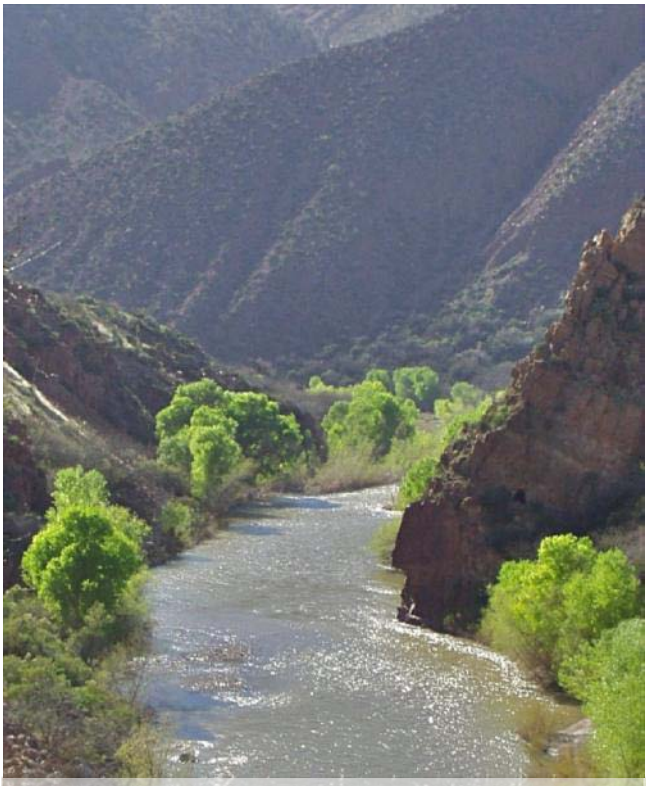
GILA WATERSHED PARTNERSHIP OF ARIZONA



Watershed Improvement Plan
San Francisco and Blue Rivers
June 2012

Acknowledgments

Gila Watershed Partnership has enjoyed robust participation of many kinds in its Targeted Watershed project for the San Francisco and Blue Rivers. The Watershed Improvement Council (WIC) meetings have attracted a broad representation of citizens and local governments. The following individuals have been important presences as the WIC and its offshoot – the volunteer organization Friends of the San Francisco – have evolved:

Greenlee County Supervisors David Gomez and Richard Lunt, Greenlee County Engineer Philip Ronnerud, Greenlee County Health Department Deputy Director Dr. Matt Bolinger, educator and rancher Dr. Suzanne Menges, retired District Ranger and environmental consultant Frank Hayes, newspaper editor Walter Mares, health care technician Chandler McElroy, geologist Ludie Henning, naturalist and educator Nancy Gregory, wildlife educator Terry Johnson, rancher Richard Kaler, educators Steve Ahmann and Susan Snyder, former Clifton town manager Alan Baker, mining heavy equipment operator Marshall Hagan, and landscape designer and arborist Bill Cook.

The following agencies have contributed on a consistent basis to research, analysis and planning: Arizona Department of Environmental Quality, Surface Water Division; University of Arizona Cooperative Extension, Arizona NEMO; University of Arizona Cooperative Extension, Graham/Greenlee Counties; University of Arizona Maricopa Agricultural Center, Water Quality Lab; U.S. Bureau of Land Management, Safford Office; U.S. Forest Service, Springerville Office and Clifton Ranger District. The following individuals in particular have contributed invaluable guidance: Dave Arthun, Christopher Morris, Deb Morris and Rich Law of the U.S. Bureau of Land Management; Bill Brandau, Cooperative Extension county director and community educator; Dr. Channah Rock, University of Arizona; Thomas Subirge, U.S. Forest Service, Apache-Sitgreaves National Forest; Kristine Uhlman, C.E., formerly of Arizona NEMO.

The following volunteers have made exceptional efforts in field work and community education: Nancy Gregory, Chandler McElroy and Terry A. Johnson.

Forward

The San Francisco River watershed is one of Arizona's most significant. It is the largest tributary to the Gila River, once a major waterway to its confluence with the Colorado, and the target of historic water rights battles and legislation. The San Francisco's waters are critical not just to downstream agriculture and recreation but increasingly to distant urban areas that are now looking east for future water supplies.

Remote by any measure with its rugged topography traversing two states and its sparse human settlement – about two people per square mile overall – the San Francisco-Blue Watershed is mostly wilderness, with soaring vistas and abundant wildlife. Greenlee is Arizona's least populous county, and the local economy is tied to the fortunes of global mining interests. The watershed, particularly the San Francisco River, has potential to help stabilize the local economy through thoughtfully developed tourism and better managed recreation. This potential has only recently been examined in earnest by a group of local leaders. The bacterial contamination of the river and that conditions that cause it are concerns for those looking to build that new economic engine.

Before our project's multiple public education efforts were unrolled, very few people in the region understand *that* there were contamination issues or *why* there were contamination issues. Those who were aware that the Arizona Department of Environmental Quality had listed sections of the San Francisco and Blue Rivers as impaired for *E. coli* did not know about *E. coli*'s role as an indicator pathogen.

The fundamental principle of this project at the beginning was to bring representatives of the various parts of the community together to build first a common vocabulary and, as understanding increased, sets of shared observations and eventually shared goals. The team did this through an *iterative assessment* process. This methodology originated in the medical world as "translation science," a process by which providers and patients exchange and integrate information. Translational science has been adapted to other contexts, and is now being used by the University of Arizona and other institutions for watershed assessment in particular. Iterative assessment emphasizes *social learning*: collective self-reflection through interaction and dialogue among diverse participants, followed by co-production of knowledge.

In this project, we have seen that once people see for themselves the conditions that research shows to be causal to *E. coli* exceedances, they grow interested in finding solutions. The evidence compiled in the course of our research rarely fails to be disturbing to people concerned with their own and their loved ones' health. And there is now a sense among our group of advisors and volunteers – our Watershed Improvement Council – that the community has the power to do something about these conditions.

There is also recognition that this could have exponential benefits over time because of the potential to protect and develop the river as a recreation and tourism center.

This Watershed Improvement Plan details the research conducted by the project team and volunteers, the results of review and discussion at various stages by the Watershed Improvement Council, and short-term best-management practices (BMPs) either implemented or in the process of implementation. It also describes and prioritizes possible BMPs for the future.

Abbreviations

A&Wc	Aquatic & Wildlife cold water
A&Ww	Aquatic & Wildlife warm water
ADEQ	Arizona Department of Environmental Quality
ADOT	Arizona Department of Transportation
AgI	Agriculture irrigation
AgL	Agriculture livestock watering
ASL	Arizona State Lands
BLM	U.S. Bureau of Land Management
BMP	Best management practice
Bo	Bovine
BR	Blue River
C	Celsius
CFS	Cubic feet per second
CFU	Colony-forming unit
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
FBC	Full body contact
FC	Fish consumption
FS	U.S. Forest Service
GWP	Gila Watershed Partnership
Hu	Human
HUC	Hydrologic unit code
MPN	Most probable number
NEMO	(Historically) Non-point Education for Municipal Officials
OHV	Off-highway vehicle
SFR	San Francisco River
SSC	Suspended sediment count
U of A	University of Arizona
WIC	Watershed improvement council
WIP	Watershed improvement plan

Chapter 1 Background

Water Quality Concern and Watershed Description

The Targeted Watershed grant, *E. coli Reduction on the San Francisco and Blue Rivers*, was devised by the Gila Watershed Partnership with the support of the Arizona Department of Environmental Quality (ADEQ) and the U.S. Department of Environmental Quality (EPA). Its purpose is to research sources of bacterial contamination on portions of the San Francisco and Blue, and to develop a stakeholder-supported plan for addressing these sources.

Pollutants of Concern

ADEQ has placed certain river reaches of the two rivers on the Clean Water Act 303(d) Impaired Waters List as impaired for the bacterium *Escherichia coli* (*E. coli*), based on testing results accumulated over years. It is widely agreed within the scientific and land management communities that *E. coli* is an "indicator pathogen" that suggests the presence of other pathogens potentially dangerous to humans. *E. coli* testing is done in place of tests for other pathogens because it is comparatively easy and inexpensive.

Since the enactment of the Clean Water Act of 1972, many rivers, lakes and other surface waters across the United States continue to fail to meet standards for various levels of use. Those standards, developed by the U.S. Environmental Protection Agency and adopted by the Arizona Department for Environmental Quality, define different levels of safety thresholds for drinking, full body contact (as in swimming) and partial body contact (as in boating).[1] In monitoring the waters of the San Francisco and Blue Rivers over the years, ADEQ has repeatedly found levels of *E. coli* that exceed the safety standard for full body contact. These findings have occurred only on particular stretches of the two rivers, and it is those stretches that have been listed as "*impaired for E. coli*."

There are several hundred types of *E. coli*, a bacterium that occurs naturally in the intestines of warm-blooded animals. The great majority are harmless to humans. It is just a handful of the types that can cause illness if ingested by humans. *E. coli* passes through the intestines of warm-blooded animals through their feces and in that way enters the environment. In a rural riparian area with rangeland and recreational uses, wildlife feces along with livestock, pet and human feces may enter recreational waters, either directly or via surface flows during rain events, contributing not just *E. coli* but a number of waterborne pathogens that pose risks to human health.

Potential Public Health Risks

As noted above, water quality monitoring professionals commonly use *E. coli* as an indicator for other waterborne pathogens that may pose more serious health risks to people. Such pathogens include other types of bacteria as well as parasites, amoebas and viruses. Some are relatively familiar to the public. *Salmonella*, a well-known type of disease-causing bacteria, is found in the

[1] See pages 6-9 for more information on Standards and Designated Uses applicable to the San Francisco-Blue watershed.

intestinal tracts of animals and humans, as well as in contaminated water. *Cryptosporidium* and *Giardia* are parasites found in contaminated water that often cause gastro-intestinal and other illness. Among the disease-causing viruses that can be found in water are adenoviruses, which can cause respiratory illness, and rotaviruses, whose effects on the human system are often mistaken for "stomach flu," but can cause very serious cases of diarrhea.

The waterborne pathogens that scientists believe are most likely to cause disease in humans from exposure during recreation include *Norovirus*, rotavirus, adenovirus, *Giardia lamblia*, *Camplyobacter jejuni*, *Cryptosporidium* spp. and *Salmonella enterica*. *E. coli* is used as the indicator pathogen in surface-water quality research because testing for other pathogens is more complex and expensive. Few laboratories have the capacity to test for other pathogens, and analysis can be very complex and time-consuming, and therefore costly.

It's not necessary to drink contaminated water to ingest harmful enteric pathogens. According to the standards of the Arizona Department of Environmental Quality, at certain times it may be unsafe to have "full body contact" with surface water. Full body contact refers to swimming, splashing or floating in the water. Boating can also lead to full body contact, whether intentional or not.

Accidentally swallowing a little stream water increases the risks of full body contact. Chances are good that a healthy person's immune system will help keep intestinal bacteria in balance so that she or he will not become ill from full body contact, but it is a chance and not a certainty. Very young children, old people and anyone with a compromised immune system are at greater risk.

There are no clear data showing how long *E. coli* can survive in the water or in sediments, outside of the warm, protected environment of an intestinal tract. Scientists are surprised again and again to see *E. coli* surviving under conditions that were believed to be inhospitable, but there is certainty that when the weather and the water start warming up, *E. coli* survives more easily. If there is suspended sediment in the water – muddied water from rains or from vehicles or animals or people stirring up the stream bed or eroding the banks – *E. coli* is assisted by the presence of those sediments, which it attaches to and travels with. Runoff from heavy summer storms can deposit fecal matter along with sediments directly into the stream, creating an environment that can sustain pathogenic life within the stream itself.

Many people, learning about this research project, have said, "But the river is self-cleaning!" In some ways this is true: particularly after significant rainfall, a river flushes out a great deal of the material. But all that material goes somewhere, and along the way downstream are the Gila Box National Conservation Area – a popular recreation site – and many agricultural fields. Moreover, this self-cleaning is far from instantaneous. GWP's research shows that *E. coli* remains at unsafe levels in the rivers for weeks after the summer rains begin.

Scientists know for certain that a few of the *E. coli* bacteria in cow intestines can be harmful or fatal to humans that ingest them. Notorious recent cases of poisoning from commercial packaged spinach have been traced back to irrigation water contaminated by bovine fecal matter. Scientists also know for certain that human intestines carry a few bacteria, viruses, amoebas and parasites that can be harmful or lethal to another human. That's why they are so concerned about disposable diapers left near public waters.

And, of course, all warm-blooded wildlife also carry *E. coli* in their intestines and disperse it into the environment all the time. ADEQ is not concerned with removing wildlife from our rivers—only with controlling the contributions that are influenced by human activities. These may include direct contributions of human fecal matter, fecal matter from pets and livestock, and increased wildlife fecal contributions attributed to recreational activity, such as trash or food scraps that attract wildlife.

Typical Sources of Contamination in the San Francisco-Blue Rivers Watershed

I. Recreation

In warm weather, when there is an increase in the recreational use of surface waters, the presence in the water of pathogens harmful to humans increases. Public health experts are most concerned about waterborne pathogens that originate from the feces of humans and cattle.[2] In studies of recreational waters, these are shown to cause more illness in humans than those originating from other animals.

Fig. 1 Unmanaged recreation on the San Francisco River, May 2010

Even in a well-managed water recreation area equipped with toilet facilities, human fecal matter may enter the stream in small quantities, particularly when there are babies and very small children playing in the water. On the San Francisco and Blue River, where there are no toilet facilities, the potential for human fecal matter in the water is far greater. Unmanaged rural recreational areas with no facilities generally have informal toilet zones not far from campsites, where it is common to see human fecal matter and toilet paper exposed to the air. The contents of such areas are often washed into the streams, either by rain flowing over the surface of the land or by high water caused by upstream precipitation and/or snowmelt. The San Francisco and Blue Rivers are particularly vulnerable to influences from open toilet areas because of steep canyon walls that contain all human activity very close to the mainstem streams.

The two rivers are also affected by lack of facilities for trash disposal. Used disposable diapers are a fairly common sight in popular recreation areas in the watershed. Babies and small children carry as many pathogens in their intestines as older people, so used diapers can present real health hazards to others, especially when left near the water where they can easily be washed in by rain or rising water levels.

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[2] P. Standish-Lee and E. Loboschevshy, Protecting public health from the impact of body contact recreation, *Water Science and Technology* Vol 53 No 10 pp 201-207; A. Soller, M.E.. Schoen, T. Bartrand, J.E. Ravenscroft, N.J. Ashbolt, Estimated human health risks from exposure to recreational waters impacted by human and non-human sources of faecal contamination, *Water Research* 44 (2010) pp 4674-4891.

Human fecal inputs to recreational waters rise and fall with the seasons. Water-based recreation is far more common during the warm months of the year, with far more full-body contact occurring than in cooler seasons. Since warmer water temperatures support the survival of *E. coli* and other pathogens outside of the intestines of host animals, the late spring through early fall months tend to be the times in which pathogen numbers are highest in recreational waters.

II. Livestock watering

For more than a century, cattle and sheep ranchers in the Gila River watershed have taken advantage of natural watering sites used by wildlife. Perennial streams like the San Francisco and Blue Rivers are year-round resources that, until the last 15 to 20 years, were available to livestock with few restrictions. In the uplands above the mainstem streams, various kinds of tanks hold gravity-fed spring water or trap rain water as it runs down canyons and draws, again concentrating both livestock and wildlife in small areas where water is available usually year-round. Fecal material from these areas is carried during rainstorms down the ephemeral drainages to the rivers.

Livestock watering is still common in the San Francisco-Blue watershed, though access has been increasingly restricted in recent years by the U.S. Forest Service and the U.S. Bureau of Land Management. This rollback of grazing and watering permits has affected some reaches of the San Francisco and Blue but has left others open to livestock watering.

III. Wildlife

The San Francisco-Blue watershed is dominated by wilderness, with wildlife naturally relying upon perennial streams for watering. Many kinds of wildlife that frequent the streams are assumed to contribute enteric pathogens from their fecal matter to the water.

Many kinds of wildlife will tend to concentrate around watering tanks created in the uplands for livestock, as described above, leading to more wildlife fecal contributions related to human activity. Also as noted above, human recreation also increases wildlife presence in an area because of trash and food scraps.

E. coli is passed into the environment from the intestines of warm-blooded animals, including humans. Fecal contributions to the environment by humans and cattle are most often linked by scientists to illness in humans who have ingested recreational water. Other pathogens potentially dangerous to humans if ingested may be contributed by birds as well as by mammals. For example, in 2006 an Arizona man became ill with vibrio cholera following full-body contact with Gila River water. ADEQ's investigation did not reach a conclusion as to the source of the bacteria but included among its hypotheses that the bacteria could have been introduced to the watershed by migrating waterfowl.[3]

IV. Faulty or sub-standard septic systems

A few longtime residents of Greenlee County have reported that at least two domestic sewage pipes emptied directly into the San Francisco River upstream of Clifton in years gone by. There is no trace of those pipes on the San Francisco today, but there is a question as to whether older habitations on either river that are outside of municipal sewage systems (as all the habitations on

[3]Arizona Department of Environmental Quality, Arizona Department of Health Services, *Gila River Vibrio cholerae Investigation* (2007) pp 10-11 http://www.azdeq.gov/environ/water/assessment/download/vibrio.pdf

the Blue River are), might have inadequate septic systems. Because there have been no *E. coli* exceedances recorded on the upper Blue River except one following the Wallow fire which we believe to be anomalous (see below), local residents have not wanted to engage in testing for septic problems. Questions remain about a handful of outlying properties on the San Francisco and lower Blue Rivers, but land owners there similarly are not interested in investigating. In both cases there is no simple way to distinguish possible contamination from inadequate septic systems from that which comes from surface runoff during the summer recreation season.

V. Fire

Fire had not been a significant factor in the San Francisco-Blue Watershed in recent years, but that changed dramatically in June of 2011 when the Wallow fire devastated some 535,000 acres in Arizona and New Mexico, an area comparable in size to the state of Rhode Island. Multiple areas of the upper San Francisco-Blue system were severely burned: the slopes feeding the San Francisco River headwaters around Alpine, Arizona, as well as the riparian corridor just upstream of Luna, New Mexico, and well over 50% of the western side of the upper Blue River watershed in Arizona along with small portions of the eastern side. Several zones on the western side of the upper Blue were classified as severely burned, including portions of the Blue Primitive Area, which is not accessible for ground-based restoration efforts. Residents of the upper Blue River would have lost their homes but for the skill of the firefighting teams whose back-burning operations saved a number of dwellings.

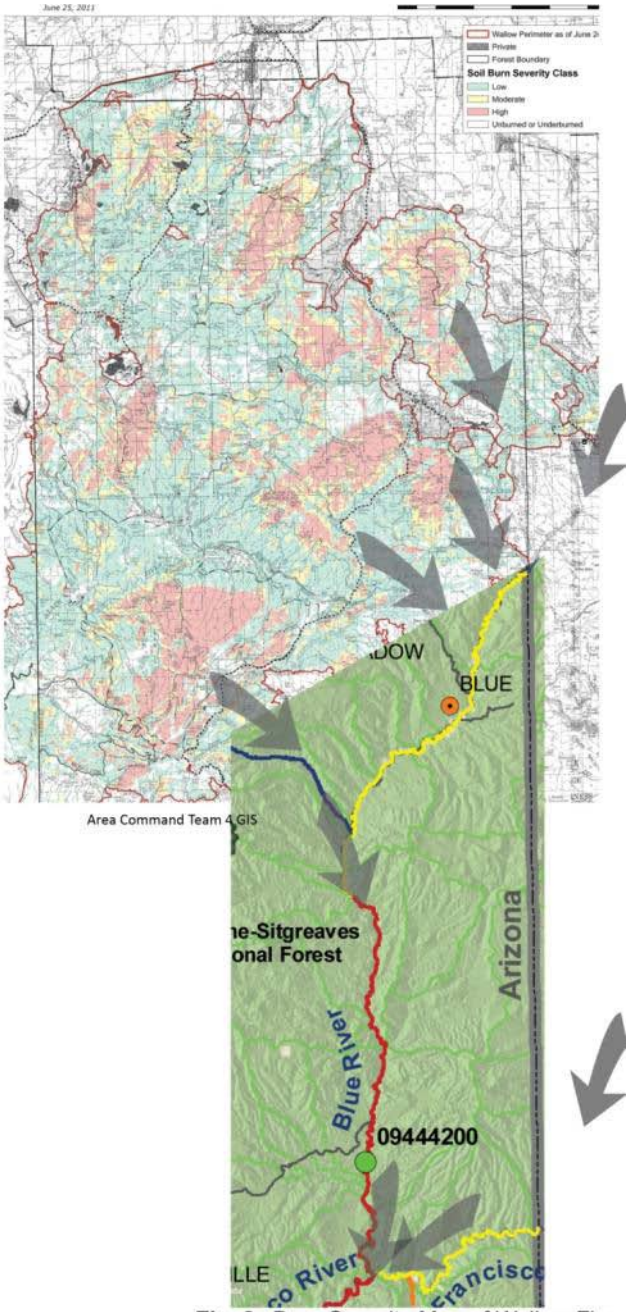


Fig. 2 Burn Severity Map of Wallow Fire, Drainages into Blue and San Francisco Rivers

Approximately 90% of the San Francisco-Blue Watershed in both states is managed by the U.S. Forest Service as the Apache-Sitgreaves and Gila National Forests. According to the Forest Service Southwestern Region Fire/Fuels report on the Wallow fire[4], a combination of low 2010-2011 winter precipitation, high loading of fine grass fuels remaining from the previous year, and forest and range vegetation far denser than the

[4] http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5333354.pdf

historical range of variability for fuel conditions, created conditions for uncharacteristic fire intensity and severity. Apache-Sitgreaves Forest Supervisor Jim Zorne has warned downstream residents that for some years to come flows will be increased during significant rainfall events: he said to expect four to five times normal flows during such events due to the fire's impacts on slopes in the watershed.

The fire's aftermath had pronounced social impacts over the summer of 2011. First were coordinated efforts to prepare for catastrophic flooding, which occupied county personnel for weeks. The summer monsoon storms came in a dispersed fashion and were relatively light, so flooding occurred only in the upper Blue after one early event. But the threat of high water remained, with so many upstream riparian area slopes destabilized by the fire. In addition, recreation on both rivers was curtailed throughout the summer of 2011 by the condition of the river and its banks. Even the lower San Francisco, many miles from the fire's boundaries, was dense with heavy, ash-colored sediment and lined with fish corpses, which altogether made the immediate banks as unattractive for recreation as the stream itself. Fishing came to a complete halt and both camping and recreational OHV use were significantly down from the prior year. By summer's end both the stream and the banks were beginning to appear normal again, but the high recreation season was over.

While some forest fires may bring biological benefits to a riparian region over time, Dr. Phil Guertin of the University of Arizona School of Natural Resources and the Environment states that the Wallow fire's extraordinarily high intensity created sterile zones in the upper watershed that would be very difficult to re-vegetate and hence would remain highly unstable, affecting both sedimentation and water chemistry with every run-off event for months and even years to come. Retired District Forest Ranger Frank Hayes, now head of the Greenlee County Firewise program, has personally investigated many areas affected by the Wallow fire and concurs with that opinion. Post-fire runoff can increase nutrients in streams, especially nitrate and phosphorus, which is transported with sediments. Higher nutrient levels in the stream are well known to promote the growth of *E. coli*.

As of this writing, the Whitewater-Baldy Complex fire is burning mountainous tracts of the San Francisco River watershed in New Mexico. Summer 2012 surface flows into Whitewater Creek will enter the San Francisco River near Glenwood, New Mexico. The potential for a destructive Sediments and ash from both the Wallow and the Whitewater-Baldy fire areas could hit the San Francisco River more or less simultaneously. Based on *E. coli* test results following the Wallow fire in 2011, it is reasonable to anticipate unusually elevated *E. coli* levels in the San Francisco River again in 2012.

Land Ownership and Uses Map

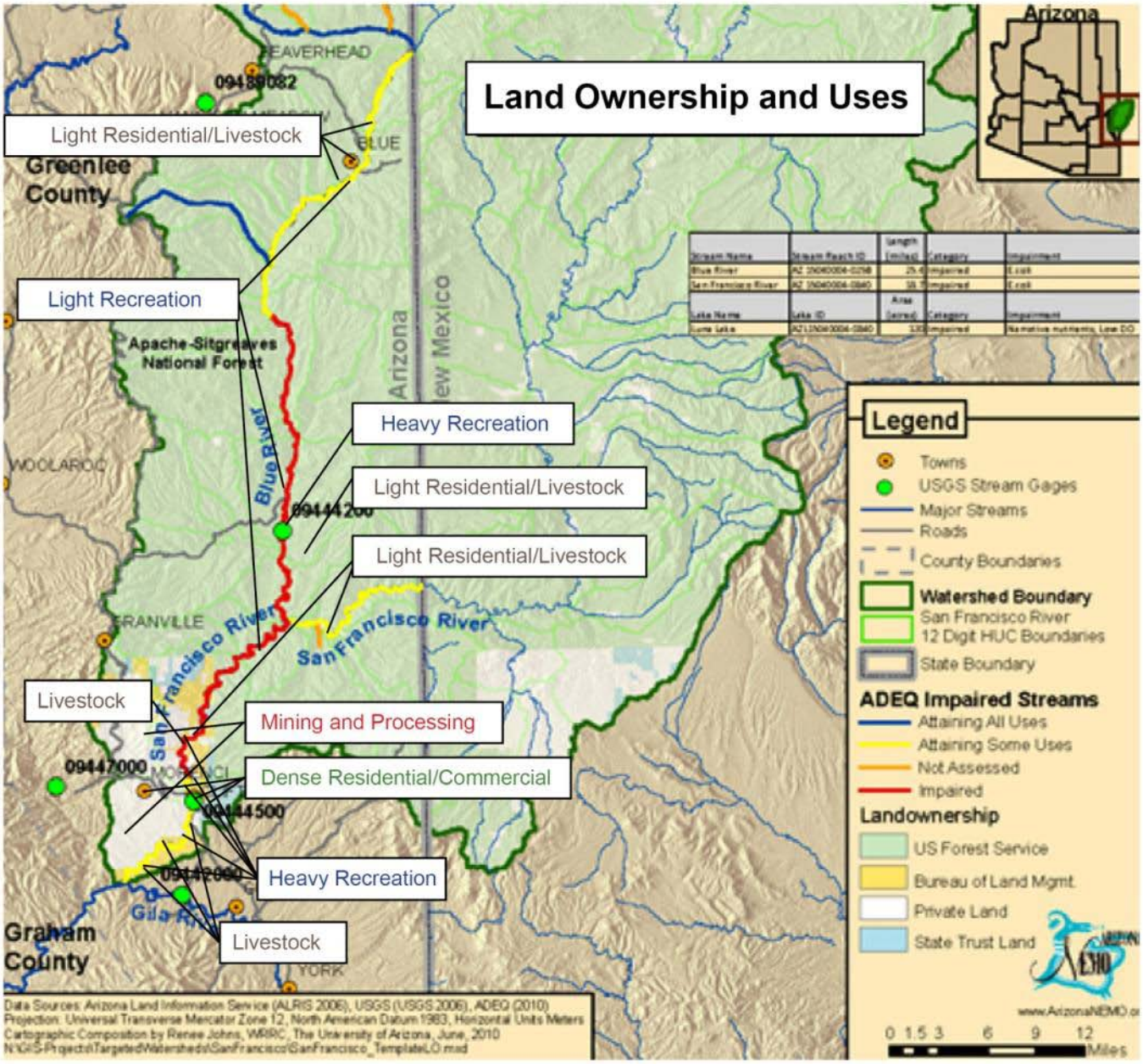


Fig. 3 Map of Land Ownership and Uses

The Watershed: Land Uses, Topography, Physical Setting and Hydrology

The 2,700 square-mile San Francisco-Blue Watershed is dominated by undeveloped mountainous tracts. It is forested with Ponderosa pine, spruce and fir at higher elevations, and juniper, cedar and piñon at lower elevations. Riparian areas are richly vegetated with cottonwoods, native willows, sedges and grasses. Grassy high pastures have evolved into semi-arid mixed high desert vegetation due to a combination of drought and historic overgrazing by cattle, sheep and goats. With elevations ranging from 3400 to 8000 feet, the county is served by a spare network of two-lane highways traversing mountain ranges, often with tight switchbacks and severely low speed limits.

In pre-historic times, Native Americans lived along the rivers seasonally to take advantage of excellent hunting grounds, and their cave dwellings are easy to spot in rock mountain faces. European-Americans are first recorded in the watershed in 1824, when trapper James Ohio Pattie led a small band up the waterway, feeding on wild turkeys and killing beaver for their pelts. Pattie gave the San Francisco River the name it has today, but he left disappointed when beaver stocks proved not to be self-replenishing. Small Apache tribes dominated the area when European-Americans first arrived, but within a half-century the Apache were confined to reservations. Ironically the San Francisco River was contained within the borders of the White Mountain Apache Reservation in an 1872 map, but a map produced two years later shows that the reservation had shrunk to exclude the watershed, most likely because of the gold deposits discovered along the river.

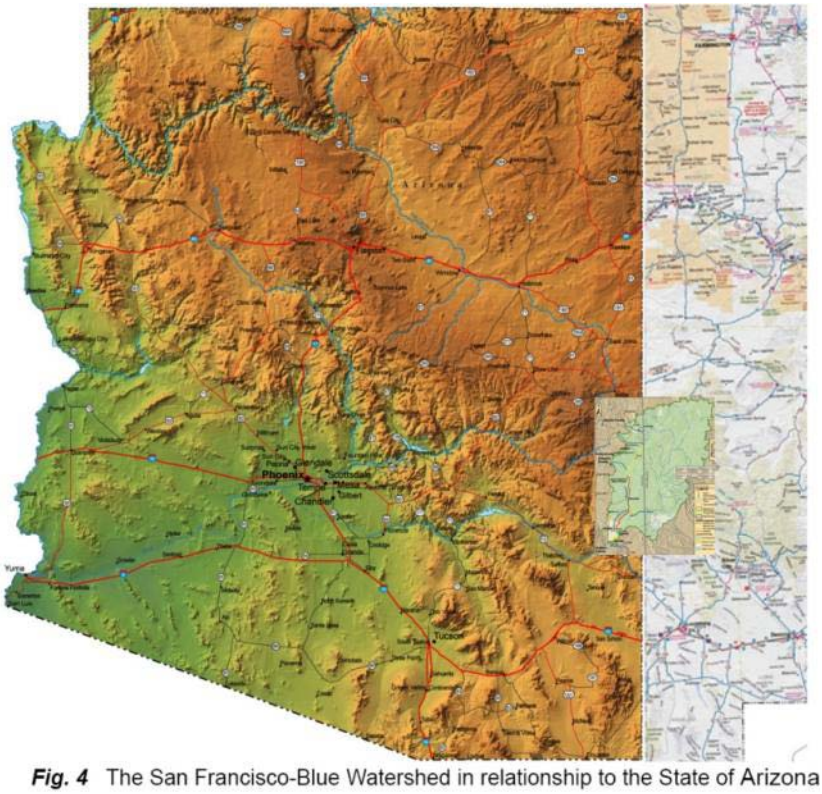


Fig. 4 The San Francisco-Blue Watershed in relationship to the State of Arizona

Pioneer ranchers were settling on both rivers by the mid 1880's, using the streambeds themselves as roadways. By the accounts of their descendents, these brave and willful entrepreneurs were passionate land stewards. Yet there is ample documentation of over-grazing – often blamed on some "Texas cattlemen" – that, compounded by severe drought that drove surviving livestock toward the shrinking streams, damaged some areas so profoundly that they are only now recovering.

In the same period that pioneers were arriving in the upper river valleys, the town of Clifton downstream arose as the hub of one of the Southwest's biggest copper mining districts. This further impacted the mountainous reaches, which were deforested for building timbers and smelter and fire wood.

In the 1990's as the U.S. Forest Service radically reduced the numbers of cattle permitted to graze on lands they managed. Despite some resistance from local cattle growers, this policy remains in place.

Mining and cattle ranching remain the dominant land uses today in the watershed. Small-scale mining continues here and there along the lower San Francisco. The great pit mines at Morenci have hollowed out the slopes just beyond the high ridge that is one part of the San Francisco watershed's western boundary, but this activity is not visible from the watershed, nor is there any known environmental consequence to the river at this time.

The San Francisco watershed's hydrology dictates that its residents live in a state of disaster preparedness at all times, or face the consequences of being unprepared. High water events are common in the region as a heat wave suddenly melts an upstream snowpack, a fall hurricane arrives, or a big summer or winter rain sends a blast of water down the narrow river canyons. Tables 1 and 2 below will allow the reader to compare recorded flows during floods of the San Francisco River to 10-, 50- and 100-year flood flows calculated in various studies.

Table 1. Peak discharges for 10-, 50- and 100-year floods

From 1988 Greenlee County Design Memorandum, Hydrology section

Discharge Frequency Comparison

San Francisco River at Clifton, Arizona

	Planning Assistance Study (1977)	Upper Gila River Study (1982)	Present Study (1988)	
	Peak Discharges, ft_3/s			
SPF	167,000	----------	167,000	
100-Year	84,100	110,000	120,000	(130,000*)
50-Year	63,200	80,000	84,000	(89,000*)
10-Year	28,000	32,000	32,200	(33,000*)

* Peak discharge based on expected probability adjustment.

Table 2. Highest recorded discharges during high water events above 20,000 cfs in Clifton, Arizona

From U.S. Geological Survey records at www.usgs.gov

12/3/1906	70,000 cfs
1/13/1949	24,100 cfs
12/23/1965	30,500 cfs
08/12/1967	34,700 cfs
12/19/1978	56,000 cfs
10/02/1983	90,900 cfs
1/11/1993	20,600 cfs
1/18/1993	42,900 cfs

Fig. 5 Clifton on January 19, 1916, *Courtesy Greenlee County Historical Society*

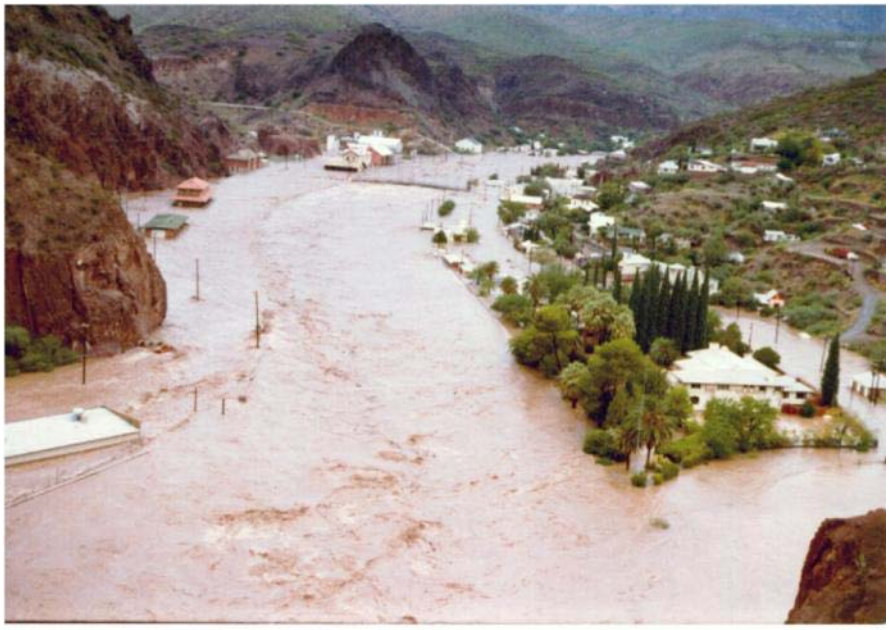


Fig. 6 Clifton on October 2, 1983, *Courtesy Greenlee County Historical Society*

Impaired Waters

Impaired Waters Summary

ADEQ initiated its Targeted Watersheds program in 2008 to empower local communities to determine and address the sources of water pollution in their areas. The Gila Watershed Partnership applied that year for one of the first Targeted Watershed grants, based on strong advocacy by the Greenlee County engineer and others who wished to ensure that thorough scientific research would drive any water quality improvement programs on the San Francisco and Blue Rivers. ADEQ awarded GWP a Target Watershed grant for the San Francisco and Blue Rivers in 2009, quoting its Acting Director in a press release, "Eventually we hope to remove the San Francisco and Blue rivers from ADEQ's list of impaired waters." That is exactly GWP's goal.

As noted earlier in this document, *Escherichia coli—E. coli*—is the pollutant of concern in this watershed. No other suspected impairments arose in the course of GWP's research. GWP's field work confirmed both spatial and temporal patterns of *E. coli* exceedances that emerged from previous sampling data accumulated by ADEQ. GWP's research also documented suspected non-point sources of the *E. coli* contamination, and ruled out other possible sources.

For its research, GWP used all of the San Francisco and Blue River exceedance sites in ADEQ's records as starting points. Research over the next two years showed exceedances occurring regularly under conditions similar to those of nearly all exceedances recorded in the past, specifically the combination of recent surface flows and warm water temperatures.

GWP attempted to discern the boundaries of river reaches where *E. coli* exceedances were occurring. It was possible to show that exceedances were not normal in the Blue River above the area listed as impaired for *E. coli*, confirming ADEQ's earlier data. It was not possible to sample in upstream reaches of the San Francisco River during the warm-water season, because high flows and dangerous weather patterns prevented access by vehicle or on foot. For that reason, GWP could not establish whether there was a reach of the San Francisco River between the Blue River confluence and the easily accessed areas above Clifton where exceedances did not occur in warm weather. However, our research did establish that exceedances were common, under warm weather conditions, as far downstream as the BLM lands that lie south and west of the popular recreation area at Morenci Gulch. Many warm-weather exceedances were also recorded at other points between Limestone Gulch and the BLM lands downstream, showing that the contamination issues did not abate downstream of Limestone Gulch.

#1 Concern: Human Sources

Our data and anecdotal research both establish clearly that there is a pattern of seasonal contamination of stream water by *E. coli* from human sources. This pattern of contamination is directly related to unmanaged recreation in multiple areas. While there has been concern about possible contamination from one or more faulty septic systems in the upper part of the watershed, there are no exceedances under normal conditions – meaning specifically no catastrophic forest fires destabilizing the drainages – in those stream reaches. Therefore, sampling data do not support attributions of exceedances to faulty septic systems.

Our scientific advisors Drs. Phil Guertin and Channah Rock, in reviewing our data, have stated that they do not believe *E. coli* exceedances in the lower Blue River can be attributed to faulty

septic systems in the upper Blue region because there are no habitations for at least 20 miles upriver from the points where we have observed exceedances with human markers. By comparison, the evidence of recreation-related non-point sources is extensive and compelling.

#2 Concern: Livestock Sources

There are two main challenges regarding bovine contributions to *E coli* exceedances. Consistent bovine markers in our lower Blue samples confounded our expert WIC, since all cattle were removed from that part of the watershed nearly 20 years ago. Our investigation ruled out the possibility of bovine fecal matter traveling 20 miles downstream from the upper Blue, where we do see cattle in the stream but do not have a history of *E. coli* exceedances. But the mystery has now been solved: a new Forest Service investigation has resulted in an estimated 40 to 100 wild cattle ranging near or in the lower Blue River. The Forest Service has contracted with a local rancher for a three-phase round-up over 18 months beginning in the fall of 2012. All three round-ups will be supported from the air by volunteers from two different volunteer aviation associations. [5]

The other challenge is that cattle ranchers in the San Francisco-Blue watershed vary widely in their land stewardship practices. Some are active in our Targeted Watershed program, and have long practiced pasturing and watering regimens that do not harm riparian areas. Some have been opposed to our research and unwilling to cooperate; one of those consistently has cattle in the stream. Yet even in this case we have remained confident for some collaboration in the future. We work with unwilling ranchers not directly but through those who are interested in collaborating. The process, while slow, progresses.

Standards and Designated Uses

The Clean Water Act, passed by the U.S. Congress in 1972, is the cornerstone of surface water quality protection in the United States. The statute employs a variety of regulatory and non-regulatory tools with the goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water." The Act required that each state establish water quality standards, determine which waters within their boundaries require protection or restoration, and define "designated uses" for each water body.

The Clean Water Act requires that each water body include "fishable/swimmable" among its dedicated uses, and that the states provide for protection of native aquatic life and for safe recreation in its surface waters. The Act also spelled out three interrelated aspects of setting water quality standards for surface water bodies: 1) designating uses, 2) establishing water quality criteria (such as the maximum concentration of a pollutant allowable), and 3) developing and implementing anti-degradation policies and procedures.

Table 3 below shows the results of ADEQ's analysis of the San Francisco and Blue Rivers and their tributaries.

[5] This Forest Service round-up plan for the lower Blue River watershed was described to the GWP project coordinator by Clifton Ranger District Rangelands Manager Ben Goodin on April 27, 2012.

Table 3. **ADEQ Designated Uses for the San Francisco River and Its Tributaries[6]**

Creek	Designated Uses	Description
San Francisco River	**A&Ww**	Aquatic & Wildlife warm water
New Mexico Border to the Gila River	**FBC**	Full Body Contact
	FC	Fish Consumption
	AgI	Agriculture Irrigation
	AgL	Agriculture Livestock Watering
Tributary: Little Creek	**A&Wc**	Aquatic & Wildlife cold water
	FBC	Full Body Contact
	FC	Fish Consumption
Tributary: Stone Creek	**A&Wc**	Aquatic & Wildlife cold water
	FBC	Full Body Contact
	FC	Fish Consumption
	AgI	Agriculture Irrigation
	AgL	Agriculture Livestock Watering
Blue River	**A&Wc**	Aquatic & Wildlife cold water
Headwaters to confluence with	**FBC**	Full Body Contact
Strayhorse Creek	**FC**	Fish Consumption
	AgI	Agriculture Irrigation
	AgL	Agriculture Livestock Watering
Blue River	**A&Ww**	Aquatic & Wildlife warm water
Below confluence with Strayhorse	**FBC**	Full Body Contact
Creek to San Francisco River	**FC**	Fish Consumption
	AgI	Agriculture Irrigation
	AgL	Agriculture Livestock Watering
Tributaries: Campbell Blue,	**A&Wc**	Aquatic & Wildlife cold water
Castle Creek, Coleman Creek, Fishhook	**FBC**	Full Body Contact
Creek, Foote Creek, Grant Creek,	**FC**	Fish Consumption
Turkey Creek, Thomas Creek head-	**AgL**	Agriculture Livestock Watering
waters to Rousensock Creek,		
Raspberry Creek (no AgL),		
Strayhorse Creek (no AgL)		
Tributaries: Pidgeon Creek, Thomas	**A&Ww**	Aquatic & Wildlife warm water
Creek below confluence with	**FBC**	Full Body Contact
Rousensock Creek to Blue River	**FC**	Fish Consumption
	AgL	Agriculture Livestock Watering

[6] From Arizona Administrative Code Title 18, Chapter 11, Appendix B.

The State of Arizona sets narrative and numeric surface water standards for water quality based on the uses people and wildlife make of the water. These "designated uses" are specified in the standards for individual surface waters. Water quality is judged acceptable or impaired based on standards established to protect each designated use. [7] Arizona's designated uses include:

Aquatic Wildlife (coldwater, warmwater, effluent-dependent, or ephemeral)
Fish Consumption
Body Contact (Full or Partial)
Domestic Water Source
Agricultural Irrigation
Agricultural Livestock Watering

Every two years, ADEQ is required by the federal Clean Water Act to conduct a comprehensive analysis of water quality data associated with Arizona's surface waters to determine whether state surface water quality standards are being met and designated uses are being supported. Monitoring data used in assessments come from a variety of sources: ADEQ's field staff, federal agencies, state agencies, permitted discharge facilities and volunteer monitoring groups. Because the objective of collecting the data and data quality varies, ADEQ reviews all readily available surface water quality related data, determines if it meets credible data requirements in the Impaired Water Identification Rule, and uses the scientifically supported data for assessment determinations. EPA created five categories for reporting assessments to provide a clearer summary of states' water quality status to Congress.

Category 1: Attaining all designated uses.

Category 2: Attaining some designated uses, and no use is threatened or impaired.

Category 3: Insufficient or no data and information to determine if any designated use is attained.

Category 4: Impaired or threatened for one or more designated uses but a TMDL is not necessary because:

4A – A TMDL has already been completed;

4B – Other pollution control requirements are reasonably expected to result in the attainment of the water quality standard;

4C – The impairment is caused by pollution but not a pollutant.

Category 5: Impaired or threatened for one or more designated uses by a pollutant, and a TMDL needs to be developed or revised.

ADEQ's concern about *E. coli* levels in the San Francisco and Blue Rivers draws on exceedances recorded as far back as 1996. However, the "impaired for *E. coli*" listings for portions of the San Francisco and Blue Rivers, published by ADEQ in 2008, refer specifically to exceedances recorded in 2006-2008.

[7] The aquatic and wildlife and body contact designated uses are exclusive. There cannot be both partial and full body contact designated uses on one stream; it is one or the other.

Table 4 below shows each reach of the San Francisco and Blue Rivers that ADEQ is monitoring for *E. coli* impairment, and the status of those reaches in several other monitoring categories. "Attaining" means that a reach is meeting standards, "impaired" means that it is not, "inconclusive" is neither attaining nor impaired based on available data.

Table 4. **ADEQ Parameters of Interest and Applicable State Surface Water Quality Standards (Showing only those reaches where E. coli impairment is a parameter of interest)**

Parameter	Grab Sample	Annual or Geometric Mean	Impairment Status Based on Draft 2010 Listing
San Francisco River *New Mexico Border to Blue River*	***E. coli***	235 cfu/100 ml	FC is attaining. FBC is inconclusive. A&Ww is inconclusive. AgL is attaining. AgI is attaining.
San Francisco River *Blue River to Limestone Gulch*	***E. coli***	235 cfu/100 ml	FC is attaining. FBC is impaired. A&Ww is attaining. AgL is inconclusive. AgI is attaining.
San Francisco River *Limestone Gulch to Gila River*	***E. coli***	235 cfu/100 ml	FC is attaining. FBC is impaired. A&Ww is attaining. AgL is inconclusive. AgI is attaining.
Blue River *Strayhorse Creek to San Francisco River*	***E. coli***	235 cfu/100 ml	FC is attaining. FBC is impaired. A&Ww is inconclusive. AgL is attaining. AgI is attaining.

Source: www.azdeq.gov

FC - fish consumption
FBC - full-body contact
A&Ww - aquatic and wildlife warm water
AgI - agriculture irrigation
AgL - agriculture livestock watering

Critical Conditions

Based on water sample tests on the San Francisco and Blue Rivers between 2004 and 2008, ADEQ placed reaches of those rivers on the Clean Water Act 303(d) Impaired Waters List as impaired for *E. coli*. Essential data are shown in Table 5 on the following page.

ADEQ was not able to conduct on-the-ground investigations into possible non-point sources of those exceedance events. But field personnel had noted the presence of cattle in or near the streams. For that reason, there was interest on ADEQ's part in researching the role of livestock watering both in the mainstem streams and in drainages to those streams.

As GWP prepared its Targeted Watershed Grant application, it stressed a second factor well-known to residents of the area: unmanaged recreation on the rivers which could produce significant seasonal impacts.

Both ADEQ and GWP were concerned to know whether any aging, faulty septic systems at older, non-urban domestic sites might also contribute to *E. coli* exceedances.

Finally, wildlife are abundant on both rivers, so it would be necessary to use modern scientific testing methods to show whether human or livestock fecal contributions were significant parts of the overall *E. coli* presence in the streams.

Table 5. ADEQ Water Quality Assessment Listings for E. coli on the San Francisco and Blue Rivers 2004-2008

E. coli applicable standard 235 cfu/100 ml

Blue River, Strayhorse Creek-San Francisco River			
7/28/2004 10/27/2004 8/9/2005	14,400 cfu/100 ml 750 cfu/100 ml 620 cfu/100 ml	At Juan Miller Road At Juan Miller Road At Juan Miller Road	FBC remains impaired. No geomean exceedances. Note: ADEQ listed this reach as Impaired for E. coli in its 2008 Integrated 305(b) Assessment and 303(d) Listing Report.
San Francisco River, Limestone Gulch-Gila River			
9/5/2006 8/7/2007 12/9/2007 8/27/2008	1020 cfu/100 ml 3629.4 cfu/100 ml 816.4 cfu/100 ml 620 cfu/100 ml	Below Clifton Below Clifton Below Clifton Above Morenci Gulch	FBC is impaired. 4 single sample maximum exceedances in 3 year period. No geomean exceedances. Note: ADEQ has listed this reach as Impaired for E. coli in its draft 2010 Integrated 305(b) Assessment and 303(d) Listing Report.
San Francisco River, Blue River-Limestone Gulch			
7/27/2004 9/5/2006 10/15/2008	480 cfu/100 ml 602 cfu/100 ml 640 cfu/100 ml	Above Clifton Above Clifton Above Clifton	FBC remains impaired (2006/8). For current assessment, impaired with 2 single sample maximum exceedances over last 3 year period, 3 over course of assessment. No geomean exceedances. Note: ADEQ listed this reach as Impaired for E. coli in its 2008 Integrated 305(b) Assessment and 303(d) Listing Report.
San Francisco River, New Mexico Border to Blue River			
8/8/2005 5/18/2006 10/15/2008	576 cfu/100 ml 480 cfu/100 ml 980 cfu/100 ml	Near Martinez Ranch Near Martinez Ranch Near Martinez Ranch	FBC is impaired. 2 single sample maximum exceedances in last 3 year period but both storm related, 3 over course of assessment. No geomean exceedances.

Sources: ADEQ Water Quality Assessment by Watershed; Upper Gila; ADEQ database produced for project

Past and Ongoing Efforts to Reduce Pollutant Loading

Water Quality Improvement Projects and BMPs

Community River Clean-ups

Under the Targeted Watershed grant, GWP has organized four community river clean-up events on the San Francisco River. Each of these has had a structured component of outreach to people camping or otherwise recreating on the river. Since the first clean-up event in October of 2010, each event has produced anecdotal evidence that more and more residents out on the river are aware of these clean-up efforts, often associating them with the local community group Friends of the Frisco (which arose as a result of GWP's public outreach). Clean-up teams have also observed a steady increase in well-groomed campsites, along with a decrease in quantity of trash and obvious open toilet areas.

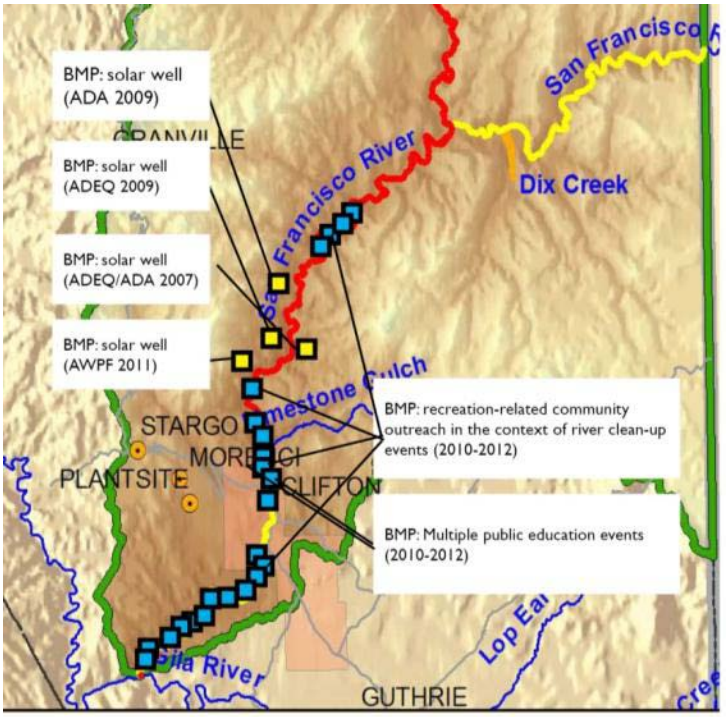
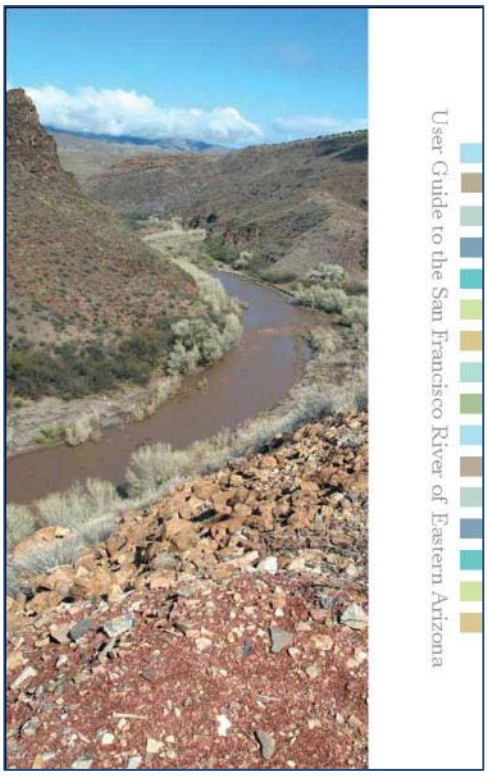


Fig. 7. Map of existing BMP sites

Though it is certain that the Wallow fire also has played a role by virtue of causing temporary decreases in recreation on the river, it is clear that many in the community are at least aware of an often very positive about a culture of river stewardship. The attendance at each major clean-up event and the support forthcoming from local businesses, organizations and governments is proof of that claim. It will be necessary to "keep the pressure on" in the near-term to reap the full benefits of this increase in awareness.



User Guide to the San Francisco River of Southeastern Arizona

In June of 2011, Gila Watershed Partnership published and began distributing a guidebook it created with help from BLM and Forest Service personnel and other local experts. The full-color 68-page book was funded through the Targeted Watershed grant and it was therefore possible to distribute it to the public at no charge. Filled with photographs and detailed maps, the guidebook covers every important aspect of recreation on the San Francisco: property ownership, wildlife, hiking, camping, swimming, boating, OHV use, fishing and hunting and more. It highlights to responsible toilet habits while recreating, explaining how to avoid contributing to fecal contamination and detailing why such contamination is potentially hazardous to health. Ten thousand copies were printed and are on display at locations across Greenlee and Graham Counties. These include all four Greenlee County Libraries, the Greenlee County Courthouse, Clifton Town Hall, the Chambers of Commerce in both counties, the Clifton Ranger District Station, the Greenlee County Historical Society Museum and the popular Chase Creek Marketplace in Clifton, and the BLM Safford District office in Safford.

Master Watershed Steward course for the San Francisco and Blue Rivers

In February of this year, GWP launched a Clifton-based MWS course specific to the sub-watershed, tapping lecturers from U of A, BLM, U.S. Fish & Wildlife Service, and the Greenlee and Graham County agricultural and environmental communities. The course includes two day-long field trips. Enrollment, with 22 fulltime students plus numerous weekly drop-ins, is higher than any of the organizers

Fig. 9. Master Watershed Steward class, Spring 2012

expected, a notable achievement in light of Greenlee County's being the least populated county in Arizona. The response to this MWS course is an indicator of rising public interest in surface water quality issues of the San Francisco-Blue watershed communities.

Off-riparian solar wells

The Kaler Ranch on the San Francisco River above Clifton, a combination of deeded land and adjacent lands leased for grazing from Freeport McMoRan, Arizona State Lands and the BLM, is the site of an ambitious, multi-stage project to create solar-powered wells and watering tanks

Fig. 10. Before and after, Kaler Ranch lease at the State Lands/BLM line

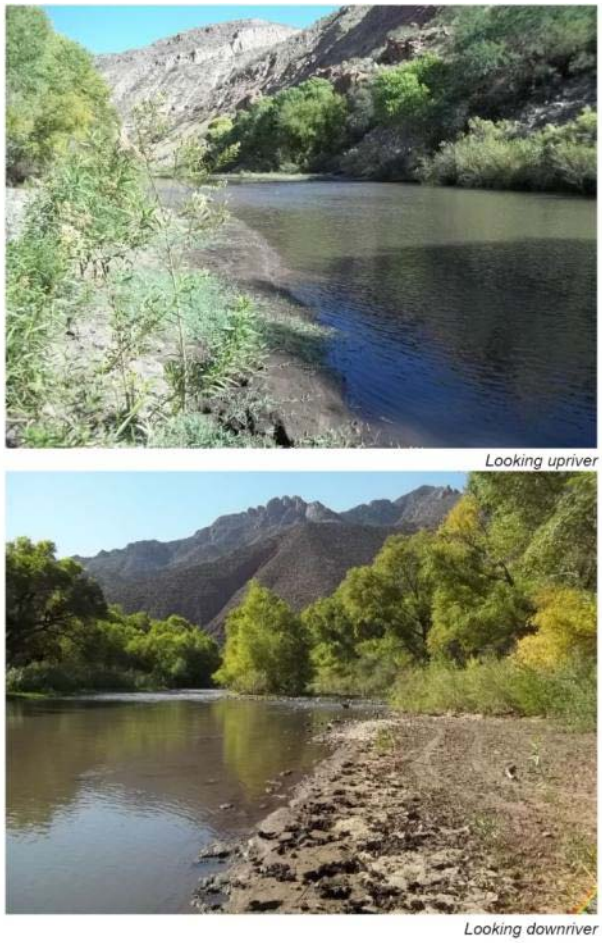


Fig. 11. Two views from one point, bottom of Kaler Ranch, Oct, 2011

outside the riparian area. Well-drilling and tank construction is now complete. The impacts to the affected riparian area were immediate and dramatic.

Recreation-related sources of *E. coli* contamination continue to enter the stream in several reaches that the Kaler Ranch has under lease, and some bovine fecal matter left in the riparian area through the fall of 2011 is still present on the surface and will be washed into the stream in future heavy rains. For these reasons the load reductions from the Kaler Wells projects will not be measurable until tests performed *after* significant surface flows and flushing are analyzed for bovine and human markers and relative contributions between the two. Dr. Channah Rock's opinion is that it may take some years for *E. coli* issues to resolve after the implementation of successful BMPs.

In the meantime, cattle on the Kaler Ranch have been removed from the stream except when crossing to a different grazing area. The vegetative recruitment for recovery on the affected reaches is captured in the photos above, both in comparative shots of one point taken in November 2010 and October 2011 and a 180˚ contrast from one photo point looking upriver into the Kaler Ranch and then downriver into the next reach.

Road Signage

Freeport McMoRan Copper & Gold management has expressed interest in coordinating with GWP on signage relating to recreation on the San Francisco River. We have been informed that FMI is considering improvements to river recreation sites on its properties. Since the beginning of this project, FMI has become much more supportive of the project, and we anticipate that their support will continue.

Together with Greenlee County and FMI, we will place high-quality, long-lasting signage along access roads, to target *everyone* headed into the river, including those who inflict the worst damage. Such people are identified in the social marketing terms as "laggards" and are at the other end of the spectrum from the "early adopters." No one expects the laggards to change overnight into good citizens. But the sign will make people aware that their behavior is under scrutiny… and that the idea that "anything goes" on the San Francisco is changing.

To finalize the content of these graffiti-resistant metal signs, GWP studied successful social marketing campaigns that addressed situations like ours, with help from the county epidemiologist who has a strong public health background.

Junior Ranger Activity Book for the San Francisco and Blue Rivers

This project is based on the great success of BLM's Junior Ranger Activity Book for the Gila Box Riparian Area. Every time our volunteer teams have gone onto the rivers to hand out trash bags and copies of our guidebook, we have also offered the BLM's Junior Ranger book to children. This colorful book, full of information and activities, was very obviously a hit with both children and parents. Our similar activity book for the San Francisco and Blue Rivers will be distributed at future clean-up events and other water quality related public education events. The BLM field office in Safford, the Forest Service Ranger Station near Clifton, and Chase Creek Marketplace in Clifton will hand out Junior Ranger badges to any child who brings in completed activity book pages. The badges will be paid for by Friends of the Frisco.

In-classroom Instruction for Elementary Students

GWP is collaborating with Graham County Cooperative Extension in presenting a group of five classroom units on surface water quality and sources of fecal and other contamination in streams in the four sixth grade classes in Morenci. There is a possibility as of this writing that the same units may be taught on the same days to the third grades in Morenci.

General Permit BMPs Normally Applied in the Watershed

In the past several years, both the Forest Service and the BLM have been fencing off areas of the watershed to prevent cattle from entering while allowing wildlife to pass over or through fences. While this has had significant impacts, some areas are still affected by wild or "trespass" cattle.

Plan development

The Background

Fig. 12. Sign on the San Francisco River Road

The San Francisco-Blue watershed is vast: 2,700 square miles spread over Arizona and New Mexico. As noted earlier, it is thinly populated, with its 4,000+ Arizona residents concentrated almost entirely in Clifton and Morenci. Most of the watershed is difficult to access under ideal conditions and impossible to reach during heavy rain or snow. Road closures and flooding are annual events. Our team also faced suspicions and fear that our project might adversely affect the lives of people in our watershed.

With ADEQ's consent, we focused from the beginning on building community involvement in the *E. coli* Targeted Watershed project, to ensure that the sources of the contamination in the rivers were correctly identified before Best Management Practices were devised. We wanted to make sure that any actions that might eventually be taken relative to surface water quality issues would be backed up by scientific facts that were fully transparent to local people, and that local people would have had a hand in designing them. We set out to achieve this by involving land owners and many other residents to the greatest extent possible in research, analysis and the long process of thinking about subsequent actions.

Our watershed's population is widely identified with cattle ranching, and in particular with wilderness ranching and its land stewardship practices that have often been passed down through generations. Because of past grazing reductions by land management agencies, any project targeting the source of *E. coli* in the San Francisco and Blue Rivers would be understandably met with some suspicion.

Another key social aspect of our project is the growing popularity of off-highway vehicles (OHVs). OHV riding is an increasingly common way to use a day off when weather permits, and the San Francisco River is a favorite destination. While many OHV riders in our watershed are clearly respectful of public lands, there are also some who damage the streambeds and banks, and leave behind open toilets and used diapers along with other trash. Open toilets and dirty diapers occur up and down the river; OHV use extends the range in which they occur.

The laws governing vehicular use of the streambed are contradictory and are fraught with political and social tensions. Several Western states are involved in controversy and litigation over applications of "RS 2477" law to user-created trails on public lands. The status of streambeds that historically served as roads until actual roads were created—as is the case for the San Francisco and the Blue—is an especially murky and contentious legal area. The Forest Service restricts vehicles on roads like the established San Francisco-Blue River trails to those with less than a 50" wheel base, but at this time they do not enforce the rule on the San Francisco (there are many vehicles that are out of compliance driving up the river on holiday weekends).

The BLM's travel management plan is still under development and there is at present no enforcement on the San Francisco.

The only sensible way to approach this complex discussion is to bring OHV riders to the process of designing solutions, along with private land owners, public land managers and other affected users of the watershed. In doing so, it will be important to reach both local OHV riders and those who travel from other areas to enjoy the San Francisco River.

How We Proceeded

Because our Targeted Watershed project was controversial, GWP moved with caution in recruiting and training volunteers and forming a WIC, always showing respect for the knowledge of those who have spent years of their lives on the rivers. After two years-plus of workshops and trainings and increasingly frank discussions, we had a group of regulars that any watershed council would envy. U of A's Dr. Channah Rock said at the end of a one workshop: "Of all the places I visit, these people ask the most stimulating questions and seem the most engaged."

Our WIC was instrumental in devising this WIP. The process for structuring the WIP was of course grounded in reviewing the results of our own research as well as the microbial source tracking tests run at the Water Quality Lab at Maricopa Ag Center. Dr. Channah Rock has continuously been a key resource to the WIC as it has undergone its reviews of our research. Dr. Phil Guertin also has been an important resource to project staff.

Important Insights

Our WIC has identified some conditions and ongoing questions, as follows:

1) In recent years the San Francisco River has become a destination for large numbers of recreationalists, and some of them have been observed by the project coordinator and several volunteers to be reckless and destructive.

2) It is generally known in the community that, due to the wild and remote nature of the area, there is little law enforcement on the rivers.

3) It appears that the San Francisco may be known outside the community as a place where "anything goes." This is the conclusion of several different local people who have studied vehicles connected to some of the worst conduct.

4) Some local people may perceive that there is no problem with the health of the riparian zone. Many locals are opposed to any kind of action regarding surface water quality in the San Francisco River. Our evidence shows that these attitudes are improving now as community outreach and education continues.

5) There are significant historical barriers to cooperation between some land owners—ranchers in particular—and federal and state agencies. It is essential to continue our successful on-the-ground collaborations, but this work must be approached with great care or overtures will be rebuffed.

6) Successful behavior change will need to be supported through *public pride* in a resource and *peer pressure* on those who abuse it.

7) It is essential that we widely disseminate information on the basics of good sanitation practices and trash disposal on the rivers, and reward people for their river stewardship.

Chapter 2 Watershed Investigations and Findings

Field Survey

The focus of investigations began with all sites on the San Francisco and Blue Rivers where *E. coli* exceedances were recorded prior to the Targeted Watershed project. Additional survey sites upstream were added to help establish where contaminants intensified or receded. At every stage of field research, the project team was concurrently accumulating observations and anecdotal information on land uses, particularly recreation and livestock watering, which also influenced target sampling site choices as the project developed.

General methods and focus of investigations

- Stream water samples: primary and control (1 liter), upstream and downstream brackets (100 ml.) tested in our local project lab using the Colilert-18[8] method for an *Escherichia coli* most probable number (mpn) of colony forming units (cfu) per 100 ml. At the project coordinator's discretion, some one-liter samples were forwarded to Dr. Channah Rock for microbial source tracking[9] (also referred to as genotyping).
- Field measurements: water and air temperature, pH, turbidity, stream width, flow.
- Conditions: weather and snowmelt (local and upstream); baseline, low flow, normal flow or high water.
- Field observations: basic topography, depth of flow and pools, dominant substrate, refuse in or near channel, algae, water clarity, vegetation density and composition, livestock watering, wildlife watering, beaver activity, stream bank erosion, fencing, habitations, camping, streambed motor crossings, and livestock, human and pet fecal waste.

Other inputs to interpretation of data and observations include the following:

- Maps supplied by NEMO's Automated Geospatial Watershed Analysis (AGWA): sediment yield and water yield.
- The observations and anecdotal material of ranchers and other land owners, as well as of those recreating on the rivers in the past and present.
- Regional field knowledge acquired over years by individuals within U.S. Bureau of Land Management and Forest Service.

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[8] Colilert-18, a product of IDEXXX Laboratories, is a test used for the detection of coliforms and *E.coli* in water samples. Colilert-18 provides results after 18-24 hours of incubation.

[9] Microbiologist Dr. Channah Rock of the University of Arizona explains the microbial source tracking aspect of this project as follows: "Microbial source tracking (MST) includes a group of methodologies aimed at ascertaining the dominant source(s) of fecal contamination in resource waters. Over the past several years, methods focused on members of the genus *Bacteroides* have been increasingly utilized in MST studies for identifying and quantifying sources of non-point fecal contaminations (Fiksdal et al 1985, Kreader 1995). *Bacteroides* have several attributes that increase their MST utility, including short survival rates outside the hosts and minimal potential for proliferation in the environment (Salyers 1984, Sghir et al 2000). *Bacteroides* also have a high degree of host specificity that likely reflects differences in host animal digestive systems (Bernhard and Field 2000, Dick et al 2005, Simpson et al 2004), and several recent studies have proposed the existence of human-specific genetic markers in *Bacteroides* and developed methods for their detection by conventional and quantitative PCR (Bernhard and Field 2000, Layton et al 2006, Seurinck et al 2005). Because PCR does not require culturing bacterial isolates, these recently developed methods have the advantage of being less labor intensive and more rapid, and consequently less expensive, than other MST approaches to the identification of human fecal pollution."

- Photographic and anecdotal documentation of seasonal recreation on the rivers by project staff and volunteers.

Since June of 2010, GWP has processed 214 water samples in Colilert-18 tests for *E. coli*. Of those, 63 samples exceeded the state water quality standard of 235 cfu/100 ml. All exceedances occurred in warm weather conditions after summer rains had begun. In areas affected by moderate to heavy recreation or livestock watering, *E. coli* levels generally remained in the exceedance range while temperatures were high, even when no rain had fallen for up to several weeks. Samples taken in cool or cold seasons invariably showed low *E. coli* levels. This suggests that, while surface runoff carrying fecal matter into the stream in warm weather appears to be causal to the seasonal jumps in *E. coli* numbers, the decline of rain in weeks following heavy summer surface run-off does not necessarily mean the end of exceedances for that season. It appears that exceedances continue to occur, though decreasingly so, when summer rains end until cool temperature cause them to fall off steeply.

E. coli numbers were higher in the summer of 2011 than in the previous summer, and exceedances were seen in more locations in 2011. This is believed to result from increased sedimentation and nutrient loading of the streams from summer rain run-off following the Wallow fire. Several severe burn areas drained and still drain directly into the upper Blue River and into the San Francisco River around Luna, New Mexico. When temperatures cooled in October of 2011, *E. coli* numbers fell as they did in the previous year.

The trends derived from GWP's field research for the presence of *E. coli* are as follows:

- One hundred percent of *E. coli* exceedances recorded by GWP occurred in the summer monsoon months between July and September, in both 2010 and 2011.
- A total of 120 samples taken in the months of October through June in 2010 through 2012 consistently produced low *E. coli* numbers regardless of location. The range of *E. coli* results from samples taken October through June in both years was 2.0 to 87.2 cfu.
- *E. coli* exceedances occurred in 29.4% of all samples taken in 2010 through 2012 (214 total samples successfully processed).
- *E. coli* exceedances occurred in 67.0% of samples taken during the months of July through September in 2010 and 2011 (94 total samples successfully processed).
- *E. coli* numbers remained low in early summer until the onset of summer monsoon rains.
- *E. coli* numbers remained high after monsoon rains tapered off, until cooler temperatures occurred in mid to late September.
- Contamination from recreation is clearly established as a cause of seasonal *E. coli* exceedances on the San Francisco River from State Lands to Morenci Gulch, based on combined Microbial Source Tracking results and field observations.
- Contamination from livestock watering in the stream is clearly established as a cause of seasonal *E. coli* exceedances on the lower Blue River in the area of Juan Miller Crossing and on the San Francisco River from just upstream of Hole in the Rock on State Lands through the Town of Clifton, based on combined Microbial Source Tracking results and field observations.
- Contamination from livestock watering in the stream is less clearly established as a cause of seasonal *E. coli* exceedances on State Lands above the upper Hole in the Rock sampling site.

Table 6 (this page and the following page) gives the reader the opportunity to compare, in brief, ADEQ's historic *E. coli* exceedance records – previously displayed as Figure X – with GWP's sampling results.

Table 6. ADEQ and GWP E. coli Exceedance Records Overview

ADEQ Water Quality Assessment Listings for E. coli on the San Francisco and Blue Rivers 2004-2008

E. coli applicable standard 235 cfu/100 ml

Blue River, Strayhorse Creek-San Francisco River			
7/28/2004	14,400 cfu/100 ml	At Juan Miller Road	FBC remains impaired. No geomean exceedances. (Note: ADEQ listed this reach as Impaired for E. coli in its 2008 Integrated 305(b) Assessment and 303(d) Listing Report.)
10/27/2004	750 cfu/100 ml	At Juan Miller Road	
8/9/2005	620 cfu/100 ml	At Juan Miller Road	
San Francisco River, Limestone Gulch-Gila River			
9/5/2006	1020 cfu/100 ml	Below Clifton	FBC is impaired. 4 single sample maximum exceedances in 3 year period. No geomean exceedances. Note: ADEQ has listed this reach as Impaired for E. coli in its draft 2010 Integrated 305(b) Assessment and 303(d) Listing Report.
8/7/2007	3629.4 cfu/100 ml	Below Clifton	
12/9/2007	816.4 cfu/100 ml	Below Clifton	
8/27/2008	620 cfu/100 ml	Above Morenci Gulch	
San Francisco River, Blue River-Limestone Gulch			
7/27/2004	480 cfu/100 ml	Above Clifton	FBC remains impaired (2006/8). For current assessment, impaired with 2 single sample maximum exceedances over last 3 year period, 3 over course of assessment. No geomean exceedances. (Note: ADEQ listed this reach as Impaired for E. coli in its 2008 Integrated 305(b) Assessment and 303(d) Listing Report.)
9/5/2006	602 cfu/100 ml	Above Clifton	
10/15/2008	640 cfu/100 ml	Above Clifton	
San Francisco River, New Mexico Border to Blue River			
8/8/2005	576 cfu/100 ml	Near Martinez Ranch	FBC is impaired. 2 single sample maximum exceedances in last 3 year period but both storm related, 3 over course of assessment. No geomean exceedances.
5/18/2006	480 cfu/100 ml	Near Martinez Ranch	
10/15/2008	980 cfu/100 ml	Near Martinez Ranch	

Sources: ADEQ Water Quality Assessment by Watershed; Upper Gila; ADEQ database produced for project

GWP Results for *E. coli* Exceedances on the San Francisco and Blue Rivers 2010-2011

E. coli applicable standard 235 cfu/100 ml

Upper Blue River			
7/16/2011	290.9 cfu/100 ml	At Steeple Creek 1	Influenced by Wallow Fire aftermath.
7/16/2011	307.6 cfu/100 ml	At Steeple Creek 2	Influenced by Wallow Fire aftermath.
7/16/2011	579.4 cfu/100 ml	At Steeple Creek 3	Influenced by Wallow Fire aftermath.
7/16/2011	272.3 cfu/100 ml	At Steeple Creek 4	Influenced by Wallow Fire aftermath.
Blue River, Strayhorse Creek-San Francisco River			
7/18/2010	410.6 cfu/100 ml	Below Juan Miller Road 1	
7/10/2011	248.1 cfu/100 ml	Below Juan Miller Road 1	Influenced by Wallow Fire aftermath.
7/10/2011	344.8 cfu/100 ml	Below Juan Miller Road 3	Influenced by Wallow Fire aftermath.
7/10/2011	248.1 cfu/100 ml	Below Juan Miller Road 4	Influenced by Wallow Fire aftermath.
8/15/2011	>2419.6 cfu/100 ml	Above Juan Miller Road 1	Influenced by Wallow Fire aftermath.
8/15/2011	>2419.6 cfu/100 ml	Above Juan Miller Road 2	Influenced by Wallow Fire aftermath.
8/15/2011	>2419.6 cfu/100 ml	Above Juan Miller Road 3	Influenced by Wallow Fire aftermath.
8/15/2011	>2419.6 cfu/100 ml	Above Juan Miller Road 4	Influenced by Wallow Fire aftermath.
San Francisco River, Blue River-Limestone Gulch			
7/12/2010	>2419.6 cfu/100 ml	State Lands at Hole in the Rock 1	
7/12/2010	>2419.6 cfu/100 ml	State Lands at Hole in the Rock 2	
7/12/2010	>2419.6 cfu/100 ml	State Lands at Hole in the Rock 3	
7/12/2010	>2419.6 cfu/100 ml	State Lands at Hole in the Rock 4	
7/21/2010	>2419.6 cfu/100 ml	State Lands at Hole in the Rock 1	
7/21/2010	2419.6 cfu/100 ml	State Lands at Hole in the Rock 2	
7/21/2010	1732.9 cfu/100 ml	State Lands at Hole in the Rock 3	
7/21/2010	1732.9 cfu/100 ml	State Lands at Hole in the Rock 4	
7/21/2010	1553.1 cfu/100 ml	State Lands Main Crossing 1	
7/21/2010	1413.6 cfu/100 ml	State Lands Main Crossing 2	
7/21/2010	1413.6 cfu/100 ml	State Lands Main Crossing 3	
7/21/2010	1413.6 cfu/100 ml	State Lands Main Crossing 4	
7/24/2010	727 cfu/100 ml	State Lands/BLM Line	
7/24/2010	1203.3 cfu/100 ml	Bottom Kaler Deeded Land 1	
7/24/2010	1119.9 cfu/100 ml	Bottom Kaler Deeded Land 2	
7/24/2010	920.8 cfu/100 ml	Bottom Kaler Deeded Land 3	
7/24/2010	1553.1 cfu/100 ml	Bottom Kaler Deeded Land 4	
7/6/2011	>2419.6 cfu/100 ml	State Lands Main Crossing 1	Influenced by Wallow Fire aftermath.
7/6/2011	>2419.6 cfu/100 ml	State Lands Main Crossing 2	Influenced by Wallow Fire aftermath.
7/6/2011	>2419.6 cfu/100 ml	State Lands Main Crossing 3	Influenced by Wallow Fire aftermath.
7/6/2011	>2419.6 cfu/100 ml	State Lands Main Crossing 4	Influenced by Wallow Fire aftermath.
8/1/2011	1986.3 cfu/100 ml	State Lands Main Crossing 1	Influenced by Wallow Fire aftermath.
8/1/2011	1732.9 cfu/100 ml	State Lands Main Crossing 2	Influenced by Wallow Fire aftermath.
8/1/2011	>2419.6 cfu/100 ml	State Lands at Hole in the Rock 1	Influenced by Wallow Fire aftermath.
8/1/2011	>2419.6 cfu/100 ml	State Lands at Hole in the Rock 2	Influenced by Wallow Fire aftermath.
8/1/2011	>2419.6 cfu/100 ml	State Lands at Hole in the Rock 3	Influenced by Wallow Fire aftermath.
8/1/2011	>2419.6 cfu/100 ml	State Lands at Hole in the Rock 4	Influenced by Wallow Fire aftermath.
9/11/2011	816.4 cfu/100 ml	State Lands Main Crossing 1	Influenced by Wallow Fire aftermath.
9/11/2011	686.7 cfu/100 ml	State Lands Main Crossing 2	Influenced by Wallow Fire aftermath.
9/11/2011	648.8 cfu/100 ml	State Lands Main Crossing 3	Influenced by Wallow Fire aftermath.
9/11/2011	727.0 cfu/100 ml	State Lands Main Crossing 4	Influenced by Wallow Fire aftermath.

(continued)

(continued)

San Francisco River, Below Limestone Gulch			
7/1/2010	261.3 cfu/100 ml	Clifton Below Old Dump	
7/21/2010	1986.3 cfu/100 ml	Below Morenci Gulch 1	
7/21/2010	1299.7 cfu/100 ml	Below Morenci Gulch 2	
7/21/2010	2419.6 cfu/100 ml	Below Morenci Gulch 3	
7/21/2010	1732.9 cfu/100 ml	Below Morenci Gulch 4	
7/23/2010	866.4 cfu/100 ml	Clifton Below Old Dump 1	
7/23/2010	686.7 cfu/100 ml	Clifton Below Old Dump 2	
7/23/2010	770.1 cfu/100 ml	Clifton Below Old Dump 3	
7/23/2010	1046.2 cfu/100 ml	Clifton Below Old Dump 4	
7/23/2010	866.4 cfu/100 ml	Clifton at North End Bridge 1	
7/23/2010	686.7 cfu/100 ml	Clifton at North End Bridge 2	
7/23/2010	770.1 cfu/100 ml	Clifton at North End Bridge 3	
7/23/2010	1046.2 cfu/100 ml	Clifton at North End Bridge 4	
8/5/2010	275.5 cfu/100 ml	Below Morenci Gulch 4	
7/5/2011	>2419.6 cfu/100 ml	At Swimming Hole Above Clifton 1	Influenced by Wallow Fire aftermath.
7/5/2011	>2419.6 cfu/100 ml	At Swimming Hole Above Clifton 2	Influenced by Wallow Fire aftermath.
8/1/2011	>2419.6 cfu/100 ml	Clifton Below Old Dump 1	Influenced by Wallow Fire aftermath.
8/1/2011	>2419.6 cfu/100 ml	Clifton Below Old Dump 2	Influenced by Wallow Fire aftermath.
8/1/2011	>2419.6 cfu/100 ml	Clifton Below Old Dump 3	Influenced by Wallow Fire aftermath.
8/1/2011	>2419.6 cfu/100 ml	Clifton Below Old Dump 4	Influenced by Wallow Fire aftermath.

Source: GWP records

Summary of findings of survey work

Prior to conducting field sampling, several preliminary activities were completed: (1) researching property ownership and land uses (2) recruiting and training both volunteers and the "community advisors" who would eventually form the project's WIC, and (3) interviewing scores of people who had knowledge of some aspect of the watershed and its streams.

A body of knowledge was assembled, corroborated by many eye-witnesses, which described sites and events to be targeted in identifying sources of bacterial contamination. There were four categories of potential contributors: wildlife, livestock, recreating people (and their pets), and old septic systems leaching sewage into the stream. By the time sampling began, the project coordinator had traveled by vehicle, on foot or by kayak through many reaches of both rivers, and had identified survey locations for the first three categories. The fourth was going to be a more difficult task: any properties that might be harboring a faulty septic system (entirely on the upper Blue River) were exactly those whose owners were unwilling to allow a sampling team through their gates. This situation has not changed, though the project's scientific advisors have recently determined that faulty septic systems on the upper Blue would not cause exceedances with human markers some 20 miles downstream on the lower Blue. Our WIC is now certain that there are no suspect septic systems affecting either the lower Blue or the San Francisco River.

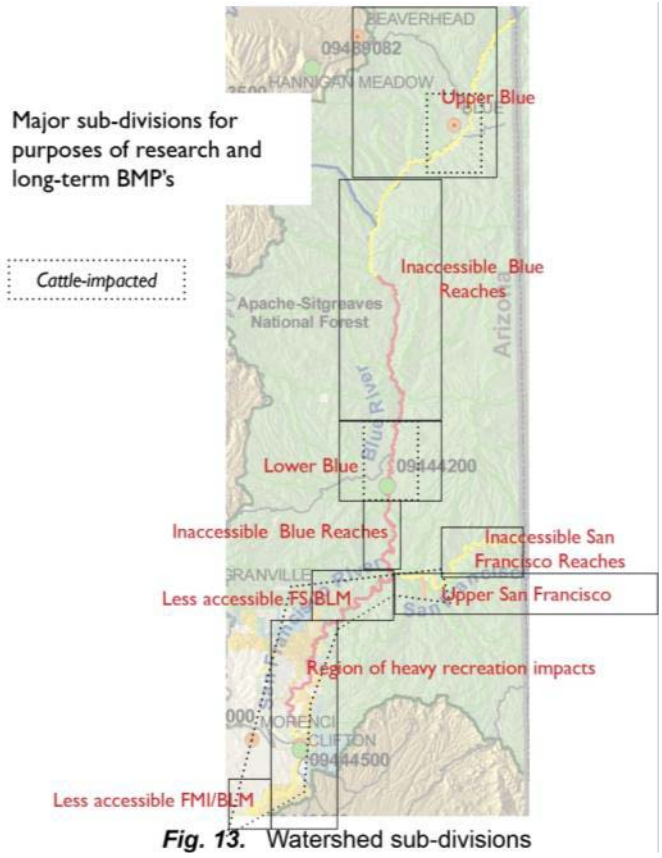

Fig. 13. Watershed sub-divisions

When survey work began in June of 2010, flows were often too low to allow for water sampling. The earliest sampling events that month produced very low *E. coli* test numbers despite warming temperatures. Early summer rains at the beginning of July created a brief window of ideal conditions (and exceedance readings in multiple locations) before a monsoon season of violent intensity overtook the region. Several survey trips had to be canceled because of high waters or flooded roads or danger from electrical storms. Others were cut short as thunder and lightning suddenly rolled in from upriver. By the time a series of sampling trips was completed in early August, the project coordinator and volunteers needed a break and the project suspended its field work until mid-October.

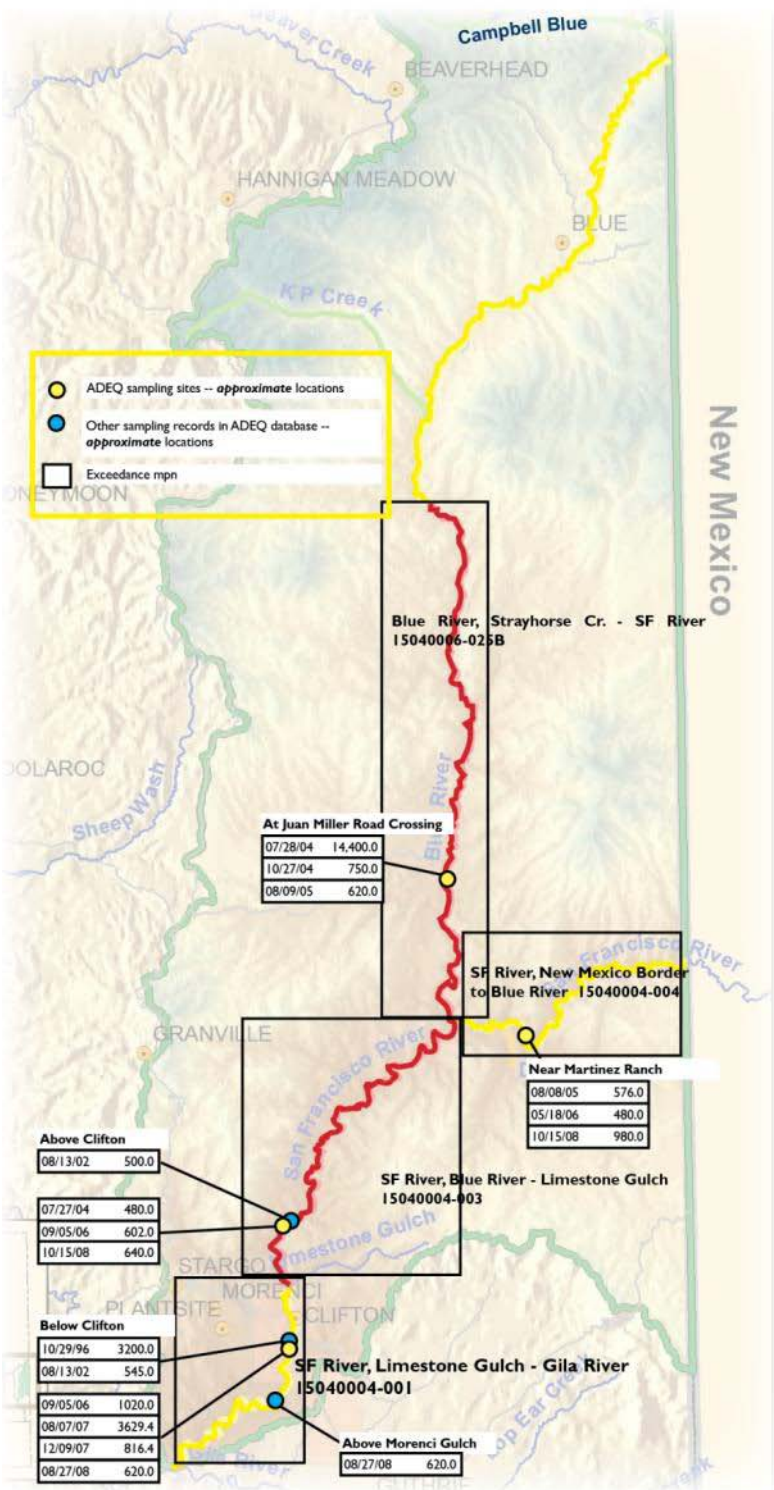

Fig. 14. *E. coli* exceedances in ADEQ records 1996-2008

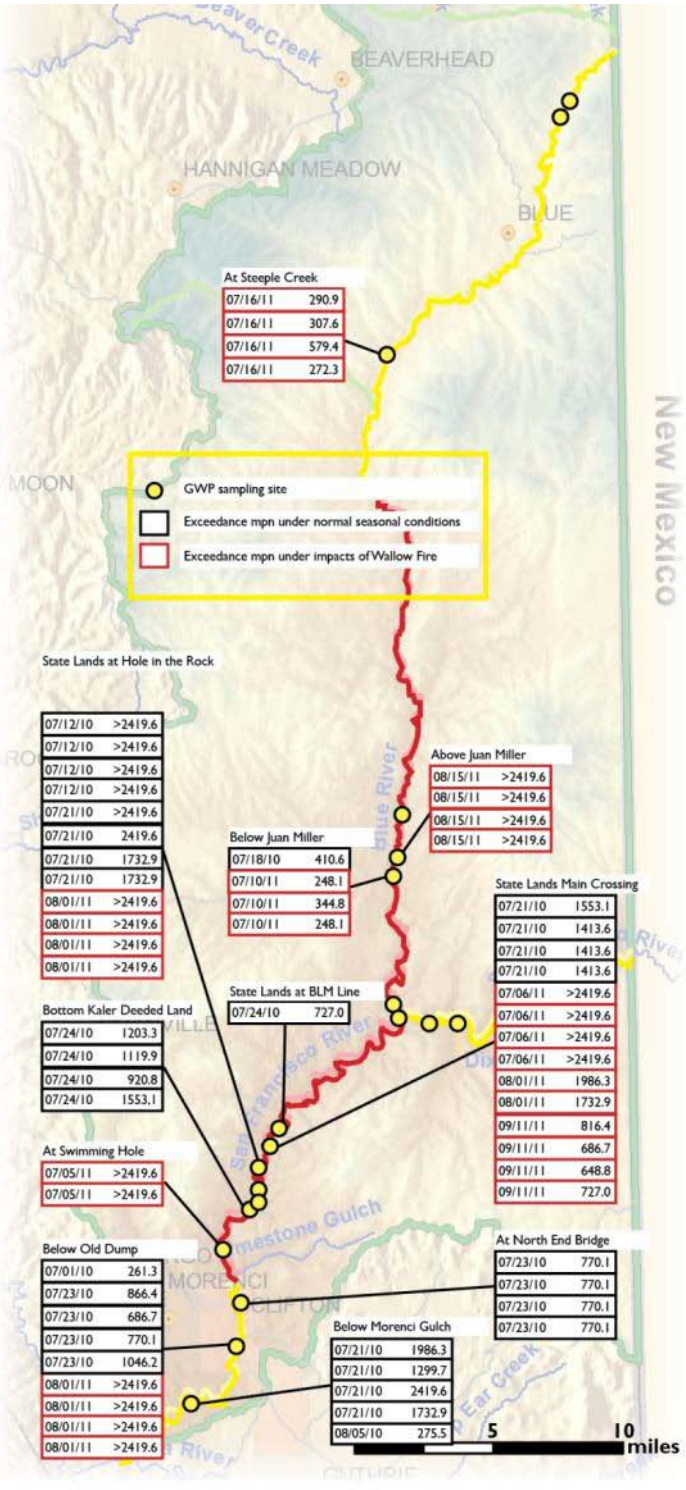

Fig. 15. Map of exceedances recorded by GWP 2010-11

The survey activity has focused mainly on the Blue River in the Juan Miller Crossing area and on the San Francisco River from the BLM line to Morenci Gulch. Sampling teams reached the upper San Francisco and upper Blue in the very late fall of 2010. Through mid-December, *E. coli* numbers at all sites remained low.

Sampling resumed briefly in early April of 2011, at which time *E. coli* numbers remained low, and then ramped up again fully when the summer rains began in July. This year the team was presented with a significant change in conditions: high sedimentation and nutrient content in the streams resulting from whole sections of the upper watershed having been severely burned in the Wallow Fire throughout the month of June. Summer 2011 sampling continued despite the high sediment and ash content—for some weeks the water was so oily with burned material that would not wash off boots or instruments that we refrained from using the FloMate wand in the stream and relied solely upon USGS gages for flow records. An indicator of the severity of the fire's effects was a fish die-off in the early weeks of the summer rains, which the BLM fisheries biologist estimated at nearly 100%.

E. coli numbers increased in the post-fire rainy weeks, nearly always exceeding the testing limit of the Colilert-18 system (2,419.6 cfu) and not receding again until early August. We also recorded exceedances in one location on the upper Blue, an area where no exceedances had ever been recorded in the past. The WIC determined that this was an anomaly caused by the extraordinary sedimentation and nutrient content descending from severely burned slopes across the upper watershed.

By October 2011, the *E. coli* numbers were still elevated but were clearly in a downward trend. In mid-November they were comparable to the previous late fall.

While the ranking system developed by Dr. Channah Rock provides relative values from the human and bovine microbial source tracking tests performed, those results do not establish the relative dangers to humans of contamination from recreation and contamination from livestock watering.

A series of four visuals addressing microbial source tracking results follows as Figures 16 through 19. They consist of four map-and-graph sets designed to highlight spatial and temporal variations in the results of microbial source tracking tests performed on water samples from the San Francisco and Blue Rivers in 2010-11.

Also see Figure 20 on page 34, a map produced by Arizona NEMO at the University of Arizona under the supervision of Dr. Phil Guertin. This map displays microbial source tracking results spatially by river miles and graphs those by human and bovine test results as well as *E. coli* CFUs.

To the immediate right of each site/date sampling event appears the "colony forming unit" (cfu) count resulting from the Colilert-18 tests performed in the project lab in Greenlee County.

The third through sixth columns display the results of tests performed by Dr. Channah Rock's staff and graduate students in the water quality lab at the University of Arizona Maricopa Agricultural Center. Each sample was tested three times. The number of "+" signs appearing represents the number of times that a positive test result occurred, i.e. one, two or three times out of three.

Allbac296 is a polymerase chain reaction (PCR) assay targeting Bacteroides species present in human, cattle, and equine feces.

Human HF183 is the test performed to detect human genetic markers.

Bovine Bac2 is a test performed to detect bovine genetic markers. This test was no longer used on our samples as of 8/15/11 (designated by "n/t" for "not taken").

Bovine CowM2 is a different test performed to detect bovine genetic markers, used on all samples.

Site and date	Colilert-18 results (cfu)	Bacteroides molecular genes: All-bac296	Human HF183	Bovine Bac2	Bovine CowM2
SFR State Lands at BLM Line					
07/24/10	727.0	+++	-	-	-
SFR State Lands Main Crossing					
07/21/10	1413.6	+++	-	-	-
SFR State Lands at Hole in the Rock					
07/12/10	>2419.6	+++	-	-	-
07/21/10	1732.9	+++	+	-	-
SFR Kaler Deeded Land South End					
7/24/10	920.8	+++	+	-	-
SFR Clifton at North End Bridge					
07/23/10	770.1	+++	-	-	-
SFR Clifton Below Old Dump					
07/01/10	261.3	+++	+	-	-
SFR Below Morenci Gulch					
07/21/10	2419.6	+++	+	-	+

Fig. 16. microbial source tracking results under exceedance conditions in 2010

To the immediate right of each site/date sampling event appears the "colony forming unit" (cfu) count resulting from the Colilert-18 tests performed in the project lab in Greenlee County.

The third through sixth columns display the results of tests performed by Dr. Channah Rock's staff and graduate students in the water quality lab at the University of Arizona Maricopa Agricultural Center. Each sample was tested three times. The number of "+" signs appearing represents the number of times that a positive test result occurred, i.e. one, two or three times out of three.

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Bovine CowM2 is a different test performed to detect bovine genetic markers, used on all samples.

		Bacteroides molecular genes			
Site and date	**Colilert-18 results (cfu)**	**All-bac296**	**Human HF183**	**Bovine Bac2**	**Bovine CowM2**
BR at Steeple Creek					
07/16/11	307.6	+++	-	-	++
07/16/11	579.4	+++	++	-	++
BR Juan Miller Above Crossing					
08/15/11	>2419.6	+++	-	-	+++
08/15/11	>2419.6	+++	-	-	+++
SFR State Lands Main Crossing					
07/06/11	>2419.6	+++	-	-	++
07/06/11	>2419.6	+++	-	-	+
08/01/11	1986.3	+++	-	-	-
08/01/11	1732.9	+++	-	-	-
09/11/11	648.8	+++	-	-	++
09/11/11	686.7	+++	+	-	-
SFR State Lands at Hole in the Rock					
08/01/11	>2419.6	+++	++	-	+++
08/01/11	>2419.6	+++	+	-	+++
SFR Clifton Below Old Dump					
08/01/11	>2419.6	+++	+	-	+
08/01/11	>2419.6	+++	+	-	++

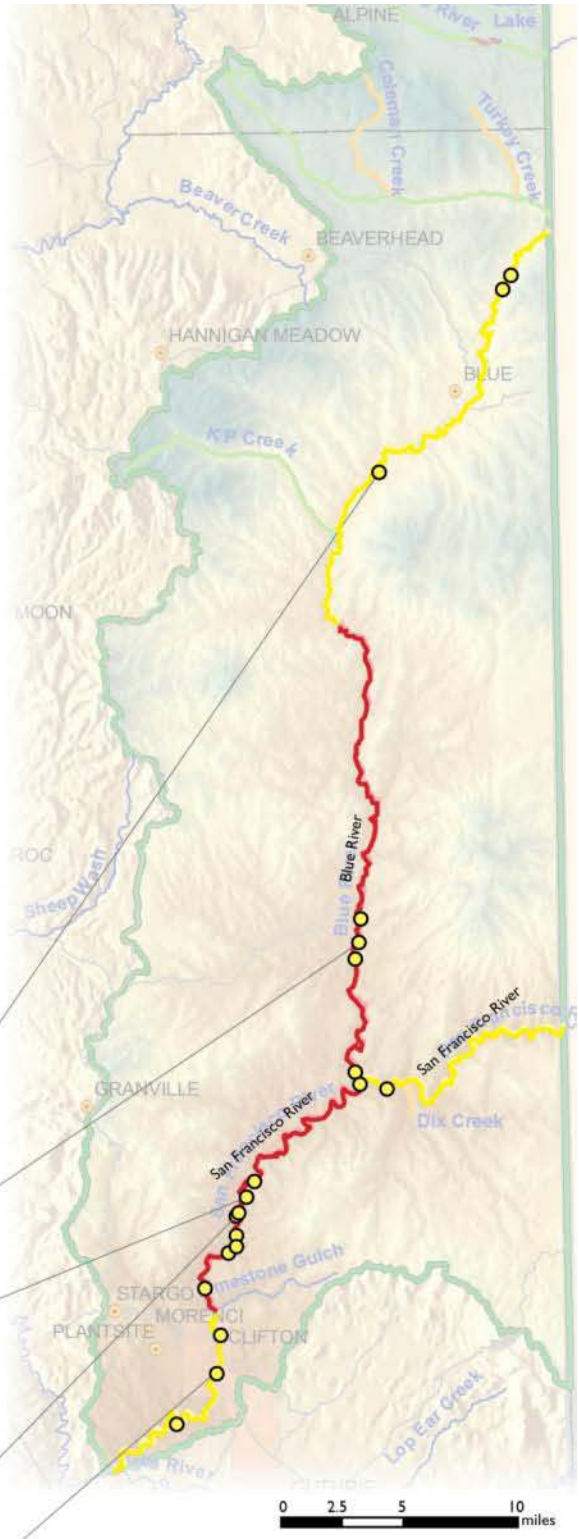


Fig. 17. microbial source tracking results under exceedance conditions in 2011

Site and date	Colilert-18 results (cfu)	Bacteroides molecular genes: All-bac296	Human HF183	Bovine Bac2	Bovine CowM2
BR Quinsler Ranch Top					
11/27/10	43.2	+++	++		+
11/27/10	43.2	+++	+		++
BR Quinsler Ranch Bottom					
10/28/10	13.4	+++	+		+
10/28/10	12.1	+++			
BR Juan Miller Above Campground					
10/26/10	58.2	+++	+++		
10/26/10	62.8	+++	+++		+
BR Juan Miller at Crossing					
07/03/10	88.2	+++	++	+++	
10/26/10	59.3	+++	+++		
10/26/10	45.9	+++	+		
BR Juan Miller Below Crossing					
11/04/10	NT	+++	+		+
11/04/10	NT	+++			+
11/16/10	64	+++	+		+++
11/16/10	77	+++	+		+
BR Above SFR Confluence					
12/15/10	30.7	+++			
12/15/10	10.3	+++			+
SFR Springs Below Glenwood NM Below Springs					
10/25/10	41.6	+++	+++		
SFR Springs Below Glenwood NM Above Springs					
10/25/10	45.7	+++	+++		++
SFR Below Martinez Ranch					
12/15/10	19.2	+++	++		
12/15/10	17.6	+++			+++
SFR Below Blue Confluence					
12/15/10	15.1	+++	+		+
12/15/10	18.1	+++			+
SFR State Lands Main Crossing					
10/17/10	14.5				+
10/17/10	19.7				+
SFR State Lands Meander Above Hole in the Rock					
11/01/10	26.9				++
11/01/10	33.5	+			+++
SFR State Lands at Hole in the Rock					
11/01/10	26.3	++			
11/01/10	14.5				
SFR Kaler Deeded Land North End					
11/09/10	32.2				
11/09/10	26.9	+	+		
SFR Kaler Deeded Land South End					
11/09/10	21.8				
11/09/10	37.5				
SFR Clifton at North End Bridge					
11/02/10	13.2	+++			++
11/02/10	19.7				
SFR Below Clifton					
11/02/10	7.4				++
11/02/10	5.2				++
Below Morenci Gulch					
11/03/10	8.5				+
11/03/10	8.5				

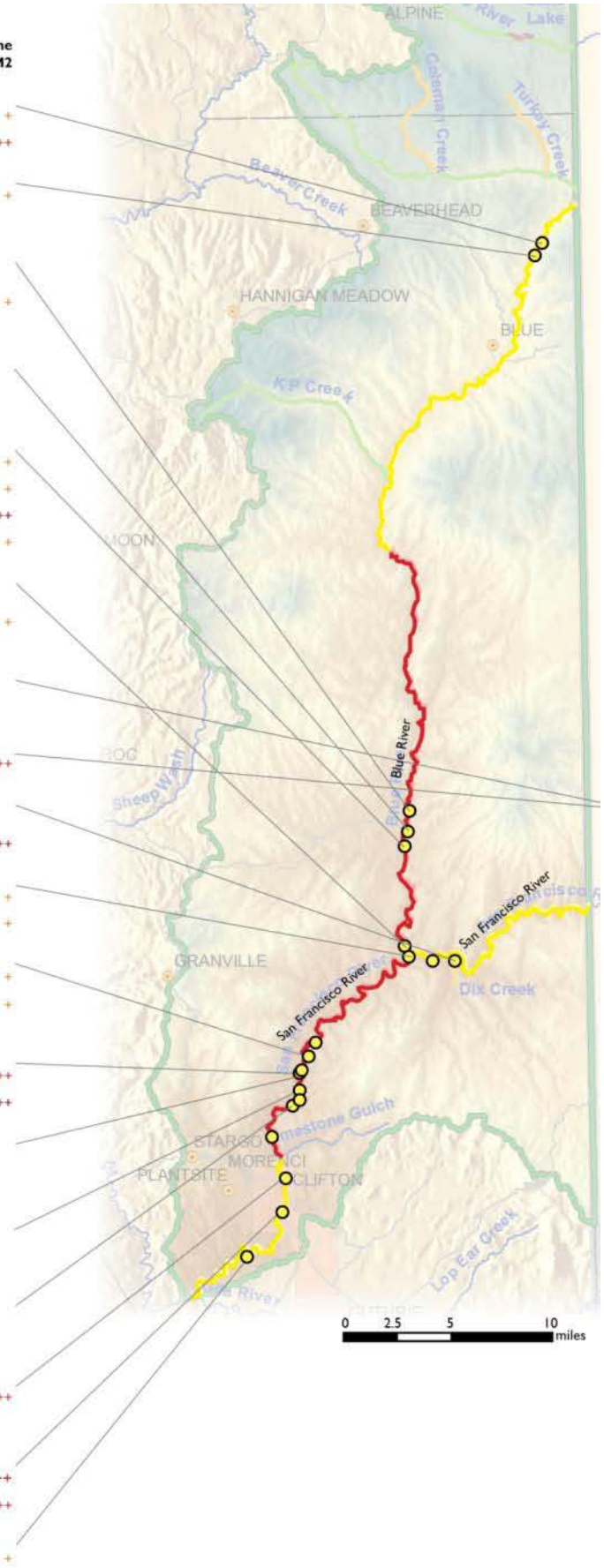


Fig. 18. microbial source tracking results under non-exceedance conditions in 2010

Please see previous page for explanation.

To the immediate right of each site/date sampling event appears the "colony forming unit" (cfu) count resulting from the Colilert-18 tests performed in the project lab in Greenlee County.

The third through sixth columns display the results of tests performed by Dr. Channah Rock's staff and graduate students in the water quality lab at the University of Arizona Maricopa Agricultural Center. Each sample was tested three times. The number of "+" signs appearing represents the number of times that a positive test result occurred, i.e. one, two or three times out of three.

Allbac296 is a polymerase chain reaction (PCR) assay targeting Bacteroides species present in human, cattle, and equine feces.

Human HF183 is the test performed to detect human genetic markers.

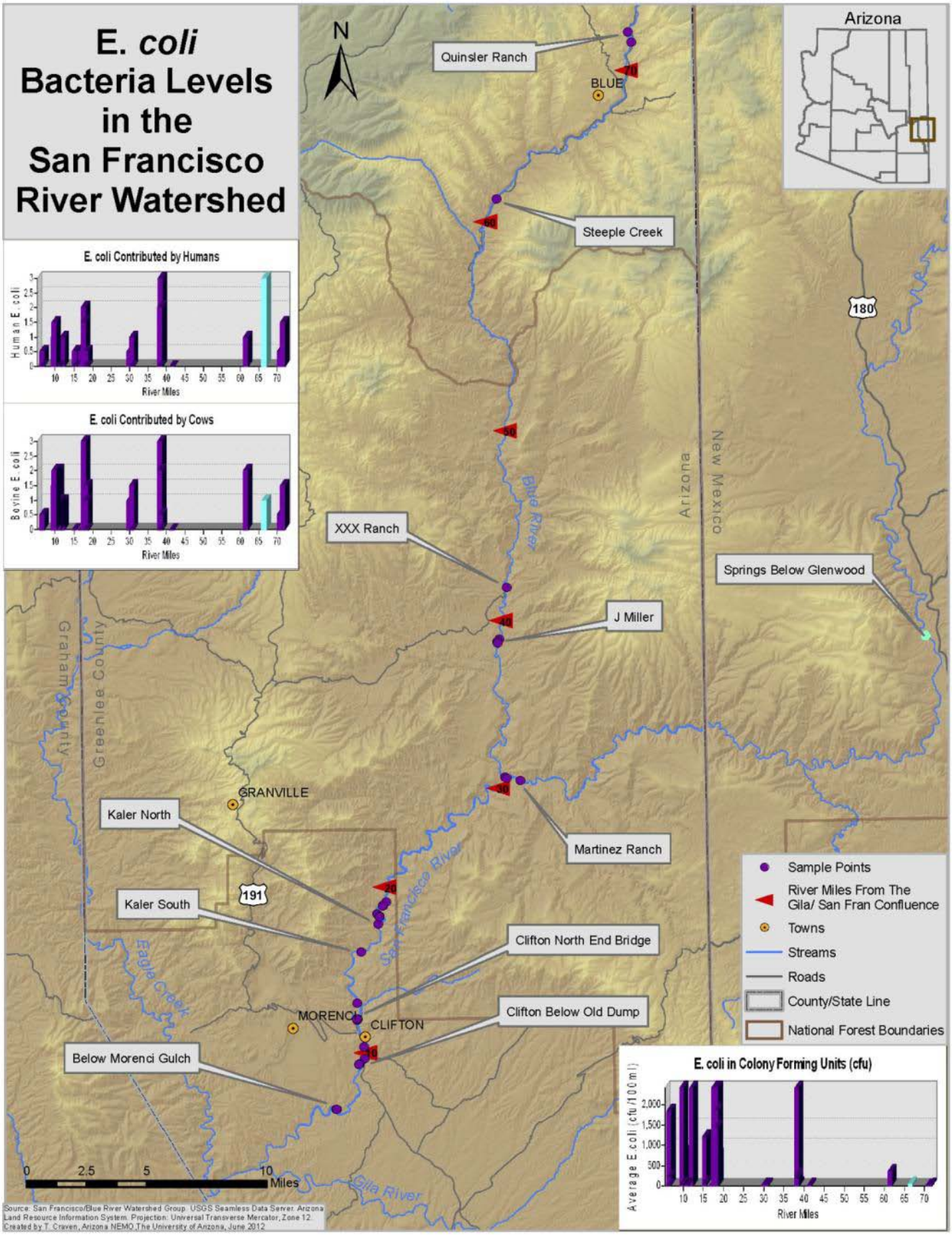
Bovine Bac2 is a test performed to detect bovine genetic markers. This test was no longer used on our samples as of 8/15/11 (designated by "n/t" for "not taken").

Bovine CowM2 is a different test performed to detect bovine genetic markers, used on all samples.

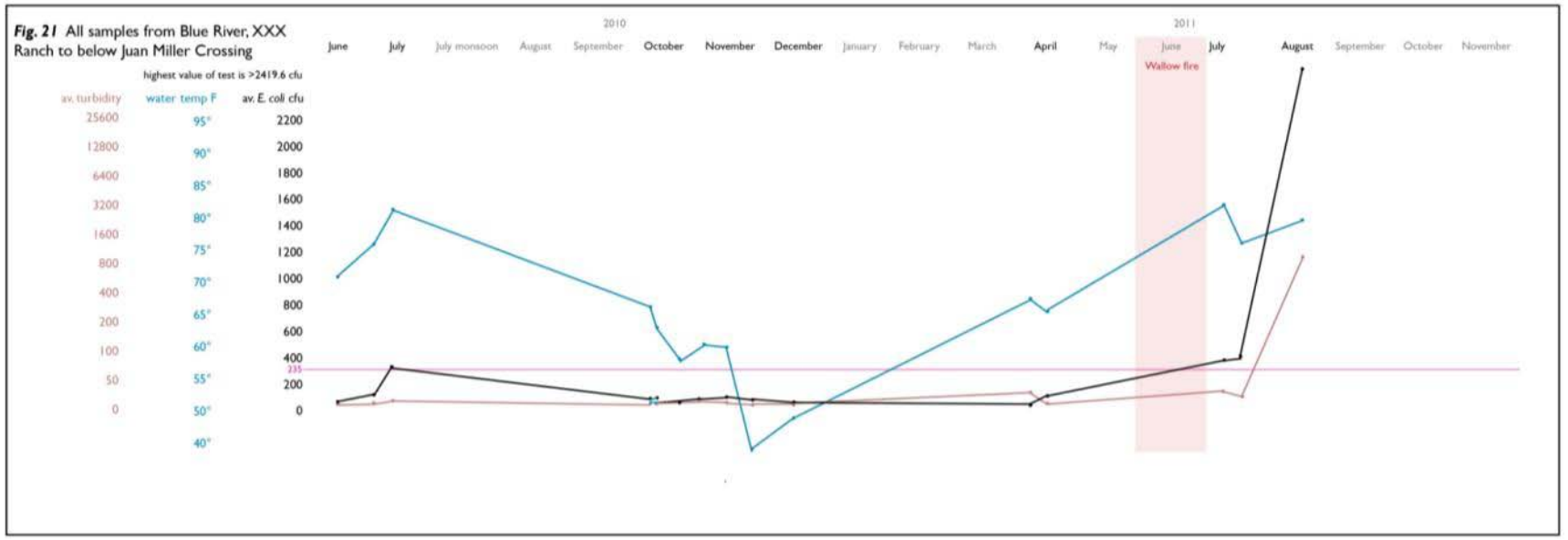
		Bacteroides molecular genes			
Site and date	**Colilert-18 results (cfu)**	**All-bac296**	**Human HF183**	**Bovine Bac2**	**Bovine CowM2**
SFR State Lands Main Crossing					
11/19/11	46.1	+++	-	n/t	-
11/19/11	37.6	+++	-	n/t	-
SFR State Lands at Hole in the Rock					
11/19/11	47.4	+++	+++	n/t	+++
11/19/11	41.6	+++	+	n/t	+
SFR Clifton Below Old Dump					
11/19/11	23.1	+++	+++	n/t	+++
11/19/11	24.9	+++	-	n/t	+

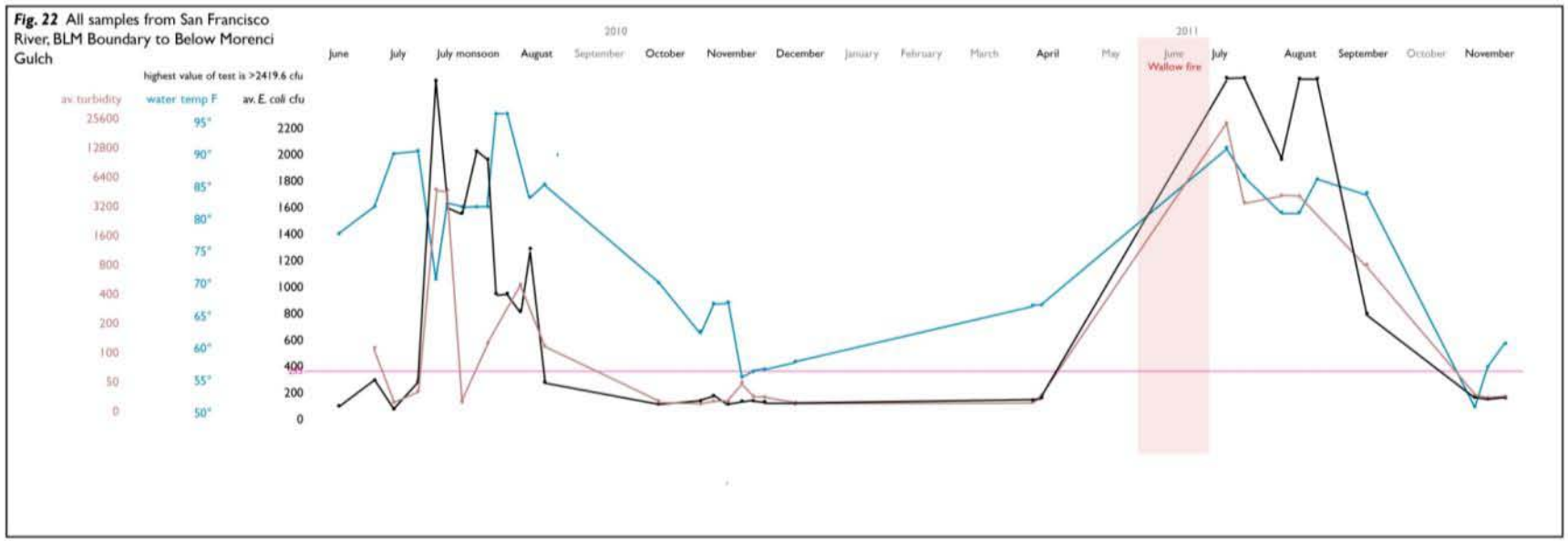
Fig. 19. microbial source tracking results under non-exceedance conditions in 2011

Fig. 20. Arizona NEMO map of microbial source tracking and *E. coli* results



The two graphs below – Figures 21 and 22 – show at a glance the relationships among turbidity, water temperature, and E. coli levels in samples taken by GWP in 2010-11. The top graph comprises all samples taken on the lower Blue River in 2010-11. The bottom graph comprises all samples taken on the lower San Francisco River in 2010.





Chapter 3 Watershed Improvement Strategy

Watershed Improvement Plan Development

Goals and Objectives

The goal of the Watershed Improvement Plan for the San Francisco and Blue Rivers is to achieve full-body contact compliance for *E. coli* in the listed impaired reaches. The plan's objectives include the following:

1) Demonstrate that field research has satisfactorily identified sources of *E. coli* exceedances in both rivers;
2) Clarify social factors pertinent to *E. coli* contamination and to measures to reduce *E. coli* loads;
3) Detail and prioritize Best Management Practices to reduce loads.
4) Recommend future monitoring and evaluation disciplines sufficient to measure reductions in *E. coli* levels in the listed reaches, and to characterize the relationships of those reductions to changes in human and/or bovine fecal inputs.

Methods

The Watershed Improvement Plan for the San Francisco-Blue Rivers watershed has been in development since the fall of 2009. Field research began in 2010 and was conducted with the ongoing involvement of community members. The field work itself involved volunteers in virtually every instance, and the data and observations were reviewed regularly by community members (see Watershed Improvement Council, below). Technical experts were recruited for training and education to help build public participation in and understanding of the project's surveys.

Because the sources of *E. coli* contamination appeared from the beginning to be related in large part to the conduct of visitors to the rivers, GWP also emphasized broad engagement of the community in river issues. A local volunteer group, Friends of the Frisco, was organized in response to GWP's outreach. Their 200+ volunteer members participate in clean up events, and distribute GWP's *User Guide to the San Francisco River* and trash bags. GWP's extensive outreach has been a key component to the behavior change this project has produced.

Watershed Improvement Council

The Watershed Improvement Council first met in 2009 as an advisory group to the Targeted Watershed project. Representation included private land owners and other concerned residents, municipal and county governments and management, and federal land management agencies. Training was provided by Dr. Channah Rock and Kristine Uhlman of Arizona NEMO. Table 7 on the following page shows the current WIC membership.

Table 7. San Francisco-Blue Rivers Watershed Improvement Council 2012

Name	Title	Organization
Jaime Aguilar	Retired investigator, Sheriff's Dept.	Greenlee County
Barbara Ahmann	Councilwoman	Town of Clifton
Steve Ahmann	Educator	Clifton Schools
Dave Arthun	Rangeland management specialist	BLM
Bill Brandau	Director	Graham County Coop. Extension
Dr. Matt Bolinger	Deputy Health Dept. Director	Greenlee County
David Gomez	Supervisor, District 2	Greenlee County
Frank Hayes	Retired District Ranger, consultant	Heart and Horn Ecological Services
Terry Johnson	Wildlife educator	Reptilist.com
Richard Law	Park and river ranger	BLM
Richard Lunt	Chair, Board of Supervisors	Greenlee County
Chandler McElroy	Health services provider	Gila Health Services
Dr. Suzanne Menges	Education consultant	various
Christopher Morris	Hydrologist	BLM
Philip Ronnerud	Engineer	Greenlee County
Steve Rutherford	Health Dept. Director	Greenlee County
Susan Snyder	Principal	Clifton Schools

Priority Water Quality Improvement Projects

GWP has determined three types of BMPs necessary to bring water quality in the San Francisco and Blue Rivers. These include the following: 1) toilet facilities in key recreation areas, augmented by prominent visitor information and public outreach; 2) off-riparian solar wells that will remove a ranchers livestock out of the riparian area, augmented by public outreach; 3) targeted signage that includes general keep-it-clean and specific pit toilet-related signage in recreation areas, augmented by public outreach.

While microbial source tracking results show bovine and human contributions to *E. coli* in the watershed in roughly comparable measures, the scientific advisors to this project, Drs. Channah Rock and Phil Guertin, both state that human contributions constitute a more serious threat to human health than bovine contributions. According to Dr. Channah Rock's analysis, bovine markers are more significant in the fall months while human markers are more significant in the summer, when most of the recreation in the stream occurs. Because of this information, GWP is prioritizing BMPs addressing human contributions above those addressing bovine contributions, though the latter are no less important to load reduction overall.

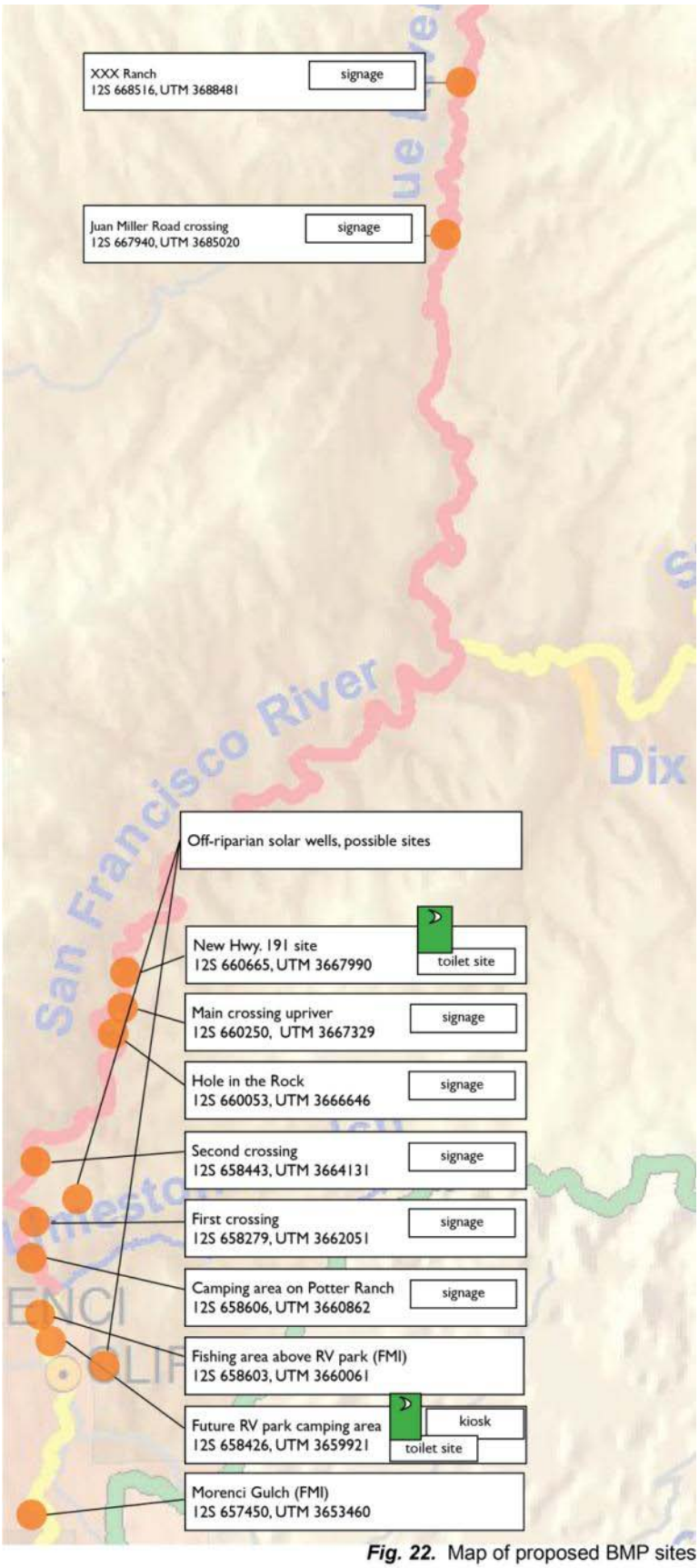


Fig. 22. Map of proposed BMP sites

BMP Type I: Toilet Facilities

Overview

The most significant contributions to fecal contamination of the lower San Francisco and Blue Rivers result from the numerous open toilet sites in recreation areas, from which human fecal matter is flushed into the streams by surface flows. Recreation on both rivers is wholly unmanaged. It occurs on private, municipal, state and federal lands, with major impacts to all. GWP has documented visible human fecal inputs, especially during the summer months, as a regular occurrence on the San Francisco. While open toilet sites are not so easily discovered on the lower Blue River, research data show that human fecal inputs are also in evidence there.

Overall, nine sites on the San Francisco River and two on the Blue River suffer from heavy recreational use with no facilities of any kind. We have identified 11 toilet sites that would be used by recreationists, however, all but two cannot be addressed at this time.

The two sites on the Blue, XXX Ranch and Juan Miller Road Crossing, are on Forest Service property and are a four-hour round trip, which is too far and costly to be maintained at this time. U.S. Forest Service personnel at the Clifton Ranger District and at Apache-Sitgreaves National Forest offices in Springerville agree that lack of toilet facilities at two locations on the lower Blue River – XXX Ranch, and the Juan Miller Road crossing – undoubtedly

contributes to human fecal contamination of the stream. They state that while they may consider new toilet facilities in the future, they are already stretched beyond their limits with the facilities they currently maintain.

Two more sites are located on state trust lands, which do not allow improvement such as restrooms by state statute. Five more are on private land, which makes installing toilet facilities an extremely difficult and expensive task.

Table 8 below shows how the recommended toilet sites relate spatially to other sites where it is not possible to install toilets at this time (the list flows downstream from the lower Blue River to the lower San Francisco River). Also see the map, Figure 22, on page 38.

Table 8. Heavy Recreation Areas and Potential Sites for Toilets

Site name	Land owner/manager	Remarks
Blue River		
XXX Ranch (aka Fritz Ranch)	U.S. Forest Service	No capacity to maintain facilities
Juan Miller Road crossing	U.S. Forest Service	No capacity to maintain facilities
San Francisco River		
Site on route of new Highway 191	U.S. Bureau of Land Management	Potential toilet site
Main crossing upriver	Arizona State Land Dept.	No structures permitted by law
Hole in the Rock	Arizona State Land Dept.	No structures permitted by law
Upper fishing area	Freeport McMoRan	Not interested at this time
First Crossing	Freeport McMoRan	Not interested at this time
Swimming Area on Potter Ranch	Private residential	Not suitable for long-term BMPs
Fishing area above RV Park	Freeport McMoRan	Not interested at this time
Clifton RV Park future campground	Town of Clifton	Potential toilet site
Morenci Gulch	Freeport McMoRan	Not interested at this time

However, the installation of toilet facilities on two sites on the main San Francisco River access road is possible. Please see locations marked in green on above map.

A load reduction analysis by Dr. Phil Guertin, University of Arizona School of Natural Resources and the Environment, follows:

One of the most significant contributors of fecal contamination on the San Francisco River is the use of numerous open toilet sites in recreation areas from which human fecal matter is washed into streams by surface flows. Installation of two toilet facilities on the main San Francisco River access road in combination with signage and a vigorous public information campaign will reduce the amount of human waste entering the stream.

The installation of ADA-compliant toilet facilities suitable for arid environments, the placement of permanent trash receptacles, signage in recreation sites, an information kiosk describing recreation settings and facilities, and continued education and outreach are all designed to eliminate the pollution contributed by recreational use of the river.

Toilet Site #1 is located in a large cleared area owned by the Town of Clifton that is 0.2 miles north of Rosenbaum Bridge. Toilet Site #2 is located seven miles up the San Francisco River Road, near the northernmost road-accessible recreation sites.

There are an estimated 6,120 visitors annually to the San Francisco Recreation area (see Table 9, this page). 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.

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) = 6120 visitors/year * 0.6 * 2066 ml/day * day/7 urinations * 1 liter/1000 ml = 1052 liters

Fecal Material (kg) = 6120 visitors/year * 0.3 * 95.5 g/day * day/2.54 movements * 1 kg/1000 g = 69 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. The CFU of E. coli in feces averages from 10^7 to 10^9 per gram (Tenaillon et al. 2010). ***Consequently, if 10% (6.9 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 6.9 x 10^{10} to 6.9 x 10^{12} CFU, representing a 100% load reduction compared to not having the toilet facilities.***

Table 9. Estimated numbers of people recreating on the San Francisco River by month

Source: Gila Watershed Partnership

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
normal	80	100	140	400	600	600	800	800	400	200	120	80
holiday weekend addl.					600		600		600			
total	80	100	140	400	1200	600	1400	800	1000	200	120	80
numbers with camp toilets	0	0	10	20	40	40	40	40	20	10	0	0
balance	**80**	**100**	**130**	**380**	**1160**	**560**	**1360**	**760**	**980**	**190**	**120**	**80**

References

Parker, D. and S. K. Gallagher, 1988. Distribution of human waste samples in relation to sizing waste processing in space. In: The Second Conference on Lunar Bases and Space Activities of the 21st Century, NASA Conference Publication 3166, Vol. 1, pp. 563-568.

Tenaillon, O., D. Skurnik, B. Picard, and E. Denamur, 2010. The population genetics of commensal *Escherichia coli*. Nature Reviews – Microbiology 8 (March): 207-217.

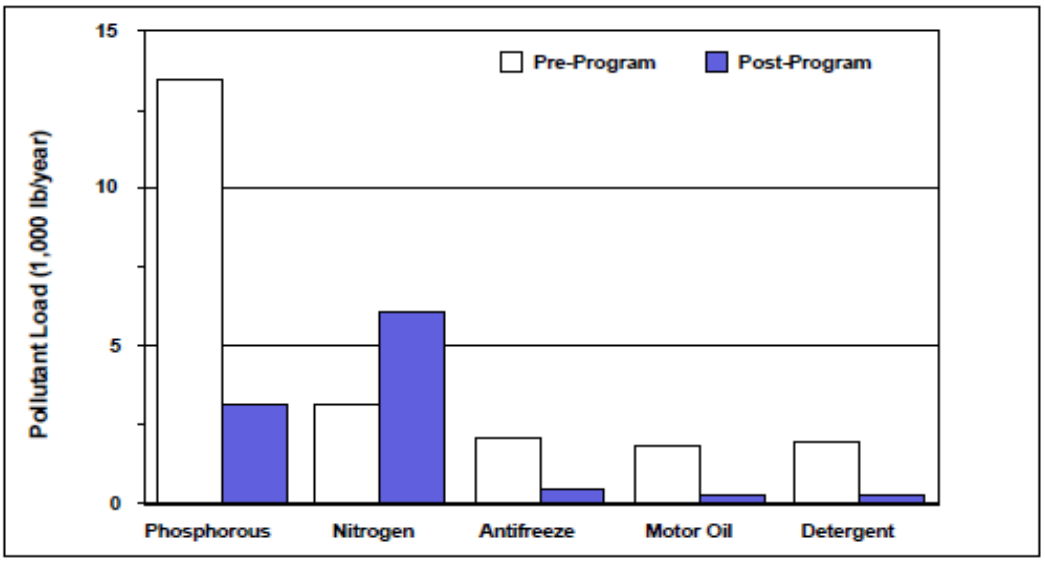
Outreach and education components linked to toilet installations will greatly increase the effectiveness of public toilets in reducing fecal pollution loads, as discussed by Dr. Phil Guertin:

Recreational visitors to the San Francisco River can be an important source of fecal material to the river environment. Over 6,000 people are expected to visit the San Francisco River area annually (Table 9, previous page). Human fecal material is an important source of enteric pathogenic protozoa and viruses. The concentration of protozoan parasites (Giardia or Cryptosporidium) in feces of infected persons can range from 10^5 to 10^7 per gram and enteric viruses (enteroviruses, adenoviruses, rotavirus) from 10^5 to 10^{12} per gram (Gerba 2000). Consequently, preventing human contamination of water resources is an important water quality management objective.

Non-structural best management practices that promote behavior modification (education, interpretation, and signage) are an important, if not the only, practice that can address diffuse human activities. Although behavior modification practices have the intended benefit of raising public awareness and therefore creating support of environmental programs, it is difficult to quantify actual pollutant reductions associated with education efforts.

Public attitudes can be used as a gauge of how these programs perform, however. In Prince George's County, Maryland, a public survey was used in combination with modeling to estimate pollutant load reductions associated with public education (from U.S. EPA 1999; Figure 23). An initial study was conducted to estimate pollution from field application of fertilizers, and use of detergents, oil and antifreeze. Pollutant reductions were then completed assuming that 70 percent of the population complied with recommendations of the public education program. A follow-up survey was used to assess the effectiveness of the program. The follow-up survey indicated that educational programs influenced many citizen behaviors, such as recycling. They were unsuccessful, however, at changing the rate at which citizens apply lawn fertilizers.

Fig. 23. Changes in pollutant load associated with a public education program based on a public survey (from U.S. EPA 1999).



Use the example, based on the load reduction computation from the Toilet BMP, assume that the Behavior Modification BMPs increase the number of potential visitors using the toilet facilities for bowel movements from 30% to 60% the new load reduction would be:

Fecal Material (kg) = 6120 visitors/year*0.6*95.5 g/day*day/2.54 movements*1 kg/1000 g = 138 kg

Given that CFU of E. coli in feces averages from 10^7 to 10^9 per gram (Tenaillon et al. 2010). ***Consequently, if 10% (13.8 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 1.38 x 10^{11} to 1.38 x 10^{13} CFU, representing a 200% load reduction compared to not having the educational program.***

Education programs also have the potential of increasing volunteers to work on pollution control efforts (Department of Conservation & Recreation 2001).

References

Department of Conservation & Recreation, 2001. The Economic Benefits of Protecting Virginia's Streams, Lakes and Wetlands and the Economic Benefits of Better Site Design in Virginia. State of Virginia, Richmond, Virginia, 23219.

Gerba, C.P., 2000. Assessment of enteric pathogen shedding by bathers during recreational activity and its impact of water quality. Quantitative Microbiology 2: 55-68.

U.S. EPA, 1999. Preliminary Data Summary of Urban Storm Water Best Management Practices. EPA-821-R-99-012.

Toilet Site #1 – New Highway.

Site description:

This site on BLM land is near the northernmost road-accessible recreation sites. It will be located on the soon-to-be-moved U.S. Highway 191. Freeport McMoRan is actively planning this project with Arizona Department of Transportation and BLM. The new road will travel up the existing San Francisco River road on the east side of the river through its terminus on BLM lands, and then bridge over the river to rejoin the existing highway on BLM lands south of the National Forest. This new construction will provide access to an ideal location for a restroom facility.

Features:

Double-vault ADA-compliant CXT "Tioga" toilet (a model suitable for arid climates)
Permanent trash receptacles
Signage

Technical assistance/resources required:

Greenlee County, BLM, Freeport McMoRan involvement.

Barriers:

In the event GWP would not be able to obtain the necessary environmental clearances, and the new highway will not be approved, we are confident that an appropriate alternate site will be found. However, the ongoing maintenance of new toilets must be addressed. The BLM does not have it in their budget to provide maintenance. They have been supportive of the issue, and they have indicated may be able to put it in their future long term maintenance budget, depending on the federal budgeting process. However, that may take five or more years to put into place. Greenlee County is very supportive of the project, but they do not own the equipment required for remote toilet maintenance and do not have the funds to purchase it. Providing the county with funding for equipment will be crucial to enable them to commit to long-term maintenance.

Financial assistance:

1) Funding for installation of all components: toilets, trash receptacles, signage
2) Funding for large equipment for long-term maintenance
3) Funding for supervised public education and outreach by trained volunteers to support use of public facilities and to monitor their effectiveness

Associated costs:

Labor		
	Engineering	3,300
	Environmental clearances	3,500
	Archeological clearances	1,500
	Permitting and general coordination	2,000
	Installation of walkways, railings and signs	4,400
	General coordination	4,200
	Education/outreach/monitoring	20,430
Equipment		
	CXT double-vault toilet, "Tioga," fully installed	42,000
	PowerPoint projector (Education and Outreach)	850
Materials and Supplies		
	Concrete, lumber, rebar	2,200
	Backhoe, truck and trailer	1,650
	Trash receptacles	550
	Signs and bases, with shipping	1,025
	Education/outreach classroom materials/supplies	2,088
Miscellaneous		
	Mileage, advertising	2,100
	TOTAL	91,793

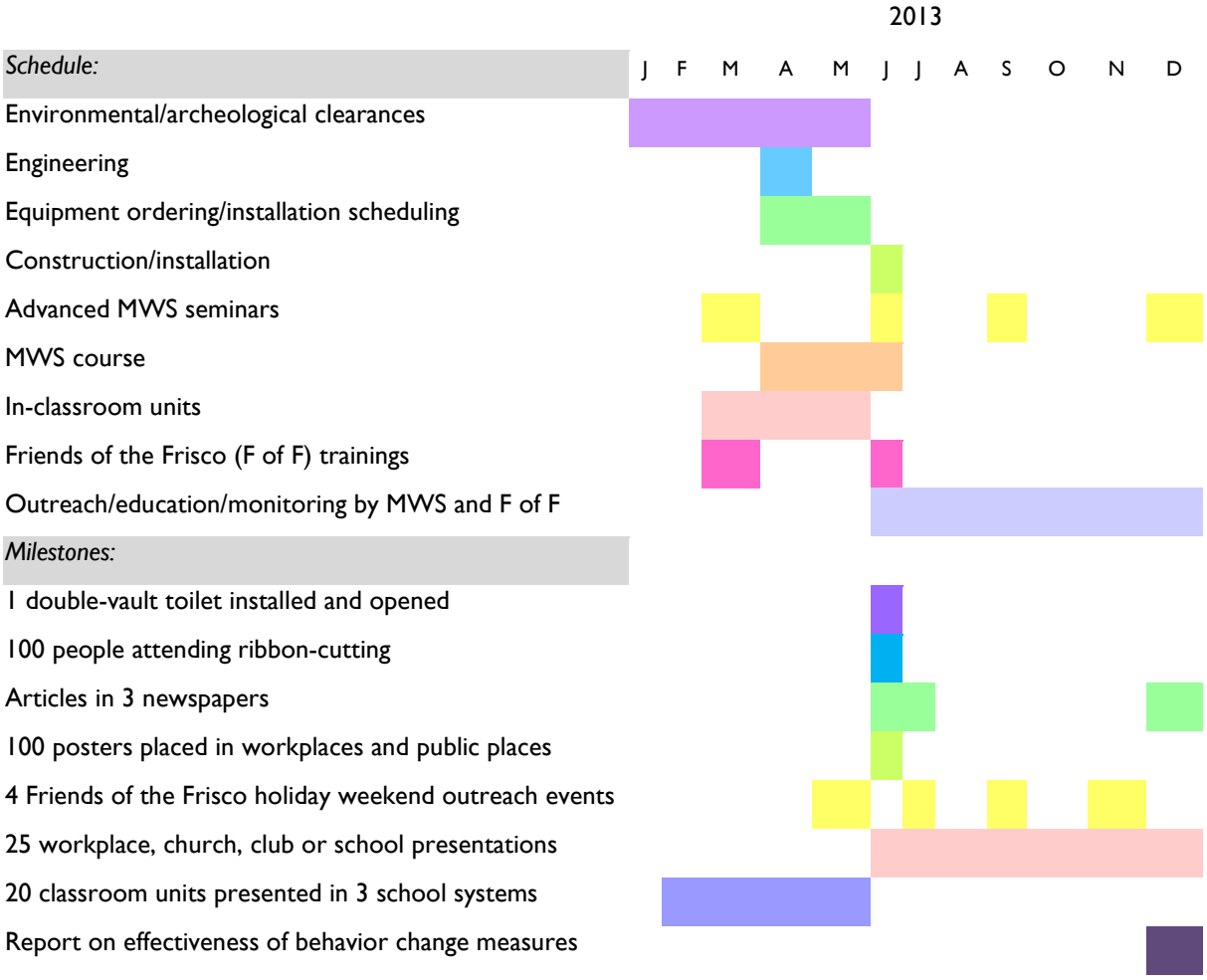
Additional costs:

Maintenance equipment for Greenlee County	
One-ton pick-up truck with water tank and sprayer	34,850
TOTAL	34,850

Notes: 1) As with the education and outreach components, the purchase of maintenance equipment is a one-time cost, covering either or both toilet installations. It is shown in both budgets to make certain it is not overlooked. Please see page 61 for a breakdown of education/outreach/monitoring costs. 2) The installation package price for the Tioga

vault toilets is higher for this site because of its more remote location.

Project schedule and milestones:



Monitoring and Evaluating Effectiveness

Criteria to determine long-term effectiveness of toilet installations on the San Francisco River include the following:

- Reduction in seasonal *E. coli* exceedances linked to increased recreation and human fecal contributions.
- Reduction in open toilet sites in recreation areas.
- Pre- and post-surveys of persons engaged in recreation on the San Francisco River demonstrating both use of toilet facilities and increased awareness of fecal contamination issues.

Monitoring should take two forms: I.) monitoring of behavior changes, conducted by trained volunteers, and II.) *E. coli* and microbial source tracking tests, using methods outlined below two years and five years after the installation of toilets (the later monitoring is important to because residual effects of earlier open toilet sites may still influence results at the two-year point).

Monitoring of behavioral changes will be accomplished by GWP within the BMP implementation period, *if* education and training funds are included in the BMP award. *E. coli* and MST testing should be conducted by ADEQ or a qualified contractor; GWP does not have discretionary funding to conduct this two-pronged phase of monitoring two and five years after toilet installations.

I. Methods for monitoring of behavior changes:

1) MWS students, guided by U of A Extension faculty, devise pre- and post-surveys to conduct with the public at recreation sites on the San Francisco River and in schools, workplaces, social clubs, churches and other sites in northern Greenlee County.
2) Pre-surveys are carried out by MWS and Friends of the Frisco volunteers in early summer, just before toilets are installed. Post-surveys are conducted in mid and late summer and early and late fall. Much of the surveying will occur in the context of presentations made by trained volunteers in the locations listed in the previous item.
3) The results of surveys are collated and formatted at the end of the implementation period by MWS students, under the supervision of U of A Extension faculty. A summary of the findings will be presented in newspapers in Graham and Greenlee Counties as well as a regional newspaper based in Glenwood, NM, that serves the entire watershed region in both states.

II. Methods for monitoring with *E. coli* and microbial source tracking tests, two and five years after toilet installations:

Site #1: San Francisco River at Arizona State Lands/BLM Line

1) Measure *E. coli* in water within one week of initial surface flows of the summer monsoon season, when any fecal matter from the surface will have been flushed into the stream.
2) Submit water samples for microbial source tracking for human markers.

Site #2: San Francisco River at Main Crossing on State Lands

1) Between Memorial Day and Fourth of July weekends, perform a physical survey of camping areas, especially at the bottoms of cliffs, and count open toilet sites.
2) Measure *E. coli* in water within one week of initial surface flows of the summer monsoon season, when any fecal matter from the surface will have been flushed into the stream.
3) Submit water samples for microbial source tracking for human markers.

Site #3: San Francisco River at Hole in the Rock

1) Between Memorial Day and Fourth of July weekends, perform a physical survey of camping areas, especially at the bottoms of cliffs, and count open toilet sites.
2) Measure *E. coli* in water within one week of initial surface flows of the summer monsoon season, when any fecal matter from the surface will have been flushed into the stream.
3) Submit water samples for microbial source tracking for human markers.

Site #4: San Francisco River in Clifton below Old Dump

1) Measure *E. coli* in water within one week of initial surface flows of the summer monsoon season, when any fecal matter from the surface will have been flushed into the stream.
2) Submit water samples for microbial source tracking for human markers.

ADEQ, working with the Water Quality Lab at the University of Arizona Maricopa Agricultural Center, should analyze the results of *E. coli* tests and MST tests to determine whether there is any increase in human fecal contamination as the river flows through some of the heaviest recreation zones, and to compare *E. coli* levels to previous sampling results.

Toilet Site #2 - Future RV park camping area.

Site Description:

This site is located at the gateway to the San Francisco River in a large cleared area along the river. It is owned by the Town of Clifton, and is .2 miles north of Rosenbaum Bridge, which crosses the river at the Clifton RV Park. All traffic to the San Francisco River above Clifton passes this site; the relocated segment of U.S. Highway 191 will also pass this location. In the last year, the Town of Clifton has cleared this site in preparation for a planned new campground.

Fig. 23. Sites for visitors kiosk and toilets in Clifton

The road that passes through this site, which is soon to become a section of the Coronado Trail, U.S. Highway 191, is the only way to reach nearly all the popular recreation areas on the San Francisco around Clifton. Currently there is no signage informing visitors about land ownership, rules and regulations, availability of toilet and trash facilities (at this time only in Clifton), dangers near recreation sites, attractions, etc.

An interpretive kiosk at this gateway site in Clifton, like educational kiosks commonly utilized on federal lands, would serve as a location for valuable visitor information. Having a range of displays – birds, reptiles, mammals, endangered species, history, geology, legal fishing and hunting areas, legal OHV trails, etc. – will increase the number of people who stop. The kiosk will include information on how not to be a contributor of fecal contamination. This will include

details on various kinds of camp toilets as well as instructions on digging and covering a pit toilet.

Features:

Double-vault ADA-compliant CXT “Tioga” toilet (a model suitable for arid climates)
Permanent trash receptacles
A covered outdoor kiosk displaying six 36” x 48” digital laminate educational signs

Financial assistance required:

1) Funding for installation of all components: toilets, walkways, trash receptacles, kiosk
2) Funding for the large equipment needed for long-term maintenance
3) Funding for supervised public education and outreach by trained volunteers to support use of public facilities and to monitor their effectiveness

Technical assistance/resources required: Greenlee County, BLM, Town of Clifton involvement.

Barriers:

In the event GWP would not be able to obtain the necessary environmental clearances, we are confident that an appropriate alternate site will be found. However, the ongoing maintenance of new toilets must be addressed. Although the site is located within the boundaries of the Town of Clifton, they do not have the budget, or equipment necessary for the on-going maintenance. Greenlee County is very supportive of the project, but they do not own the equipment required for remote toilet maintenance and do not have the funds to purchase it. Providing the county with funding for equipment will be crucial to enable them to commit to long-term maintenance.

Associated costs:

Labor		
	Engineering	4,000
	Environmental clearances	3,500
	Archeological clearances	1,500
	Permitting and general coordination	6,800
	Installation of walkways and kiosk	2,400
	Design of information panels	3,600
	Education/outreach/monitoring	20,430
Equipment		
	CXT double-vault toilet, "Tioga," fully installed	39,000
	PowerPoint projector (Education and Outreach)	850
	Outdoor six-panel roofed kiosk, with shipping	18,000
Materials and Supplies		
	Concrete, lumber, rebar	3,000
	Backhoe, truck and trailer	1,650
	Trash receptacles	550
	Panels (6) with shipping	2,280
	Education/outreach/monitoring materials/supplies	2,088
Miscellaneous		
	Mileage, advertising	2,100

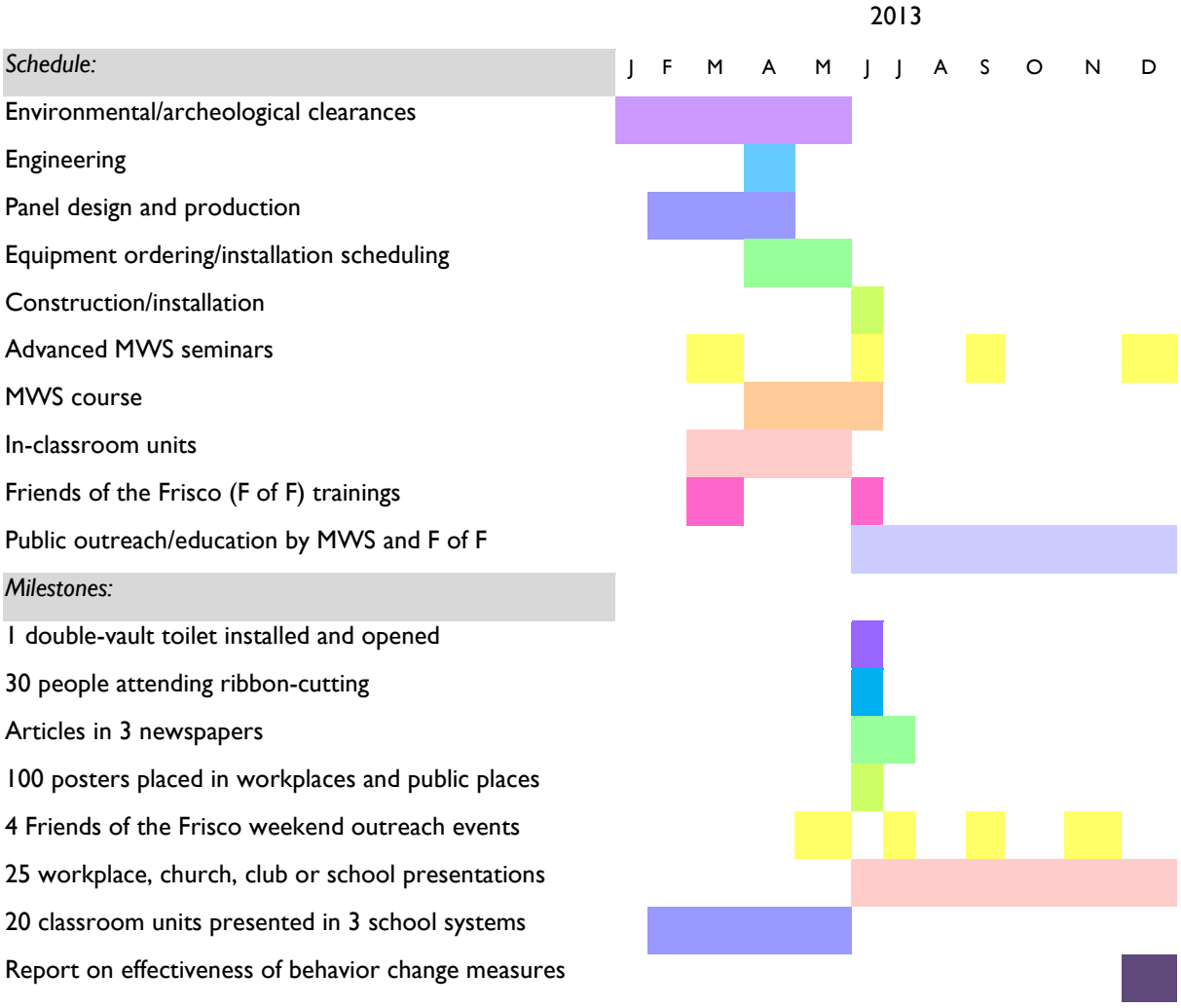
TOTAL	111,748

Additional costs:

Maintenance equipment for Greenlee County	
One-ton pick-up truck with water tank and sprayer	34,850
TOTAL	34,850

Note: As with the education and outreach components, the purchase of maintenance equipment is a one-time cost, covering either or both toilet installations. It is shown in both budgets to make certain it is not overlooked. Please see page 63 for a breakdown of education/outreach/monitoring costs.

Project schedule and milestones:



Monitoring and Evaluating Effectiveness

Criteria to determine long-term effectiveness of toilet installations on the San Francisco River include the following:

- Reduction in seasonal *E. coli* exceedances linked to increased recreation and human fecal contributions.
- Reduction in open toilet sites in recreation areas.
- Pre- and post-surveys of persons engaged in recreation on the San Francisco River demonstrating both use of toilet facilities and increased awareness of fecal contamination issues.

Monitoring should take two forms: I.) monitoring of behavior changes, conducted by trained volunteers, and II.) *E. coli* and microbial source tracking tests, using methods outlined below two years and five years after the installation of toilets (the later monitoring is important to because residual effects of earlier open toilet sites may still influence results at the two-year point). Monitoring of behavioral changes will be accomplished by GWP within the BMP implementation period, *if* education and training funds are included in the BMP award. *E. coli* and MST testing should be conducted by ADEQ or a qualified contractor; GWP does not have discretionary funding to conduct this two-pronged phase of monitoring two and five years after toilet installations.

I. Methods for monitoring and evaluating behavior changes:

1) MWS students, guided by U of A Extension faculty, devise pre- and post-surveys to conduct with the public at recreation sites on the San Francisco River and in schools, workplaces, social clubs, churches and other sites in northern Greenlee County.
2) Pre-surveys are carried out by MWS and Friends of the Frisco volunteers in early summer, just before toilets are installed. Post-surveys are conducted in mid and late summer and early and late fall. Much of the surveying will occur in the context of presentations made by trained volunteers in the locations listed in the previous item.
3) The results of surveys are collated and formatted at the end of the implementation period by MWS students, under the supervision of U of A Extension faculty. A summary of the findings will be presented in newspapers in Graham and Greenlee Counties as well as a regional newspaper based in Glenwood, NM, that serves the entire watershed region in both states.

II. Methods for monitoring with *E. coli* and microbial source tracking tests, two and five years after toilet installations:

Site #1: San Francisco River at Arizona State Lands/BLM Line

1) Measure *E. coli* in water within one week of initial surface flows of the summer monsoon season, when any fecal matter from the surface will have been flushed into the stream.
2) Submit water samples for microbial source tracking for human markers.

Site #2: San Francisco River at Main Crossing on State Lands

1) Between Memorial Day and Fourth of July weekends, perform a physical survey of camping areas, especially at the bottoms of cliffs, and count open toilet sites.
2) Measure *E. coli* in water within one week of initial surface flows of the summer monsoon season, when any fecal matter from the surface will have been flushed into the stream.
3) Submit water samples for microbial source tracking for human markers.

Site #3: San Francisco River at Hole in the Rock

1) Between Memorial Day and Fourth of July weekends, perform a physical survey of camping areas, especially at the bottoms of cliffs, and count open toilet sites.
2) Measure *E. coli* in water within one week of initial surface flows of the summer monsoon season, when any fecal matter from the surface will have been flushed into the stream.
3) Submit water samples for microbial source tracking for human markers.

Site #4: San Francisco River in Clifton below Old Dump

3) Measure *E. coli* in water within one week of initial surface flows of the summer monsoon season, when any fecal matter from the surface will have been flushed into the stream.
4) Submit water samples for microbial source tracking for human markers.

ADEQ, working with the Water Quality Lab at the University of Arizona Maricopa Agricultural Center, should analyze the results of *E. coli* tests and MST tests to determine whether there is any increase in human fecal contamination as the river flows through some of the heaviest recreation zones, and to compare *E. coli* levels to previous sampling results.

BMP Type II: Off-riparian Livestock Watering and Fencing

A ranch located on the San Francisco River less than one mile upstream of the Town of Clifton has grazing leases for 29 cattle with BLM, Forest Service, State Lands and Freeport McMoRan Copper & Gold. The rancher has water right to water his livestock in the San Francisco River year-round, often trespassing downstream within the town limits as well as upstream. The impacts of these cattle on the riparian area are now accentuated by the contrast with vegetative recovery on the Kaler Ranch (now the property of FMI), which shares a boundary with the most upstream lease of the ranch under discussion. See Figure 11 on page 19.

The ranch owner has not been a supporter of the Targeted Watershed project, nor does he agree that there is a problem with livestock fecal material in the river. However, Safford BLM rangeland personnel are willing to approach the rancher about off-riparian solar wells, which would serve their own goal of removing cattle from sensitive riparian habitat that hosts threatened & endangered species. With BLM's support, we believe we can remove the rancher's livestock permanently from the riparian area, which will successfully eliminate 100% of the *E.coli* contribution from livestock in this area of the San Francisco River.

Site Description: Both wells would be situated on the east site of the river on BLM property. We would need a relatively small amount of fencing due to the rocky, steep topography. Cattle guards and gates will be required.

Outreach by trained volunteers will be essential to presenting these improvements throughout different sectors of the community. There are segments of the community that believe that grazing the riparian areas reduce the risk of flooding.

By training and deploying volunteers from the local community to educate people in their workplaces, schools, clubs and other locations, the benefits of off-riparian wells can be highlighted and public support for riparian recovery enhanced. The same volunteers will be able to monitor changes in perception of the river due to widespread awareness of the solar wells

project, including to what extent those changes involve individuals' feeling more of a sense of personal responsibility for the riparian area.

Features:

Two solar wells in uplands east of the San Francisco River
Fencing to prevent livestock from entering the mainstem stream

Technical assistance/resources required: BLM and/or Forest Service coordination with land owner; BLM and/or Forest Service involvement in environmental and archeological clearances.

Financial assistance required: all costs of well drilling and installation and fencing installation; costs of volunteer training for outreach and monitoring.

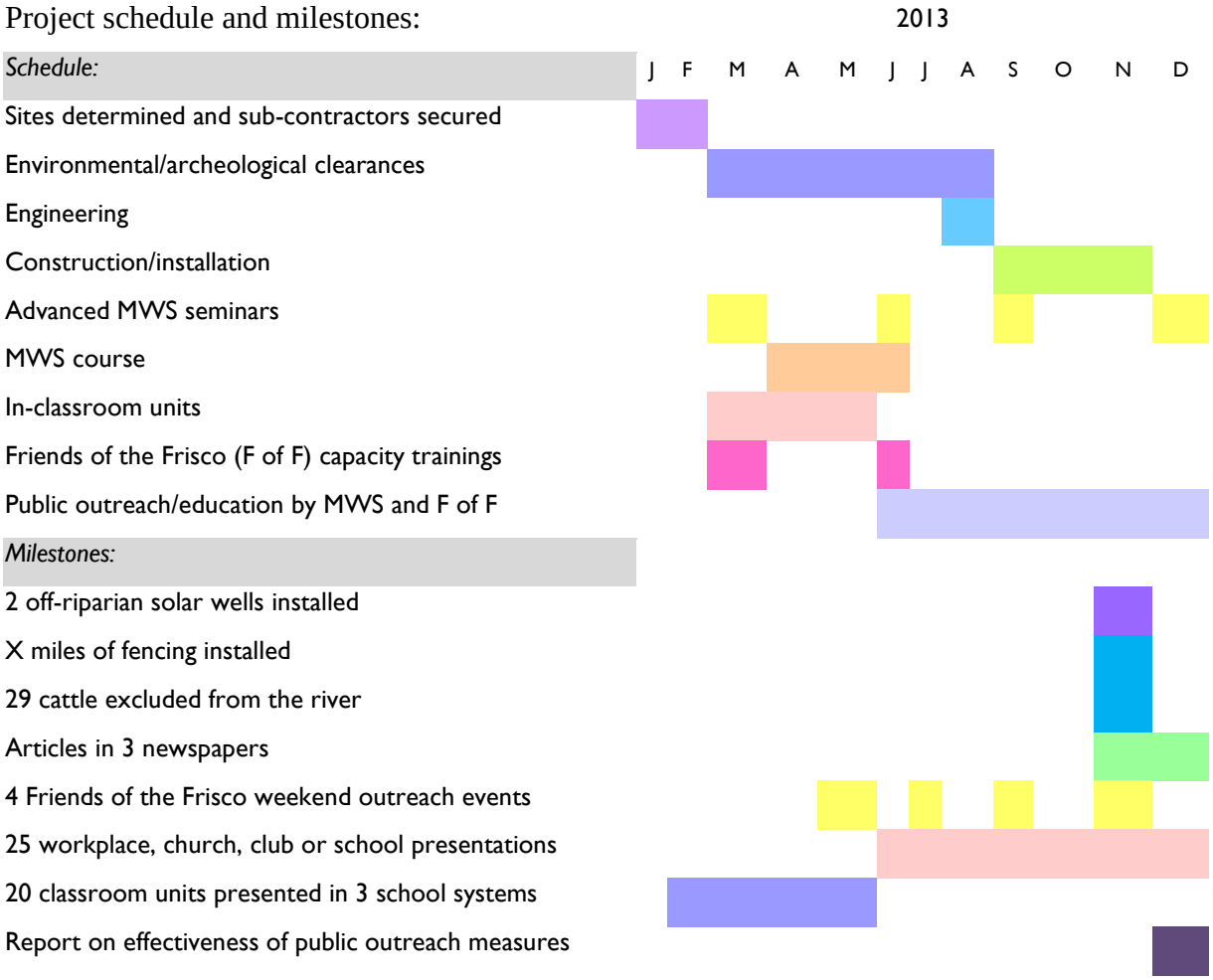
Associated costs:

Labor		
	Well driller	6,750
	Solar installer	3,050
	Fence labor	8,190
	Fence take-down labor	1,345
	Wildlife jump labor	364
	Cattle guard labor	800
	Coordination	7,000
	Education/outreach/monitoring	20,430
Equipment		
	Well equipment	10,000
	Drill rig	4,000
	Back hoe	1,000
	Submersible motor	2,925
	Solar modules	38,135
	Mounting poles	1,469
	Control system	6,175
	Other	728
	Fencing vehicle	182
	Punjar/rock drill/gas/oil-day	455
	Chainsaw/oil/gas/safety equip-day	205
	PowerPoint projector	850
Materials and Supplies		
	Well casing	1,475
	Down rod & discharge pipe	1,275
	Down wire & pump cable	2,142
	Misc. well supplies	4,972
	Freight (mule)	273
	Steel posts	1,922

	Barb and smooth wire	1,402
	Brace posts	910
	Stays, staples, stay wire and nails	529
	Rails and posts for wildlife jumps	612
	Gates	900
	Cattle guards	6,400
	Misc. supplies	1,600
	Education/outreach/monitoring supplies	2,088
Miscellaneous		
	Mileage	300
	Reports	1,750
	Photo monitoring	200
	TOTAL	142,802

Barriers: lack of cooperation of ranch owner.

Project schedule and milestones:



Estimated load reduction by Dr. Phil Guertin, University of Arizona School of Natural Resources and the Environment:

The development of alternative livestock water infrastructure will have two effects on E. coli levels in the San Francisco River reach just north of Clifton, Arizona. First, removing the cattle from the riparian area will improve vegetation conditions near the river creating sediment filter. The result will be a reduction in sediment, including manure, to the river. Second, the new water infrastructure will allow the rancher to remove his cattle from the near river environment. Currently, the river is the ranch's primary water source which results in the cattle being within the near river environment most of the year. With the new water infrastructure the cattle will only be in the near river environment for short periods of time during their movement between pastures and short periods of grazing.

Sediment Load Reduction Due to Riparian Buffer

The Gila Watershed Partnership has determined that this ranch may be a major contributing factor to the E. coli impairment of the San Francisco River. The purpose of the modeling effort is to determine the sediment load reduction that can be expected by limiting bovine access to the stream and the subsequent reestablishment of normal riparian vegetation. Riparian areas affected are a 3.3 mile reach of the San Francisco River which cattle from the ranch are able to access. The modeled riparian areas represented less than 0.2% of the total area of the AGWA-delineated sub-watershed which includes the upland portions of the ranch.

The GIS-based modeling was performed using land cover data that had been modified in order to reflect the disturbed soils in the riparian areas due to ungulate activity. The model was then performed using land cover data that represents normal riparian vegetation. The resulting difference in the two models reflects the optimal load reduction in sediment entering the stream as a result of the exclusion of cattle from the stream.

The Soil and Water Assessment Tool (SWAT) within the Automated Geospatial Watershed Assessment tool (AGWA) was used for the hydrology and erosion modeling. The data sources including: 10m Digital Elevation Model (DEM) acquired from USGS at http://seamless.usgs.gov; 30m land cover data acquired from Southwest Regional GAP (SWReGAP) http://earth.gis.usu.edu/swgap/mapserver/; soil data acquired from Natural Resources Conservation Service (NRCS) at http://soildatamart.nrcs.usda.gov/USDGSM.aspx and precipitation data acquired from National Climatic Data Center (NCDC) at http://www.ncdc.noaa.gov/oa/ncdc.html

The average sediment load reduction for the 3.3 mile reach was 46.4 tons/year or a 1.4% sediment load reduction for the entire subwatershed section.

Load Reduction Due to Changes in Animal Movement

There are 29 head of cattle currently grazing on the privately owned ranch above Clifton, with grazing leases on adjacent Freeport McMoRan, BLM and State Lands properties. Watering facilities are currently not available on the upland section of the ranch resulting in cattle spending considerable amount time in the near river environment (9 months or 75% of the

time). The new livestock water infrastructure will allow the ranch to move the cattle to the upland portions of the ranch and avoid the near river environment except when the cattle are moved between pastures and short periods of grazing (2 months or 17% of the time).

A mature cow weighting 1000 lbs produces an average of 8.7 lbs/day of manure (NRCS, 2012)

Assuming an average weight of 850 lbs per cow the annual manure production for 29 cows is:

*Manure Production (tons/year) = 29 cows * 8.7 lbs/day * 850 lbs/cow * 352 days/year * ton/2000 lbs Manure Production (tons/year) = 37,744 tons/year*

Pre-treatment Manure Production (tons/year) = 0.75 * 37,744 tons/year = 28,308 tons/year

Post-treatment Manure Production (tons/year) = 0.17 * 37,744 tons/year = 6,416 tons/year

Percent Reduction = 23%

Wang et al. 2004 showed that E. coli populations extracted from fresh cow manure ranging from 6.55 x 10^6 to 7.6 x 10^6 cfu per gram of manure. Using an average of 7.1 x 10^6 cfu per gram of fresh manure the potential E. coli contributions to the river are:

Pre-Treatment E. coli Contribution (CFU/year) = 28,308 tons/year * 907,184.74 grams/ton * 7,100,000 cfu/gram = 1.8 x 10^{17} CFU of E. coli /year

Post-Treatment E. coli Contribution (CFU/year) = 6,416 tons/year * 907,184.74 grams/ton * 7,100,000 cfu/gram = 4.1 x 10^{16} CFU of E. coli /year

Percent Reduction = 23%

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/

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.

Monitoring and Evaluating Effectiveness

Criteria to determine long-term effectiveness of off-riparian solar well installations on the San Francisco River include the following:

- Elimination of *E. coli* exceedances linked to livestock watering and bovine fecal contributions.
- Elimination of livestock from the San Francisco River near Clifton.
- Pre- and post-surveys of persons recreating on the San Francisco River demonstrating favorable public perception of restricting livestock from the stream and increased awareness of fecal contamination issues.

Monitoring should take two forms: I.) monitoring of changes in public perception, conducted by trained volunteers, and II.) *E. coli* and microbial source tracking tests, using methods outlined below two years and five years after the installation of toilets (the later monitoring is important

to because residual effects of earlier open toilet sites may still influence results at the two-year point). Monitoring of behavioral changes will be accomplished by GWP within the BMP implementation period, *if* education and training funds are included in the BMP award. *E. coli* and MST testing should be conducted by ADEQ or a qualified contractor; GWP does not have discretionary funding to conduct this two-pronged phase of monitoring two and five years after toilet installations.

I. Methods for monitoring and evaluating changes in public perception:

1) MWS students, guided by U of A Extension faculty, devise pre- and post-surveys to conduct with the public in schools, workplaces, social clubs, churches and other sites in northern Greenlee County.
2) Pre-surveys are carried out by MWS and Friends of the Frisco volunteers in summer and fall, before wells and fencing are installed. Post-surveys are conducted in late fall. Much of the surveying will occur in the context of presentations made by trained volunteers in the locations listed in the previous item.
3) The results of surveys are collated and formatted at the end of the implementation period by MWS students, under the supervision of U of A Extension faculty. A summary of the findings will be presented in newspapers in Graham and Greenlee Counties as well as a regional newspaper based in Glenwood, NM, that serves the entire watershed region in both states.

II. Methods for monitoring with *E. coli* and microbial source tracking tests, two and five years after toilet installations:

Monitoring should be done by the following methods two years and five years after the installation of one or more solar wells (the later monitoring is important to because residual effects of earlier livestock watering may still influence results at the two-year point):

Site #1: San Francisco River at Hole in the Rock

1) Measure *E. coli* in water within one week of initial surface flows of the summer monsoon season, when any fecal matter from the surface will have been flushed into the stream.
2) Submit water samples for microbial source tracking for bovine markers.

Site #2: San Francisco River in Clifton below Old Dump

1) Measure *E. coli* in water within one week of initial surface flows of the summer monsoon season, when any fecal matter from the surface will have been flushed into the stream.
2) Submit water samples for microbial source tracking for bovine markers.

Site #3: San Francisco River on BLM land below Morenci Gulch

1) Measure *E. coli* in water within one week of initial surface flows of the summer monsoon season, when any fecal matter from the surface will have been flushed into the stream.
2) Submit water samples for microbial source tracking for bovine markers.

ADEQ, working with the Water Quality Lab at the University of Arizona Maricopa Agricultural Center, should analyze the results of *E. coli* tests and MST tests to determine whether there is any bovine fecal contamination of the river appearing between these two points after two and five years.

BMP Type III: Signage

Dr. Phil Guertin's remarks on outreach and education components (pages 41-42) apply equally to this area of BMPs. Some signage was created under the Targeted Watershed grant. However, to be effective, we need more to create a widespread sense of surveillance and further reduce the *E.coli* exceedances. Additional signage on both the Blue and San Francisco Rivers, augmented by vigorous outreach by trained volunteers, is another essential component of a comprehensive plan to improve water quality by reducing human fecal contributions.

See Table 10 below for estimates of potential visitor impacts on both rivers, by month.

The proposed additional signage will have two focus areas: the lower Blue River, at the XXX Ranch and Juan Miller Road crossing sites, and five popular recreation areas on the San Francisco River above and below Clifton, Arizona. All of these areas suffer the effects of heavy recreation and none is a candidate for public toilets and trash facilities. See Figure 21 on page 38 for locations of the various sites.

Table 10. Estimated of potential visitors on the San Francisco and Blue Rivers, Arizona, based on local information. Source: Gila Watershed Partnership.

Estimated numbers of people recreating on the San Francisco River by month												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Normal Use	80	100	140	400	600	600	800	800	400	200	120	80
Holiday weekend addl.					600		600		600			
Total	80	100	140	400	1200	600	1400	800	1000	200	120	80
Numbers with Camp Toilets	0	0	10	20	40	40	40	40	20	10	0	0
Balance	**80**	**100**	**130**	**380**	**1160**	**560**	**1360**	**760**	**980**	**190**	**120**	**80**
Estimated numbers of people recreating on the lower Blue River by month												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Normal	10	10	15	25	50	80	100	100	75	50	35	10
Holiday weekend addl.					25		25		25			
Total	10	10	15	25	75	80	125	100	100	50	35	10
Numbers with Camp Toilets	2	2	3	5	12	15	20	18	18	10	6	2
Balance	**8**	**8**	**12**	**20**	**63**	**65**	**105**	**82**	**82**	**40**	**29**	**8**

The signage campaign proposed here has been guided by past programs that have tested to successfully change behavior. The nationally recognized "Don't Mess with Texas" campaign,[10]

[10] http://dontmesswithtexas.org/

has been proven to reduce litter on Texas highways by 72% between 1986 and 1990. The campaign's target market is 18-35 year old males, who are shown statistically be the most likely demographic to engage in littering. Field observations on the San Francisco and Blue Rivers tell us that this is also our number one target population. Although the Greenlee County Sheriff does not have adequate staffing in this time of tight budgets to patrol the rivers, placing signs in numerous locations throughout the recreation areas sends a strong message that their behavior is being monitored. As documented in the extensive market research in the Don't Mess with Texas anti-littering campaign,[11] putting signage in remote areas where people previously littered heavily resulted in steep drops in littering.

Two types of signs are indicated. The first and larger sign will feature a photograph of a local child at the San Francisco River, with the words "keep our river clean." A second kind of sign, smaller and geared to people on foot, gives detailed instructions on how to dig and cover a pit latrine so that it will compost properly. These will be located where open toilets tend to occur. The smaller signs will be manufactured and mounted in such a way as to deter both graffiti and bullet damage.

Blue River Sites

On the lower Blue River where exceedances have proven to be caused in part by human fecal contributions, signage is the only option. The Apache-Sitgreaves National Forest and Clifton Ranger District are both stretched to their limits on recreational site maintenance and cannot add long round trips to lower Blue River sites. Forest Service personnel have indicated that signage has helped reduce recreation issues in other areas

Forest Service managers agree that both the Juan Miller Road crossing and XXX Ranch, about three miles upstream of the Juan Miller Road crossing, must be targeted for signage. Although XXX Ranch is much more difficult to access than the Juan Miller Road crossing, it has periods of intensive use by campers.

Signage Site #1 – XXX Ranch

Location: camping area near the Blue River on XXX Ranch

Features:

> One set of two thick, digital laminate signs mounted on custom extruded aluminum low-profile bases angled at 30˚ to the ground to discourage graffiti and shooting, asking visitors to keep the river clean and describing the proper steps to create and cover a pit toilet. One sign is a general "keep it clean" message, the other is instructions for digging and covering a pit toilet that will compost and not get washed into the stream by surface flows.

Technical assistance/resources required: Apache-Sitgreaves Forest and Clifton Ranger District for site selection and oversight of installation

Financial assistance required: costs of designing, manufacturing and shipping signs, concrete for setting signs; costs of volunteer-based public outreach and monitoring components.

[11] McClure, Tim and Spence, Roy. *Don't Mess with Texas: The Story Behind the Legend*. Idea City Press, 2006.

Associated costs: see combined budget at the end of this section.

Resources: Forest Service collaboration, MWS and Friends of the Frisco volunteer labor.

Barriers: None.

Project schedule and milestones: see end of section.

Signage Sites #2 and #3 – Juan Miller Road Crossing on the Lower Blue River

Locations: two popular camping areas on either side of the Blue River at Juan Miller Road crossing.

Features:

> Two sets of two thick, digital laminate signs mounted on custom extruded aluminum low-profile bases angled at 30˚ to the ground to discourage graffiti and shooting, asking visitors to keep the river clean and describing the proper steps to create and cover a pit toilet. One sign is a general "keep it clean" message, the other is instructions for digging and covering a pit toilet that will compost and not get washed into the stream by surface flows.

Technical assistance/resources required: Apache-Sitgreaves Forest and Clifton Ranger District for site selection and oversight of installation

Financial assistance required: costs of manufacturing and shipping signs, concrete for setting signs; costs of volunteer-based public outreach and monitoring components.

Associated costs: see combined budget at the end of this section.

Resources: Forest Service collaboration, MWS and Friends of the Frisco volunteer involvement.

Barriers: None.

Project schedule and milestones: see end of section.

San Francisco River Sites

Popular camping, OHV-riding and fishing sites on Freeport McMoRan property will benefit from signage designed by GWP in consultation with FMI, to be purchased and installed in the near future by FMI. There remain five heavily used camping areas where signage describing the proper way to dig and cover pit toilets is needed. Where signs cannot be placed in the camping areas – i.e. on State Lands – they will be placed along county right-of-ways on access roads.

Features:

> Thick, digital laminate signs mounted on custom extruded aluminum low-profile bases angled at 30˚ to the ground to discourage graffiti and shooting, describing the proper steps to create and cover a pit toilet that will compost and not get washed into the stream by surface flows.

Technical assistance/resources required: Greenlee County for site selection and oversight of installation.

Financial assistance required: costs of manufacturing and shipping signs, concrete for setting signs, costs of volunteer-based public outreach and monitoring components.

Associated costs: see combined budget at the end of this section.

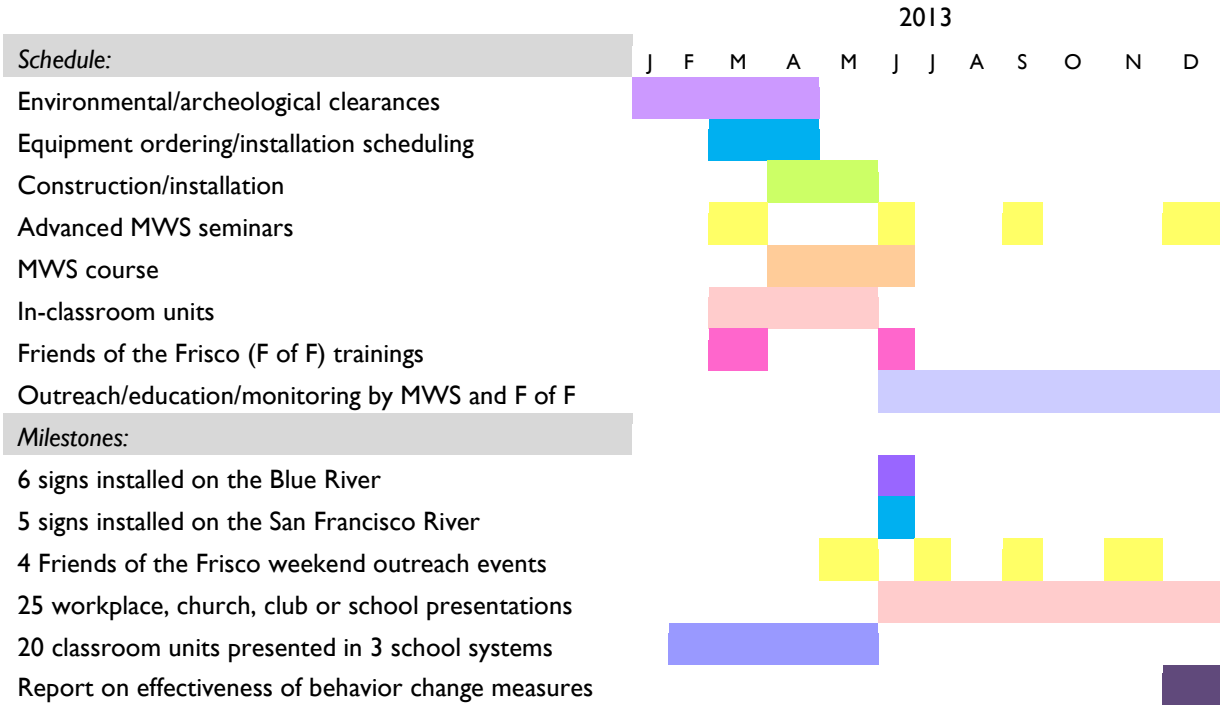
Resources: Forest Service collaboration, Friends of the Frisco volunteer involvement.

Barriers: None.

Associated costs for all signage:

Labor		
	Design services	900
	Coordination	2,720
	Education and Outreach	20,430
Equipment		
	PowerPoint projector (Education and Outreach)	850
Materials and Supplies		
	11 digital laminate signs with shipping	3,450
	11 custom extruded aluminum bases with shipping	6,750
	Concrete	300
	Education/outreach classroom materials/supplies	2,088
Miscellaneous		
	Mileage, advertising	2,100
	Total	39,588

Project schedule and milestones: (all signage projects together)



Education/Outreach/Monitoring Components of Proposed BMPs

Overview

GWP's education and outreach campaign in its Targeted Watershed program has been very successful in educating the community in water quality issues. A high degree of behavior change is occurring. Measurement of those impacts includes the following milestones that have occurred since the campaign began in 2009.

- To date, more than 250 men, women and children have volunteered in GWP activities on the San Francisco and Blue Rivers, and several hundred more have been exposed to community outreach activities.
- Among the MWS graduates, five are teachers in Clifton or Morenci schools and are integrating river and water quality material into their courses. A graduate has just been elected to the Clifton Town Council, where she plans to make surface water quality a priority issue. A graduate who is running for the Greenlee County Board of Supervisors plans to champion water quality issues. Another, who is a candidate for county sheriff in the upcoming election, pledged to begin regular patrols of the river if he wins office. Another is a young employee of the Forest Service. Another is a retired District Forest Ranger and an environmental consultant. Four are mid- or upper-level employees of Freeport McMoRan, the largest employer in the region, who are interested in helping create orientation material for mine employees regarding conduct on the rivers. All of the MWS students left the class committed to working to improve the riparian environment and the water quality of the rivers.
- The Master Watershed Steward course used local expertise, in addition to inviting lecturers from the University of Arizona. Importantly to those on all sides of the controversies surrounding grazing in the area, several influential members of the cattle community served as presenters.
- In cooperation with Graham County Cooperative Extension, third graders in Clifton and Morenci and sixth through ninth graders in Clifton had a series of classroom units on river water quality, including a field trip for a water sampling experiment on the river. Some 50 students were included, along with teachers, parent volunteers, and several visiting U of A graduate students. Numerous teachers have asked that the program be repeated every year.
- The Clifton and Morenci school systems, Freeport McMoRan, Gila Health Resources and other prominent community organizations have become increasingly supportive of GWP's activity, inviting us to be present at their teen and adult health fairs in Morenci and to be represented at meetings of local leaders with FMI management.
- The Target Watershed program spawned Friends of the Frisco, a highly effective volunteer community organization whose focus is improving the water quality and the environment of the San Francisco River.
- The Friends of the Frisco river clean-ups often have more than 50 volunteers in attendance, which is a high turnout for sparsely populated Greenlee County.
- GWP, with Friends of the Frisco, held the First Annual San Francisco River Festival in late 2011, providing a range of educational programs so that people could learn while they helped with keeping river areas clean.
- Clean-up volunteers distribute the *User Guide to the San Francisco River of Southeast Arizona*, along with trash bags, when they communicate with people during clean-up

events. Soon they will also distribute the *San Francisco River Junior Ranger Workbook*, now under development by GWP.

- Volunteers have consistently noted improvements in the behavior of visitors to the river since Friends of the Frisco began its regular clean-ups and outreach. Volunteers are noting less trash, and more portable camp toilets.
- All of our activities are covered in The Copper Era, Greenlee County's weekly newspaper.

How Public Outreach and Education Will Reduce the *E.coli* Exceedances

Please see Dr. Phil Guertin's remarks on pages 41-42 regarding behavior change.

Public behavior is the #1 factor in human fecal contamination of the streams. Unfortunately the areas on the San Francisco River where GWP has documented the greatest number of open toilets are owned by Arizona State Lands and are not available as sites for toilet structures. And, unfortunately, The State Land Department does not have the capacity to enforce its camping and day-use regulations.

As a result, to successfully reduce the human fecal load on State Lands' river reaches, as well as on other sites that are similarly impacted, it is crucial to continue the public outreach and education program. Increasing the numbers of citizens who have knowledge of contamination issues and the solutions, penetrating further into the different communities from which river visitors come, will greatly reinforce good behavior as a new social norm, replacing the "anything goes" attitude that has led to the volume of human fecal contamination seen in GWP's surveys.

In light of the above, GWP has combined intensive, targeted public outreach with each of its proposed BMPs, a component of which will be monitoring for project effectiveness. (Note: this does not include long-term monitoring of *E. coli* levels or microbial source tracking recommended in this WIP as a second phase of project monitoring and evaluation.)

Associated costs for entire education/outreach/monitoring program (costs of individual components are broken out on the following pages):

Labor	20,430
Equipment	850
Materials and Supplies	2,088
Miscellaneous	2,100
Total	25,468

Specific Public Education and Outreach BMPs

Master Watershed Steward Course

Master Watershed Steward course in Clifton has educated and motivated a significant group of local citizens whose influence penetrates wide segments of the community, but it needs to continue. The MWS graduates were unanimous in asking GWP to continue the course so that

others could understand water quality issues and help change public attitudes and behavior. The sales force for continuing MWS education is already in place.

MWS students and graduates will provide exceptional leadership in surveys of public attitudes that will help evaluate BMP projects. Graduates can be uniquely effective in working on BMPs, such as toilets, off-riparian wells and signage, as well as community outreach activities such as employee seminars in workplaces, parent education on safe recreation through the schools, and church-based water quality education projects.

Through the structure of the MWS course, more students will be able to consult with U of A Cooperative Extension faculty and assist in designing surveys for measuring changes in public behavior and attitudes. Current and future MWS graduates will serve as captains of volunteer teams interacting with the public in multiple locations and gathering survey information for project monitoring and evaluation.

Advanced Seminars

The Spring 2012 MWS grads requested that GWP organize occasional day-long Saturday seminars to go into greater depth the specific water quality and other riparian issues introduced in the regular course. These advanced seminars will serve as training sessions for volunteer leaders in surveys and other on-the-ground projects in which a sound grasp of scientific facts is essential.

Growing this motivated volunteer workforce will have lasting and far-reaching impacts. Target populations: all adults and teenagers in Greenlee County, with emphasized outreach to county and municipal officials and employees, local educators and Freeport McMoRan employees.

Associated costs:

Labor		
	Coordination	5,100
	Instructor honoraria	3,600
Equipment		
	PowerPoint projector	850
Materials and Supplies		
	Binders and dividers	160
	Ink and paper	500
	White board and pens	175
	Large pads	120
	High-quality map printing	200
Miscellaneous		
	Mileage	700
	Advertising	400
	Drinking water for field work	200
	Total	12,005

In-school Surface Water Quality Education

Water quality units taught by Graham County Cooperative Extension's Cindy Pearson to third graders and some high school students were popular and effective. They should continue until the great majority of school-aged children in northern Greenlee County are reached. This should include the small school in Blue Village, on the upper Blue River. In addition, making school children aware of other BMPs in progress in the area and of their impacts on water quality will ensure that the next generation's positive behavior in relation to our rivers, water and water quality continues.

Target populations: high school students and third and sixth graders in Clifton, third and sixth graders in Clifton, all students in Blue Village.

Associated costs:

Labor		
	Coordination	850
	Teacher and assistant	4,800
Equipment		
		0
Materials and Supplies		
	Misc.	400
Miscellaneous		
	Mileage	500
	Total	6,550

Friends of the Frisco Training

Friends of the Frisco has high visibility now in northern Greenlee County. Its activity is regularly featured in The Copper Era, Greenlee County's weekly newspaper. The group has outstanding and unflagging volunteer spirit and continues to attract new faces of all ages at every event. Friends of the Frisco plans to continue organizing clean-up events three times a year, including the annual San Francisco River Festival.

Friends of the Frisco volunteers, like MWS graduates, can be uniquely effective in introducing other BMPs, such as toilets or off-riparian wells, to their circles in the community, representing such BMPs as the direct result of community involvement rather than something introduced by authorities in other places. They will also be a key support in keeping toilet facilities and signage looking well-groomed. Finally, Friends of the Frisco can perform the essential on-the-ground activities of monitoring and evaluation created in the context of MWS.

GWP has kept its supporting role in Friends of the Frisco low-key. However, the support of professional staff has been essential to the success of the volunteer organization, along with funding for many of the community group's costs. Members of the group are not prepared at this time to take over the leadership functions that GWP has provided. Training in the scientific basics of the watershed's issues and in techniques of community outreach will help Friends of the Frisco take on role assumed over the last two years by Targeted Watershed program staff.

Target populations: ten to twelve committed volunteers in Friends of the Frisco.

Associated costs:

Labor		
	Coordination and research	4,080
	Additional trainers	2,000
Equipment		
	PowerPoint projector*	850
Materials and Supplies		
	Binders and dividers	48
	Ink and paper	250
	White board and pens	175
	Large pad	60
Miscellaneous		
	Mileage	300
	Total	7,763

* duplicative cost -- see MWS and Advanced Seminars. Only one PowerPoint projector purchase is required.

Cost Effectiveness Comparison

Cost Effectiveness Comparison

BMP	Cost without education/outreach/monitoring component	Estimated load reduction	Cost of additional benefits of education/outreach/ volunteer monitoring component	Estimated load reduction
Toilet #1	$68,425	6.9 x 10^{10} to 6.9 x 10^{12} CFU or 100%	$23,368	1.38 x 10_{11} to 1.38 x 10_{13} CFU or 200%
Toilet #2	$58,800	6.9 x 10^{10} to 6.9 x 10^{12} CFU or 100%		
add visitor kiosk	$29,580	(incl. at right)	$23,368	1.38 x 10_{11} to 1.38 x 10_{13} CFU or 200%
Off-riparian solar wells and fencing	$119,434	1.8 x 10^{17} CFU to 4.1 x 10_{16} CFU or 23%	$23,368	1.38 x 10_{11} to 1.38 x 10_{13} CFU or 200%
Signage	$16,220	(unknown)	$23,368	1.38 x 10_{11} to 1.38 x 10_{13} CFU or 200%