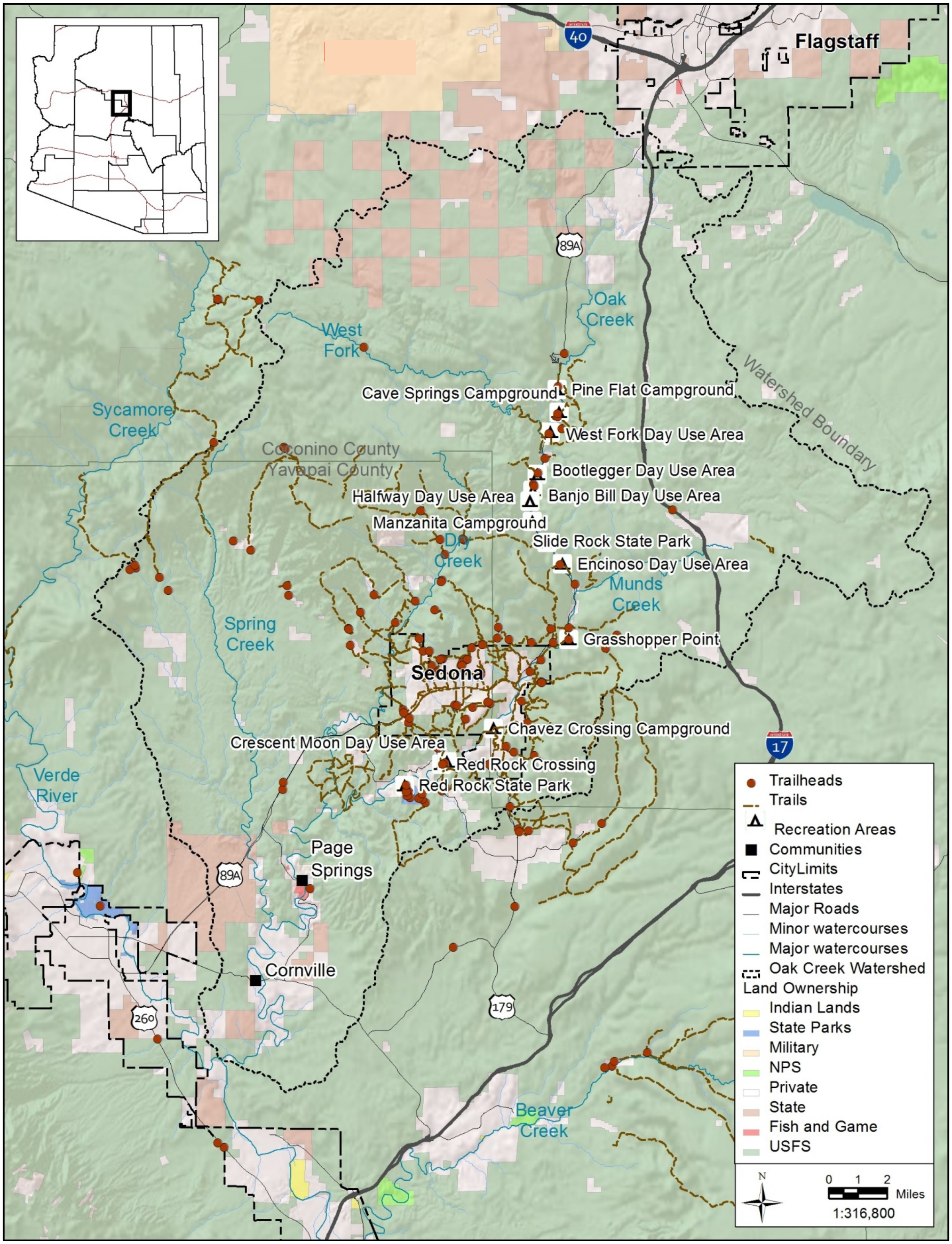
- *Monitoring and reference condition sites*:

  Pre- and post-implementation litter counts in the vicinity of waste receptacle placement sites. *E. coli* monitoring in Oak Creek downstream of popular recreation sites, such as Midgely Bridge where trash receptacles have been added.
- *Parameters & critical conditions:*
  - Litter counts (average values $\geq$ to values prior to installation of receptacles)
  - *E. coli* (>235 cfu/100 ml during storm events; > 90% of average baseline concentration prior to installation of trash receptacles)

- *Schedule, frequency and duration*:
  Twice monthly litter counts during summer 2012-2013. *E. coli* monitoring in early, mid- and late summer during high use weekends and during or the day after at least 3 storm events.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants; Coconino Rural Environmental Corp? [See if CREC be recruited to conduct litter counts and other monitoring activities. If OCWC subcontracts to have CREC provide services, make a requirement that the crew has at least one Spanish speaking member for interfacing with the public.]
- *Reporting plan:*
  Annual accomplishments and monitoring report in the fall of each year. Final report.

**Education effectiveness monitoring**

- *Long-term behavior change criteria:*
  Recreators exhibit an understanding and willingness to use trash receptacles rather than litter to reduce *E.coli* contamination of Oak Creek.
- *Generation and implementation of second generation improvement projects:*
  Recreators provide feedback on additional locations for waste receptacles to reduce litter that contributes to *E. coli* pollution.
- *Measurable reductions of pollutant loading:*
  Reduced *E.coli* concentrations. Reduced litter counts, including used diapers and food waste.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants; Coconino National Forest; Coconino Rural Environmental Corp
- *Reporting plan, how findings will be used:*
  Annual accomplishments and monitoring report in the fall of each year posted to OCWC website. Feature stories in local media on project implementation and effectiveness.



Flagstaff
Oak Creek
West Fork
Cave Springs Campground
Pine Flat Campground
Watershed Boundary
Sycamore Creek
West Fork Day Use Area
Coconino County
Yavapai County
Bootlegger Day Use Area
Halfway Day Use Area
Banjo Bill Day Use Area
Manzanita Campground
Slide Rock State Park
Dry Creek
Encinoso Day Use Area
Munds Creek
Spring Creek
Grasshopper Point
Sedona
Chavez Crossing Campground
Crescent Moon Day Use Area
Red Rock Crossing
Verde River
Red Rock State Park
Page Springs
Cornville
Beaver Creek
Trailheads
Trails
Recreation Areas
Communities
CityLimits
Interstates
Major Roads
Minor watercourses
Major watercourses
Oak Creek Watershed
Land Ownership
Indian Lands
State Parks
Military
NPS
Private
State
Fish and Game
USFS
N
0 1 2
Miles
1:316,800

# Second Tier Priority Projects

## EO-1 Sedona Dog Waste Reduction Outreach Project

**Need**

Stormflow events in Sedona deliver large doses of *E. coli* to Oak Creek, often > 2,419 cfu/100 ml, the maximum level measurable by Colilert ® without sample dilution, and as high as 8,202 cfu/100 ml as measured using sample dilution. Although dog DNA analysis of summer 2011 water samples was inconclusive (6 of 6 samples collected in the Sedona areas tested negative for dog DNA, which seems to be an errror, since dog DNA was found everywhere in Oak Creek Canyon in past studies), there is still reason to believe dog feces are a major source of fecal bacteria since significant concentrations are often seen along popular trails in the Sedona area. Dog owners need to know the seriousness of leaving dog waste along trails and in yards where it can wash into tributaries of Oak Creek during storms. They need to be encouraged to pick up and properly dispose of dog feces. While the City of Sedona does encourage pick-up of animal feces, through signage, information on their website, and the stocking of feces bag stations at some trailheads, and the the City tries to control of sediment from the Sedona Dog Park, additional actions can be taken to build on these efforts and more comprehensively address the dog waste problem.

**Description**

Implement an outreach program that includes radio and newspaper stories, public service announcements, and presentations to civic groups. Use brief motivational messages that get across 4 points: 1. the danger of *E.coli* and health effects on children, 2. causes of *E. coli* contamination, 3. pet-owner behaviors that reduce *E. coli* contamination, 4. "Deputizing the World", i.e. encouraging residents to speak up when they see others leaving dog waste unattended. Time outreach to correspond with establishment of dog waste stations. Before and after trailhead surveys will be conducted to determine effectiveness of outreach campaign.

**Estimated load reduction**

*Dog waste*

*E. coli* bacteria are bacteria that are common to the intestinal tracts of humans and animals. Walker and Garfield (2008) found that a gram of fresh dog feces contained an average of 50 million CFU/gram with a range of 2 million to 200 million CFU/gram of *E. coli* bacteria. The average dog excretes 0.75 pounds (340 grams) of waste per day (Clear Choices Clean Water, 2012). That equates to an average 17 billion CFU of *E. coli* bacteria per day per dog. If the Sedona Dog Waste Reduction Outreach/Oak Creek Watershed Dog Waste Station Installation Projects prevents 100 dog/days from contaminating Oak Creek this would result in a load reduction 34 kg of dog feces and $17 \times 10^{12}$ CFU of *E. coli* bacteria.

The goal of the Outreach Project is to improve community awareness on the role of dog waste in water quality impairment of Oak Creek. The Outreach Project should increase the use of the dog waste stations and the rate of dog waste removal. If the Outreach Project increases use of the dog waste stations from 100 to 300 dog/days the result would be a load reduction of 102 kg of dog feces and $5.1 \times 10^{13}$ CFU of *E. coli* bacteria.

The actual load reduction will depend on the number of people that utilize the dog waste stations, before and after the Outreach Project. A monitoring program should be implemented to assess the use of the dog waste stations.

References:

Clear Choices Clean Water Organization, access on June 27, 2012 http://clearchoicescleanwater.org/wp-content/uploads/2011/08/pet-waste-FAQs_final.pdf

Walker, M. and L. Garfield, 2008. Dog wastes and water quality: Evaluating the connection at Lake Tahoe. University of Nevada Cooperative Extension, Fact Sheet-08-18.

*Multiple effects*

Because the project is a multi-faceted approach to overall watershed improvement, using different methods and making some assumptions of effectiveness of the BMP when modeling each facet separately is necessary in order to formulate a reasonable estimation of load reduction. The project seeks to reduce the amount of *E. coli* and sediment delivered to Oak Creek during summer stormflow events by first surveying and determining where there are concentrations of human and animal waste, and where erosion problems exist.

If the watershed survey reveals that jeep use is a significant cause of soil disturbance and sediment discharge, then BMP's will be implemented along trails and public outreach will promote practices that will reduce erosion. Each subwatershed with hiking or jeep trails was modeled assuming that the total area of the disturbance by humans was either 10%, 20% or 30% of the total area of subwatersheds with jeep and/or hiking trails, and that BMP's were utilized in the model in those proportions. The Automated Geospatial Watershed Assessment tool (ARS, 2012) with the SWAT model was used to estimate the sediment runoff of the areas of with landcover data that represents normal vegetation, then with landcover data that had been modified to reflect the disturbed areas near jeep and hiking trails within the six subwatersheds. If 10% of the areas were disturbed, recovered normal vegetation would be responsible for the reduction of 19.5 tons of sediment per year.

The STEP L Model (U.S. EPA, 2012) was used to estimate the effectiveness of installing water bars and bioretention ponds to slow runoff and reduce erosion, and the revegetation of areas denuded by erosion in areas near jeep and hiking trails. If humans and jeeps disturbed 10% of the area of subwatersheds with trails, the load reduction as a result of the installation of water bars, bioretention ponds, and native vegetation is 153.9 tons of sediment per year.

Dog waste stations will be installed at all trailheads. Walker and Garfield (2008) found that a gram of dog feces contained an average of 50 million CFU/gram of *E. coli* bacteria. The average dog excretes 340 grams per day (Clear Choices Clean Water, 2012). That equates to 17 billion CFU of *E.coli* bacteria per dog per day. If the project successfully prevents 100 dog/days per year from contaminating Oak Creek, the result would be a reduction of 34 kg of dog feces and 17 x $10^{12}$ CFU of *E. coli* bacteria.

Public outreach efforts aimed at eliminating human waste contributions to the watershed will be implemented. Brandys (2007) found that human stool contained an average of 5 million

CFU/gram of *E. coli* bacteria. Parker and Gallagher (1988) found that the mean human waste in over 25,000 subjects was 95 grams per day of solid fecal matter. That equates to 475 million CFU of *E. coli* per person per day. If the project successfully prevents 100 people per day from contaminating Oak Creek, the result would be a reduction of 9.5 kg of human feces and 4.75 x $10^{10}$ CFU of *E. coli* bacteria.

Average annual load reduction:

AGWA SWAT (Soil Disturbance and Normal Vegetation)
19.5 tons of sediment per year

STEP L (Water Bars, Bioretention Ponds, Revegetation)
153.9 tons of sediment per year

Combined Sediment Load Reduction: 173.4 tons of sediment per year

Dog Waste
34 kg (75 lbs) of feces and 17 x $10^{12}$ CFU per year of *E. coli* bacteria

Human Waste
9.5 kg (21 lbs) of feces and 4.75 x $10^{10}$ CFU per year of *E. coli.* bacteria

References:

Agricultural Research Service (ARS) Website, Access on June, 2012. Automated Geospatial Watershed Assessment Tool located at http://www.tucson.ars.ag.gov/agwa/.

Clear Choices Clean Water Organization Website, access June 27, 2012. Located at http://clearchoicescleanwater.org/wp-content/uploads/2011/08/pet-waste-FAQs_final.pdf

Walker, M. and L. Garfield, 2008. Dog Wastes and Water Quality; Evaluating the Connection at Lake Tahoe. University of Nevada Cooperative Extension, Fact Sheet-08-18.

Brandys, B. 2007. Quantifying Bacteria Levels in Water Categories 1-3. Occupational and Environmental Health Consulting Services, accessed July 11, 2012. Located at: http://www.bio-reveal.com/AdminWeb/userfiles/image/file/IICRC%20S520%20-%20IICRC%20S500/Quantifying-Levels-02-07.pdf

Parker, D. and S. Gallagher, 1988. Distribution of Human Waste Samples in Relation to Sizing Waste Processing in Space, accessed July 9, 2012. Located at http://www.nss.org/settlement/moon/library/LB2-611-WasteProcessing.pdf

U.S. EPA Website, Access June, 2012. Welcome to STEPL and Region 5 Model, http://it.tetratech-ffx.com/stepl/

**Project schedule and milestones**

<table>
<tr><td rowspan="2">Implementation schedule:<br>March 2012 through September 2014<br><br>Measurable milestones:<br>~ Design of literature, presentations, PSA scripts, and press releases<br>~ Pre-campaign trailhead survey<br>~ Spring media campaign completed<br>~ #? presentations to civic groups<br>~ Late summer follow-up trailhead survey<br>~ Late summer “Thank you” message in media<br>~ Report on year one and year two activities and results</td><td>Resources and other support commitments:<br><ADEQ 319(h) grants<br><????><br>Commitment date(s):<br><None at this time></td></tr>
<tr><td>Pending commitments:<br><Unknown at this time><br>Estimated commitment date:<br><None at this time></td></tr>
</table>

**Education and Outreach Strategy**

*Findings of education needs survey:*

20% of watershed residents walk their dog near Oak Creek.

Dog feces were rated as 1st, 2nd and 3rd biggest contributors to creek contamination by 7.2%, 10.6%, and 10.6% or watershed residents respectively.

44.5 % of watershed residents own a dog.

Of those who own dogs 45.6% walk their dog in the watershed.

Most dog-owning residents (64%) said they always pick up their dog waste, while 19.2% said “most of the time”, 5.6 % said “sometimes”, 3.2% said “rarely”, and 8.0% said “never”.

83.5% of watershed residents with dogs say they would use dog waste stations if more were made available at parks and trails.

Watershed residents’ opinion of whether dog feces threaten Oak Creek water quality is as follows:

| | Not sure | Not a problem | Slight problem |
|---|---|---|---|
| Dog feces that are not picked up and disposed properly | 10% | 12% | 28% |

*Goals and target audiences:*
~ Outreach to residents of Sedona who walk their dogs on trails in and around the city.
~ Outreach to Sedona Humane Society.
~ Increase understanding of importance of picking up dog waste.
~ Affect behaviors so that more pet owners pick up and properly dispose of dog waste.

*Priority education and outreach projects schedule:*
~ Early 2012 - surveys and outreach
~ Late summer 2012 - follow-up surveys
~ Early 2013 - Year 2 surveys and outreach

~ Late summer 2013 - Year 2 follow-up surveys
~ 2013 - success stories coverage

## Monitoring and Evaluating Effectiveness

**Long-term effectiveness criteria:** Survey results indicate a change in attitude about the importance of picking up dog waste. At least 20% more people report picking up waste and telling others to do so.

### On-the-ground project effectiveness monitoring plan

- *Monitoring and reference condition sites*:
  Fecal counts will be conducted once per month May through September on 4 popular trails in the Sedona area: Huckaby Trail, Baldwin Trail, West Fork Trail (all FS System trails) and Chavez Crossing trail (social trail). These trails all parallel significant reaches of Oak Creek and West Fork and have some tradition of dog use.
- *Parameters & critical conditions:*
  - number of presentations given to civic groups
  - feces counts (>20 feces per ¼ mile)
  - percentage of people reporting desired attitude
  - percentage of people exhibiting desired behavior
- *Schedule, frequency and duration*:
  - Monthly fecal counts, May-September, 2012 and 2013
  - Late spring and late fall hiker surveys, 2012 and 2013
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan:*
  - Year 1 accomplishments report.
  - Project implementation report

### Education effectiveness monitoring

- *Long-term behavior change criteria:*
  Residents exhibit an understanding of the importance of proper dog feces disposal and willingness to pick-up dog waste and encourage others to do so.
- *Generation and implementation of second generation improvement projects:*
  Residents seek expansion of dog waste stations to trailheads that do not have them.
- *Measurable reductions of pollutant loading:*
  Fecal counts by volunteer monitors show decreases in pollutant loading along Sedona trails.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan, how findings will be used:*
  - Year 1 accomplishments report.
  - Project implementation report.
  - Feature stories in local media on project implementation and effectiveness.


Soldier Wash
Mormon Canyon
Sedona
Dry Creek
89A
Carroll Canyon Wash
Chavez Crossing Campground
179
Crescent Moon Day Use Area
Red Rock Crossing
Red Rock Loop Rd
Red Rock State Park
Oak Creek
Verde Valley School Rd
Trailheads
Trails
Arterial Road
Residential Road
CityLimits
Recreation Areas
Major Roads
Minor watercourses
Major watercourses
Oak Creek Watershed
Land Ownership
State Parks
Private
State
Fish and Game
USFS
N
0 0.25 0.5
Miles
1:63,360

## Photos

Dog feces in drainage on national forest land upstream of Elf Neighborhood. This drainage is a tributary of Carroll Canyon Wash.

Multiple dog feces in the channel and on the bank. Little Elf drainage

## EO-3 Lower Oak Creek Watershed Outreach Project

**(aka The "Don't Put Crap in the Creek" Project")**

**Need**

Dumping of animal waste into ditches or the creek may be increasing instream *E. coli* concentrations. Construction of irrigation diversion dams may cause sediment deposition that contributes to *E. coli* sediment reservoirs. *E. coli* concentrations were higher (56.4 cfu/100 ml average) at Page Springs and Cornville during July 2012 prior to the monsoon than upstream reaches of Oak Creek (eg. 31.4 cfu/100 ml at Chavez Crossing Campground in Sedona and 10.3 cfu/100 ml in Oak Creek Canyon on average). Turbidity was also noticeably greater. Increased sediment and sediment-water contact in these reaches seems to be the cause of higher *E. coli* concentrations. Although the July 2011 values did not exceed the Full Body Contact standard, there is a concern about *E. coli* loading in this reach that could contribute to exceedences during storm events that disturb sediments.

**Description**

Work collaboratively with Cooperative Extenstion Service to educate land owners about the impacts of animal waste dumping and provide technical assistance for implementing best management practices for animal waste management. Provide technical assistance to identify best practices for reducing erosion and sedimentation associated with annual earth moving for irrigation diversions. Outreach may involve best management practices workshops.

**Estimated load reduction**

*E. coli* bacteria are bacteria that are common to the intestinal tracts of humans and animals. A 1000-pound horse will defecate from 4-13 times each day and produce 35 to 50 pounds of wet manure (feces plus urine) daily, or approximately 9.1 tons per year. E. coli concentrations in fresh and dry manure from horses are $6.17 \times 10^4$ CFU per gram and $6.31 \times 10^5$ CFU per gram, respectively (NERA, 2012).

A mature cow weighting 1000 lbs produces an average of 8.7 lbs/day of manure (NRCS, 2012) or approximately 1.5 tons per year. Wang et al. (2004) showed that *E. coli* populations extracted from fresh cow manure ranging from $6.55 \times 10^6$ to $7.6 \times 10^6$ cfu per gram of manure (average of $7.1 \times 10^6$ cfu per gram).

If the fresh waste from one animal was dumped into the stream the potential average annual *E. coli* load would be:

Horse (CFU/year) = 9.1 tons/yr * $6.17 \times 10^4$ CFU per gram * 907,184.74 grams/ton = $5.1 \times 10^{11}$ CFU per year

Cow (CFU/year) = 1.5 tons/yr * $7.1 \times 10^6$ CFU per gram * 907,184.74 gram/ton = $9.7 \times 10^{12}$ CFU per year

The actual load reduction is based on the number of people currently dumping waste into the streams and the resulting number of people that stop dumped after the implementation of the Outreach Programs. A monitoring program would be implemented to assess the current rate of dumping and to evaluate the behavior changes after the implementation of Outreach Programs.

References:


Natural Resource Conservation Service (NRCS), access on June 25, 2012. Wyoming Comprehensive Nutrient Management Plan Workbook located at http://www.wy.nrcs.usda.gov/technical/wycnmp/

NERA Website, Access July 2012. NE1041: Environmental Impacts of Equine Operation located at http://lgu.umd.edu/lgu_v2/homepages/attachs.cfm?trackID=11196.

Wang, L., K.R. Mankin, and G.L. Marchin, 2004. Survival of Fecal Bacteria in Dairy Cow Manure. Transactions of the ASAE 47(4): 1239-1246.


**Project schedule and milestones**

<table>
<tr>
<td rowspan="2">Implementation schedule:<br>January 2012 through December 2014<br><br>Measurable milestones:<br>~ Enter into MOU with Cooperative Extension Service<br>~ Plan and implement a workshop or series of workshops to<br>o listen to landowners’ concerns and needs<br>o teach BMPs for animal waste management and irrigation diversions and<br>~ Follow-up with assistance for implementing BMPs</td>
<td>Resources and other support commitments:<br><ADEQ 319(h) grants<br><????><br>Commitment date(s):<br><None at this time ></td>
</tr>
<tr>
<td>Pending commitments:<br><Unknown at this time><br>Estimated commitment date:<br><None at this time ></td>
</tr>
</table>

**Education and Outreach Strategy**

*Findings of education needs survey:*

The educational needs survey showed that at least 15% of residents do not think livestock waste poses a threat Oak Creek water quality.

At least 17% of residents do not think irrigation diversions cause erosion and sedimentation that poses a threat Oak Creek water quality.

*Goals and target audiences:*

~ Reach private property owners who irrigate along Oak Creek and/or raise livestock along Oak Creek.

~ Inform them of risks to human health from dumping of animal waste into ditches or the Creek.

~ Educate them about *E. coli* sediment reservoirs and the importance of reducing sedimentation, such as through better practices when constructing irrigation diversion.

~ Offer incentives (technical assistance, evaluation, subsidy) for implementing best management practices.

~ Work cooperatively with land owners to assure implementation of BMPs.

*Priority education and outreach projects schedule:*

~ Fall 2012 - MOU or informal agreement with Cooperative Extension Service
~ Spring 2013 - BMP workshops; identify land owner needs and challenges; seek ways of helping to meet needs
~ 2013-2014 - Follow-up assistance to landowners for implementing BMPs
~ 2014 - Success stories coverage

## Monitoring and Evaluating Effectiveness

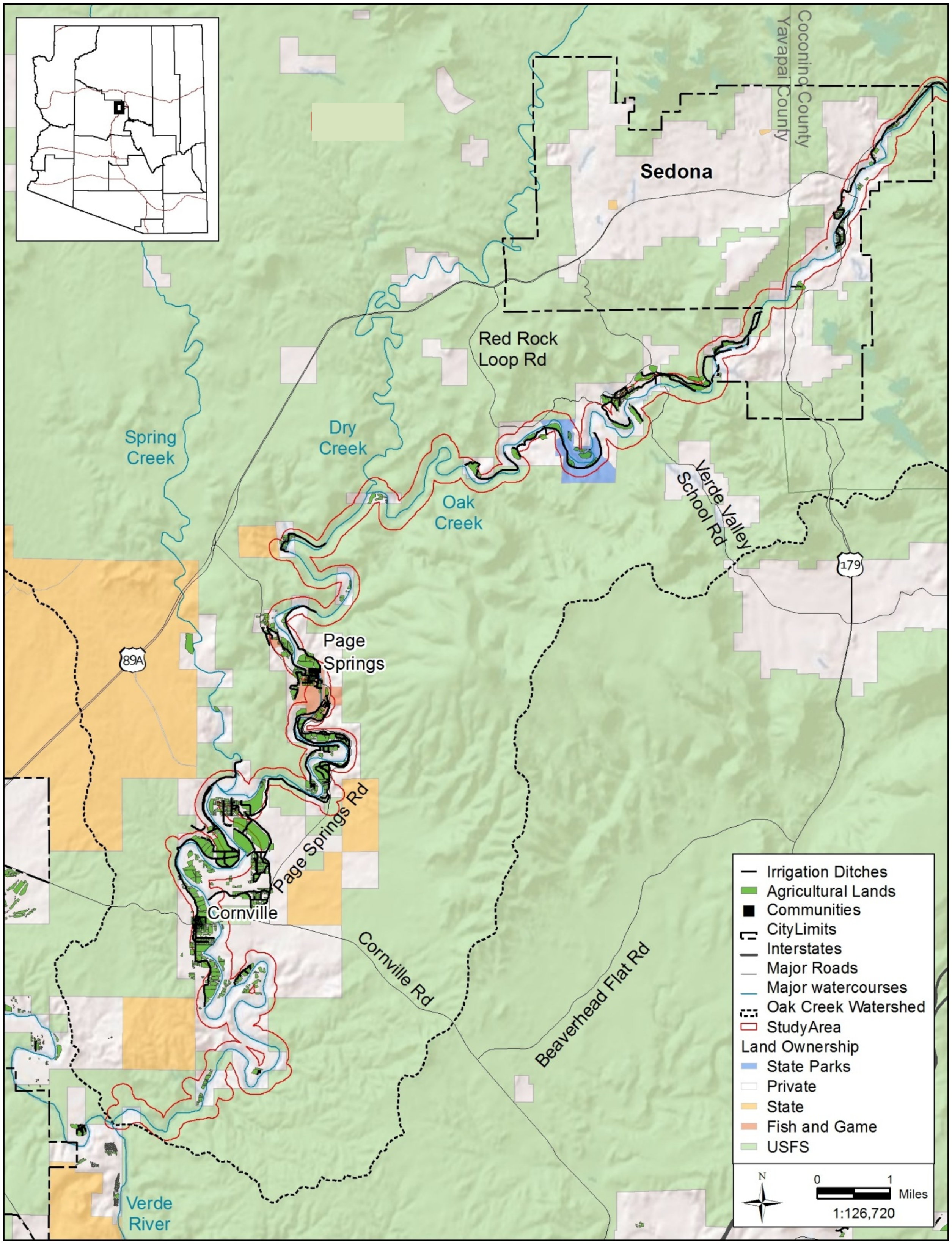
**Long-term effectiveness criteria:** Landowners at Page Springs and Cornville adopt the regular use of BMPs to reduce sedimentation and pollution by animal waste in Oak Creek.

**On-the-ground project effectiveness monitoring plan**

- *Monitoring and reference condition sites*:
  At least 3 sites each in Page Springs and Cornville will be selected to monitor sediment accumulation, turbidity and *E. coli* concentrations.
- *Parameters & critical conditions:*
  - turbidity (50 NTU)
  - sediment observed through aerial photography and/or field survey
  - *E. coli* (>60 cfu/100 ml)
- *Schedule, frequency and duration*:
  <Early and late summer samples for 1 year pretreatment and 2 years post-treatment.>
- *Volunteers and/or staff for monitoring and data analysis:*
  <OCWC volunteers, staff and consultants>
- *Reporting plan:*
  <Project implementation report, 2-year follow-up monitoring report>

**Education effectiveness monitoring**

- *Long-term behavior change criteria:*
  At least 10 property owners attend workshop(s) hosted by Cooperative Extension Service and OCWC and learn animal waste management or irrigation diversion practices that reduce sedimentation and fecal pollution of Oak Creek.
- *Generation and implementation of second generation improvement projects:*
  Land owners may provide insight into projects needed to reduce erosion, sedimentation and animal waste inputs into lower Oak Creek.
- *Measurable reductions of pollutant loading:*
  Reduced *E. coli* concentrations
  Lower turbidity measurements during pre-monsoon
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan, how findings will be used:*
  Workshop outcomes report
  BMP implementation report
  Feature stories in local media on project implementation and effectiveness.


Sedona
Coconino County
Yavapai County
Red Rock Loop Rd
Spring Creek
Dry Creek
Oak Creek
Verde Valley School Rd
179
89A
Page Springs
Page Springs Rd
Cornville
Cornville Rd
Beaverhead Flat Rd
Verde River
Irrigation Ditches
Agricultural Lands
Communities
CityLimits
Interstates
Major Roads
Major watercourses
Oak Creek Watershed
StudyArea
Land Ownership
State Parks
Private
State
Fish and Game
USFS
N
0
1
Miles
1:126,720

## EO-4 Recreational Vehicle Proper Waste Disposal Outreach Project

**(aka The "Don't Put Crap in the Creek" Project)**

**Need**

RV owners may be dumping "black water" into ditches or the creek as evidenced by sewage odor at the Page Springs bridge adjacent to an RV park and past observance of dumping into Oak Creek at Pine Flat and at Cave Springs Crossing. Such dumping, although hopefully not common practice, poses an enormous health risk to downstream swimmers and waders when it occurs.

**Description**

Work with RV park owners and Coconino National Forest to inform campers of the health effects of dumping waste and assure that they know where to properly dispose of waste.

**Estimated load reduction**

A typical recreational vehicle holding tank is 40 gallons, although most people will discharge the tank before it is full due to odors. A University of North Dakota study for the U.S. Department of Agriculture regarding human waste distributions reveals the average stool produced is 95.5 grams per day, and 2066 ml of urine per day (Parker and Gallagher 1988). Assuming the average family size of 2.6 people and one week of use the amount of waste created would be:

Urine (l) = 2.6 people * 2066 ml/day * 7 days * 1 liter/1000 ml = 37.6 liters

Fecal Material (kg) = 2.6 people * 95.5 g/day * 7 days * 1 kg/1000 g = 1.7 kg

The Fecal Material estimate is more important in regard to *E. coli*. *E. coli*, as member of the intestinal flora, is part of the digestive process and is excreted in feces. Brandys (2007) found that human stool contained an average of 5 million CFU/gram of *E. coli* bacteria.

Assuming that the Outreach Project changes the behavior of 100 recreational vehicle users per year the average annual E coli load reduction would be $8.7 \times 10^{11}$ CFU per year.

In order estimate the actual load reduction a survey of recreational vehicle users should be conducted.

**Project schedule and milestones**

| | |
|---|---|
| *Implementation schedule:*<br>January 2013 through December 2014<br>*Measurable milestones:*<br>~ Engage RV park owners and CNF in discussions regarding the best approach to educating campers.<br>~ Design a simple, brief, punchy flier(s) that educates campers about health risks of RV waste dumping and a map of waste station | *Resources and other support commitments:*<br>ADEQ 319(h) grants<br>????<br>*Commitment date(s):*<br><None at this time ><br><br>*Pending commitments:*<br><Unknown at this time><br>*Estimated commitment date:*<br><None at this time > |

| | |
|---|---|
| locations in the watershed.<br>~ Implement RV owner outreach through fliers and campground visits by volunteers. | |

**Education and Outreach Strategy**

*Findings of education needs survey:*

The education needs survey targeted residents not campers, so we do not have data on educational needs. However, we will solicit information from RV park owners, the Forest Service and Forest Service's vendor to determine what prevailing attitudes and beliefs are among RV camper owners.

*Goals and target audiences:*

~ Recreational Vehicle (RV) owners camping in the Oak Creek Watershed
~ Educate RV owners about health risks of "black water" dumping into Oak Creek or its irrigation ditches
~ Provide locations of legitimate waste dump sites, including costs and contact information.
~ Amend attitudes and practices of some RV owners who do not think dumping is a problem.

*Priority education and outreach projects schedule:*

~ Early 2013 - Meet with CNF and RV park owners
~ Early 2013 - Develop flier
~ Summer 2013 and 2014 - Distribute flier through RV park managers and CNF staff and/or vendor
~ Mid-summer 2013 and 2014 – Volunteers check to see if fliers are being distributed and talk with RV owners in campgrounds to see if they have gotten the message and to survey attitudes, including soliciting input on where disposal stations are needed.

## Monitoring and Evaluating Effectiveness

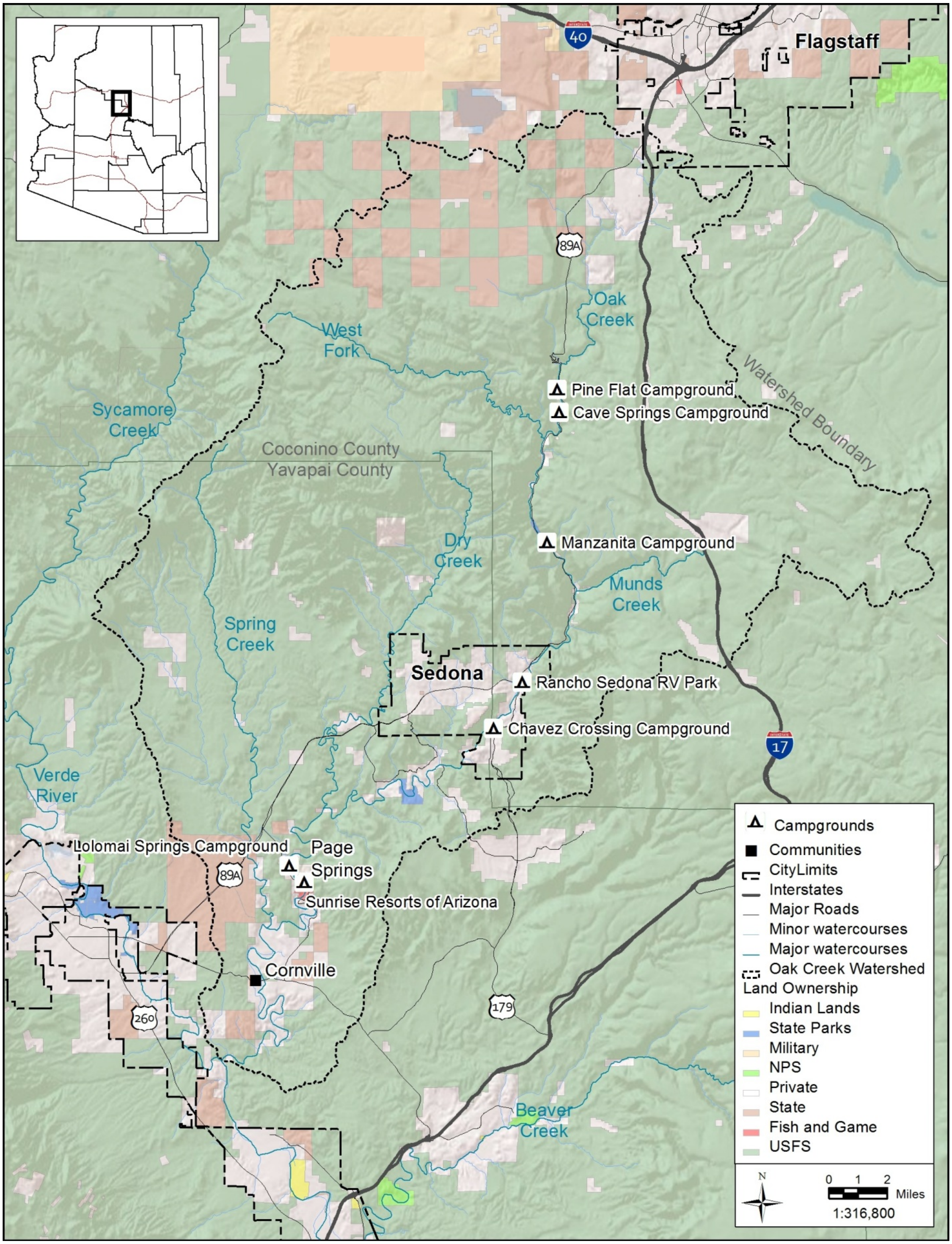
**Long-term effectiveness criteria:** Decreased observations of illegal dumping of RV black water

**On-the-ground project effectiveness monitoring plan**

- *Monitoring and reference condition sites*:
  The number of RVs using CNF campgrounds will be surveyed by volunteers. Use of dumping stations will be observed.
- *Parameters & critical conditions:*
  - Number of RVs in campground
  - Number of RV waste dumpings per weekend
  - Statements by RV owners regarding attitudes and practices related to waste
  - Statements by RV owners regarding places where RV waste stations are needed
- *Schedule, frequency and duration*:
  Volunteers conduct biweekly surveys of RV campground use, waste dumping, and RV owner attitudes and provide information during summer 2013 and 2014.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan:*
  Annual reports in the fall of 2013 and 2014

**Education effectiveness monitoring**

- *Long-term behavior change criteria:*
  RV owners recognize health risks of dumping RV black water into Oak Creek or its ditches and modify behavior as evidenced by fewer incidences of dumping and expressions of RV owners' attitudes.
- *Generation and implementation of second generation improvement projects:*
  RV owners express outstanding needs for waste disposal stations so future projects can help support an adequate density of disposal stations.
- *Measurable reductions of pollutant loading:*
  Reduced incidences of black water dumping
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan, how findings will be used:*
  Annual reports in the fall of 2013 and 2014. Success story feature articles.


Flagstaff
40
89A
Oak Creek
West Fork
Pine Flat Campground
Cave Springs Campground
Watershed Boundary
Sycamore Creek
Coconino County
Yavapai County
Dry Creek
Manzanita Campground
Munds Creek
Spring Creek
Sedona
Rancho Sedona RV Park
Chavez Crossing Campground
17
Verde River
Lolomai Springs Campground
Page Springs
Sunrise Resorts of Arizona
Cornville
260
179
Beaver Creek
Campgrounds
Communities
CityLimits
Interstates
Major Roads
Minor watercourses
Major watercourses
Oak Creek Watershed
Land Ownership
Indian Lands
State Parks
Military
NPS
Private
State
Fish and Game
USFS
N
0 1 2 Miles
1:316,800

## SS-2 Oak Creek Residential Septic System Improvement Project

### Oak Creek Residential Septic System Improvement Project

**Need**

Some septic systems in the watershed appear to have effluent that is intercepted by springs that carry *E. coli* and/or other pathogens to the creek. During summer 2011 monitoring in Oak Creek Canyon, 20 to 200 cfu/100 ml (average = 72 cfu/100 ml) *E. coli* was found in spring water that emerges from underneath some properties with septic systems. By contrast, only an average *E. coli* concentrations of 9.5 cfu/100ml based was found in creek water. Although E. coli concentrations in spring discharge are below the water quality standard for *E. coli*, they are elevated compared to other spring water and compared to Oak Creek. Therefore, these possibly septic-influenced springs may provide more or less steady supplies of *E. coli* during the summer months that might innoculate sediment reservoirs that are later disturbed by recreation or storm events to cause exceedences of *E. coli* in the water column. Evaluation and upgrade of residential septic systems appears warranted, particularly for community systems with large loads or systems installed during the period of approximately the 1970s to 1980s when deep trenches were a preferred installation and may not have left adequate separation between the leachfield and spring beds.

**Description**

Technical assistance will be offered to property owners for septic system evaluation and remediation design, and a subsidy will be offered for system upgrades. OCWC will continue monitoring *E. coli* and nutrients in spring discharge, as well as other markers such as DNA and possible tracer dyes, to identify properties where septic system upgrades appear to be in order.

**Estimated load reduction**

Approximately 10 springs in the Oak Creek Canyon area contain elevated concentrations of *E. coli.* Some failing septic systems in the watershed produce effluent that is intercepted by the springs and carried to the creek. These septic-influenced springs may provide a steady supply of *E. coli* to Oak Creek that may suffuse sediment reservoirs that can be later disturbed by recreational activity or a storm event causing exceedances of *E. coli* in the water column.

The project seeks to reduce the amount of effluent from failing septic systems by offering property owners technical assistance for septic system evaluation and remediation design. Upgrades to the failing septic systems will reduce contaminants from entering the springs, and improve water quality.

The STEPL model (U.S. EPA, 2012) is a spreadsheet tool that uses data inputs provided by the EPA to estimate nutrient and sediment loads. Best management practices can be incorporated into the model to determine the load reductions that would occur if the BMPs are implemented.

The numbers reflected in the load reduction results represent the remediation of all failing septic systems within the five subwatersheds adjacent to Oak Creek Canyon.

Using nitrogen and phosphorus as indicates for *E. coli* the average annual load reduction is:
Sediment – 77.9 tons per year (14.2%)

Nitrogen (N) – 3,506.5 lbs per year (10.3%)
Phosphorus (P) – 601.6 lbs per year (7.8%)

References:

U.S. EPA Website, Access June, 2012. Welcome to STEPL and Region 5 Model, http://it.tetratech-ffx.com/stepl/

**Costs** ????

**Project schedule and milestones**

| | |
|---|---|
| *Implementation schedule:*<br>January 2012 through December 2014<br>*Measurable milestones:*<br>~ Baseline springs monitoring complete<br>~ Septic upgrades identified & prioritized<br>~ Upgrade funding secured<br>~ Upgrades implemented<br>~ Implementation report<br>~ Follow-up monitoring complete<br>~ Follow-up report complete | *Resources and other support commitments:*<br>ADEQ 319(h) grants<br>????<br>*Commitment date(s):*<br><None at this time><br>*Pending commitments:*<br><Unknown at this time><br>*Estimated commitment date:*<br><None at this time > |

**Education and Outreach Strategy**

*Findings of education needs survey:*

Watershed residents' opinions about whether improperly functioning septic systems threaten water quality are as follows:

| | Not sure | Not a problem | Slight problem | Moderate problem | Large problem |
|---|---|---|---|---|---|
| Improperly built or maintain residential septic systems | 13% | 10% | 14% | 29% | 25% |
| Improperly built or maintain commercial septic systems | 13% | 11% | 16% | 25% | 25% |

Watershed residents rank septic systems as one of the top three biggest contributors to creek contamination that can cause human illness as follows:

#1 – 23.4%

#2 – 13.2%

#3 – 9.1%

There seems to be a pretty high awareness in the general population about the potential impacts of septic system on water quality. Outreach should be focused on owners of septic systems in locations of concern, such as where there is shallow groundwater.

*Goals and target audiences:*

- ~ Reach private septic system owners in Oak Creek Canyon and the Page Springs area where spring underlie septic leachfields.
- ~ Inform them of risks to human health from poorly functioning septic systems.
- ~ Offer incentives (technical assistance, evaluation, subsidy) for upgrading septic systems.
- ~ Work cooperatively with land owners to assure completion of upgrades.

*Priority education and outreach projects schedule:*

- ~ Early 2012 - outreach
- ~ Late 2012 - cooperative agreements
- ~ 2013 - success stories coverage

## Monitoring and Evaluating Effectiveness

**Long-term effectiveness criteria:** *E. coli* concentrations below 5 cfu/100 ml in spring discharge near septic systems.

**On-the-ground project effectiveness monitoring plan**

- *Monitoring and reference condition sites*:
  Approximately 3 springs in Oak Creek Canyon with a history of elevated *E. coli* and suspected residential septic system influence will be monitored along with one reference spring in each vicinity (one spring could serve as reference for multiple affected springs in close proximity).
- *Parameters & critical conditions:*
  - *E. coli* (>5 cfu/100 ml)
  - DNA (presence of human DNA)
- *Schedule, frequency and duration*:
  Early and late summer samples for 1 year pretreatment and 2 years post-treatment
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan:*
  Project implementation report, 2-year follow-up monitoring report

**Education effectiveness monitoring**

- *Long-term behavior change criteria:*
  Residents exhibit an understanding and willingness to have properly functioning septic systems.
- *Generation and implementation of second generation improvement projects:*
  Residents seek additional assistance with septic system improvements.
- *Measurable reductions of pollutant loading:*
  Reduced *E.coli* concentrations in spring discharge where *E. coli* was previously elevated
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan, how findings will be used:*
  Report on outreach effort. Feature stories in local media on project implementation and effectiveness.

## RC-2 Oak Creek Canyon Sediment Source Reduction Project

### Need

Past studies have noted that sediment reservoirs of *E. coli* buildup at Slide Rock throughout the summer. These reservoirs are composed of fine sediment. Some fine sediment may be yielded from the upper watershed due to hundreds of miles of minimally maintained forest roads, timber harvest by heavy equipment, ATV use, fire scars, soil sculpting actions, and/or grazing. Other sediment is likely generated locally due to soil disturbance from people hiking into the Oak Creek on unmaintained social trails. While Coconino National Forest has done some work to stabilize slopes where social trails have caused erosion, a comprehensive evaluation of erosion problems and implementation of solutions may be needed, in both the riparian areas and the larger watershed.

### Description

Evaluate erosion problems upstream of Slide Rock S.P. and within the park, as well as at other high use areas in Oak Creek Canyon where recreators hike down steep slopes from the highway to the creek. Couple this localized evaluation with a more comprehensive study of sediment production and transport in Oak Creek watershed to determine the relative sediment contributions from streamside erosion and erosion in the uplands. Implement best management practices to reduce erosion. Establish well engineered and maintained trails where feasible. Work within national forest trail system guidelines to enable volunteers to perform trail maintenance work. Post signs regarding importance of avoiding erosion to reduce *E. coli* sediment reservoirs that contribute to water quality problems that can close Slide Rock State Park and cause human illness. Have volunteers interface with recreators to discuss the importance of reducing erosion as well as other practices for reducing pollution. Work with Coconino National Forest to develop a plan for addressing sediment source areas in the uplands.

### Estimated load reduction

The project seeks to reduce the amount of erosion and sediment entering Oak Creek as a result of soil disturbance from people hiking into Oak Creek Canyon and Slide Rock State Park on unmaintained social trails.

Without knowing the locations of the BMPs that will be implemented, some assumptions must be made in order to formulate a reasonable estimation of load reduction. The Automated Geospatial Watershed Assessment tool (AGWA) with the SWAT model (ARS, 2012) was first run using land cover data downloaded from the SWReGAP server. Land cover was then modified starting at the bridge just below the public swimming area at Slide Rock S.P. upstream just over 0.5 miles to the Halfway Day Use Area in order to represent disturbed soils due to hiking off-trail. Assuming that twenty percent of the entire area could be considered disturbed by people going off the trails and making their own pathways to the stream, the Land Cover Modification Tool within AGWA allows for a partial change of landcover within an area, and the second model reflects that percentage.

The difference between the SWAT model run with normal landcover, and a model run with landcover that reflects 20% of disturbed soil within an area of approximately 50 acres is the reduction of sediment load as a result of trail engineering and maintenance.

Load Reduction: 7.02 tons of sediment per year

References:

Agricultural Research Service (ARS) Website, Access on June, 2012. Automated Geospatial Watershed Assessment Tool located at http://www.tucson.ars.ag.gov/agwa/.

**Costs**

????

**Project schedule and milestones**

<table>
<tr>
<td>
Implementation schedule:<br>
January 2012 through December 2014<br>
Measurable milestones:<br>
~ Comprehensive study of sediment production and transport in Oak Creek watershed complete, including recommendations to Coconino N.F.<br>
~ Streamside soil stability survey complete<br>
~ Trail improvement and erosion control measures planned<br>
~ All USFS permits and clearances acquired<br>
~ Trail improvement and erosion control measures installed<br>
~ Outreach activities complete<br>
~ Reporting complete
</td>
<td>
Resources and other support commitments:<br>
ADEQ 319(h) grants<br>
<????><br>
Commitment date(s):<br>
<None at this time ><br>
<br>
Pending commitments:<br>
<Unknown at this time><br>
Estimated commitment date:<br>
<None at this time >
</td>
</tr>
</table>

**Education and Outreach Strategy**

*Findings of education needs survey:*

Watershed residents' opinions of whether erosion and sediment related to recreational activities threaten water quality are as follows:

| Activity | Not sure | Not a problem | Slight problem | Moderate Problem | Large 3Problem |
|---|---|---|---|---|---|
| Low water creek crossings | 17 | 26 | 28 | 14 | 3 |
| Unmaintained "social" trails | 18 | 23 | 31 | 13 | 4 |
| Jeeps/ORV trails | 15 | 16 | 22 | 21 | 13 |
| Other sources | 17 | 3 | 2 | 2 | 2 |

*Goals and target audiences:*

~ Swimmers, waders, hikers and fishermen in Oak Creek Canyon.

~ Inform them of risks to human health from *E. coli* sediment reservoirs in the stream that are partly due to erosion along way trails.

~ Have volunteers offer incentive items to people observed using proper trails rather than cutting across steep slopes and causing erosion.

*Priority education and outreach projects schedule:*

~ Early summer 2012 - outreach

~ July 2012 - radio PSA about risks of elevated *E. coli* and what people can do to reduce the risk, including reducing erosion, and protect themselves (eg. not swimming in turbid water).

~ 2013 - success stories coverage

## Monitoring and Evaluating Effectiveness

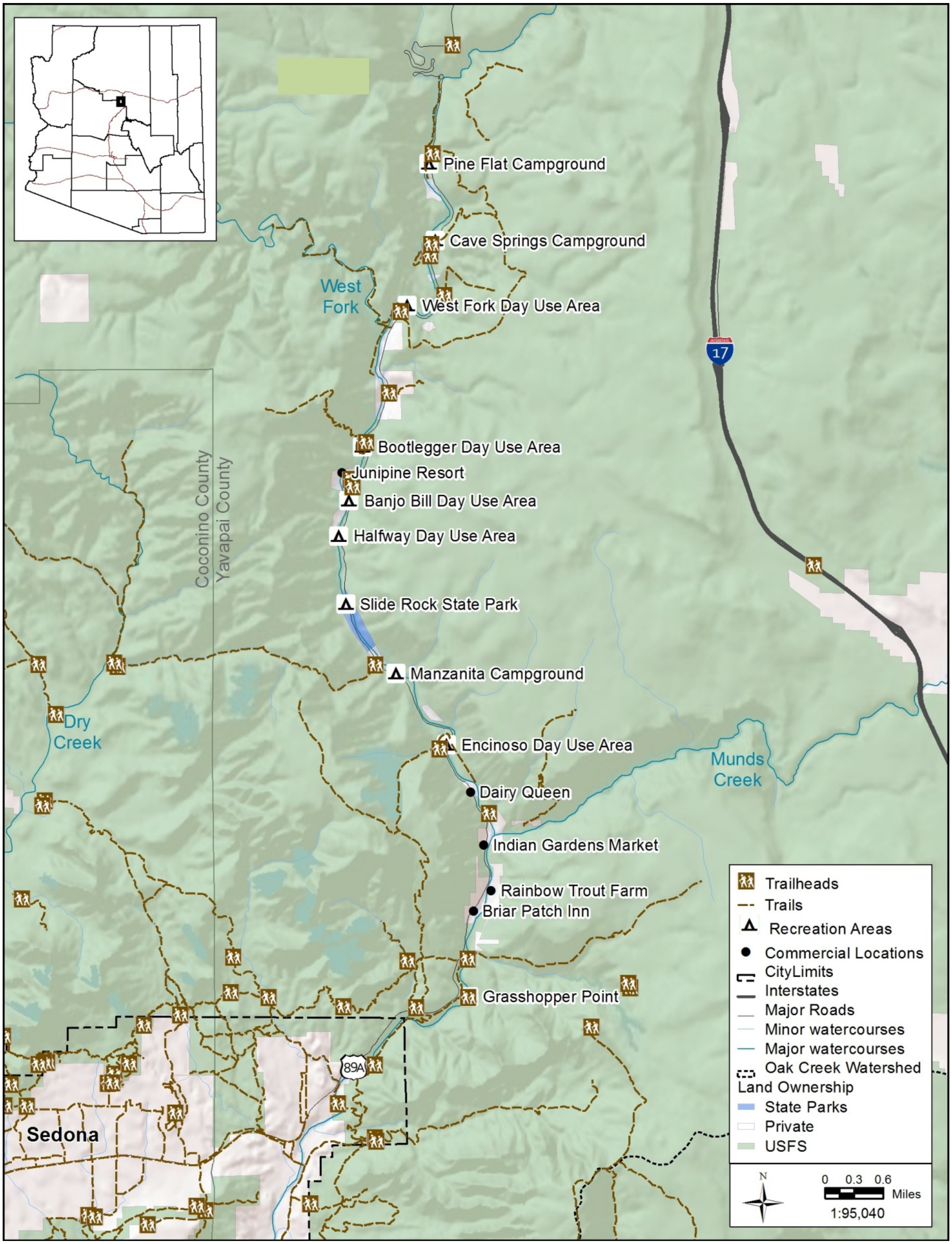
**Long-term effectiveness criteria:** Reduced *E. coli* exceedances at Slide Rock State Park. Turbidity during peak visitation at S.R.S.P. reduced.

### On-the-ground project effectiveness monitoring plan

- *Monitoring and reference condition sites*:
  Approximately #? sites along the creek in Oak Creek Canyon will be monitored for *E. coli* and turbidity where soil erosion due to unmaintained way trails (ie. "social trails") is apparent.
- *Parameters & critical conditions:*
  - *E. coli* (>10 cfu/100 ml for elevated values, >235 cfu/100 ml for exceedence)
  - turbidity (>10 NTU for elevated values, >50 NTU for values associated with *E. coli* exceedences)
- *Schedule, frequency and duration*:
  Sampling will occur during high-use weekends in the early-, mid- and late summer. Baseline monitoring will be accomplished in 2012 and effectiveness monitoring will be conducted in 2013-2014.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants; Slide Rock S.P. and Coconino National Forest
- *Reporting plan:*
  Annual report on summer monitoring results and interpretation by November of each year. Final analysis report in Fall 2014.

### Education effectiveness monitoring

- *Long-term behavior change criteria:*
  Recreators exhibit an understanding and willingness to reduce erosion when accessing the creek on way trails in order to reduce *E. coli* sediment reservoirs that can contribute to water contamination and human illness.
- *Generation and implementation of second generation improvement projects:*
  Volunteer organizations, such as Friends of the Forest, provide access trail maintenance and outreach to continue reduced sediment loads.
- *Measurable reductions of pollutant loading:*
  Reduced *E.coli* concentrations and turbidity
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants; Slide Rock S.P. and Coconino National Forest
- *Reporting plan, how findings will be used:*
  Implementation accomplishments and monitoring results will be included in an annual report that will be posted to the OCWC website. Feature stories in local media will describe project implementation and effectiveness. Utilize any local hotel/restaurant/campground/chamber of commerce publications to run a small advertisement or mini-feature on protecting Oak Creek.


Pine Flat Campground
Cave Springs Campground
West Fork
West Fork Day Use Area
17
Bootlegger Day Use Area
Junipine Resort
Banjo Bill Day Use Area
Halfway Day Use Area
Coconino County
Yavapai County
Slide Rock State Park
Manzanita Campground
Dry Creek
Encinoso Day Use Area
Munds Creek
Dairy Queen
Indian Gardens Market
Rainbow Trout Farm
Briar Patch Inn
Grasshopper Point
89A
Sedona
Trailheads
Trails
Recreation Areas
Commercial Locations
CityLimits
Interstates
Major Roads
Minor watercourses
Major watercourses
Oak Creek Watershed
Land Ownership
State Parks
Private
USFS
N
0 0.3 0.6
Miles
1:95,040

## RC-4 Oak Creek Watershed Dog Waste Station Installation Project

### Need

As evidenced by historic and recent investigations that have included DNA source testing of fecal bacteria, dog feces contribute to *E. coli* contamination in Oak Creek. This is especially true in the Sedona area where residents regularly walk their dogs on trails and often do not pick up their dog's feces. Picking up dog feces would be greatly encourage if pet owners had bags readily available for waste and an appropriate trash receptacle at the trailhead instead of having to put bagged feces in their vehicle to carry it home and dispose.

### Description

In conjunction with the Sedona Dog Waste Reduction Outreach Project which will encourage social pressure to pick up dog waste, this project will establish dog waste stations at as many trailheads as possible within 3 miles of Oak Creek. OCWC will work collaboratively to secure funding for establishment and maintenance of dog waste stations. Prior to the selection of sites and installation of waste stations, meetings will be convened with collaborators to discuss roles and responsibilities, cost-sharing, necessary permits and clearances, etc. One topic of discussion will be the issue of whether USFS policy allows establishing dog waste stations where there are not official national forest system trails, such as at the Chavez Ranch area that is heavily used for exercising dogs.

### Estimated load reduction

#### *Dog feces*

*E. coli* bacteria are bacteria that are common to the intestinal tracts of humans and animals. Walker and Garfield (2008) found that a gram of fresh dog feces contained an average of 50 million CFU/gram with a range of 2 million to 200 million CFU/gram of *E. coli* bacteria. The average dog excretes 0.75 pounds (340 grams) of waste per day (Clear Choices Clean Water, 2012). That equates to an average 17 billion CFU of *E. coli* bacteria per day per dog. If the Sedona Dog Waste Reduction Outreach/Oak Creek Watershed Dog Waste Station Installation Projects prevents 100 dog/days from contaminating Oak Creek this would result in a load reduction 34 kg of dog feces and $17 \times 10^{12}$ CFU of *E. coli* bacteria.

The goal of the Outreach Project is to improve community awareness on the role of dog waste in water quality impairment of Oak Creek. The Outreach Project should increase the use of the dog waste stations and the rate of dog waste removal. If the Outreach Project increases use of the dog waste stations from 100 to 300 dog/days the result would be a load reduction of 102 kg of dog feces and $5.1 \times 10^{13}$ CFU of *E. coli* bacteria.

The actual load reduction will depend on the number of people that utilize the dog waste stations, before and after the Outreach Project. A monitoring program should be implemented to assess the use of the dog waste stations.

References:

Clear Choices Clean Water Organization, access on June 27, 2012 http://clearchoicescleanwater.org/wp-content/uploads/2011/08/pet-waste-FAQs_final.pdf

Walker, M. and L. Garfield, 2008. Dog wastes and water quality: Evaluating the connection at Lake Tahoe. University of Nevada Cooperative Extension, Fact Sheet-08-18.

### Costs

| Item | Units | price/unit | cost |
|---|---|---|---|
| Permits and clearances for waste station installation | # | $$ | $$$ |
| Dog waste stations | # | $$ | $$$ |
| Legal fees for permit processing, establishment of maintenance agreements, installation contracting (inkind?) | # | $$ | $$$ |

### Project schedule and milestones

<table>
<tr>
<td rowspan="2">Implementation schedule:<br>January 2012 through December 2014<br><br>Measurable milestones:<br>~ Meeting with collaborators (USFS, State Parks) to discuss roles and responsibilities, cost-sharing, necessary permits and clearances, etc.<br>~ Completed inventory of trails with dog waste stations and those without; identify gaps that must be filled and prioritize the sequence of installations<br>~ Completed permits, clearances, construction contracting and maintenance agreements<br>~ Installation of dog waste stations and sign explaining the importance of using them to reduce fecal contamination of Oak Creek and human health risks<br>~ Effectiveness monitoring complete<br>~ Reporting complete</td>
<td>Resources and other support commitments:<br>ADEQ 319(h) grants<br>????<br>Commitment date(s):<br><None at this time ></td>
</tr>
<tr>
<td>Pending commitments:<br><Unknown at this time><br>Estimated commitment date:<br><None at this time ></td>
</tr>
</table>

### Education and Outreach Strategy

*Findings of education needs survey:*

20% of watershed residents walk their dog near Oak Creek.

Dog feces were rated as 1st, 2nd and 3rd biggest contributors to creek contamination by 7.2%, 10.6%, and 10.6% or watershed residents respectively.

44.5 % of watershed residents own a dog.

Of those who own dogs 45.6% walk their dog in the watershed.

Most dog-owning residents (64%) said they always pick up their dog waste, while 19.2% said "most of the time", 5.6 % said "sometimes", 3.2% said "rarely", and 8.0% said "never".

83.5% of watershed residents with dogs say they would use dog waste stations if more were made available at parks and trails.

Watershed residents' opinion of whether dog feces threaten Oak Creek water quality is as follows:

| | Not sure | Not a problem | Slight problem |
|---|---|---|---|
| Dog feces that are not picked up and disposed properly | 10% | 12% | 28% |

*Goals and target audiences:*
~ Pet owners who walk dogs on trails within 3 miles of Oak Creek.
~ Work collaboratively with the Sedona Human Society.
~ Increase understanding of importance of picking up dog waste.
~ Affect behaviors so that more pet owners pick up and properly dispose of dog waste.
~ See "Sedona Dog Waste Reduction Outreach Project" for complete details of outreach activities

*Priority education and outreach projects schedule:*
~ Early 2012 - outreach; trailhead surveys of pet owner attitudes and behaviors
~ Late summer 2012 - follow-up surveys
~ 2013-2014 - continued outreach and follow-up surveys
~ 2013-2014 - success stories coverage

## Monitoring and Evaluating Effectiveness

**Long-term effectiveness criteria:** Reduced dog feces counts along trails in Oak Creek watershed. Reduced *E. coli* concentration in Oak Creek, especially *E. coli* with dog-sourced bacterial DNA.

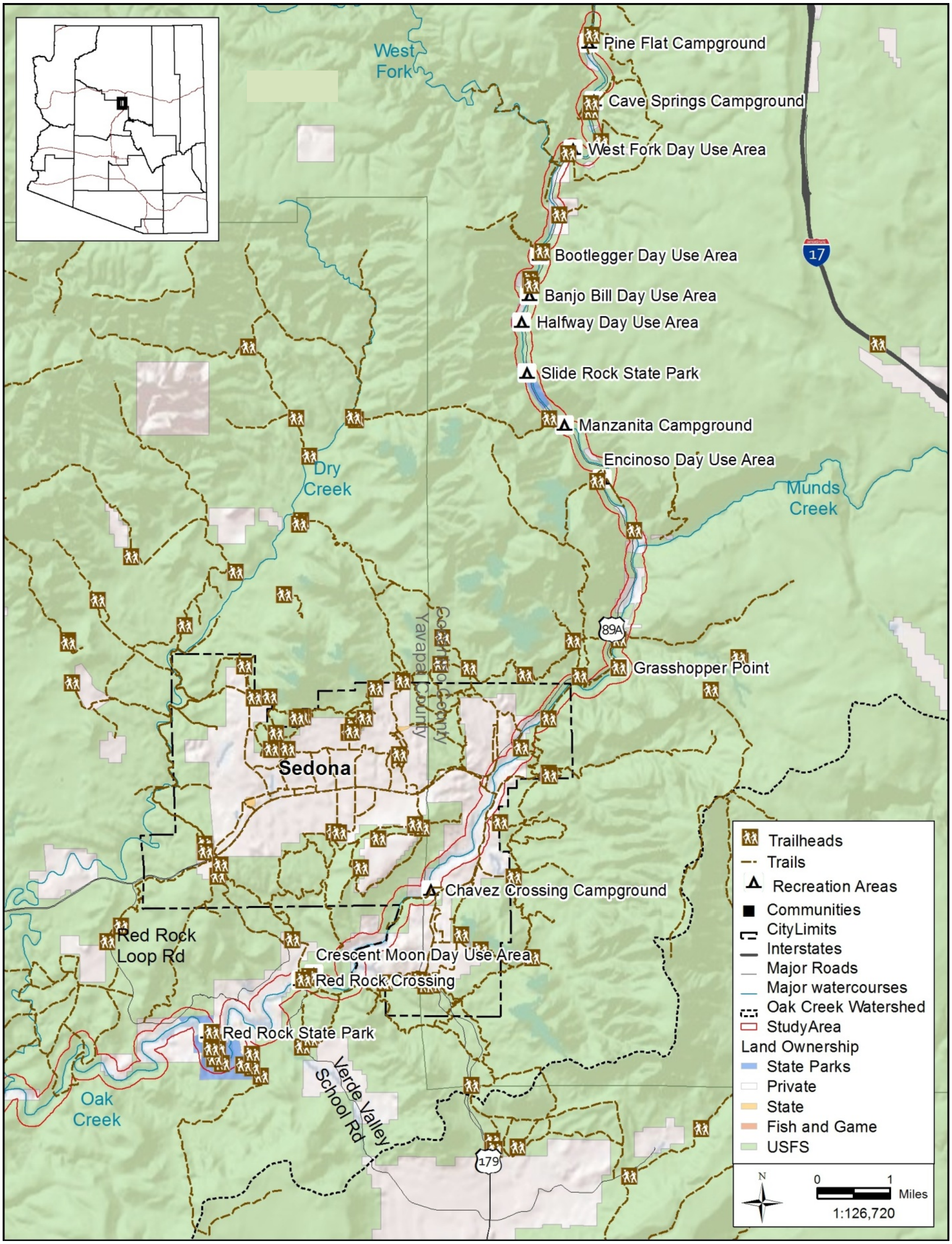
### On-the-ground project effectiveness monitoring plan

- *Monitoring and reference condition sites*:
  Conduct regular dog feces counts in the summer along trails with a large volume of dog walking, especially Huckaby Trail, Baldwin Trail, West Fork Trail (all FS System trails) and Chavez Crossing trail (social trail). Monitor *E. coli* concentrations and bacterial DNA in Oak Creek during storm events or the day after storm events downstream of the mouths of tributary watersheds with a large volume of dogs walking on trails, including Jordan Pump, Soldier Wash, and Carroll Canyon.
- *Parameters & critical conditions:*
  - Fecal counts along popular trails (>20 dog feces per ¼ mile); feces may be picked up and bagged so they are not double counted.
  - Volume of dog feces collected at waste stations (number of bags dispersed and weight of collection at the waste station)

  - *E.coli* (> 90% of average past background or stormflow concentrations; >235 cfu/100 ml for exceedence)
  - DNA (seasonal average equal to or greater than baseline or past percentages of dog-sourced DNA in fecal bacteria)
- *Schedule, frequency and duration*:
  Dog fecal counts twice per month in summer. *E. coli* and DNA sampling at least 3 times per summer during or the day after stormflow events.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants; Coconino National Forest; Coconino County Rural Environmental Corp. [Try to contract CREC for services to conduct fecal counts and *E. coli* sampling. Require at least one Spanish speaking crew member to interface with the public. Try to have crews along trails on the weekend for a presence to make dog walkers aware of the ramifications of their actions.]
- *Reporting plan:*
  Annual report on summer monitoring results and interpretation by November of each year. Final analysis report in Fall 2014.

**Education effectiveness monitoring**

- *Long-term behavior change criteria:*
  Pet owners exhibit an understanding and willingness to use dog waste stations rather than leaving dog waste on the ground where it can wash into Oak Creek and cause fecal contamination that threaten human health.
- *Generation and implementation of second generation improvement projects:*
  Pet owners may identify additional sites where dog waste stations may be appropriate, initiating future projects.
- *Measurable reductions of pollutant loading:*
  Reduced *E. coli* concentrations and dog-sourced bacterial DNA in Oak Creek water. Reduced dog feces along trails.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants; Slide Rock State Park; Coconino National Forest; Coconino Rural Environmental Corp
- *Reporting plan, how findings will be used:*
  Annual accomplishments and monitoring report in the fall each year will be posted to OCWC website. Feature stories in local media will describe project implementation and effectiveness.



West Fork
Pine Flat Campground
Cave Springs Campground
West Fork Day Use Area
Bootlegger Day Use Area
Banjo Bill Day Use Area
Halfway Day Use Area
Slide Rock State Park
Manzanita Campground
Encinoso Day Use Area
Munds Creek
Dry Creek
17
89A
Grasshopper Point
Coconino County
Yavapai County
Sedona
Chavez Crossing Campground
Red Rock Loop Rd
Crescent Moon Day Use Area
Red Rock Crossing
Red Rock State Park
Oak Creek
Verde Valley School Rd
179
Trailheads
Trails
Recreation Areas
Communities
CityLimits
Interstates
Major Roads
Major watercourses
Oak Creek Watershed
StudyArea
Land Ownership
State Parks
Private
State
Fish and Game
USFS
N
0
1
Miles
1:126,720

## AG-1 Animal Waste BMPs for Oak Creek Watershed

### Need

Some livestock owners have reportedly dumped animal waste into irrigation ditches that drain into Oak or into Oak Creek directly. Elevated *E. coli* concentrations in Oak Creek in areas where livestock are kept appears to corroborate waste dumping and its impacts. For example, from Page Springs to the Verde Confluence the average baseline *E. coli* concentration in summer 2011 was 56.4 cfu/100 ml, compared to 31.4 cfu/100 ml at Chavez Crossing Campground in the City of Sedona and 10.3 cfu/100 ml in Oak Creek Canyon. Concentrated doses of fecal matter can cause spikes in *E. coli* and other related pathogens as well as innoculate *E. coli* sediment reservoirs that later contaminate water when disturbed by storm flows or recreation activities. The resulting pathogen loads may threaten the health of people wading and swimming in Oak Creek. The excess nutrients and organic matter can also have a deleterious impact on aquatic life. Perhaps some livestock owners do not know the serious environmental impacts of dumping animal waste into water bodies. Outreach, education and technical support are needed to help landowners initiate best management practices for animal waste.

### Description

OCWC will collaborate with Cooperative Extension Service, the Verde Natural Resources Conservation District, local ditch assocations and any livestock organizations in the watershed. The location of all livestock owners will be determined through aerial and driveby surveys and any available databases related to livestock producers and horse, goat, sheep, llama etc. owners. A focused outreach effort will be made to educate livestock owners on the water quality impacts of dumping animal waste into water. Assistance will be provided to implement best management practice alternatives to dumping, such as those listed on the Cooperative Extension Service website: http://ag.arizona.edu/animalwaste. Demonstration workshops will be held in the watershed to teach BMP background and techniques to livestock owners. Workshop presenters should appeal to landowners environmental ethics but also emphasize if there is an economic advantage to proper waste management, such use of waste for improving soil fertility or selling composted waste to farmers and gardeners. Material and technical assistance will be provided to operators as they initiate BMPs. USFS hydrologist Amina Sena recommends pursuing a grant to fund a pick up for livestock waste at no cost for one year to quantify exactly how much people may potentially be dumping in the creek

### Estimated load reduction

*E. coli* bacteria are bacteria that are common to the intestinal tracts of humans and animals. A 1000-pound horse will defecate from 4-13 times each day and produce 35 to 50 pounds of wet manure (feces plus urine) daily, or approximately 9.1 tons per year. E. coli concentrations in fresh and dry manure from horses are $6.17 \times 10^4$ CFU per gram and $6.31 \times 10^5$ CFU per gram, respectively (NERA, 2012).

A mature cow weighting 1000 lbs produces an average of 8.7 lbs/day of manure (NRCS, 2012) or approximately 1.5 tons per year. Wang et al. (2004) showed that *E. coli* populations extracted from fresh cow manure ranging from $6.55 \times 10^6$ to $7.6 \times 10^6$ cfu per gram of manure (average of $7.1 \times 10^6$ cfu per gram).

If the fresh waste from one animal was dumped into the stream the potential average annual *E. coli* load would be:

Horse (CFU/year) = 9.1 tons/yr * 6.17 x $10^4$ CFU per gram * 907,184.74 grams/ton = 5.1 x $10^{11}$ CFU per year

Cow (CFU/year) = 1.5 tons/yr * 7.1 x $10^6$ CFU per gram * 907,184.74 gram/ton = 9.7 x $10^{12}$ CFU per year

The actual load reduction is based on the number of people currently dumping waste into the streams and the resulting number of people that stop dumped after the implementation of the Outreach Programs. A monitoring program would be implemented to assess the current rate of dumping and to evaluate the behavior changes after the implementation of Outreach Programs.

References:


Natural Resource Conservation Service (NRCS), access on June 25, 2012. Wyoming Comprehensive Nutrient Management Plan Workbook located at http://www.wy.nrcs.usda.gov/technical/wycnmp/

NERA Website, Access July 2012. NE1041: Environmental Impacts of Equine Operation located at http://lgu.umd.edu/lgu_v2/homepages/attachs.cfm?trackID=11196.

Wang, L., K.R. Mankin, and G.L. Marchin, 2004. Survival of Fecal Bacteria in Dairy Cow Manure. Transactions of the ASAE 47(4): 1239-1246.


**Costs**

????

**Project schedule and milestones**

<table>
<tr>
<td rowspan="2">Implementation schedule:<br>January 2012 through December 2014<br><br>Measurable milestones:<br>~ Collaboration agreement with Cooperative Extension Service and the Verde Natural Resources Conservation District<br>~ Map of irrigation 22 irrigation ditches and contact information for each<br>~ Survey of livestock properties including location, livestock type and estimated number of animals<br>~ #? BMP workshops<br>~ #? livestock owners provided material and technical assistance for initiating BMPs<br>~ Quarterly and final reports</td>
<td>Resources and other support commitments:<br>ADEQ 319(h) grants<br>????<br>Commitment date(s):<br><None at this time ></td>
</tr>
<tr>
<td>Pending commitments:<br><Unknown at this time><br>Estimated commitment date:<br><None at this time></td>
</tr>
</table>

**Education and Outreach Strategy**

*Findings of education needs survey:*

The following reflects watershed residents' views on the whether livestock waste threatens water quality:

| Ag. Runoff | Not sure | Not a problem | Slight problem |
|---|---|---|---|
| Livestock manure | 20% | 15% | 22% |

*Goals and target audiences:*

~ Owners of warm-blooded livestock in Oak Creek watershed

~ Advertise workshops in local specialty publications (eg. 4H newsletter), bulletin boards at feed stores, NRCD list serve or newsletter, etc.

~ Inform livestock owners of risks to human health from dumping livestock excrement into water, because of pathogens and dosing of *E. coli* sediment reservoirs that later cause water contamination when reservoirs are disturbed by stormflows or recreation activity.

~ Provide educational workshops and hands-on demonstrations while assisting livestock owners with the initiation of BMPs.

*Priority education and outreach projects schedule:*

~ Spring 2012 - Establish collaboration with other natural resources professionals who can provide expert instruction

~ Fall through Spring 2012-2014 – BMP workshops and demonstrations

~ 2014 - success stories coverage

## Monitoring and Evaluating Effectiveness

**Long-term effectiveness criteria:** Reduced *E.coli* concentrations in reaches of Oak Creek where livestock are common.

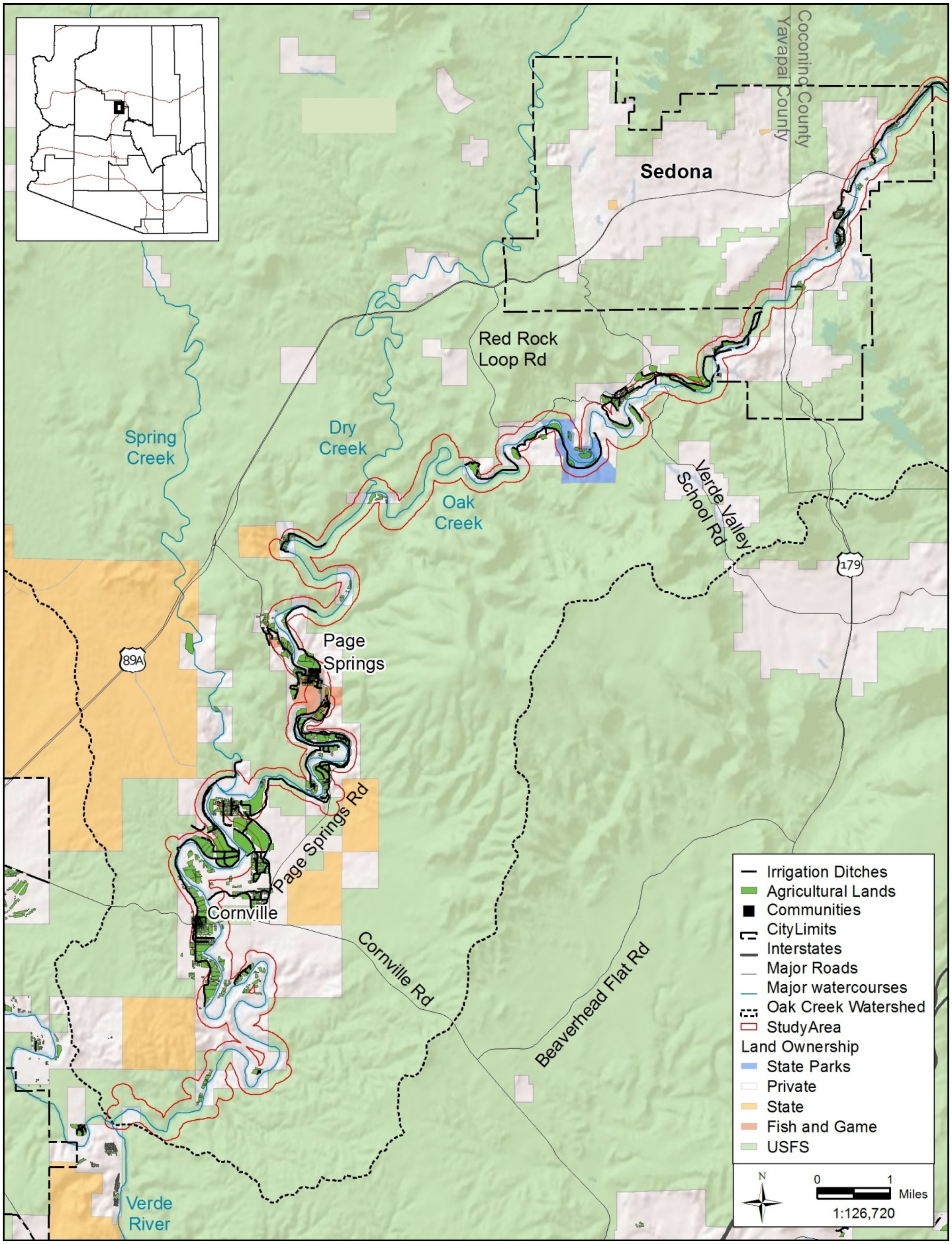
**On-the-ground project effectiveness monitoring plan**

- *Monitoring and reference condition sites*:
  Continue monitoring *E. coli* and DNA at OCWIP monitoring sites during summer months in reaches where livestock are common, from below Red Rock State Park (M29) to Cornville Estates (M41).
- *Parameters & critical conditions:*
  - *E. coli* (greater than average baseline concentration for each site in 2011)
  - DNA, if practical and affordable (% horse-, sheep-, etc.-sourced bacterial DNA greater than percentages found in Oak Creek Canyon by Southam in 1999) University of Arizona could test bovine DNA and forward water samples or extracted DNA to other lab(s) for testing of other livestock species.
- *Schedule, frequency and duration*:
  At least 3 samples each during baseline and stormflow conditions throughout the summer months, 2012-2014. Sampling may be combined with sampling efforts for other projects.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants, University of Arizona and other contracted genetics laboratories

- *Reporting plan:*
  Annual report on sampling, data analysis and interpretation. Assessment of BMP effects on water quality in project final report.

**Education effectiveness monitoring**

- *Long-term behavior change criteria:*
  Livestock owners exhibit an understanding and willingness to use animal waste management BMPs to reduce fecal contamination of Oak Creek.
- *Generation and implementation of second generation improvement projects:*
  Local ditch associations seek grant funding for projects to improve animal waste management to maintain quality of irrigation tail water.
- *Measurable reductions of pollutant loading:*
  Reduced *E.coli* concentrations. Reduced percentage of bacterial DNA attributed to livestock species.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants, University of Arizona and other contracted genetics laboratories
- *Reporting plan, how findings will be used:*
  Annual reports on workshop and demonstration attendance. Feature stories in specialty publications for livestock owners regarding progress of project and results of monitoring. Success stories in local media.


Sedona
Coconino County
Yavapai County
Red Rock
Loop Rd
Spring
Creek
Dry
Creek
Oak
Creek
Verde Valley
School Rd
179
89A
Page
Springs
Page Springs Rd
Cornville
Cornville Rd
Beaverhead Flat Rd
Verde
River
Irrigation Ditches
Agricultural Lands
Communities
CityLimits
Interstates
Major Roads
Major watercourses
Oak Creek Watershed
StudyArea
Land Ownership
State Parks
Private
State
Fish and Game
USFS
N
0
1
Miles
1:126,720

## AG-2 Oak Creek Irrigation Diversion Erosion Reduction Project

### Need

Annual earth moving activities to build or restore irrigation diversion structures may be introducing large quantities of sediment to creek, which can contribute to *E. coli* sediment reservoirs, which in turn cause water contamination when sediments are disturbed by stormflows or recreation activities. This is evidenced by anecdotal accounts, aerial photo interpretation and *E. coli* concentrations that have been found higher in reaches with irrigation diversions that appear to be contributing sediment to the stream channel. Also, irrigation tailwater that enters ditches may deliver sediment to the creek from fields with unstable soils. Besides sediment inputs potentially increasing *E. coli* in to Oak Creek water, sediment is also disruptive to benthic organisms that are essential to the stream's food web. Most of the sediment problems associated with irrigation appear to be in the lower reaches of Oak Creek where stream bed and bank material is finer grained and usually must by reworked on an annual basis for maintenance of diversion structures. In Oak Creek Canyon there are several diversion structions, but the coarseness of the material and the infrequency with which it is disturbed may mean there is less erosion and sedimentation.

### Description

Map all irrigation diversions and ditches. Have volunteers float/wade the creek with a GPS unit, camera, and notebook to inventory irrigation infrastructure (diversion dams, gates, ditch starts, ditch outfalls, etc.). Work collaboratively with Yavapai County GIS, ADWR, NRCD and Cooperative Extension on mapping ditches. Engage local ditch associations. Interface with Army Corp of Engineers to ascertain whether there are current 404 permits for diversions or whether some diversions predate the 404 rules and are thereby exempt due to a grandfather clause. For any diversions that do require a 404 permit, evaluate structures to see if excavations may be out of compliance. Identify problem areas and provide incentives to implement Best Management Practices, such as using larger diameter material for diversion dams, as recommended by NRCD, Cooperative Extension Service or others, to reduce erosion and sedimentation associated with irrigation diversions. Develop a plan for at least 3 diversion structures to reduce erosion/sedimentation and provide assistance in applying for grants to fix problems.

### Estimated load reduction

The StepL modeling tool was used to estimate the load reductions by reducing sediment caused by irrigation structures. It was assumed that the BMPs would have a load reduction efficiency of 50%. The estimated average annual load reduction is:
Sediment – 10.2 tons per year
Nitrogen (N) – 267.6 lbs per year
Phosphorus (P) – 30.2 lbs per year

References:

U.S. EPA Website, Access June, 2012. Welcome to STEPL and Region 5 Model, http://it.tetratech-ffx.com/stepl/

**Costs**

????

**Project schedule and milestones**

| | |
|---|---|
| *Implementation schedule:*<br>January 2012 through December 2014<br><br>*Measurable milestones:*<br>~ Collaboration agreement with Cooperative Extension Service and the Verde Natural Resources Conservation District<br>~ Map of irrigation 22 irrigation ditches and contact information for each<br>~ Survey of irrigation infrastructure condition and erosion/sedimentation trouble spots<br>~ #? 404 permits identified as out of compliance (if relevant)<br>~ #? diversion renovation plans/grant proposal frameworks<br>~ Quarterly and final reports | *Resources and other support commitments:*<br>ADEQ 319(h) grants<br>????<br>*Commitment date(s):*<br><None at this time><br><br>*Pending commitments:*<br><Unknown at this time><br>*Estimated commitment date:*<br><None at this time (Sept 2011)> |

**Education and Outreach Strategy**

*Findings of education needs survey:*

The following reflects watershed residents' views on the whether irrigation diversions can cause erosion and sedimentation that may threaten water quality:

| Activity | Not sure | Not a problem | Slight problem |
|---|---|---|---|
| Construction and maintenance of irrigation diversions | 21% | 17% | 28% |

*Goals and target audiences:*

~ Irrigation association members along Oak Creek
~ Contact association administrators (ie. ditch bosses or similar) and invite them to a round table discussion about irrigation infrastructure on Oak Creek and how it might be affecting water quality. Dangle the carrot of assistance with writing grant proposals to obtain funds for system upgrades. Establishing a friendly working relationship with ditch administrators is critical.
~ After irrigation systems have been surveyed and problem spots are identified, go on a "show me" tour of the good, the bad and the ugly with interested members of irrigation associations. Advertise and/or invite though contact information provided by ditch administrators.
~ Solicit volunteers among ditch associations to participate in demonstration projects and collaboratively write grant proposals with volunteers for further system upgrades.
~ Host demonstrations of BMPs to reduce erosion and sedimentation associated with irrigation diversions.

*Priority education and outreach projects schedule:*

~ Fall 2012 to Spring 2013 – Round table discussions

~ Spring 2013 – Show me tour(s)

~ Fall 2014 to Spring 2014 - Demonstration projects (might be combined with animal waste BMP demonstration projects in a 2-day conference, maybe rent the Dancing Apache?)

## Monitoring and Evaluating Effectiveness

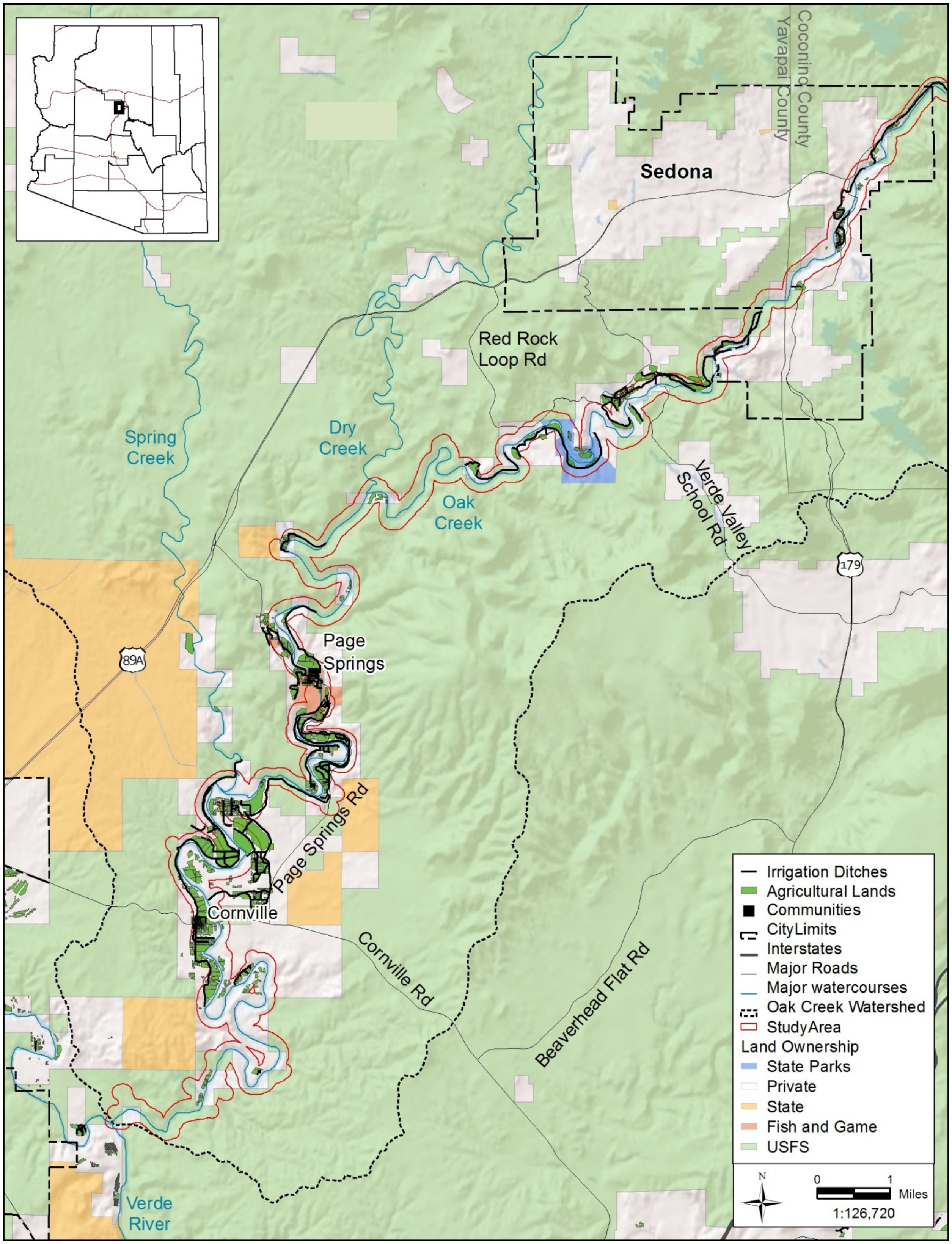
**Long-term effectiveness criteria:** Reduced *E. coli* concentrations and sediment in reaches of Oak Creek where irrigation diversions correspond with erodible materials.

### On-the-ground project effectiveness monitoring plan

- *Monitoring and reference condition sites*:
  Continue monitoring *E. coli* and turbidity at OCWIP monitoring sites during summer months in reaches where irrigation diversions correspond with erodible materials, from below Red Rock State Park (M29) to Cornville Estates (M41).
- *Parameters & critical conditions:*
  - *E. coli* (greater than average baseline concentration for each site in 2011)
  - Turbidity (>50 NTU)
- *Schedule, frequency and duration*:
  At least 3 samples each during baseline and stormflow conditions throughout the summer months, 2012-2014. Sampling may be combined with sampling efforts for other projects.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan:*
  Annual report on sampling, data analysis and interpretation. Assessment of the adoption irrigation diversion BMPs and potential effects on water quality in project final report.

### Education effectiveness monitoring

- *Long-term behavior change criteria:*
  Irrigators exhibit an understanding and willingness to use BMPs to reduce erosion and sedimentation associated with irrigation diversions in Oak Creek.
- *Generation and implementation of second generation improvement projects:*
  Local ditch associations seek grant funding for projects to upgrade irrigation diversions so that annual maintenance is less disruptive and generates less sediment.
- *Measurable reductions of pollutant loading:*
  Reduced *E.coli* concentrations. Reduced turbidity.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan, how findings will be used:*
  Annual reports on show me tour and demonstration attendance. Feature stories in specialty publications for livestock owners regarding progress of project and results of monitoring. Success stories in local media.


Sedona
Coconino County
Yavapai County
Red Rock Loop Rd
Spring Creek
Dry Creek
Oak Creek
Verde Valley School Rd
179
89A
Page Springs
Page Springs Rd
Cornville
Cornville Rd
Beaverhead Flat Rd
Verde River
Irrigation Ditches
Agricultural Lands
Communities
CityLimits
Interstates
Major Roads
Major watercourses
Oak Creek Watershed
StudyArea
Land Ownership
State Parks
Private
State
Fish and Game
USFS
N
0
1
Miles
1:126,720

## Photos

Examples of how excavation of fine-grained material can be very disruptive to the channel. These photos are from the Verde River upstream of Deadhorse Ranch State park.

## AG-3 Lower Oak Creek Erosion Reduction Project

**Need**

Turbidity is persistent in the lower reaches of Oak Creek – Page Springs through Cornville to Verde River confluence – even during dry weather when upper reaches of Oak Creek are clear, indicating multiple sources of sediment in the lower reaches. These same reaches have baseline *E. coli* concentrations higher that upper reaches (56.4 cfu/100ml average compared to 31.4 cfu/100 ml in Sedona area and 10.3 cfu/100 ml in Oak Creek Canyon). Reportedly there is a least one low-water crossing (a.k.a. ford) across Oak Creek downstream of Cornville that may be contributing sediment to the creek. Sediment is a problem because it causes turbidity which has been strongly correlated with *E. coli* in Oak Creek, probably because *E.coli* on sediment particles transfers to the water when the particles are suspended in the water column. Low water crossings need to be mapped and evaluated and alternatives explored to reduce erosion and sedimentation. Also, erosion has been observed after summer monsoon rain along roadways in the Cornville area, eg. along Sexton Ranch Road, which is likely delivering sediment to Oak Creek. Sediment production from roadways, properties under development, and recently developed needs to be evaluated to determine whether Yavapai County should revise policies, road mainteance procedures, regulations or building codes to limit erosion and sedimentation.

**Description**

Map all low-water crossings on Oak Creek. Have volunteers float/wade the creek with a GPS units, camera, and notebook to inventory low water crossings and notes locations with apparent elevated turbidity. (Field work can be combined with inventory of irrigation infrastructure.) Assess road network conditions for adequate drainage to avoid erosive flows along road beds or ditches. Inspect recently developed properties that are without established vegetation to see whether stormwater BMPs are needed to slow runoff and reduce erosion. Work collaboratively with property owners and/or Yavapai County to explore implementing improvements to reduce sediment inputs. Improvements may include cement fords or bridges (depending on resources available) terracing, additional culverts, improved road prisms and so forth. Offer to help write grant proposals to secure funding to upgrade low-water crossings and road drainage.

**Estimated load reduction**

The project will map low-water crossing on Oak Creek which in itself will not produce a load reduction in sediment. The project will provide information for the formulation of future BMPs to reduce sedimentation.

**Costs**

????

**Project schedule and milestones**

| | |
|---|---|
| *Implementation schedule:*<br>January 2012 through December 2014<br>*Measurable milestones:*<br>~ Meet with Roads Division of Yavapai County Public Works to discuss road | *Resources and other support commitments:*<br>ADEQ 319(h) grants<br>????<br>*Commitment date(s):*<br><None at this time > |

| | |
|---|---|
| maintenance and improvements that could reduce erosion and sedimentation<br>~ Low-water crossings inventoried<br>~ Roadway inspections complete<br>~ Meet with property owners regarding low-water crossings and any properties with overt erosion problems<br>~ Report with recommendations and grant proposal frameworks<br>~ Quarterly and final reports | *Pending commitments:*<br><Unknown at this time><br>Approach SRP; they may be interested in erosion control projects to reduce sedimentation of water storage reservoirs<br>*Estimated commitment date:*<br><None at this time > |

**Education and Outreach Strategy**

*Findings of education needs survey:*

The following reflects watershed residents' view on the impacts of road construction and road maintenance on erosion and sedimentation which can affect water quality:

| Activity | Not sure | Not a problem | Slight problem |
|---|---|---|---|
| Road construction | 17% | 17% | 30% |
| Road maintenance | 17% | 20% | 34% |

*Goals and target audiences:*

~ Property owners in the lower reaches of Oak Creek watershed
~ Contact property owners and/or Yavapai County regarding low-water crossings, roadways or building sites that appear to be contributing to erosion and sedimentation and discuss options for improving the road network and overall soil stability. Keep in mind that Yavapai County has a very strong property rights ethic and may not welcome any strangers who appear on their door step regardless of your intentions. Send a post card in advance of visit to inform property owner about the project, give them a link to the OCWC website, and provide a contact phone number.
~ Take interested property owners on a "show me" trip to see erosion problems. Pitch idea of helping with grant proposals and/or lobbying the county for upgrades to reduce erosion. Also sell the idea of better access to their properties during storm events.

*Priority education and outreach projects schedule:*

~ Winter/spring 2013 – post cards and site visits
~ Summer 2013 – Show me tour(s)
~ Fall 2013 to Spring 2014 – Writing grant proposal and holding forums with Yavapai County and residents to seek funding and develop a plan for improving roadways to reduce erosion.

## Monitoring and Evaluating Effectiveness

**Long-term effectiveness criteria:** Reduced turbidity and *E. coli* concentrations in the lower reaches of Oak Creek

**On-the-ground project effectiveness monitoring plan**

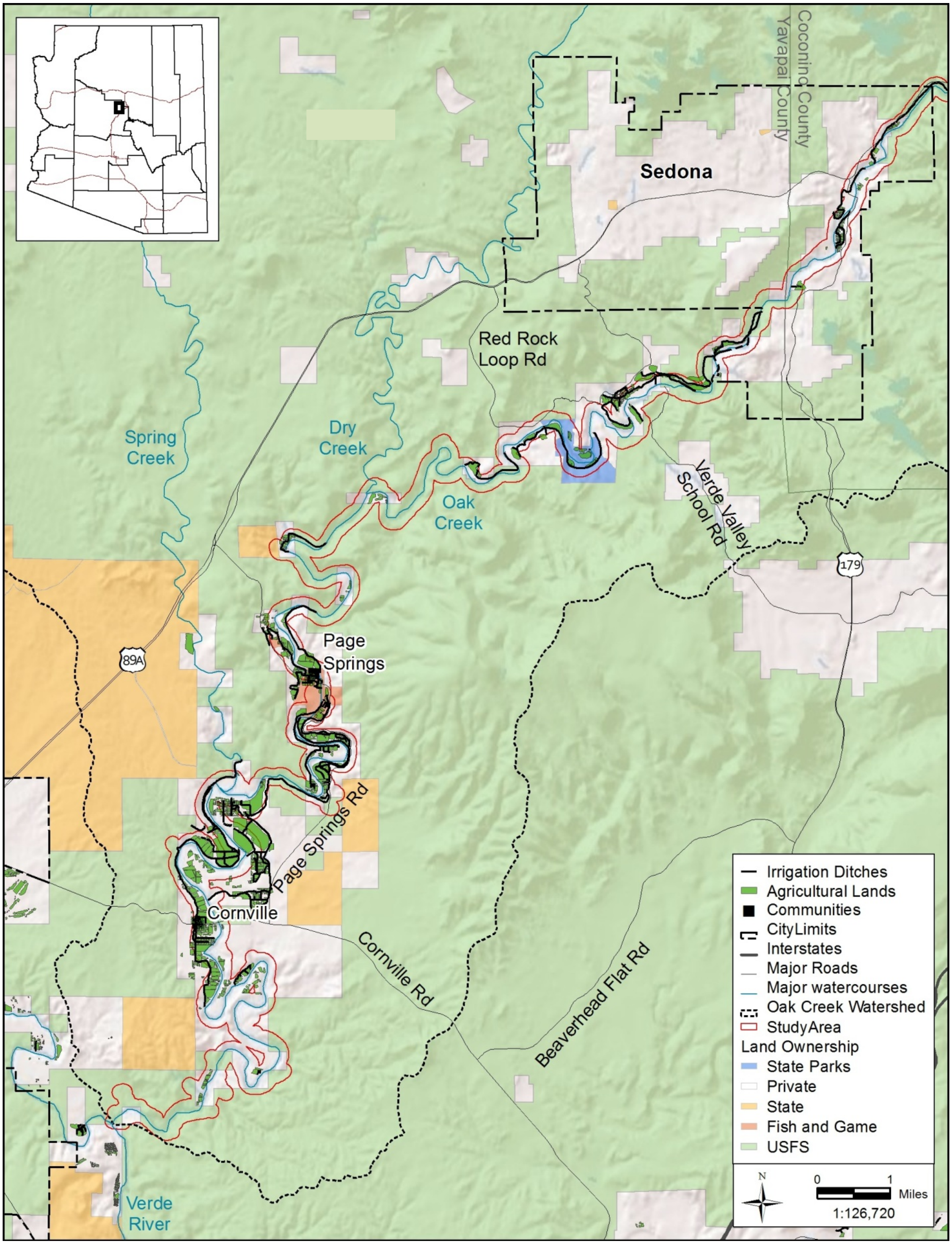
- *Monitoring and reference condition sites*:

Continue monitoring *E. coli* and turbidity at OCWIP monitoring sites during summer months in reaches where turbidity is usually elevated compared to upstream reaches, from Page Springs down to the Verde River confluence.

- *Parameters & critical conditions:*
  - *E.coli* (greater than average baseline concentration for each site in 2011)
  - turbidty (>50 NTU)
- *Schedule, frequency and duration*:
  At least 3 samples each during baseline and stormflow conditions throughout the summer months, 2012-2014. Sampling may be combined with sampling efforts for other projects.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan:*
  Annual report on sampling, data analysis and interpretation. Assessment of possible correlations between road conditions and turbidity in project final report.

**Education effectiveness monitoring**

- *Long-term behavior change criteria:*
  Property owners appreciate the importance of reducing sedimentation through proper roadway design, construction and maintenance to help reduce water quality impacts and take action to improve road conditions.
- *Generation and implementation of second generation improvement projects:*
  Property owners seek grant funding and/or Yavapai County support for projects to upgrade roadways and low-water crossing to reduce sedimentation.
- *Measurable reductions of pollutant loading:*
  Reduced turbidity. Reduced *E.coli* concentrations.
- *Volunteers and/or staff for monitoring and data analysis:*
  OCWC volunteers, staff and consultants
- *Reporting plan, how findings will be used:*
  Annual reports on show me tours. Feature stories in local media.


Sedona
Coconino County
Yavapai County
Red Rock Loop Rd
Spring Creek
Dry Creek
Oak Creek
Verde Valley School Rd
179
89A
Page Springs
Page Springs Rd
Cornville
Cornville Rd
Beaverhead Flat Rd
Verde River
Irrigation Ditches
Agricultural Lands
Communities
CityLimits
Interstates
Major Roads
Major watercourses
Oak Creek Watershed
StudyArea
Land Ownership
State Parks
Private
State
Fish and Game
USFS
N
0
1
Miles
1:126,720