The State of the Verde River

A summary of five years of water quality data collection by the Arizona Water Sentinels (December 2006 to December 2011)

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”To explore, enjoy and protect the wild places of the Earth; to practice and promote the responsible use of the Earth’s ecosystems and resources; to educate and enlist humanity to protect and restore the quality of the natural and human environment; and to use all lawful means to carry out these objectives.”

Mission Statement of the Sierra Club

Acknowledgements

This report would not have been possible without the dedication and outstanding work of the volunteers of the Arizona Water Sentinels program. For the past five years, Water Sentinels have volunteered hundreds of hours collecting water quality samples, measuring stream flow, and making field measurements and observations on the Verde River.

The Arizona Water Sentinels also have volunteered for stream clean-ups, native fish restoration projects, and invasive species removal service projects within the Verde River watershed. These volunteers provide inspiring examples of watershed stewardship for all Arizonans who are concerned about watershed protection and the conservation of streams and riparian areas in our arid state. This report is dedicated to the volunteers who "get their hands dirty and their feet wet" while working to maintain and protect the Verde River, one of Arizona's most important riparian ecosystems. To all of our volunteers, thank you.

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While the author is grateful for the many contributions others made to improve this report, he remains entirely responsible for its content.

This report is available on-line at the Grand Canyon Chapter of the Sierra Club website:

http:// arizona.sierraclub.org.

Cover photo: Arizona Water Sentinel Gerry McCullough collects a water sample near the headwaters of the Verde River. Photo credit: Gary Beverly

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Executive Summary

The Arizona Water Sentinels program is a grassroots organization with approximately 200 volunteers who do "hands-on" conservation work and who like to "get their hands dirty and their feet wet" while working to protect local streams and watersheds in our desert state. This program seeks to further the mission of the Sierra Club by connecting Arizona citizens to local watersheds through meaningful volunteer work to maintain and protect streams near their communities. Through public outreach and education, the Arizona Water Sentinels are working to develop a greater sense of watershed stewardship in the public at large.

The current focus of the Water Sentinels' conservation work is on maintaining and protecting Arizona's remaining perennial rivers and streams. The work of the Water Sentinels can be grouped into three broad categories: 1) volunteer water quality and flow monitoring, 2) stream clean-ups, and 3) stream restoration work, which includes removing invasive plant species and restoring native plant and animal species in riparian areas.

The Grand Canyon Chapter of the Sierra Club began developing a proposal for a Water Sentinels program early in 2006 and received a small amount of funding in mid year to fund training, transportation, and laboratory analyses. The "birthday" of the Arizona Water Sentinels program is July 15, 2006. On that date, a group of 20 National Sierra Club and Grand Canyon Chapter staff and volunteers organized and attended the first training program to discuss the creation and implementation of a Water Sentinels program in Arizona. The first monitoring trip to obtain water quality data at sampling sites on the Verde River was conducted on December 2, 2006.

Since December 2006, the Water Sentinels have implemented a volunteer water quality and flow monitoring program on the Verde River. Teams of Water Sentinels volunteers have collected water samples, made field measurements of water quality parameters, and measured the flow of the river at six to eight sampling sites on the Verde River over the last five years. The data summarized in this report was collected between December 2, 2006, and December 10, 2011. The suite of water quality parameters include *E. coli* bacteria, total arsenic, total nitrogen, total phosphorus, and suspended sediment concentration. Water Sentinels also made field measurements of dissolved oxygen concentration, pH, electrical conductivity, total dissolved solids, and air and water temperature. They collected hundreds of water samples at six to eight sampling sites along the upper and middle reaches of the Verde River during all seasons in the five-year period, visiting sampling sites on the Verde River five or six times each calendar year.

Water Quality Findings

The Water Sentinels dataset provided enough data to reasonably draw several conclusions about the water quality of the Verde River for the parameters selected for analysis. In general, the dataset indicates that the water quality of the Verde River is good with respect to those water quality parameters.

Microbiological water quality: The *E. coli* bacteria dataset indicates that the Verde River is safe for swimming and water-based recreation such as kayaking, canoeing, and tubing. The data show only a few, isolated exceedances of Arizona's bacteria standards to protect human health and recreational use. In five years of data collection, the Water Sentinels obtained 13 sample results out of 194 samples that exceeded the single sample maximum water quality standard for *E. coli* bacteria adopted by the State of Arizona (235 CFU/100). Over 95 percent of the sample results obtained complied with applicable water quality standards for bacteria to maintain and protect water quality for recreation, including full body contact recreational uses such as swimming. The largest number of *E. coli* standard violations was found at the Highway 89A Bridge site near downtown Cottonwood. Our dataset suggests that there may be sources of fecal contamination of the Verde River in the more developed river corridor in the area between Clarkdale and Cottonwood. More frequent monitoring at more sampling sites in this middle reach of the Verde River is recommended to determine possible source[s] of contamination in the area.

Total arsenic: The dataset for total arsenic in the Verde River confirms the findings of previous investigators that total arsenic concentrations in the Verde River are elevated above drinking water standards. The Water Sentinels collected 184 water samples for total arsenic analysis over a five-year period. Ninety-eight percent of sample results for total arsenic met the applicable Arizona surface water quality standard designed to protect human health and recreational uses of the Verde River (30 µg/L). The Water Sentinels found four violations of this standard over the last five years. In contrast, total arsenic concentrations in samples collected from the Verde River routinely exceeded the Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) for arsenic in drinking water (10 µg/L). The dataset shows that 94 percent of the sample results exceeded the drinking water MCL for arsenic and only 11 of 184 sample results complied with the standard.

Elevated arsenic concentrations in the Verde River are thought to be due to natural causes relating to the geology of the Verde River watershed. Elevated concentrations are caused by the leaching of water infiltrating through the arsenic-bearing soils of the Verde Formation to groundwater, which ultimately is discharged to the Verde River. The Water Sentinels dataset shows that total arsenic concentrations in water exceeding 10 µg/L are widespread. For this reason, we recommend that residents of the Verde Valley who rely on wells for their drinking water have their well water tested for arsenic to determine whether it meets drinking water standards. Water from the Verde River used by public water systems for drinking water supply should be blended or treated to reduce total arsenic concentrations in finished drinking water to less than 10 µg/L.

Nutrients – Total Nitrogen and Total Phosphorus: The Verde River does not appear to have water quality problems associated with excessive nutrient concentrations at this time. The dataset documents that Total Kjeldahl Nitrogen (TKN) concentrations of water samples from the Verde River have been consistently low over the five-year period of record with concentrations ranging from less than 0.2 mg/L to 0.7 mg/L. Nitrate plus nitrite concentrations range from less than 0.01 mg/L to a maximum of 1.34 mg/L during the two-year period this constituent was sampled (2010 and 2011). Water Sentinels collected 58 sample sets that permitted the calculation of total nitrogen concentrations from March 13, 2010 to December 10, 2011. The sample results show that water quality of the Verde River with respect to total nitrogen consistently complied with the applicable single sample maximum (SSM) water quality standard of 3.0 mg/L for total nitrogen. There were no violations of this standard over the two-year period of time that the Water Sentinels conducted more complete nutrient sampling to permit the calculation of a total nitrogen concentration.

The Water Sentinels collected 192 water samples for total phosphorus analysis from December 2, 2006, to December 10, 2011. There were no violations of the SSM total phosphorus water quality standard over that time. The maximum concentration of total phosphorus reported by the Water Sentinels was 0.644 mg/L from a sample obtained at the White Bridge sampling site on August 16, 2008. This sample result is still well below the SSM standard of 1.0 mg/L for total phosphorus. The dataset demonstrates that Verde River water quality with respect to total phosphorus is excellent and consistently complies with the SSM standard.

Suspended Sediment Concentration (SSC): The Water Sentinels collected 64 SSC samples on the Verde River over a two-year period (2010 and 2011). We, therefore, have only a limited SSC dataset to interpret. However, the limited dataset indicates that water quality with respect to suspended sediment in the Verde River appears to be good when the river is at base flow. No violations of the Arizona water quality standard of 80 mg/L (a median value based on a minimum of four samples) were found. Median SSC values ranged from a low of 4.68 mg/L at the Water Sentinels Reitz property sampling site to a high median value of 22.26 mg/L at Beasley Flat. In general, it appears that suspended sediment concentrations are, on average, higher in the more developed, middle reaches of the Verde River near the towns of Clarkdale, Cottonwood, and Camp Verde than the average SSC concentrations found in the upper Verde River.

Dissolved Oxygen (DO): Dissolved oxygen (DO) concentrations of the Verde River are adequate to support healthy populations of aquatic organisms. A total of 74 field measurements were taken for DO, ranging from a low of 2.5 mg/L (White Bridge site on September 19, 2009) to 12.9 mg/L (Bear Siding sampling site on November 21, 2009). The average DO concentration calculated from all valid dissolved oxygen field measurements from the Verde River over the last two years is 7.5 mg/L.

The Water Sentinels made 18 field measurements (24 percent) of DO in the Verde River that were less than Arizona's minimum DO water quality standard of 6.0 mg/L that has been adopted to protect aquatic life in the Verde River. Eight of these violations were measured at the Water Sentinels sampling site above Verde Springs. These violations may have been due to natural causes relating to low DO concentrations in groundwater discharged to create the base flow of the Verde River above Verde Springs

The other 10 field measurements (13 percent) violating the 6 mg/L water quality standard were scattered among the following Water Sentinels sites: Reitz property (2 violations), 89A Bridge (3 violations), Black Bridge (1 violation), White Bridge (2 violations), and Beasley Flat (2 violations). Eighty-seven percent of DO measurements made at sampling sites other than the site above Verde Springs complied with applicable water quality standards. Also, it should be noted that six of the 10 violations are relatively minor, with field measurements falling between 5 mg/L and 6 mg/L.

pH: The Water Sentinels made 194 field measurements of pH at seven sites on the Verde River between February 2, 2007, and December 10, 2011. In general, these data show that the water quality of the Verde River with respect to pH is very good and that there is little variability in pH measurements between sampling sites. Ninety-nine percent (192 out of 194) of field measurements complied with the 6.0 to 9.0 Standard Unit (S.U.) range established by the Arizona water quality standard for pH to protect aquatic life and wildlife. Overall, pH measurements show that the Verde River is slightly alkaline. The minimum pH value measured by the Water Sentinels over the last five years was 6.9 S.U. at Beasley Flat, which is only slightly below neutral at 7.0 S.U. In fact, only two pH measurements in the last five years were below 7.0 S.U.; both were only slightly below neutral with pH values of 6.9 and 6.99 S.U. The maximum pH value measured by the Water Sentinels was 9.57 S.U. at Beasley Flat on February 17, 2007.

Total dissolved solids (TDS): Water Sentinels field measurements show that TDS concentrations in the Verde River are typically in the 200 to 300 parts per million (PPM) range. All but three of the 168 field measurements of TDS over the last five years were below the EPA Secondary Maximum Contaminant Level (MCL) for drinking water of 500 mg/L. More than 98 percent of the Water Sentinels TDS measurements were less than this standard.

In general, TDS concentrations tend to increase as the Verde River flows downstream from its source above Verde Springs to Beasley Flat. However, the increase is not uniform. Arizona Water Sentinels data show that average TDS concentrations are variable, increasing or decreasing in different reaches of the river. This variability may be explained by contributions of water from different tributaries with different TDS concentrations, possible irrigation return flows, or discharges from springs with different salinities in different reaches of the Verde River.

Chapter 1. The Verde River Photo Gallery

It is has been said that "one picture is worth a thousand words."[1] The photographs of the Verde River in this gallery are worth many thousands of words. They speak eloquently of the beauty and biological diversity of the Verde River and show why the river merits protection and preservation. With the exception of the photograph below, the photographs in the gallery were taken at Water Sentinels sampling sites.

Figure 1. The upper Verde River near Duff Springs
Photo credit: Gary Beverly

[1] The phrase, "One picture is worth a thousand words," is attributed to Mr. Fred R. Barnard, who is believed to have coined a similar phrase in the advertising trade journal *Printers' Ink*. The December 8, 1921, issue of *Printer's Ink* carried an ad entitled "One Look is Worth a Thousand Words" to promote the use of images as advertisements on the sides of streetcars. Source: Wikipedia.

Figure 2. The upper Verde River at the Above Verde Springs sampling site
Photo credit: Gary Beverly

Figure 3. The upper Verde River near Bear Siding
Photo credit: Tom Slaback

Figure 4. Looking upstream on the Verde River at the Reitz property sampling site
Photo credit: Carole Piszczek-Sheffield

Figure 5. Looking upstream at the Highway 89A Bridge sampling site in Cottonwood, AZ
Photo credit: Carole Piszczek-Sheffield

Figure 6. Verde River at the Black Bridge sampling site
Photo credit: Mark Coryell

Figure 7. Contemplating the Verde River at the White Bridge sampling site
Photo credit: Sandy Bahr

Figure 8. Verde River at the Beasley Flat sampling site
Photo credit: Scott Mittelsteadt

Chapter 2. The Arizona Water Sentinels Program

The Who, What, Where, When, and Why of the Water Sentinels

The Arizona Water Sentinels program is a "hands-on" conservation program of the Sierra Club, the oldest, largest, and most influential grassroots environmental organization in the United States. Founded by John Muir in 1892, the Sierra Club now has more than 1.3 million members and supporters who participate in 450 local chapters and groups nationwide. In Arizona, the Sierra Club is represented by its Grand Canyon Chapter with 12,000 members. Since its founding, the members of the Sierra Club have worked to protect over 250 million acres of wild lands and 8,000 miles of wild and scenic rivers nationwide.[2]

The national Water Sentinels program was established in 2001. The primary purposes of the program are to educate the public about water quality problems in the United States and to advocate for effective implementation and enforcement of the Clean Water Act:

> "We are the first line of defense for America's waters. We work to protect, improve, and restore our waters by engaging volunteers and fostering alliances to promote water quality monitoring, public education, and citizen action."[3]

The Water Sentinels program is designed to engage people in protecting local water bodies through citizen water quality monitoring, stream clean-ups, stream restoration work, and grassroots conservation work. This program provides the tools and training that volunteers need to be successful in this important conservation work. Since its inception, the national Water Sentinels program has trained, equipped, and fielded 12,000 volunteers who participate in 51 project sites in 21 states.[4] The Arizona Water Sentinels program is one of these state projects.

One of the organizing principles of the Water Sentinels program is that the best way to maintain and protect America's water resources is to empower citizen activists by providing them with accurate information and training in water quality monitoring techniques and grassroots advocacy for local water bodies. The Water Sentinels program puts it this way: "Standing knee deep in the local waters they cherish is a powerful position from which to advocate for positive change for the strongest protections…."[5] Water Sentinels provide proof for the proposition that ordinary citizens can accomplish important environmental victories

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[2] Current Sierra Club membership brochure

[3] "Protecting America's Waterways, Sierra Club's Water Sentinels Program," Sierra Club Water Sentinels website: http://www.sierraclub.org/watersentinels

[4] *Id.*

[5] *Id.*

when they are connected to a water body and they become personally engaged in efforts to protect it.

Who are the Arizona Water Sentinels?

The Arizona Water Sentinels are volunteers who are dedicated to the maintenance, protection, and preservation of streams and riparian areas in Arizona. Water Sentinels have a love for the outdoors, and we share a special concern for water resources in our desert state, especially its perennial rivers and streams. As dwellers in a dry land, we are drawn to water. We enjoy hiking, bird-watching, wildlife viewing, nature photography, camping, fishing, swimming, wading, kayaking, canoeing, rafting, or simply contemplating the beauty of Arizona's rivers and streams. Water Sentinels are deeply concerned about the continuing loss of streams and riparian habitats in Arizona. Acting on this concern, volunteers do "hands-on" conservation work to preserve and protect Arizona's critically important rivers, streams, and diminishing riparian areas.

The Arizona Water Sentinels program is a grassroots organization with one full-time program coordinator and approximately 200 volunteers. The program seeks to further the mission of Sierra Club by connecting Arizona citizens to local watersheds through meaningful volunteer work to maintain and protect streams near their communities. We seek to build a community of activists for clean water who will advocate for greater protection of Arizona's water resources statewide through the development of personal connections to local watersheds. Through public outreach and education, the Arizona Water Sentinels are working to develop a greater sense of watershed stewardship in the public at large across the state.

What do Arizona Water Sentinels do?

The Arizona Water Sentinels do "hands-on" conservation work. As we like to say, they like to "get their hands dirty and their feet wet" while working to protect local streams and watersheds. The current focus of the Water Sentinels' conservation work is on maintaining and protecting Arizona's remaining perennial rivers and streams. This work can be grouped into three broad categories: 1) volunteer water quality and flow monitoring, 2) stream clean-ups, and 3) stream restoration work, which includes removing invasive plant species and restoring native plant and animal species in riparian areas.

Volunteer water quality monitoring on the Verde River

Since December 2006, the Arizona Water Sentinels have implemented a volunteer water quality and flow monitoring program on the Verde River. Teams of volunteers have collected water samples, made field measurements of water quality parameters, and measured the flow of the river at six to eight sampling sites. A team of volunteers measures discharge (i.e., the flow) monthly at two sites on the upper Verde River: Above Verde Springs and Perkinsville. Three other teams of volunteers go to six sampling sites on the upper and middle Verde River to make field measurements of dissolved oxygen, pH, electrical conductivity, total dissolved solids, and water temperature.[6] They collect water samples from the Verde River for later laboratory analyses to determine the concentrations of *Escherichia coli (E. coli)* bacteria, total arsenic, total nitrogen, total phosphorus, and the suspended sediment concentration of the river.[7] Arizona Water Sentinels have gone to the Verde River monitoring sites at least five times during each calendar year between December 2, 2006, and December 31, 2011.

Figure 9. Arizona Water Sentinels sampling at Beasley Flat
Photo credit: Sandy Bahr

[6] The Water Sentinels water quality monitoring sites are called Above Verde Springs, Perkinsville, Reitz, Highway 89A Bridge, Black Bridge, and Beasley Flat. We previously sampled at two other sampling sites, Bear Siding and White Bridge, but discontinued water quality monitoring at these sites in 2010.

[7] *See Arizona Water Sentinels Verde River Sampling Plan – 2011*, (January 1, 2011, to December 31, 2011). Aquatic Consulting and Testing in Tempe, AZ, is the laboratory that performs analyses of water samples collected by the Water Sentinels.

Stream clean-ups

Arizona Water Sentinels have conducted numerous stream clean-ups over the last five years, including on the Verde River, San Pedro River, and along Fossil Creek, a tributary of the Verde River. The Water Sentinels often partner with a state or federal land management agency, such as the U.S.D.A. Forest Service, Bureau of Land Management, or Arizona Game and Fish Department that have management responsibilities for the public lands or wildlife areas where the stream clean-ups take place. Water Sentinels also partner with other non-profit organizations such as Friends of the Verde River Greenway and Friends of the San Pedro River on stream clean-ups.

Figure 10. Water Sentinels volunteers with some of the trash picked up during a clean-up on the Verde River
Photo credit: Scott Sprague

Stream restoration

Arizona Water Sentinels volunteer to restore riparian habitats along streams. For example, Water Sentinels are working to maintain and restore the Rio Salado Habitat Restoration Area, a part of the Salt River watershed in the Phoenix metropolitan area. Volunteers gather once a month on a Sunday morning for a “Rio Salado Weed & Clean” event, during which they spend several hours digging up and removing buffel grass, a non-native, invasive grass species that competes with desirable native plant species. Water Sentinels also pick up litter and garbage that has washed into the Rio Salado Habitat Restoration Area through storm drains and has accumulated in the Salt River channel. They have also helped with revegetation in the Habitat Restoration Area.

Figure 11. Water Sentinels remove and bag buffel grass in the Rio Salado Habitat Restoration Area in Phoenix, AZ Photo credit: Sandy Bahr

Where do the Water Sentinels work in Arizona?

The Arizona Water Sentinels do conservation work on rivers, streams, and riparian areas within the State of Arizona. We currently implement volunteer monitoring and service projects on the Verde River and some of its major tributaries (e.g., Fossil Creek, Arizona's second Wild and Scenic River), the upper San Pedro River, the Rio Salado Habitat Restoration Area (an urban stream restoration project located along the Salt River in the Phoenix metropolitan area), and the Tres Rios Ecosystem Restoration and Flood Control Project (located on the Gila River in the West Valley of the Phoenix metropolitan area).

The Arizona Water Sentinels program is growing. We seek to expand to become a statewide volunteer program, connecting Arizona citizens to local watersheds throughout the state and engaging citizens in volunteer monitoring, stream clean-ups, and service projects to protect and enhance Arizona's remaining rivers and riparian habitats. Our immediate, short-term goals are to maintain current Water Sentinels programs on the Verde River, San Pedro River, and Rio Salado Habitat Restoration Area. We hope to expand the program to engage Water Sentinels volunteers in conservation work on the lower Gila River within the Tres Rios Ecosystem Restoration and Flood Control Project in the Phoenix metropolitan area, the Santa Cruz River in southeastern Arizona, and along Oak Creek, an Outstanding Arizona Water that is a tributary to the Verde River. Long-term goals are to expand our volunteer efforts to have a Water Sentinels presence in each of Arizona's major watersheds, including the lower Colorado River, Little Colorado River, and the upper Gila River watersheds.

When did the Arizona Water Sentinels program begin?

The Grand Canyon Chapter of the Sierra Club began developing a proposal for a Water Sentinels program early in 2006 and received a small amount of funding in mid year to fund training, transportation, and laboratory analysis. If the Arizona Water Sentinels program can be said to have a birthday, it is July 15, 2006. On that date, a group of 20 national and Grand Canyon Chapter staff and volunteers organized and participated in the first training program to discuss the creation and implementation of a Water Sentinels program in Arizona. The first monitoring trip to obtain water quality data at sampling sites on the Verde River was conducted on December 2, 2006. Since then, the Water Sentinels have returned to the Verde River on 34 sampling trips over the last five years to collect samples and obtain water quality data. Water Sentinels' water quality monitoring continues, but the last trip to the Verde River to obtain water quality data used in this report was on December 10, 2011. Water Sentinels flow monitoring teams have made 60 separate trips to measure discharge at sites on the upper Verde River over the last five years.

Why do Arizona Water Sentinels volunteer?

People volunteer for the Arizona Water Sentinels program for many reasons. However, Water Sentinels volunteers are inspired, at least in part, by the mission statement of the Sierra Club:

> "To explore, enjoy, and protect the wild places of the Earth; to practice and promote the responsible use of the Earth's ecosystems and resources; to educate and enlist humanity to protect and restore the quality of the natural and human environment; and to use all lawful means to carry out these objectives."

Water Sentinels volunteer to "explore, enjoy, and protect" Arizona's rivers and streams. The program provides excellent opportunities for people to get outside, connect to nature, and do real, meaningful conservation work while exploring and enjoying the beauty and incredible biological diversity of Arizona's rivers, streams, and riparian areas.

Chapter 3. The Verde River Watershed

Every river is located within a watershed. A simple definition of a watershed is the area of land where all of the water that falls on it or is under it drains to the same place. Major John Wesley Powell, the first known non-native explorer to run the length of the Colorado River through Grand Canyon, defined a watershed as follows: "…that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community."[8]

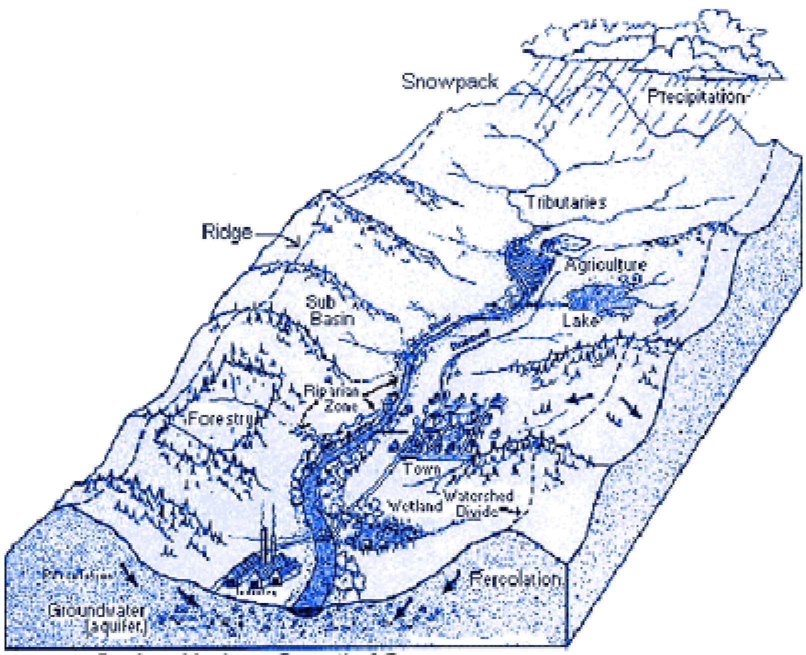

Figure 12. A generic watershed
Source: EPA "What is a Watershed" web page[9]

The Verde River watershed is one of 2,110 watersheds in the continental United States.[10] As John Wesley Powell so cogently observed, there is an inextricable link between the human, animal, and plant communities of the Verde River watershed and its common water course, the Verde River. As part of the Verde River watershed, the future of each of these communities is inextricably bound to the preservation, health, and sustainable future of the Verde River.

[8] EPA website, "What is a Watershed?" *See* http://water.epa.gov/type/watersheds/whatis.cfm.
[9] *Id.*
[10] *Id.*

Where is the Verde River watershed?

The Verde River watershed is located in central Arizona [*See* inset in Figure 13 below]. The Verde River watershed area is large, encompassing approximately 6,622 square miles or 4.2 million acres.[11] As the inset below illustrates, the Verde River watershed is located entirely within the borders of the State of Arizona.

Figure 13. The Verde River watershed
Source: Arizona Department of Water Resources Water Atlas

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[11] Arizona Nonpoint Education for Municipal Officials (NEMO) Watershed Plan. 2005.

The Verde River watershed is within the Colorado River Basin

The Verde River watershed is a sub-watershed of the much larger Colorado River Basin [*See* Figure 14 below]. The Verde River is a tributary of the Salt River, meaning that it flows downstream from its source to join the Salt River. The Salt River, in turn, flows west to join the Gila River. The Gila River flows intermittently across southwestern Arizona and ultimately joins the lower Colorado River near Yuma, Arizona. Because the Gila River drains to the lower Colorado River, the Verde River watershed is considered one of many sub-watersheds within a much larger Colorado River Basin, a huge watershed (or basin) that encompasses seven states, much of the area of the western United States, and part of Mexico. The area of the Colorado River Basin is approximately 243,000 square miles or about 10 percent of the area of the continental United States.

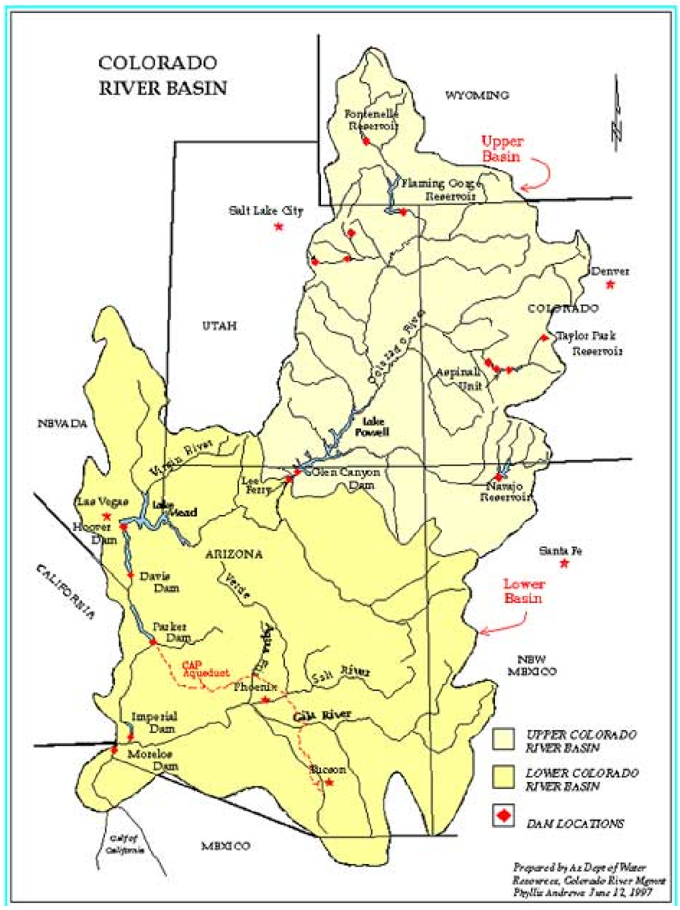

Figure 14. The Colorado River Basin
Source: Arizona Department of Water Resources

The Verde River is within the Transition Zone

Physiographic regions, provinces, and sections are broad-scale, geomorphic subdivisions based on the terrain and geology of a land area.[12] There are three major physiographic provinces or sections in Arizona: 1) the Colorado Plateau province, 2) the Basin and Range province, and 3) the Transition Zone. The Transition Zone is a physiographic section located between the Colorado Plateau physiographic province to the north and the Basin and Range physiographic province to the south [*See* Figure 15 below]. A large area of the Verde River watershed is located within the Transition Zone. The upper, northwestern part of the Verde River watershed extends into the Colorado Plateau physiographic province. The terminus of the Verde River, at its confluence with the Salt River (i.e., at the "bottom" of the Verde River watershed), is located within the Basin and Range physiographic province.

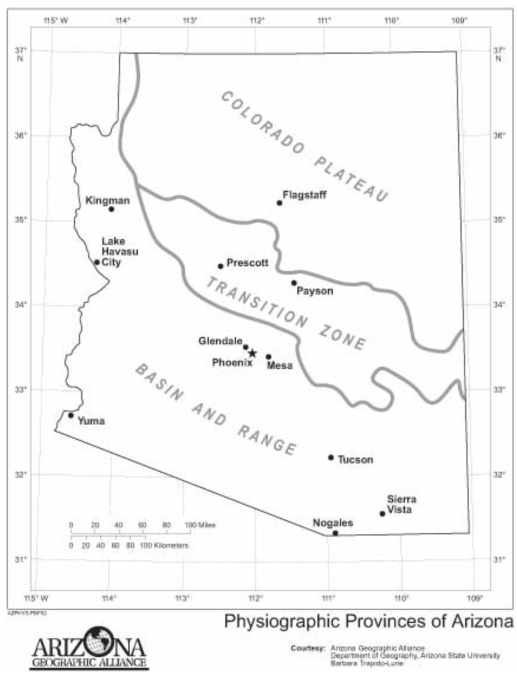

Figure 15. Physiographic provinces of Arizona
Source: Arizona Geographic Alliance

One of the most significant physical features of the Transition Zone is the Mogollon Rim, a 200-mile long escarpment that runs across central Arizona to the border with New Mexico. The Mogollon Rim demarcates the southern boundary of the Colorado Plateau physiographic province and forms the watershed divide between the Little Colorado River watershed to the north and the Verde River watershed to the south. Most of the streams in Arizona that flow

[12] The list of physiographic regions in the continental United States includes 8 regions, 25 provinces, and 85 sections. The physiographic classification system dates to Nevin Fenneman's paper *Physiographic Subdivision of the United States*, published in 1917. Fenneman expanded and presented his classification system more fully in two books, *Physiography of Western United States* (1931) and *Physiography of Eastern United States* (1938). In these two works, Fenneman described 25 provinces and 85 sections of the United States physiography.

year-round are located in the Transition Zone.[13] The Verde River is one of the longest and most important perennial rivers in the Transition Zone.

Geography of the Verde River watershed

The northwestern boundaries of the Verde River watershed extend north of Interstate 40 and the towns of Seligman and Ash Fork; the watershed is bordered on the east by Big Black Mesa and on the west by the Juniper Mountains. The Big Chino Valley is the principal drainage within the headwaters region of the Verde River watershed.

The northeastern and eastern boundaries of the middle and lower parts of the Verde River watershed are demarcated by the watershed divide along the Mogollon Rim and the ridgelines of the Mazatzal Mountains to the north and east. The western and southwestern boundaries of the Verde River watershed are bounded by hills and several mountain ranges. These include the Santa Maria Mountains, Black Hills, and the Bradshaw Mountains. These mountain ranges are generally oriented in a northwest to southeast direction. The maximum elevations of the mountains and hills in the Verde River watershed range from 6,000 to 7,800 feet above mean sea level. The main stem of the Verde River flows through the Verde Valley near the towns of Clarkdale, Cottonwood, and Camp Verde. The southern boundary of the Verde River watershed extends to the confluence of the Verde River and the Salt River located north of the City of Mesa and east of the Phoenix metropolitan area.

Figure 16. The combined Salt and Verde Rivers at the Granite Reef Diversion Dam
Photo Credit: Salt River Project

[13] Cordy, Gail E., D.J. Dellenbeck, Joseph B. Gebler, David W. Anning, Alissa L. Coes, R.J. Edmonds, Julie A.H. Rees, and H.W. Sanger. 2000. *Water Quality in the Central Arizona Basins, Arizona, 1995-1998*. U.S. Geological Survey Circular 1213, U.S. Geological Survey, p.3.

Geology of the Verde River watershed

The uplands of the Verde River valley generally consist of volcanic and metamorphic rocks from the Precambrian geologic era (over 600 million years ago), overlain by sedimentary strata from Paleozoic times (542 million years ago to 251 million years ago), and capped by volcanic rocks from the Cenozoic era (65.5 million years ago to the present). Outcrops of Mesozoic rocks appear above the Paleozoic strata in the upper parts of Sycamore Creek and Oak Creek canyons. Elements of the Paleozoic strata and the Cenozoic volcanic rocks may be partly or entirely absent, leaving a patchwork of exposed outcrops throughout the uplands of the Verde River watershed.[14]

The Chino Valley and the Verde River valley from Clarkdale to Camp Verde are relatively broad and are composed of basin fill and alluvium underlain by Paleozoic sedimentary rocks. The basin fill alluvium is greater than 2,500 feet thick in some parts of the Chino Valley. Lacustrine (i.e., lake) sediments and volcanic rocks are inter-bedded with the alluvium. From the headwaters of the Verde River to Clarkdale, the Verde River has cut down through a narrow canyon that contains little or no alluvium fill.[15]

The predominant structural features of the Verde River watershed are northwest- to north-trending faults, including the Big Chino fault along the northeastern border of Chino Valley and the Verde fault zone along the southwest side of the Verde River valley. These fault zones are the primary geologic influences on the present-day topography of the Verde Valley.[16]

Hydrology of the Verde River

The Verde River is a perennial river, which means that it flows continuously throughout the year. Perennial rivers are critically important water resources because there are relatively few in the state. The Arizona Department of Environmental Quality estimates that less than 10 percent of the total miles of stream channel in Arizona contain perennial streams.[17] It is estimated that the State of Arizona has lost approximately 35 percent of its perennial stream miles within the last 200 years.[18]

Many rivers and streams in Arizona are temporally or spatially intermittent. A temporally intermittent stream is a stream that flows seasonally or for only a part of the year. For example,

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[14] Woodhouse, Betsy, Marilyn E. Flynn, John T.C. Parker, and John P. Hoffman, *Investigation of the Geology and Hydrology of the Upper and Middle Verde River Watershed of Central Arizona: A Project of the Arizona Rural Watershed Initiative*, U.S. Department of Interior, U.S. Geological Survey, USGS Fact Sheet 059-02.

[15] *Id.*

[16] *Id.*

[17] Jones, Jason, ed. 2011. *Arizona's Comprehensive Water Quality Monitoring Strategy for Fiscal Years 2007 to 2017*, Arizona Department of Environmental Quality, June 2011, p. 4.

[18] Turner, D.S and Richter, Holly E., 2011, *Wet / Dry Mapping: Using Citizen Scientists to Monitor the Extent of Perennial Surface Flow in Dryland Regions*, Environmental Management, published online February 10, 2011.

a temporally intermittent stream may flow during the spring in response to runoff from precipitation or melting snow at higher elevations in the watershed. Melting snow and other precipitation flows overland or infiltrates into the ground, recharging the water table and causing small springs and seeps to discharge to stream channels during the early spring. A temporally intermittent stream may flow for weeks or months during early spring depending on the depth of the winter snowpack and the amount of groundwater recharge. Temporally intermittent streams in Arizona usually dry back and will stop flowing after the winter snowpack melts away completely. The spring runoff slowly decreases, and eventually the seeps and springs will cease discharging water to the stream channels.

A spatially intermittent stream is one in which water may flow on the surface for some distance, infiltrate into the ground, and then re-appear some distance downstream. A spatially intermittent stream can be visualized as "pearls on a string" with the "pearls" being the wet reaches of the stream where water flows on the surface in the stream channel. The "string" consists of dry stream reaches where the water goes underground between the wet reaches. The length of the wet and dry reaches of a spatially intermittent stream can vary depending on drought conditions, the amount of precipitation that falls during the year, and consumptive uses of water. The San Pedro River in southeastern Arizona is a good example of a spatially intermittent stream. Wet/dry mapping on the San Pedro River reveals that approximately 50 percent of the river's length flows on the surface of the ground throughout the year.[19] In contrast, the Verde River is *not* spatially intermittent. The Verde River flows continuously from its source to its confluence with the Salt River 175 miles downstream.

An ephemeral stream is one that flows only in direct response to a local precipitation event. Washes and arroyos are good examples of ephemeral streams that flow for short periods of time after a local rain storm. Ephemeral streams may flow for a few minutes or hours in response to storm runoff from a local rain storm. Sometimes, these brief flows result in flash floods. Ephemeral streams are completely disconnected from the underlying water table. That is, the stream bed of an ephemeral stream is, at all times, above the water table, so there is no opportunity for groundwater to discharge to the stream channel through springs or seeps. There are many ephemeral tributary streams to the Verde River.

The vast majority of stream miles in Arizona, more than 95 percent, are either intermittent or ephemeral streams. The Arizona Department of Environmental Quality estimates that only five percent of the river miles in Arizona flow perennially throughout the year.[20] This small percentage of perennial stream miles highlights the critical importance of the Verde River, one of the longest remaining perennial rivers in Arizona.

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[19] *Id.*

[20] 2006/2008 Status of Ambient Surface Water Quality in Arizona, Arizona's Integrated 305(b) Assessment and 303(d) Listing Report, November 2009.

The source of the Verde River

The Verde River begins as a small discharge from a network of springs and seeps near the confluence of Granite Creek and the main Verde River channel, a few miles east of the community of Paulden, Arizona. The Verde River begins in a canyon at the confluence of the Big Chino Valley and Little Chino Valley alluvial basin-fill aquifers. These two aquifers discharge approximately 25 cubic feet of water per second (cfs) to create the base flow of the upper Verde River. The "upper" Verde River extends from the network of springs and seeps that are its source to Perkinsville, a reach that is approximately 24 miles in length. Most of the groundwater discharges that create the base flow of the upper Verde River occur within the first few miles below its source. It is estimated that at least 80 percent of the base flow of the upper Verde River, as measured at the U.S. Geological Survey gage at Paulden, is supplied by this network of springs and seeps. The Water Sentinels established a sampling site within this gaining reach of the upper Verde River that we call "Above Verde Springs."[21]

Tributaries of the Verde River

The Verde River flows approximately 175 miles east and south from its source above Verde Springs to its terminus at the confluence of the Verde River and the Salt River east of the Phoenix metropolitan area. At 175 miles, the Verde River is one of the longest perennial rivers in Arizona.

If someone hiked or paddled down the Verde River from its source to its terminus, he or she would see many stream channels joining the river from both banks on the journey downstream. These stream channels are called tributary streams. Most of the tributaries to the Verde River drain south from higher elevations along the Mogollon Rim. Some of the named tributaries are perennial streams that add water to sustain the base flow of the Verde River. There also are many unnamed, intermittent, or ephemeral channels that contribute water to the river only after local storm events.

Major tributary streams of the upper Verde River watershed include Big Chino Wash, Williamson Valley Wash and Walnut Creek (with perennial or intermittent flow in their upper reaches and ephemeral further downstream), and Pine Creek and Partridge Creek (intermittent). In the middle Verde River watershed, major tributaries to the Verde River include Sycamore Creek, Oak Creek, Beaver Creek, and West Clear Creek. Major tributary streams in the lower Verde River watershed include Fossil Creek and the East Verde River.

[21] Wirt, L. 2005, *The Verde River Headwaters, Yavapai County, Arizona*, in Wirt, Laurie, DeWitt, Ed, and Langenheim, V.E. eds., Geologic Framework of Aquifer Units and Ground-Water Flowpaths, Verde River Headwaters, North Central Arizona: U.S. Geological Survey Open File Report 2004-1411-A, p. A1.

Land ownership and political subdivisions within the Verde River watershed

The area of the Verde River watershed is 6,622 square miles.[22] Approximately 64 percent of this watershed is public lands administered by the U.S.D.A. Forest Service and the Bureau of Land Management. Less than one percent of federal lands are managed by other federal agencies such as the National Park Service or the Department of Defense. Approximately one quarter of the land area in the Verde River watershed (ten percent) are trust lands, state parks, or wildlife areas owned by the State of Arizona. Tribal nations own approximately two percent of the land within the watershed. Approximately 23 percent is privately owned; the large majority of private land is located in the upper Verde River watershed.[23]

The Verde River watershed encompasses four Arizona counties: Coconino, Gila, Maricopa, and Yavapai. About 50 percent of the watershed area is located within Yavapai County.[24] The Verde River watershed is primarily rural in character with a few urban or developed areas. Principal cities and towns within the Verde River watershed include the City of Prescott, City of Sedona, and the towns of Clarkdale, Cottonwood, and Camp Verde.

Climate

The climate of the Verde River watershed is arid to semiarid. Precipitation is highly variable from year to year and from place to place. Precipitation in the watershed is bimodal with two seasons of the year when precipitation most frequently occurs.

In winter, from December to March, precipitation usually occurs as a result of storm systems moving into the Verde River watershed from the west, bringing rain in the lower elevations and snow in higher elevations. Winter storms are typically of lower intensity and longer duration than summer thunderstorms. Winter storms are also usually more widespread and affect larger areas of the watershed than summer thunderstorms.

The other period when precipitation occurs in the watershed is during the summer “monsoon” season. The monsoon season usually begins in July and lasts into September. In contrast to winter storms, summer monsoon precipitation is usually in the form of higher intensity, shorter duration, and highly localized thunderstorms. Intense summer thunderstorms sometimes cause flash floods in local areas within the Verde River watershed.

Precipitation is affected by varying altitudes. Rain and snow fall more frequently at higher elevations above 6,000 feet. For example, the Bill Williams Mountain (9,256 feet) in the northern part of the Verde River watershed may receive up to 30 inches of precipitation each year. The higher elevations of the Bradshaw Mountains, Juniper Mountains, and Santa Maria

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[22] West, Patricia, Smith, D.H, and Auberle, W.M. 2009. *Final Report for the Verde River Ecosystem Values Project*, Northern Arizona University, January, 2009.
[23] Id.
[24] Id.

Mountains typically receive 20 inches of rain and snow each year. In contrast, the lower elevations of the watershed near the towns of Chino Valley (4,600 feet) and in the Verde Valley typically receive only 10 to 12 inches of precipitation each year.

Temperatures are highly variable from season to season and also depend on altitude. High summer temperatures exceeding 95° Fahrenheit are common in the lower elevations of the Verde Valley and sometimes exceed triple digits. During the winter months, daytime temperatures average 70° F with nighttime temperatures falling to freezing at night.

Riparian communities along the Verde River

A riparian area is defined as "…vegetation, habitats, or ecosystems that are associated with bodies of water (streams or lakes) or are dependent on the existence of perennial, intermittent, or ephemeral surface or water drainage."[25] Riparian areas are green ribbons of life with trees, shrubs, and grasses that grow along rivers and streams such as the Verde River. Riparian areas are found at every elevation in Arizona from the high elevations of the White Mountains to the desert floors.

It is easy to spot a riparian area in Arizona's arid and semiarid landscape. Riparian areas have more undergrowth, grasses, shrubs, vines, trees, woody debris, and fallen trees. Riparian areas also have more shade, and they tend to be cooler and moister than adjacent arid or semiarid landscapes.[26]

The riparian plant community along the Verde River is characterized as a mixed, broadleaf, deciduous plant community, dominated by Arizona ash (*Fraxinus velutina*), box elder (*Acer negundo*), Arizona walnut (*Juglans major*), and netleaf hackberry (*Celtis reticulata*). Tamarisk (*Tamarisk pentandra*), a non-native tree species, is occasionally interspersed with native tree species in the riparian area. Gooddings willow (*Salix gooddingii*), red willow (*Salix laevigata*), and Fremont cottonwood (*Populus fremontii*) are also found. The low floodplain terraces are dominated by large stands of desert willow (*Chilopsis linearis*), while the highest river terraces are vegetated with velvet mesquite (*Prosopis velutina*).

The riparian forest provides cover, food sources, and shade for the many animals inhabiting the riparian area. Shade from the riparian forest canopy reduces air and water temperatures, allowing the water in the river to hold more oxygen, permitting native fish to thrive. The shade is particularly important in the early summer when flows in the Verde River decrease and are

[25] Arizona Riparian Council Fact Sheet No. 1. 2004. *Riparian*
[26] *Id.*

typically at their lowest levels.[27] Riparian areas such as the one that exists along the Verde River provide many functions and values: [28]

- Improving water quality by providing buffer zones, swales, and wetlands that filter out pollutants
- Stabilizing water supply and moderating flood flows
- Reducing soil erosion and stabilizing stream banks
- Increasing biological diversity by providing plant and animal habitats
- Providing travel corridors for a wide variety of animals and migratory birds
- Providing recreation sites for people

Animal communities of the Verde River

The great plant diversity of the Verde River riparian area provides significant habitat for a large collection of wildlife species, including endangered, threatened, and other special status species. A wide diversity of wildlife inhabit the riparian areas along the Verde River, including insects, amphibians, reptiles, fishes, birds, and mammals. Ecologists estimate that the Verde River watershed supports 78 percent of breeding bird species found in Arizona, 89 percent of bat and mammal carnivore species, 76 percent of reptiles and amphibian genera, and an impressive concentration of other Arizona wildlife. Ecologists estimate that 80 percent of vertebrate species found in the watershed depend on the riparian habitats along the Verde River for at least some part of their life cycle.[29]

Threatened and endangered species and other special status wildlife species

Threatened, endangered, and other special status species occurring in the Verde River watershed have been identified through the Arizona Game and Fish Department's Heritage Data Management System. Native fish species listed under the Endangered Species Act (ESA) include the endangered razorback sucker (*Xyrauchen texanus*) Colorado pikeminnow (*Ptychocheilus lucius*), the threatened spikedace (*Meda fulgida*), and roundtail chub (*Gila robusta*), which is a candidate species. Listed bird species include the endangered southwestern willow flycatcher (*Empidonax traillii extimus*) and the candidate western yellow-billed cuckoo (*Coccyzus americanus occidentalis*). The Northern Mexican garter snake (*Thamnophis eques megalops*) is also listed as a candidate species.

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[27] *Id.*
[28] Arizona Riparian Council Fact Sheet No. 2. 2004. *Riparian Functions and Values*
[29] Upper Verde Wild and Scenic River, A Citizen's Proposal, Executive Summary, August 2011, p. 4.

Figure 17. Southwestern willow flycatcher
Source: U.S. Geological Survey

Other Wildlife of Special Concern that occupy the Verde River watershed include the northern leopard frog (*Rana pipiens*), Arizona toad (*Bufo microscaphus*), belted kingfisher (*Ceryle alcyon*), bald eagle (*Haliaeetus leucocephalus*), common black hawk (*Buteogallus anthracinus*), peregrine falcon (*Falco peregrinus*), red bat (*Lasiurus borealis*), and spotted bat (*Euderma maculatum*).

Fish species of the Verde River

The fishes of the Verde River have been extensively studied. Thirty-one fish species are known to exist in the Verde River watershed.[30] Twenty-three of these species are non-natives that have been introduced to the river. Some of these are game fish species that have been introduced for recreational fishing, including trout, channel and flathead catfish, smallmouth and largemouth bass, and several species of sunfish. Some introduced fish species are voracious predators that have decimated the native fish species of the Verde River. Predatory fish, particularly green sunfish and smallmouth and largemouth bass, present a serious threat to native fish populations. In general, non-native fish species are more abundant and more dominant in the middle and lower reaches of the Verde River and relatively less abundant in the upper reaches of the river.[31]

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[30] National Wild and Scenic Rivers Verde River fact sheet at www/rivers.gov/wsr-verde.html. p. 4.

[31] Haney, J.A.. D.S. Turner, A.E. Springer, J.C. Stromberg, L.E. Stevens, P.A. Pearthree, and V. Supplee. 2008. Ecological Implications of Verde River Flows. A report of the Verde River Basin Partnership, Arizona Water Institute, and The Nature Conservancy, p. 64.

Eight native fish species occur in the Verde River and its tributaries. Arizona's native fish have been described as "one of the most imperiled fauna in North America," and the Verde River is home to one of the most diverse assemblages of native fish remaining in Arizona.[32] Native fish species of the Verde River include Colorado pikeminnow (*Ptychocheilus lucius*), razorback sucker (*Xyrauchen texanus*), desert sucker (*Catostomus clarkia*), Sonora sucker (*Catostomus insignis*), roundtail chub (*Gila robusta*), longfin dace (*Agosia chrysogaster*), speckled dace (*Rhinichthys osculus*), and spikedace (*Meda fulgida*). The roundtail chub is threatened in Arizona and is a federal candidate species. Federal candidate status has been recommended for longfin dace, speckled dace, desert sucker, and Sonora sucker. The roundtail chub, Sonora sucker, desert sucker, and longfin dace are the most common native fish species in the Verde River.[33]

Figure 18. Roundtail chub
Photo credit: Scott Trageser

The Arizona Game and Fish Department is studying the loach minnow, a native fish species that is no longer present in the Verde River, as a candidate for reintroduction to the river. The loach minnow occurred historically in the Verde River but was last collected from the river in 1938. The loach minnow is a federally-listed threatened species under the ESA, and the Verde River has been designated as critical habitat for the species. "Critical habitats" are defined by the ESA as "specific geographic areas, whether occupied by a listed species or not, that are *essential for its conservation* and that have been formally designated by rule published in the Federal Register."

[32] Upper Verde Wild and Scenic River, A Citizen's Proposal, Executive Summary, August, 2011, p. 4.
[33] National Wild and Scenic Rivers Verde River fact sheet at www.rivers.gov/wsr-verde.html. p. 4.

Mammals

A total of 92 mammal species have been reported in the Verde River watershed.[34] Most mammal species inhabit the uplands and use the Verde River riparian corridor opportunistically for water, hunting, and habitat. Species that depend on a riparian area and use it opportunistically for part of their life cycle are called facultative riparian species. Species that depend entirely on riparian habitats are called obligate riparian species. Three obligate aquatic mammal species inhabit the Verde River: beaver (*Castor canadensis*), muskrat (*Ondatra zibethecus*), and the southwestern river otter (*Lontra canadensis sonora*). The Verde River is one of only three rivers in Arizona known to support populations of river otter.

Other mammal species in the Verde River watershed include mule deer (*Odocoileus hemionus*), javelina (*Tayassu tajacu*), striped skunk (*Mephitis mephitis*), badger (*Taxidea taxus*), coyote (*Canis latrans*), gray fox (*Urocyon cineroargenteus*), and bobcat (*Felis rufus*). Rocky Mountain elk (*Cervus elaphus*) are relatively rare, but they have been reported in the upper Verde River area. Pronghorn (*Antilocapra americana*) are present in low numbers, using the grasslands of the Chino Valley and the pinyon-juniper uplands adjoining the upper Verde River. Mountain lion (*Felis concolor*) occupy the riparian corridor and side drainages of the Verde River watershed.

Figure 19. Verde River otters
Source: Verde River Facebook photo gallery

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[34] Haney, J.A.. D.S. Turner, A.E. Springer, J.C. Stromberg, L.E. Stevens, P.A. Pearthree, and V. Supplee. 2008. Ecological Implications of Verde River Flows. A report of the Verde River Basin Partnership, Arizona Water Institute, and The Nature Conservancy, p. 56.

Birds

Birds represent the most diverse and visible vertebrate group in the Verde River riparian corridor. The Verde River watershed is home to more than 248 resident and migratory bird species.[35] Breeding bird densities in cottonwood stands along the Verde River have exceeded 1,000 pairs per 100 acres, the highest avian density per unit area ever recorded in North America.[36] Federally-listed species such as the southwestern willow flycatcher (*Empidonax traillii extimus*) and the western yellow-billed cuckoo (*Coccyzus americanus occidentalis*) depend on the riparian habitats of the Verde River for their survival. Both species are in decline in Arizona and of management concern throughout the state.

Figure 20. Eagle nest on the Verde River
Photo credit: Dave Menke, U.S. Fish and Wildlife Service

The Verde River supports the largest number of bald eagle breeding areas of any river in Arizona. There are several resident nesting pairs of the southwestern bald eagles (*Haliaeetus leucopcephalus*) on the Verde River, and it is estimated that 200 to 300 individual eagles overwinter in the Verde River watershed. Other birds of prey associated with the Verde River include osprey (*Pandion haliaetus*), peregrine falcon (*Falco peregrinus*), common black hawks *(Buteogallus anthracinus)*, grey hawks (*Buteo nitidus*), and ferruginous hawks (*Buteo regalis*).

Many species of ducks, water birds, and shore birds have been recorded along the Verde River. The great egret (*Ardea alba*), snowy egret (*Egretta thula*), white-faced ibis (*Plegadis chihi*), green heron *(Butorides virescens)*, and belted kingfisher (C*eryle alcyon*) are present. Great blue

[35] Patricia West, Dean Smith, William Auberle. 2009. Final Report for the Verde River Ecosystem Values Project, Northern Arizona University, January 2009, p. 12.
[36] National Wild and Scenic Rivers Verde River fact sheet at www/rivers.gov/wsr-verde.html. p. 4.

herons (*Ardea herodias*) are common.[37] Neotropical migratory birds use the Verde River riparian corridor for breeding and as a migration corridor. Migratory bird species include the vermillion flycatcher (*Pyrocephalus rubinus*), common yellowthroat (*Geothlypis trichas*), yellow warbler (*Dendroica aestiva*), summer tanager (*Piranga rubra*), blue-throated hummingbird (*Lampornis clemenciae*), Cassin's kingbird (*Tyrannus vociferans*), Bullock's oriole (*Icterus bullockii*), western bluebird (*Sialia Mexicana*), sage thrasher (*Oreoscoptes montanus*), and others. Violet green swallows (*Tachycineta thalassina*), white throated swifts (*Aeronautes saxatalis*), and other insectivorous birds are associated with the river and its adjacent riparian areas.[38]

Snakes, lizards and amphibians

The upper and middle Verde River support at least six species of amphibians, five species of turtles and tortoises, 21 species of lizards, and 24 species of snakes for a total of 56 aquatic, wetland, and obligate or facultative riparian herpetofaunal species.[39] Five sensitive herpetofaunal species survive in the Verde River watershed: the northern Mexican gartersnake (*Thamnophis eques megalops*), the narrow headed gartersnake (*Thamnophis rufipunctatus*), the lowland leopard frog (*Rana yavapaiensis*), northern leopard frog (*Rana pipiens*), and Chiricahua leopard frog (*Lithobates chiricahuensis*).[40]

Human communities along the Verde River

There is archeological evidence of early human occupation of the Verde Valley by hunter-gatherer peoples. The earliest known archeological artifact found in the Verde Valley is the base of an obsidian Clovis point that dates back to between 8,000 and 12,000 B.C. This artifact proves that human beings have lived along the Verde River for at least 10,000 years. The Hohokam people occupied the Verde Valley from approximately 800 A.D. to 1425 A.D. The Hohokam constructed shallow pit houses, ball courts, mounds, communal structures, and canals for agricultural irrigation. The Sinagua people lived in the Verde Valley between approximately 1000 A.D. and 1400 A.D. They constructed multi-room pueblos and cliff dwellings that are now preserved at Tuzigoot and Montezuma Castle National Monuments. Tuzigoot is an ancient pueblo consisting of two- and three-story structures located on a hill overlooking the Verde River near Clarkdale, Arizona. Montezuma Castle is a cliff dwelling located along Beaver Creek, a tributary to the Verde River.

Native Americans continue to live in community with the Verde River. The Verde River, its tributaries, and springs are essential to the cultures and traditions of many native people who

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[37] *Id.*

[38] *Importance of the River and Riparian Habitat in the Upper Verde River Threatened by Diminished Base Flow*, CWAG Science Committee

[39] Haney, J.A.. D.S. Turner, A.E. Springer, J.C. Stromberg, L.E. Stevens, P.A. Pearthree, and V. Supplee. 2008. Ecological Implications of Verde River Flows. A report of the Verde River Basin Partnership, Arizona Water Institute, and The Nature Conservancy, p. 59.

[40] *Id.*

still call the Verde River watershed home, including the Yavapai Apache, Yavapai Prescott Tribe, Salt River Pima-Maricopa Indian Community, and the Fort McDowell Yavapai Tribe.

Figure 21. Tuzigoot National Monument
Photo source: National Park Service

Modern cities and towns in the Verde River watershed include the cities of Prescott and Sedona. The City of Prescott is the largest population center within the watershed. Smaller towns include Clarkdale, Cottonwood, and Camp Verde. Other small towns in the watershed include Seligman and Ash Fork in the far northwestern part of the watershed. The Town of Chino Valley and the community of Paulden are located near the headwaters of the Verde River.

Cities and towns in the Verde River watershed have grown rapidly in the last decade. For example, according to the 2000 U.S Census report, the total population of Yavapai County was 167,517. According to the 2010 U.S. Census report, the total population of Yavapai County was 211,033, an increase of 43,516 people or approximately 24.6 percent over the decade.

Chapter 4. Water Quality of the Verde River

The Arizona Water Sentinels have been monitoring water quality at sampling sites and collecting water quality data on the Verde River since December 2006. What do these data reveal about the water quality of the Verde River? Is it safe to swim, kayak, or canoe in the river? Is it safe to eat the fish caught from the Verde River? Is water quality good enough for the fish, birds, otters, beavers, and other animals that live in and along the river? Is water from the Verde River suitable for agricultural irrigation or for livestock watering? Is it safe to use the Verde River as a source of drinking water supply?

It is not easy to answer such questions with a definitive "yes" or "no." There is uncertainty surrounding the answers to these questions because of our limited knowledge base. Definitive answers to these water quality questions depend primarily on two factors: 1) the availability and amount of water quality data and 2) the existence of water quality standards to compare available water quality data against to determine whether the Verde River is of acceptable quality for its various designated uses.

A disclaimer: Data gaps impede comprehensive water quality assessment of the Verde River

Comprehensive assessment of Verde River water quality is hindered by significant data gaps. It is difficult to provide definitive answers to questions about overall water quality of the Verde for several reasons. First, there is a relatively small amount of water quality data available. Second, water quality of the Verde River, like all rivers, is variable and is constantly changing; Water Sentinels sample results provide only "snapshots" of existing water quality at the time of sampling. Third, there are relatively few state-adopted water quality standards with which we can compare sample results.

The Arizona Department of Environmental Quality (ADEQ) adopts surface water quality standards for the Verde River. These standards establish numeric and narrative water quality criteria to maintain and protect water quality for drinking water supply, recreation, aquatic life and wildlife, agricultural irrigation, and livestock watering. ADEQ has adopted water quality standards for a relatively small set of water quality parameters in a very large universe of potential pollutants. For many pollutants, we simply do not know whether they are present in the Verde River or what the human health or aquatic life effects may be, nor do we have standards to tell us what safe concentrations of pollutants in water may be.

For these reasons, Water Sentinels water quality data provide a limited picture of overall water quality of the Verde River, and caution is warranted before making broad generalizations. However, the "snapshots" of water quality taken by the Water Sentinels suggest an encouraging water quality picture. In general, the data indicate that the Verde River appears to be healthy and that water quality is good.

Water Sentinels Sampling Sites

The Water Sentinels have monitored water quality at eight different sampling locations on the upper and middle Verde River over the last five years at the following locations:

Site Name	Abbreviation on Map (Fig. 22)	Latitude	Longitude
Above Verde Springs	VS	34° 52.074’ N	112° 25.177’ W
Bear Siding	BEARSID	34° 54.500’ N	112° 15.500’ W
Perkinsville Bridge	PKBR	34° 53.650’ N	112° 12.433’ W
Reitz	REITZ	34° 48.575’ N	112° 03.317’ W
Highway 89A Bridge	89ABR	34° 43.335’ N	111° 59.469’ W
Black Bridge	BLKBR	34° 34.400’ N	111° 51.305’ W
White Bridge	WHITBR	34° 33.000’ N	111° 51.000’ W
Beasley Flat	BEASFLAT	34° 28.383’ N	111° 48.077’ W

These sites were selected to characterize water quality of different reaches of the upper and middle Verde River from its source near our Above Verde Springs site to the most downstream sampling site at Beasley Flat, located approximately 10 miles below the Town of Camp Verde. For purposes of this report, the “upper” Verde River is defined as the reach of the Verde River from its source near our Above Verde Springs sampling site to Perkinsville Bridge, a distance of approximately 24 river miles. The “middle” Verde River is defined as the reach from the Perkinsville Bridge to Beasley Flat.

Sampling sites were selected for ease of access by motor vehicle. Access to sampling sites is very important because of holding times for bacteria samples prescribed in Water Sentinels sampling protocols. Our sample plans state that *E. coli* bacteria samples must be delivered to the testing laboratory within six hours of the time of sample collection.

A brief description of the eight Water Sentinels sampling sites follows:

- The Above Verde Springs sampling site was established to characterize water quality of the Verde River as close as possible to its source. This site is located near the confluence of Granite Creek and the Verde River, a short distance above the network of seeps and springs known locally as Verde Springs. The discharge of groundwater from Verde Springs is estimated to create 80 percent or more of the base flow of the upper Verde River.

- The Bear Siding sampling site was established to characterize water quality conditions at a reasonably accessible mid-point on the upper Verde River. The Water Sentinels discontinued sampling at Bear Siding in 2010 because of its relatively remote location, the lack of human disturbance in the upper Verde River upstream of the site, and the relatively close proximity of the Perkinsville Bridge sampling site located a few miles downstream.

- The Perkinsville Bridge sampling site is located approximately 24 miles downstream from the Above Verde Springs site. The Perkinsville site was chosen to characterize water quality conditions at the downstream boundary of the upper Verde River and because it is located at the only road crossing across the upper Verde River with reasonable access to the river. The Perkinsville Bridge demarcates the boundary between the upper and middle reaches of the Verde River.

- The Water Sentinels established the Reitz sampling site because of its location upstream of the more developed river corridor near the towns of Clarkdale and Cottonwood. The Reitz site was selected to characterize water quality conditions of the relatively undisturbed reaches of the middle Verde River as the river emerges from the Prescott National Forest and before it flows into the more developed Verde Valley river corridor. The Reitz sampling site is the only sampling site located on private property. The Water Sentinels would like to acknowledge the Reitz family and thank them for giving permission to the Water Sentinels to enter their property to conduct water quality monitoring.

- The 89A Highway Bridge site is located immediately upstream of the State Highway 89A bridge over the Verde River near downtown Cottonwood. The site was selected to characterize any water quality impacts from point and non-point source discharges to the Verde River in the urbanizing area near the towns of Clarkdale and Cottonwood.

- The Black Bridge sampling site is located a short distance downstream of the Black Bridge road crossing over the Verde River, north of the Town of Camp Verde. The Water Sentinels selected the Black Bridge sampling site to characterize possible changes in water quality between the State Highway 89A Bridge in Cottonwood and the Town of Camp Verde. This reach of the middle Verde River also includes potential water quality impacts associated with the I-17 crossing over the Verde River. Sampling at this site began in 2010.

- The White Bridge site is located a short distance upstream of the Highway 260 bridge crossing over the Verde River, downstream of the Town of Camp Verde. The Water Sentinels discontinued sampling at the White Bridge sampling site in 2010 and moved to the Black Bridge site in order to take advantage of the installation of a Salt River Project low flow gage at Black Bridge that continuously monitors the flow of the Verde River.

- The most downstream sampling site is Beasley Flat, located approximately 10 miles downstream of the Town of Camp Verde. The Beasley Flat site was selected to characterize water quality impacts from upstream developments in the Verde

Valley, including towns, roads, diversions and return flows, recreational uses, and agriculture and to compare water quality with data obtained at our upstream sites. Finally, the Beasley Flat site is the last site on the Verde River with easy access by motor vehicle. Below Beasley Flat, the Verde River enters a designated Wild & Scenic River segment, and road access is difficult and limited.

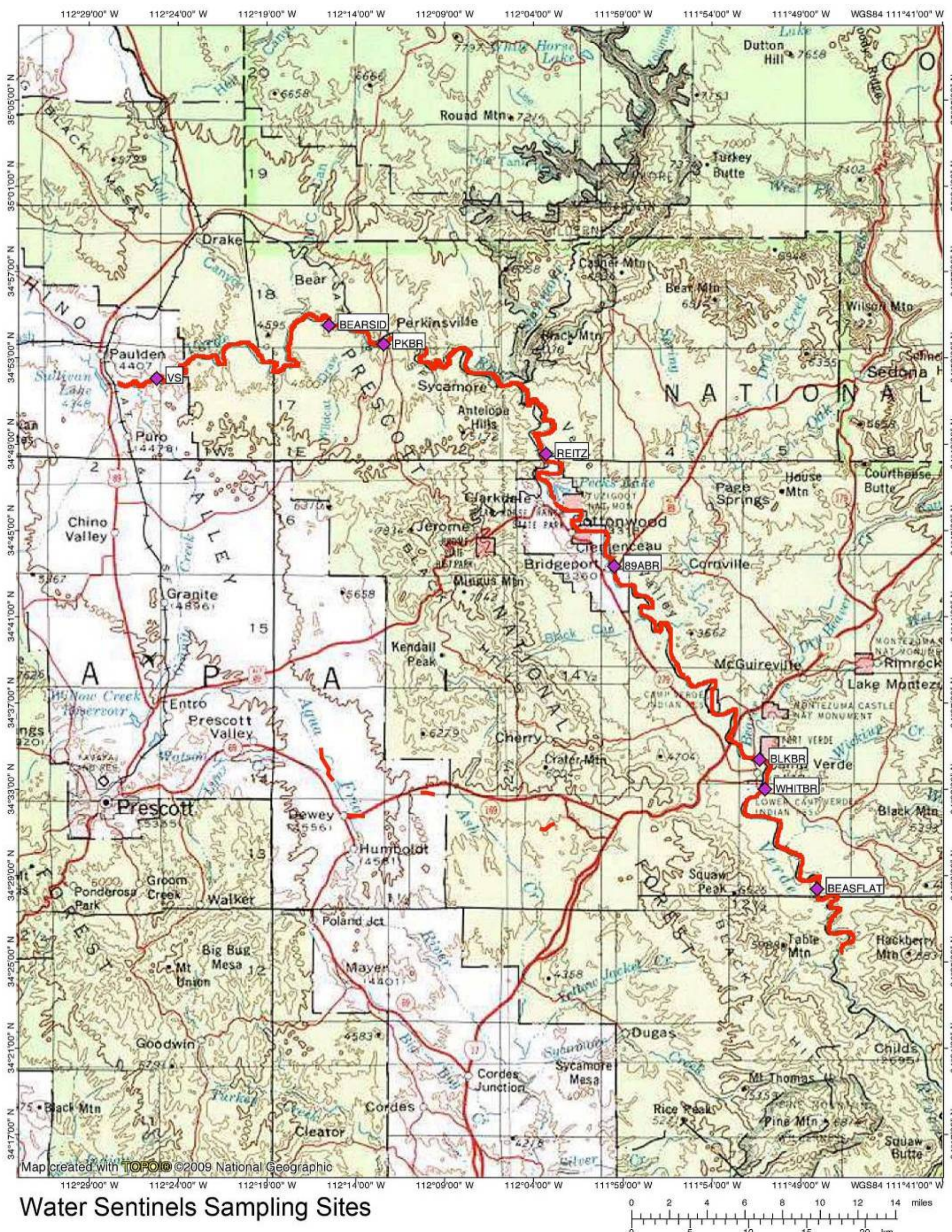

Figure 22. Water Sentinels sampling sites on the Verde River
Map credit: Gary Beverly

Microbiological water quality of the Verde River (E. coli)

Arizona Water Sentinels collect water samples from the Verde River for *Escherichia coli* (*E. coli*) bacteria analyses. *E. coli* bacteria are a widely accepted indicator organism of fecal contamination of water. Water Sentinels have collected water quality data for *E. coli* bacteria since the inception of our volunteer monitoring program on the Verde River. The dataset includes 194 *E. coli* sample results from seven sampling sites on the Verde River from samples collected between December 2, 2006, and December 10, 2011.

Figure 23. Water Sentinel collecting an *E. coli* bacteria sample
Photo credit: Steve Pawlowski

In general, *E. coli* sample results obtained over the last five years indicate that microbiological water quality of the Verde River is good. In five years of data collection, the Water Sentinels obtained 13 sample results that exceeded the single sample maximum (SSM) water quality standard for *E. coli* bacteria adopted by the State of Arizona.[41] Over 95 percent of the sample results complied with applicable state water quality standards adopted to maintain and protect water quality for recreation, including full body contact recreational uses such as swimming. While these sample results are "snapshots" in time taken only at specific sampling sites, they

[41] The Arizona surface water quality standards for *E. coli* bacteria are expressed two ways: 1) as a 4-sample geometric mean value, and 2) as a single sample maximum concentration. The 4-sample geometric mean value is 126 colony forming units (cfu) per 100 mL. The single sample maximum concentration is 235 cfu / 100 mL.

cumulatively indicate that the microbiological water quality of the Verde River, particularly the upper Verde River, is good.

Current Arizona water quality standards for *E. coli* bacteria

The current Arizona water quality standards for *E. coli* bacteria are expressed as a 30-day geometric mean (four sample minimum) and as SSM concentrations. Arizona Water Sentinels data cannot be compared to the Arizona water quality standard expressed as a geometric mean value because water samples are not collected with enough frequency. Water Sentinels go to the Verde River six times per year to collect samples for *E. coli* bacteria analysis (i.e., approximately once every two months). Because Water Sentinels do not collect four water samples within a 30-day period, it would be invalid to compare our sample results to Arizona's current water quality standard for *E. coli* expressed as a geometric mean. Water Sentinels sample results can be compared only to the state's water quality standard expressed as a SSM concentration (i.e., 235 cfu/100 mL).

Arizona Water Sentinels *E. coli* bacteria sample results

Thirteen out of a total of 194 sample results obtained by the Water Sentinels over the last five years violated Arizona's SSM *E. coli* water quality standard. Six of these violations of the SSM water quality standard were from samples obtained at the Highway 89A Bridge sampling site near the Town of Cottonwood. Two sample results indicating a violation were obtained at the White Bridge sampling site near the Town of Camp Verde; two were obtained at the sampling site at Beasley Flat; and one violation was determined at each of the Black Bridge, Perkinsville Bridge, and the Above Verde Springs sampling sites. There were no violations of the *E. coli* SSM standard at the Bear Siding or the Reitz property sites.

The location of the sampling sites where *E. coli* bacteria standard violations occurred suggests a geographic pattern. Eleven of the 13 SSM water quality standard violations were obtained at sampling sites located near or downstream of the towns of Clarkdale, Cottonwood, and Camp Verde. Only two of the 13 violations occurred at a sampling site located on the upper Verde River (i.e., from samples collected at Perkinsville on July 29, 2007, and at Above Verde Springs on September 17, 2011). The *E. coli* bacteria standard violation at Perkinsville was a relatively minor violation (i.e., the reported *E. coli* concentration was 291 MPN/100 mL, compared to the SSM standard of 235 cfu/100 mL). With the exception of these two isolated water quality standards violations, there were no other *E. coli* bacteria standards violations on the upper Verde River in the last five years. Water Sentinels sample results for *E. coli* bacteria showed no violations of the *E. coli* bacteria standard at the Reitz property above the Town of Clarkdale or at our Bear Siding site on the upper Verde River. The relatively few bacteria standard violations on the upper Verde River are probably explained by the relatively remote, undeveloped character and the absence of human disturbances in the upper Verde River watershed.

In contrast, eleven out of thirteen *E. coli* bacteria standard violations occurred at sampling sites located in the more developed river corridor in the Verde Valley near the towns of Cottonwood and Camp Verde. Our data show that the largest number of the *E. coli* bacteria standard violations occurred at the Highway 89A Bridge site. These sample results suggest that there may be sources of bacterial contamination of the Verde River in the more developed area downstream of the Reitz property near Clarkdale and upstream of the Highway 89A Bridge in Cottonwood. More frequent *E. coli* bacteria monitoring at additional sampling sites in this reach are required to identify potential sources of contamination in this reach of the middle Verde River.

E. coli sample results by sampling site

Above Verde Springs: Table 1 shows *E. coli* bacteria sample results obtained by the Water Sentinels at the Above Verde Springs sampling site between December 2, 2006, and December 8, 2011. In general, microbiological water quality of the Verde River at the Above Verde Springs site was very good over the five-year period of record. The minimum concentration of *E. coli* bacteria, less than 1 MPN/100 mL, was obtained by the Water Sentinels on March 10, 2007. This concentration represents the detection level for the analytical method used by the laboratory to analyze the *E. coli* bacteria sample.

The median *E. coli* concentration for all bacteria samples (n=27) collected at Above Verde Springs is 13 MPN/100 mL. This median concentration of 13 MPN represents the “middle” value in the Above Verde Springs dataset. A median value is one way to express the central tendency of the dataset for Above Verde Springs. A median value means that half of the *E. coli* bacteria results obtained by the Water Sentinels at the Above Verde Springs site were below 13 MPN/100 mL and half of the sample results were above 13 MPN per 100 mL.

Another way to express the central tendency of a dataset is to calculate an average concentration from all of the sample results. The arithmetic average *E. coli* bacteria concentration at Above Verde Springs is 43 MPN/100 mL. This “average” concentration also indicates very good microbiological water quality because it is well below Arizona’s *E. coli* bacteria water quality standard of 235 MPN or cfu/100 mL. It should be noted that calculation of an arithmetic average can be skewed by one or two high values in a small dataset. In the Above Verde Springs dataset, there was one relatively high concentration (579 MPN/100 mL) out of a total of 27 sample results. This relatively high *E. coli* bacteria concentration skewed the calculation of the arithmetic average and may misrepresent the true “average” *E. coli* concentration at Above Verde Springs. Because of the relatively small dataset (n=27), the median value of 13 MPN is probably a better representation of the typical or “average” microbiological water quality of the Verde River at Above Verde Springs.

Water Sentinels sample results show only one violation of the applicable water quality standard for *E. coli* bacteria at Above Verde Springs over the last five years (highlighted in yellow in Table 1 below). This single sample result, 579 MPN/100 mL, was from a sample collected on September 17, 2011. Approximately 97 percent of 27 sample results obtained at Above Verde Springs comply with the applicable SSM *E. coli* bacteria standard for the Verde River.

While there are only 27 sample results, the dataset suggests that *E. coli* bacteria concentrations at Above Verde Springs may be increasing over time. The majority of sample results (8 of 11) from December 2, 2006, through December 20, 2008, were less than 10 MPN/100 mL, and the maximum *E. coli* bacteria concentration obtained in the first two years of data collection at Above Verde Springs was only 25 MPN/100 mL. In contrast, *E. coli* bacteria sample results are generally higher after 2009. For example, the majority of *E. coli* bacteria sample results from February 28, 2009, through December 10, 2011 are greater than 10 MPN/100 mL (11 of 16 samples). While microbiological water quality of the Verde River at Above Verde Springs remains very good and continues to meet applicable water quality standards to protect recreational use and human health, the Water Sentinels dataset suggests that *E. coli* bacteria concentrations at Above Verde Springs are increasing over the last five years.

Table 1. *E. coli* bacteria sample results for Above Verde Springs

Date	Sample result Most Probable Number/100 mL
December 2, 2006	5
February 17, 2007	2
March 10, 2007	<1
August 25, 2007	5
October 20, 2007	13
December 15, 2007	3
February 9, 2008	1
April 26, 2008	1
June 14, 2008	25
August 16, 2008	16
December 20, 2008	2
February 28, 2009	9
April 11, 2009	55
May 30, 2009	25
July 25, 2009	77
September 19, 2009	39
November 21, 2009	16
March 13, 2010	8
May 22, 2010	32
July 10, 2010	178
November 20, 2010	12
February 26, 2011	3
April 23, 2011	9
June 18, 2011	13
September 17, 2011	579
October 22, 2011	21
December 10, 2011	5

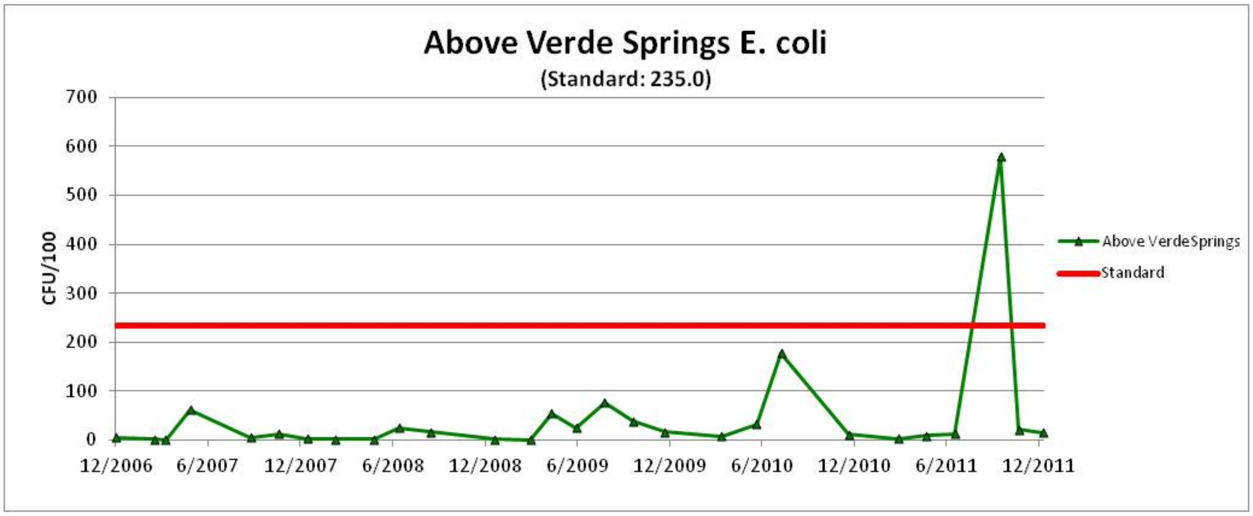

Chart 1. Above Verde Springs *E. coli*

Bear Siding: Water Sentinels collected a total of 18 water samples at the Bear Siding sampling site on the upper Verde River between December 2, 2006, and November 21, 2009. We discontinued water quality sampling at Bear Siding in 2010 because of the relatively remote location of the sampling site on the upper Verde River, the lack of human disturbance in the area, and the existence of other sampling sites at Above Verde Springs and at Perkinsville, which provide good baseline water quality data for the upper Verde River.

The dataset (n=18) for Bear Siding shows that microbiological water quality of the Verde River was excellent over a three-year period of record. The minimum concentration of *E. coli* bacteria was less than 1 MPN/100 mL (i.e., less than the method detection level) and was obtained on December 20, 2008. The maximum concentration of *E. coli* bacteria in a water sample was only 61 MPN/100 mL, well below the applicable water quality standard of 235 cfu/100 mL.

The median *E. coli* bacteria concentration for the 18 sample results from Bear Siding is 14 MPN/100 mL, which is very close to the median *E. coli* bacteria concentration of 13 MPN/100 mL determined for Above Verde Springs. Both low median values (13 MPN and 14 MPN, respectively) for *E. coli* bacteria indicate excellent microbiological water quality for the reach of the upper Verde River from its source springs to Bear Siding.

This inference of excellent microbiological water quality for the upper Verde River is further supported by the arithmetic average *E. coli* bacteria concentration at Bear Siding of 21 MPN/100 mL. This average concentration at Bear Siding is actually lower than the average concentration calculated for the Above Verde Springs dataset (i.e., 43 MPN/100 mL). The lower average *E. coli* bacteria concentration calculated for Bear Siding is likely explained by the fact that the relatively small Bear Siding dataset was *not* skewed by a single large sample result. The range of *E. coli* bacteria sample results for Bear Siding was less than 1 MPN/100 mL to 61 MPN/100 mL. The median value (14 MPN/100 mL) and the calculated average concentration (21 MPN/100 mL) support an inference that microbiological water quality of the upper Verde

River at the Bear Siding location is excellent. This is further supported by the fact that there were no violations of the SSM water quality standard for *E. coli* bacteria in three years of Water Sentinels' data collection at Bear Siding.

Table 2. *E. coli* bacteria sample results for Bear Siding

Date	Sample result Most Probable Number/100 mL
December 2, 2006	6
February 17, 2007	3
March 10, 2007	24
April 28, 2007	4
August 25, 2007	5
October 20, 2007	9
December 15., 2007	16
February 9, 2008	5
April 26, 2008	4
June 14, 2008	12
August 16, 2008	25
December 20, 2008	<1
February 28, 2009	16
April 11, 2009	54
May 30, 2009	38
July 25, 2009	61
September 19, 2009	46
November 21, 2009	44

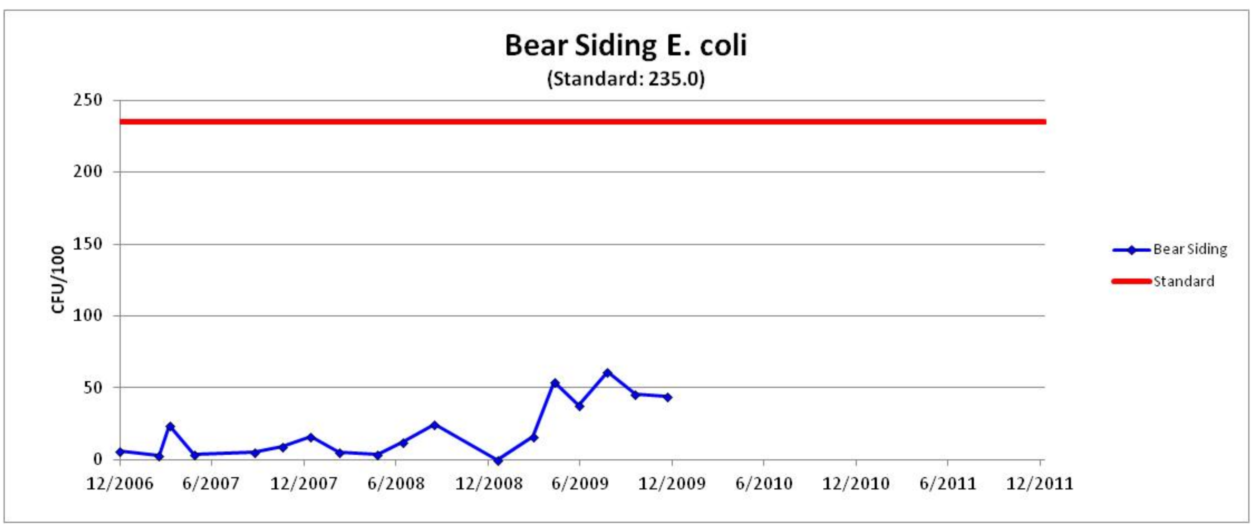

Chart 2. Bear Siding *E. coli*

Perkinsville: The Water Sentinels' sampling site at Perkinsville is located a short distance upstream of the Perkinsville Bridge at approximately river mile 26 on the upper Verde River. Water Sentinels established a sampling site near the Perkinsville Bridge because it is located at the downstream boundary of what the Water Sentinels define as the "upper" Verde River. Also, the Perkinsville sampling site is located at one the few places on the upper Verde River easily accessible by a motor vehicle. Easy access by motor vehicle to a sampling site is needed to comply with the six-hour holding time requirement for *E. coli* bacteria samples prescribed in Water Sentinels' sampling protocols.

Water Sentinels collected 28 water samples for *E. coli* bacteria analysis between December 2, 2006, and December 8, 2011, at Perkinsville. The minimum *E. coli* bacteria concentration was less than 1 MPN/100 mL (i.e., below the method detection level). The maximum *E. coli* bacteria concentration in the dataset was 291 MPN/100 mL. The latter result, highlighted in yellow in Table 3 below, represents the only violation of the SSM water quality standard for *E. coli* bacteria from the Perkinsville sampling site in five years of data collection. The median *E. coli* bacteria concentration at Perkinsville was 17.5 MPN/100 mL, and the calculated arithmetic average concentration is 28 MPN/100 mL. These "average" values are well below the applicable SSM standard and they indicate very good microbiological quality of the upper Verde River at the sampling site.

Table 3. *E. coli* sampling results for Perkinsville

Date	Sample result in MPN/100 mL
December 2, 2006	32
February 17, 2007	3
March 10,2007	1
April 28, 2007	20
August 25,2007	13
October 20,2007	16
December 15, 2007	23
February 9, 2008	2
April 26, 2008	9
June 14, 2008	24
August 16, 2008	28
December 20, 2008	1
February 28,2009	<1
April 11, 2009	19
May 30, 2009	45
July 25, 2009	291
September 19, 2009	66
November 21, 2009	20
March 13, 2010	24
May 22, 2010	28
July 10, 2010	48
November 20, 2010	15
February 26, 2011	9
April 23, 2011	1
June 18, 2011	22
September 17, 2011	13
October 22, 2011	5
December 10,2011	5

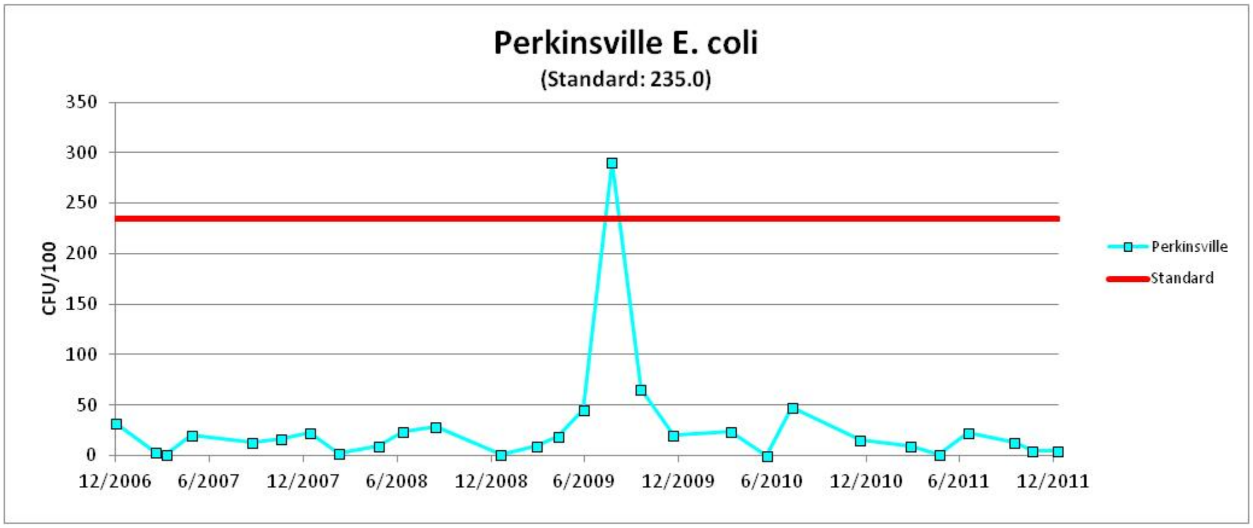

Chart 3. Perkinsville *E. coli*

Reitz: The Water Sentinels' sampling site at the Reitz property is located downstream of the confluence of Sycamore Creek and upstream of the Town of Clarkdale. Water Sentinels established a sampling site at the Reitz property because it is upstream of the more developed middle reaches of the Verde River as the river emerges from the Prescott National Forest and starts to flow through the Verde Valley near the towns of Clarkdale, Cottonwood, and Camp Verde.

Water Sentinels collected 29 water samples for *E. coli* bacteria analysis between December 2, 2006, and December 8, 2011, at the Reitz property sampling site. The minimum *E. coli* bacteria concentration was less than 1 MPN/100 mL. The maximum *E. coli* bacteria concentration in the dataset was 225 MPN/100 mL. There were **no** violations of the SSM water quality standard for *E. coli* bacteria at the Reitz property site over the entire five-year period of record. The median *E. coli* bacteria concentration at Reitz was only 8 MPN/100 mL, and the calculated arithmetic average concentration was 22 MPN/100 mL. Both indicators of the central tendency of the *E. coli* bacteria dataset obtained at the Reitz sampling site show that microbiological quality of the Verde River at the Reitz sampling site has been excellent over the last five years.

Table 4. *E. coli* sampling results for Reitz

Date	Sample result in MPN/100 mL
December 2,2006	21
February 17, 2007	8
March 10, 2007	6
April 28, 2007	4
August 25, 2007	7
October 20, 2007	16
December 15, 2007	4
February 9, 2008	2
April 26,2008	9
June 14,2008	12
August 16, 2008	13
December 20, 2008	<1
February 28, 2009	1
April 11, 2009	9
May 30, 2009	20
July 25, 2009	225
September 19, 2009	15
November 21, 2009	8
March 13, 2010	33
May 22, 2010	6
July 10, 2010	4
September 18, 2010	5
November 20, 2010	33
February 26, 2011	3
April 23, 2011	4
June 18, 2011	9
September 17, 2011	150
October 22, 2011	9
December 10, 2011	2

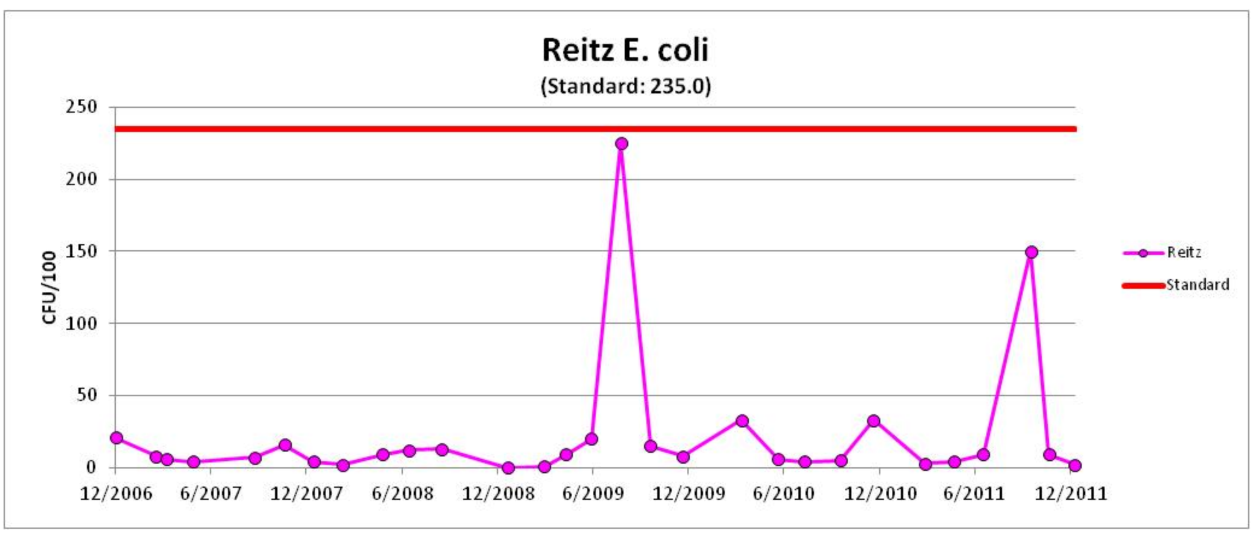

Chart 4. Reitz *E. coli*

Highway 89A Bridge: Water Sentinels established a sampling site immediately upstream of the Highway 89A Bridge over the Verde River near downtown Cottonwood. Water Sentinels established the 89A Bridge sampling site to characterize water quality of the Verde River in the more developed river corridor near the Town of Cottonwood and to provide water quality data for comparison to data obtained from upstream sampling sites located on the less developed reaches of the upper Verde River.

Water Sentinels collected 29 water samples for *E. coli* bacteria analysis between December 2, 2006, and December 8, 2011, at the Highway 89A Bridge site. The minimum *E. coli* bacteria concentration was less than 1 MPN/100 mL. The maximum *E. coli* bacteria concentration in the Highway 89A Bridge dataset was 686 MPN/100 mL. There were six violations of the SSM water quality standard for *E. coli* bacteria at the Highway 89A Bridge sampling site over the five-year period of record. These six water quality violations are highlighted in yellow in Table 5 below. Six violations of the *E. coli* bacteria standard represent the highest number of violations recorded at any Water Sentinels' sampling site on the Verde River. Approximately 79 percent of sample results complied with the SSM water quality standard for *E. coli* bacteria. This means that approximately one out of five sample results (21 percent) from the Highway 89A Bridge sampling site violated Arizona's SSM *E. coli* bacteria standard.

The median *E. coli* bacteria concentration at the Highway 89A Bridge site was 60 MPN/100 mL, and the arithmetic average concentration was 148 MPN/100 mL. The central tendency of the *E. coli* bacteria dataset obtained at Highway 89A Bridge site shows that, while "average" microbiological water quality of the Verde River still meets applicable *E. coli* bacteria standards, the Highway 89A Bridge sampling site has relatively lower microbiological water quality than other Water Sentinels' sampling site on the Verde River. The sample results suggest that there are sources of fecal contamination of the Verde River between the sampling site at the Reitz property above Clarkdale and the Highway 89A Bridge site near downtown Cottonwood. More frequent water quality monitoring at additional sites are recommended to identify these possible sources of fecal contamination.

Table 5. *E. coli* sampling results for Highway 89A Bridge

Date	Sample result in MPN/100 mL
December 2,2006	10
February 17, 2007	16
March 10, 2007	16
April 28, 2007	185
August 25, 2007	99
October 20, 2007	32
December 15, 2007	38
February 9, 2008	3
April 26,2008	686
June 14,2008	186
August 16, 2008	157
December 20, 2008	<1
February 28, 2009	17
April 11, 2009	53
May 30, 2009	214
July 25, 2009	435
September 19, 2009	194
November 21, 2009	31
March 13, 2010	16
May 22, 2010	142
July 10, 2010	248
September 18, 2010	248
November 20, 2010	4
February 26, 2011	5
April 23, 2011	105
June 18, 2011	435
September 17, 2011	613
October 22, 2011	60
December 10, 2011	31

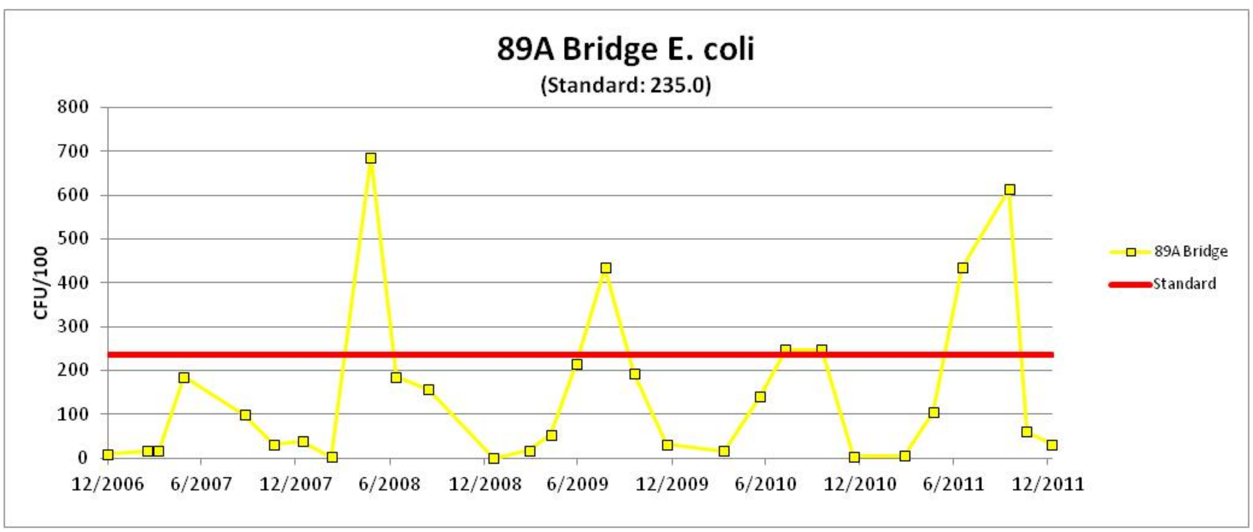

Chart 5. 89A Bridge *E. coli*

Black Bridge: Water Sentinels began monitoring water quality at the Black Bridge sampling site on March 13, 2010. The Black Bridge site was established as a background site to characterize water quality conditions upstream of the Town of Camp Verde. The sampling site is located north of the Town of Camp Verde a short distance downstream of the Black Bridge over the Verde River. Arizona Water Sentinels collected 11 *E. coli* bacteria samples at the Black Bridge site between March 13, 2010, and December 10, 2011. The minimum *E. coli* bacteria concentration was 5 MPN/100 mL, and the maximum concentration was 687 MPN/100 mL. The *E. coli* sample result of 687 MPN/100 mL, highlighted in yellow in Table 6 below, represents the single violation of the SSM water quality standard for *E. coli* bacteria in the Black Bridge dataset.

The median *E. coli* bacteria concentration at Black Bridge was 14 MPN/100 mL, and the arithmetic average concentration was 79 MPN/100 mL. Because there are only 11 data points in the Black Bridge dataset, the median concentration is likely a better indicator of "average" *E. coli* bacteria concentrations at Black Bridge. Even though the dataset is small, the sample results indicate that microbiological water quality at Black Bridge is good with 10 of 11 data points under 35 MPN/100 mL. The small size of the Black Bridge dataset for *E. coli* makes any inferences about overall microbiological water quality of the Verde River at the Black Bridge site more uncertain.

Table 6. *E. coli* sampling results for Black Bridge

Date	Sample Result in MPN/100 mL
March 13, 2010	12
May 22, 2010	30
July 10, 2010	23
September 18, 2010	13
November 20, 2010	12
February 26, 2011	5
April 23, 2011	14
June 18, 2011	26
September 17, 2011	687
October 22, 2011	35
December 10, 2011	10

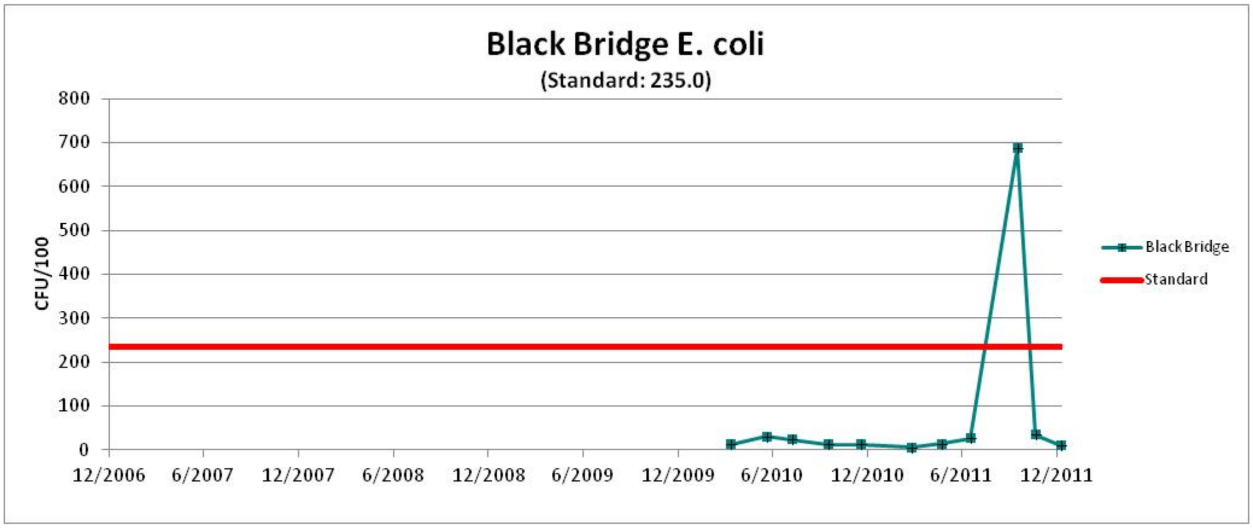

Chart 6. Black Bridge *E. coli*

White Bridge: Arizona Water Sentinels monitored water quality at White Bridge between December 2, 2006, and November 21, 2009. Sampling at this site was discontinued after this date because the Water Sentinels established the Black Bridge site to characterize background water quality upstream of the Town of Camp Verde. The White Bridge sampling site was located a short distance upstream of the Highway 260 Bridge over the Verde River and downstream of the Town of Camp Verde. Water Sentinels collected a total of 18 *E. coli* bacteria samples at White Bridge over a three-year period. The minimum *E. coli* concentration was 5 MPN/100 mL, and the maximum concentration was greater than 2,420 MPN/100 mL. The latter sample result of greater than 2,420 MPN represents the upper boundary of the estimate of bacterial density that the testing laboratory can make with the Colilert analytical method. The reported sample result means that the actual *E. coli* bacteria concentration is unknown but it is more than 2,420 MPN/100 mL.

The median *E. coli* bacteria concentration at White Bridge was 36 MPN/100 mL, and the arithmetic average concentration was 201 MPN/100 mL. There were two violations of the SSM *E. coli* bacteria standard at White Bridge in three years of data collection: 1) greater than 2,420 MPN/100 mL on August 16, 2008, and 2) 579 MPN/100 mL on May 30, 2009. Because there are only 18 data points in the White Bridge dataset, the median concentration is likely a better indicator of "average" *E. coli* bacteria concentrations at White Bridge. Fourteen of 18 data points at White Bridge were under 100 MPN/100 mL. The single datum of greater than 2,420 MPN/100 mL within a limited dataset of 18 sample results skewed the calculation of the arithmetic average. While the Water Sentinels recorded two violations of the SSM *E. coli* standard at White Bridge, highlighted in yellow in Table 7 below, 16 of 18 sample results (88 percent) complied with the applicable SSM water quality standard for *E. coli* bacteria, indicating that microbiological water quality is generally good.

Table 7. *E. coli* sample results for White Bridge

Date	Sample Result in MPN/100 mL
December 2, 2006	28
February 17, 2007	38
March 10, 2007	31
April 28, 2007	8
August 25, 2007	60
October 20, 2007	83
December 15, 2007	34
February 9, 2008	16
April 26, 2008	5
June 14, 2008	40
August 16, 2008	>2,420
December 20,2008	10
February 28, 2009	25
April 11, 2009	46
May 30, 2009	579
July 25, 2009	105
September 19, 2009	102
November 21, 2009	34

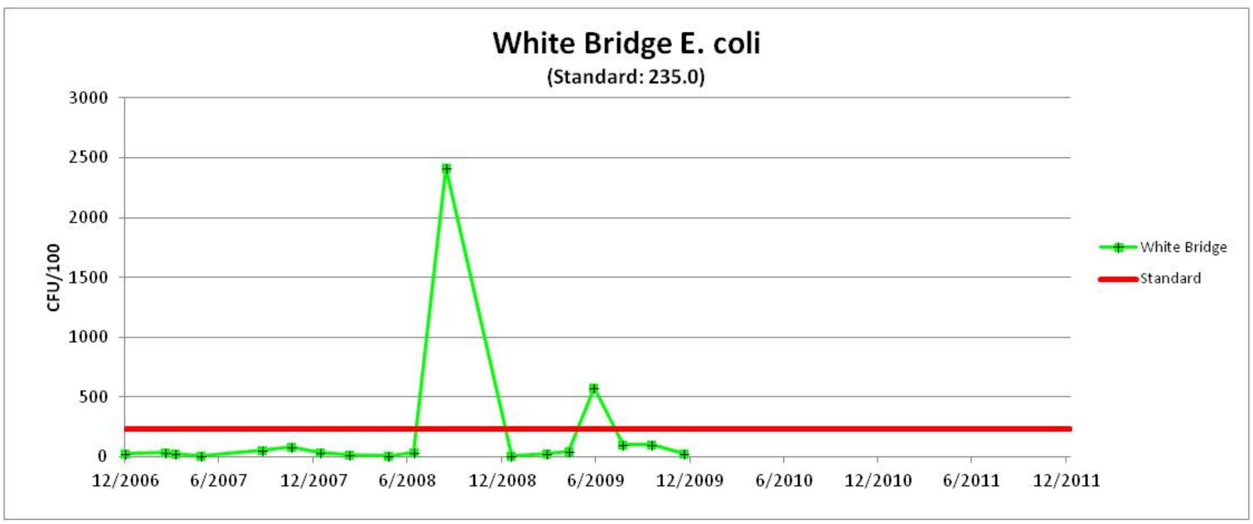

Chart 7. White Bridge E. coli

Beasley Flat: Water Sentinels have monitored water quality at Beasley Flat from the start of our volunteer water quality monitoring program on the Verde River. Beasley Flat is located approximately 10 miles downstream of the Town of Camp Verde and is our most downstream sampling site. Water Sentinels established a sampling site at Beasley Flat to characterize water quality of the Verde River before the river flows downstream into the reach of the Verde River designated as a Wild and Scenic River. Also, the Beasley Flat sampling site is the last location on the middle Verde River that is relatively easy to access by vehicle. Vehicle access to the sampling site is an important consideration because the Water Sentinels' sampling protocol requires that *E. coli* bacteria samples be delivered to the testing laboratory within six hours of sample collection.

The Water Sentinels collected 29 water samples for *E. coli* bacteria analysis between December 2, 2006, and December 8, 2011, at Beasley Flat. The minimum *E. coli* bacteria sample result was 1 MPN/100 mL, and the maximum concentration was 345 MPN/100 mL. There were two violations of the SSM water quality standard for *E. coli* bacteria at Beasley Flat over the five-year period of record (highlighted in yellow in Table 8 below). Approximately 93 percent of sample results obtained by the Water Sentinels comply with the SSM water quality standard for *E. coli* bacteria. The median *E. coli* bacteria concentration at Beasley Flat was 25 MPN/100 mL, and the arithmetic average concentration was 44 MPN/100 mL. Again, both indicators of the central tendency of the *E. coli* bacteria dataset show that average microbiological water quality of the Verde River at Beasley Flat is good and generally meets applicable *E. coli* bacteria standards. Microbiological water quality of the river can be described as safe for water-based recreational uses such as swimming and kayaking.

Figure 24. Verde River at Beasley Flat
Photo credit: Mark Coryell

Table 8. *E. coli* sample results for Beasley Flat

Date	Sample Result in MPN/100 mL
December 2,2006	16
February 17, 2007	20
March 10, 2007	12
April 28, 2007	3
August 25, 2007	35
October 20, 2007	35
December 15, 2007	36
February 9, 2008	1
April 26,2008	5
June 14,2008	25
August 16, 2008	39
December 20, 2008	10
February 28, 2009	33
April 11, 2009	8
May 30, 2009	98
July 25, 2009	51
September 19, 2009	248
November 21, 2009	34
March 13, 2010	6
May 22, 2010	21
July 10, 2010	29
September 18, 2010	25
November 20, 2010	19
February 26, 2011	49
April 23, 2011	23
June 18, 2011	3
September 17, 2011	345
October 22, 2011	30
December 10, 2011	22

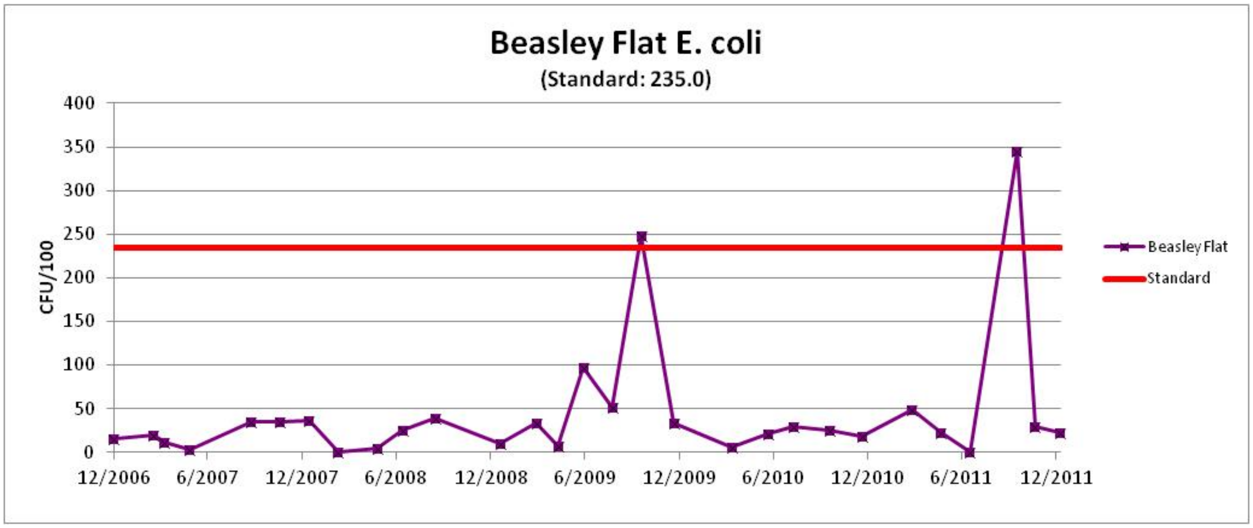

Chart 8. Beasley Flat *E. coli*

A seasonal pattern of violations: There were 13 violations of the SSM *E. coli* water quality standard over the five-year period at six different sampling sites on the Verde River. The Water Sentinels dataset suggests a seasonal pattern to these *E. coli* bacteria standards violations. The dates and locations of the 13 water quality standards violations are as follows:

Table 9. *E. coli* violations

Sampling Site	Date	Sample result (MPN/100 mL)
89A Bridge	04/26/2008	686
White Bridge	08/16/2008	>2,420
White Bridge	05/30/2009	579
Perkinsville	07/25/2009	291
89A Bridge	07/25/2009	435
Beasley Flat	09/19/2009	248
89A Bridge	07/10/2010	248
89A Bridge	09/18/2010	248
89A Bridge	06/18/2011	435
Above Verde Springs	09/17/2011	579
89A Bridge	09/17/2011	613
Black Bridge	09/17/2011	687
Beasley Flat	09/17/2011	345

With the exception of a one *E. coli* standard violation in April 2008, 12 of 13 *E. coli* bacteria standards violations occurred during warmer months of the year with one violation in May, one in June, three in July, one in August, and six in September. The single violation in August is probably a product of Water Sentinels scheduling as we avoid sampling during the hottest month of the year. Conversely, there were no *E. coli* bacteria standard violations in October through March during the five-year period of record. These data suggest that *E. coli* bacteria standards are more likely to occur in the summer or early fall when water temperatures of the Verde River are warmer. It appears that *E. coli* bacteria concentrations in the Verde River are suppressed by colder water temperatures during the fall and winter months from October to March.

Table 10 presents the Water Sentinels' *E. coli* bacteria sample results for all sampling trips conducted between December 2, 2006, and December 10, 2011. Water Sentinels conducted 29 sampling trips over a five-year period and collected a total of 194 samples. The data are presented chronologically by the date of the Water Sentinels sampling trip. Violations of the SSM *E. coli* bacteria standard are highlighted in yellow in Table 10 below. Some sample results are qualified with an asterisk. Sample results with an asterisk indicate that delivery of the water sample to the laboratory exceeded the six-hour holding time for *E. coli* bacteria analysis.

Table 10. *E. coli* results grouped by sampling trip

Sampling Site	Date	*E. coli* sample result (MPN/100 mL)
Above Verde Springs	12/02/2006	5
Bear Siding	12/02/2006	6
Perkinsville	12/02/2006	32
Reitz	12/02/2006	21
89A Bridge	12/02/2006	10
White Bridge	12/02/2006	28
Beasley Flat	12/02/2006	16
Above Verde Springs	2/17/2007	2
Bear Siding	2/17/2007	3
Perkinsville	2/17/2007	3
Reitz	2/17/2007	8
89A Bridge	2/17/2007	16
White Bridge	2/17/2007	38
Beasley Flat	2/17/2007	20
Above Verde Springs	03/10/2007	<1
Bear Siding	03/10/2007	24
Perkinsville	03/10/2007	1
Reitz	03/10/2007	6
89A Bridge	03/10/2007	16
White Bridge	03/10/2007	31
Beasley Flat	03/10/2007	12
Above Verde Springs	04/28/2007	Not available
Bear Siding	04/28/2007	4
Perkinsville	04/28/2007	20
Reitz	04/28/2007	4
89A Bridge	04/28/2007	185
White Bridge	04/28/2007	8
Beasley Flat	04/28/2007	3
Above Verde Springs	08/25/2007	5*
Bear Siding	08/25/2007	5
Perkinsville	08/25/2007	13
Reitz	08/25/2007	7*
89A Bridge	08/25/2007	99*
White Bridge	08/25/2007	60
Beasley Flat	08/25/2007	35

Sampling Site	Date	*E. coli* sample result (MPN/100 mL)
Above Verde Springs	10/20/2007	13
Bear Siding	10/20/2007	9
Perkinsville	10/20/2007	16
Reitz	10/20/2007	16
89A Bridge	10/20/2007	32
White Bridge	10/20/2007	83
Beasley Flat	10/20/2007	35
Above Verde Springs	12/15/2007	3
Bear Siding	12/15/2007	16
Perkinsville	12/15/2007	23
Reitz	12/15/2007	4
89A Bridge	12/15/2007	38
White Bridge	12/15/2007	34
Beasley Flat	12/15/2007	36
Above Verde Springs	02/09/2008	1
Bear Siding	02/09/2008	5
Perkinsville	02/09/2008	2
Reitz	02/09/2008	2
89A Bridge	02/09/2008	3
White Bridge	02/09/2008	16
Beasley Flat	02/09/2008	1
Above Verde Springs	04/26/2008	1
Bear Siding	04/26/2008	4
Perkinsville	04/26/2008	9
Reitz	04/26/2008	9
89A Bridge	04/26/2008	686
White Bridge	04/26/2008	5
Beasley Flat	04/26/2008	5
Above Verde Springs	06/14/2008	25
Bear Siding	06/14/2008	12
Perkinsville	06/14/2008	24
Reitz	06/14/2008	12
89A Bridge	06/14/2008	186
White Bridge	06/14/2008	40
Beasley Flat	06/14/2008	25
Above Verde Springs	08/16/2008	16
Bear Siding	08/16/2008	25
Perkinsville	08/16/2008	28
Reitz	08/16/2008	13
89A Bridge	08/16/2008	157
White Bridge	08/16/2008	>2,420
Beasley Flat	08/16/2008	39

Sampling Site	Date	*E. coli* sample result (MPN/100 mL)
Above Verde Springs	12/20/2008	2
Bear Siding	12/20/2008	<1
Perkinsville	12/20/2008	1
Reitz	12/20/2008	<1
89A Bridge	12/20/2008	<1
White Bridge	12/20/2008	10
Beasley Flat	12/20/2008	10
Above Verde Springs	02/28/2009	9
Bear Siding	02/28/2009	16
Perkinsville	02/28/2009	<1
Reitz	02/28/2009	1
89A Bridge	02/28/2009	17
White Bridge	02/28/2009	25
Beasley Flat	02/28/2009	33
Above Verde Springs	04/11/2009	55
Bear Siding	04/11/2009	54
Perkinsville	04/11/2009	19
Reitz	04/11/2009	9
89A Bridge	04/11/2009	53
White Bridge	04/11/2009	46
Beasley Flat	04/11/2009	8
Above Verde Springs	05/30/2009	25
Bear Siding	05/30/2009	38
Perkinsville	05/30/2009	45
Reitz	05/30/2009	20
89A Bridge	05/30/2009	214
White Bridge	05/30/2009	579
Beasley Flat	05/30/2009	98
Above Verde Springs	07/25/2009	77
Bear Siding	07/25/2009	61
Perkinsville	07/25/2009	291
Reitz	07/25/2009	225
89A Bridge	07/25/2009	435
White Bridge	07/25/2009	105
Beasley Flat	07/25/2009	51
Above Verde Springs	09/19/2009	39
Bear Siding	09/19/2009	46
Perkinsville	09/19/2009	66
Reitz	09/19/2009	15
89A Bridge	09/19/2009	194
White Bridge	09/19/2009	102
Beasley Flat	09/19/2009	248

Sampling Site	Date	*E. coli* sample result (MPN/100 mL)
Above Verde Springs	11/21/2009	16
Bear Siding	11/21/2009	44
Perkinsville	11/21/2009	20
Reitz	11/21/2009	8
89A Bridge	11/21/2009	31
White Bridge	11/21/2009	31
Beasley Flat	11/21/2009	34
Above Verde Springs	03/13/2010	8
Perkinsville	03/13/2010	24
Reitz	03/13/2010	33
89A Bridge	03/13/2010	16
Black Bridge	03/13/2010	12
Beasley Flat	03/13/2010	6
Above Verde Springs	05/22/2010	32
Perkinsville	05/22/2010	28
Reitz	05/22/2010	6
89A Bridge	05/22/2010	142
Black Bridge	05/22/2010	30
Beasley Flat	05/22/2010	21
Above Verde Springs	07/10/2010	178
Perkinsville	07/10/2010	48
Reitz	07/10/2010	4
89A Bridge	07/10/2010	248
Black Bridge	07/10/2010	23
Beasley Flat	07/10/2010	29
Above Verde Springs	09/18/2010	Not available
Perkinsville	09/18/2010	Not available
Reitz	09/18/2010	5
89A Bridge	09/18/2010	248
Black Bridge	09/18/2010	13
Beasley Flat	09/18/2010	25
Above Verde Springs	11/20/2010	12
Perkinsville	11/20/2010	15
Reitz	11/20/2010	33
89A Bridge	11/20/2010	4
Black Bridge	11/20/2010	12
Beasley Flat	11/20/2010	19
Above Verde Springs	02/26/2011	3
Perkinsville	02/26/2011	9
Reitz	02/26/2011	3
89A Bridge	02/26/2011	5
Black Bridge	02/26/2011	5
Beasley Flat	02/26/2011	49

Sampling Site	Date	*E. coli* sample result (MPN/100 mL)
Above Verde Springs	04/23/2011	9
Perkinsville	04/23/2011	1
Reitz	04/23/2011	4
89A Bridge	04/23/2011	105
Black Bridge	04/23/2011	14
Beasley Flat	04/23/2011	23
Above Verde Springs	06/18/2011	13
Perkinsville	06/18/2011	22
Reitz	06/18/2011	9
89A Bridge	06/18/2011	435
Black Bridge	06/18/2011	26
Beasley Flat	06/18/2011	3
Above Verde Springs	09/17/2011	579
Perkinsville	09/17/2011	13
Reitz	09/17/2011	150
89A Bridge	09/17/2011	613
Black Bridge	09/17/2011	687
Beasley Flat	09/17/2011	345
Above Verde Springs	10/22/2011	21
Perkinsville	10/22/2011	5
Reitz	10/22/2011	9
89A Bridge	10/22/2011	60
Black Bridge	10/22/2011	35
Beasley Flat	10/22/2011	30
Above Verde Springs	12/10/2011	15 *
Perkinsville	12/10/2011	5 *
Reitz	12/10/2011	2
89A Bridge	12/10/2011	31
Black Bridge	12/10/2011	10
Beasley Flat	12/10/2011	22 *

*Six-hour holding time exceeded. The Water Sentinels sampling protocol states that *E. coli* bacteria samples should be delivered to the testing laboratory within six hours of the time of sample collection.

Dissolved oxygen in the Verde River

Dissolved oxygen (DO) in water is essential to aquatic life. Water Sentinels measure DO concentrations on each sampling trip to the Verde River to assess the health of the river and how well it supports aquatic life. In general, a high DO concentration (>6 mg/L) is an indicator that the Verde River is healthy and adequately supports aquatic life, while a low dissolved oxygen concentration (<4 mg/L) is an indicator of oxygen-deficient conditions and an unhealthy river.

The Water Sentinels' logo reminds us that a water molecule is made up of two hydrogen atoms and one oxygen atom – H_2O. Although a water molecule contains an oxygen atom, that oxygen atom is not available to aquatic organisms for respiration because it is tightly bound to the two hydrogen atoms in the water molecule. Aquatic organisms breathe free oxygen (O_2) mixed in the water between the water molecules. Water Sentinels make field measurements of DO concentration to determine how much free oxygen is dissolved in the water column and is available for respiration by fish and other organisms living in the river. Just like humans, aquatic organisms need oxygen to breathe and they will be stressed and can even suffocate if there is not enough DO in the water.

Rapidly moving water tends to contain more DO because the water is more turbulent and well-aerated. Slow-moving or stagnant water tends to contain less DO. Also, bacteria in water consume oxygen as organic matter decays in the water. Excessive organic material in a river may cause eutrophic conditions (i.e., oxygen-deficient conditions). In some cases, the DO concentration in the water gets so low that it causes fish mortality. The graphic below illustrates the range of fish tolerances for dissolved oxygen. A dissolved oxygen concentration greater than 6 mg/L is an indicator of a healthy stream with enough oxygen to support healthy populations of fish and other aquatic life. DO concentrations below 4 mg/L are an indicator of stressful conditions for fish and aquatic organisms in the river.

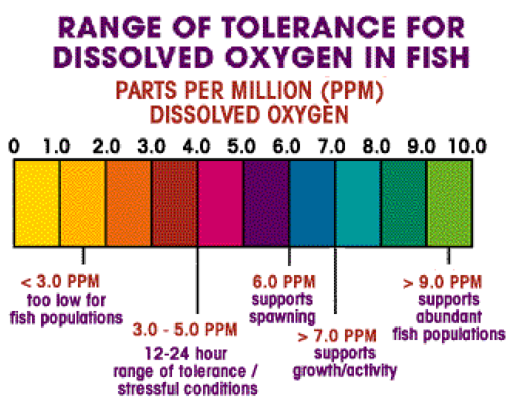

Figure 25. Range of tolerance for dissolved oxygen in fish
Source: Cyber Field Trip Teaching Guide - Water World: The Blue Planet[42]

The concentration of DO in water is controlled by temperature. Cold water holds more DO than warm water. In winter and early spring, when water temperatures are lower, DO concentrations in the water are usually higher. In summer and fall, when water temperatures are higher, the DO concentrations tend to be lower. For this reason, there is a seasonal cycle to the DO concentrations in the Verde River.

[42] http://www.pbs.org/safarchive/5_cool/galapagos/g52a_water.html

DO concentrations in the Verde River also have a daily or diurnal cycle. Photosynthesis by aquatic plants is the primary biological process affecting this diurnal cycle. Photosynthesis by aquatic plants and algae during the day produces free DO in the water column and causes an increase in the DO concentrations during the daylight hours. At night, photosynthesis by aquatic plants stops, but respiration by aquatic organisms in the river continues to consume the available free oxygen in the water. For this reason, DO concentrations in the river gradually decrease through the night and usually are at their lowest in the morning hours before dawn. The chart below illustrates this diurnal cycle:

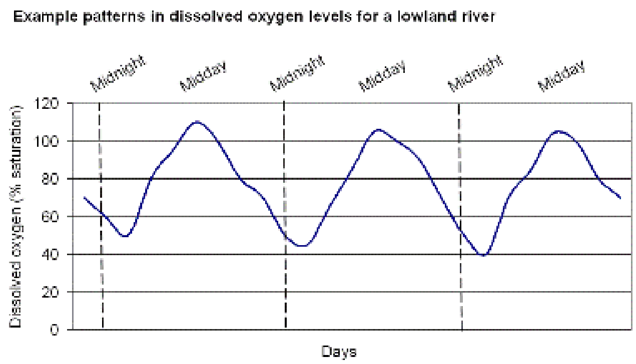

Figure 26. Example patterns in dissolved oxygen levels for a lowland river
Source: New Zealand Ministry of the Environment website[43]

Water Sentinels do not measure DO concentrations of the Verde River at night. Water Sentinels volunteers typically arrive at sampling sites in the morning and finish data collection around mid-day. For this reason, the Water Sentinels' dataset for DO is biased because our data is typically obtained on the rising limb of the DO diurnal cycle when DO concentrations in the Verde River are expected to be increasing or approaching their highest levels of the 24-hour cycle.

Arizona water quality standards for dissolved oxygen

The Arizona Department of Environmental Quality has adopted water quality standards for DO in surface water to protect aquatic life. These water quality standards are expressed as minimum DO concentrations for cold water, warm water, and effluent dependent waters. The minimum DO standard to protect aquatic life in the Verde River is 6.0 mg/L [*See* Arizona Administrative Code R18-11-109]. DO concentrations in water greater than 6 mg/L are considered adequate to support the growth, habitation, and reproduction of aquatic organisms of the Verde River. DO concentrations below 6.0 mg/L represent a violation of Arizona's water quality standard for DO for the Verde River.

[43] http://www.mfe.govt.nz/environmental-reporting/freshwater/river/temperature-oxygen

How do Arizona Water Sentinels measure dissolved oxygen concentrations in the Verde River?

The Arizona Water Sentinels use a Sper Scientific DO pen meter to measure DO concentrations.

Figure 27. A Sper Scientific dissolved oxygen pen meter
Source: Sper Scientific web site.

Water Sentinels calibrate their DO pen meters before making a measurement in the Verde River. Field calibration of the instrument is done in the open air at each sampling site. After the pen meter is successfully calibrated, volunteers make the DO measurement by immersing the black part on the meter below the water surface of the river. For an accurate DO measurement, water should be flowing across the probe. The sampler allows enough time for the DO concentration to stabilize (i.e., the value on the liquid crystal display of the instrument stops increasing or decreasing) before recording the DO concentration in milligrams per liter (mg/L) on the field data sheet.

Arizona Water Sentinels field measurements of dissolved oxygen in the Verde River

The Water Sentinels' monitoring program began in December 2006, but measurement of DO concentrations did not begin until February 2009 when the program purchased Sper Scientific pen meters to make field measurements of DO concentration in the river. Table 11 at the end of this section of the report shows all of the DO measurements made by the Water Sentinels at sampling sites on the Verde River between February 28, 2009, and December 10, 2011. A total of 88 DO measurements were made at seven sampling sites on the upper and middle reaches of the Verde River in that three-year time period.

Several DO concentrations reported in Table 11 were rejected as invalid but have been included in the data table for information purposes. Rejected DO measurements are highlighted in grey in Table 11. They were rejected because the DO values recorded on the field data sheets exceed the highest DO concentration that is physically possible to obtain in water (approximately 18 mg/L). These invalid data points were <u>not</u> used to determine maximum concentrations or ranges nor to calculate descriptive statistics for this report. They are included in Table 11 for information purposes only.

Table 11 also includes a note, "not available," for some sampling events. For eight sampling events, it was not possible for Water Sentinels to make a field measurement of DO because the DO pen meter malfunctioned during the sampling event. The total number of DO field measurements in the Water Sentinels dataset is 74 (n=74).

The minimum DO concentration measured by the Water Sentinels was 2.5 mg/L. This field measurement was made at the White Bridge site on September 19, 2009. The maximum DO concentration measured was 12.9 mg/L and was measured at the Bear Siding sampling site on November 21, 2009. The average DO concentration calculated from all valid DO field measurements from the Verde River over the last two years is 7.5 mg/L.

Eighteen field measurements of DO indicated a DO concentration less than the minimum DO water quality standard of 6.0 mg/L for the protection of aquatic life in the Verde River. Eighteen violations out of a total of 74 field measurements represent approximately 24 percent of all valid DO field measurements made by the Water Sentinels. Eight of these 18 water quality standards violations for DO were measured at the Above Verde Springs sampling site. Other field measurements for DO indicating a violation of the 6.0 mg/L water quality standard to protect aquatic life were made at the following sites: Reitz property (two violations), 89A Bridge (three violations), Black Bridge (one violation), White Bridge (two violations), and Beasley Flat (two violations). Ten violations out of 74 field measurements represent approximately 13 percent of the field measurements, which means that 87 percent of the field measurements of DO in the Verde River obtained at sampling sites other than the site above Verde Springs, or almost 9 out of 10 field measurements, complied with the water quality standard for DO for the Verde River. It should be noted that six of the ten violations reported by the Water Sentinels were relatively minor violations of the single sample minimum standard with field measurements falling between 5 mg/L and 6 mg/L.

Eight of the 18 DO measurements that did not comply with the water quality standard for DO were made at the Above Verde Springs sampling site. The eight field measurements at the Above Verde Springs site were 5.3 mg/L, 5.1 mg/L, 4 mg/L, 5.4 mg/L, 4.9 mg/L, 4.7 mg/L, 3.6

mg/L and 4.9 mg/L. These low DO concentrations measured at Above Verde Springs are explained by natural causes. The Above Verde Springs sampling site is located above the network of springs and seeps that discharge groundwater to create the base flow of the upper Verde River. Groundwater is often naturally low in DO. The minor violations of the water quality for DO are believed to be caused by naturally low DO concentrations in the groundwater discharged to the Verde River at Above Verde Springs. This interpretation of the water quality data is supported by DO measurements made farther downstream at the Bear Siding and Perkinsville sampling sites. By the time the water in the river arrives at these downstream sampling sites, turbulence and the interaction of the water with the atmosphere has aerated the water. No field measurements of DO made at Bear Siding or Perkinsville indicated a violation of the DO standard in the last five years.

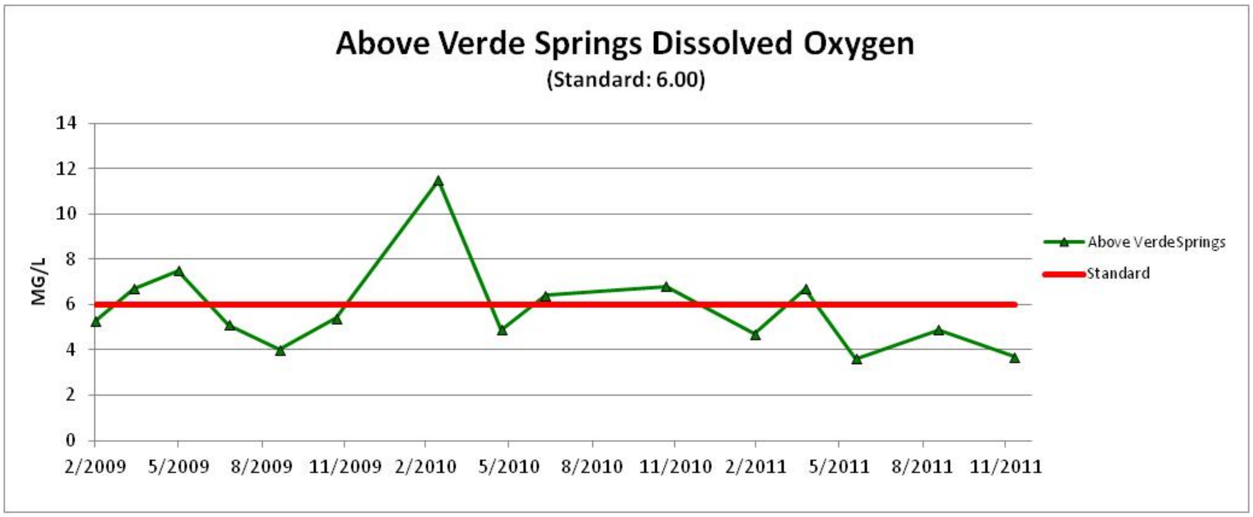

Chart 9. Above Verde Springs dissolved oxygen

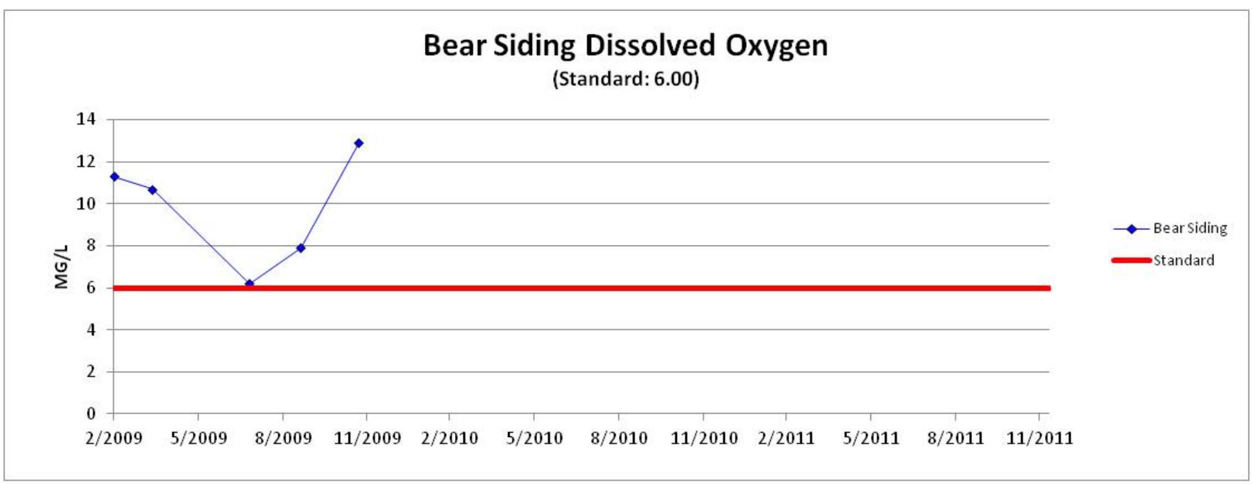

Chart 10. Bear Siding dissolved oxygen

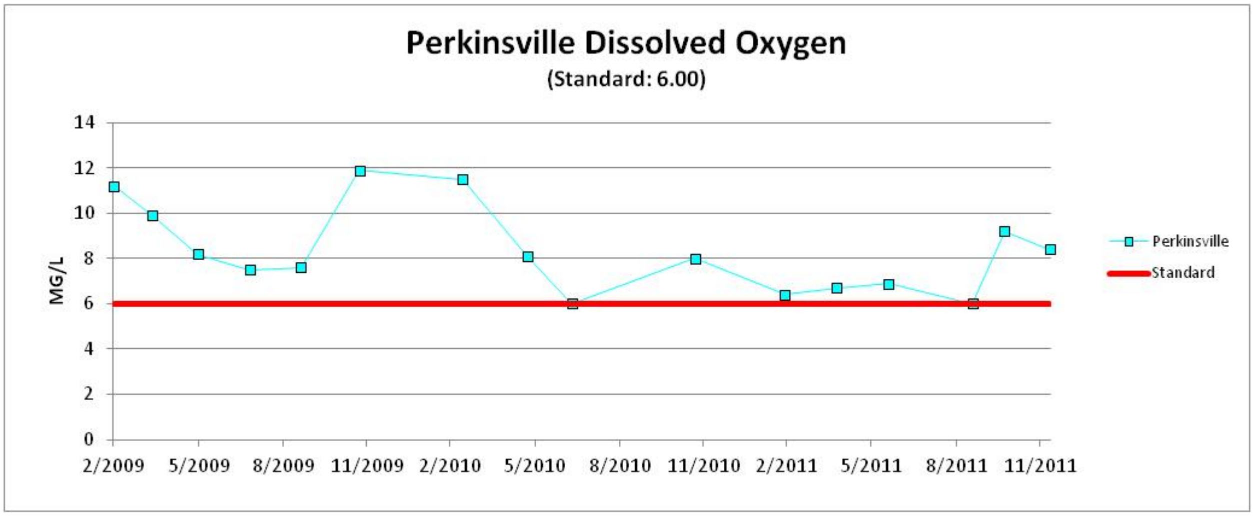

Chart 11. Perkinsville dissolved oxygen

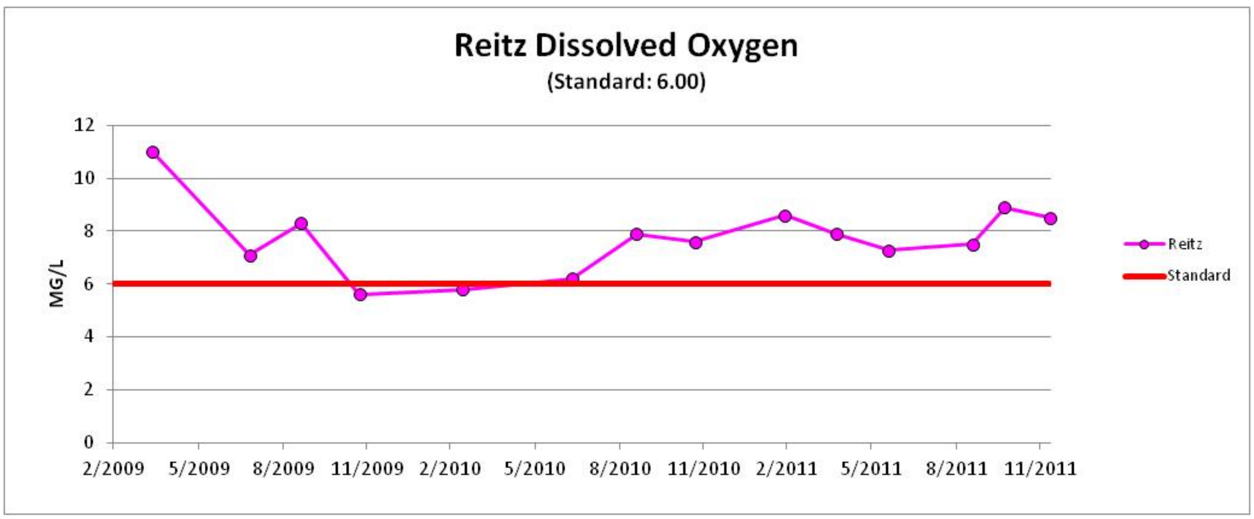

Chart 12. Reitz dissolved oxygen

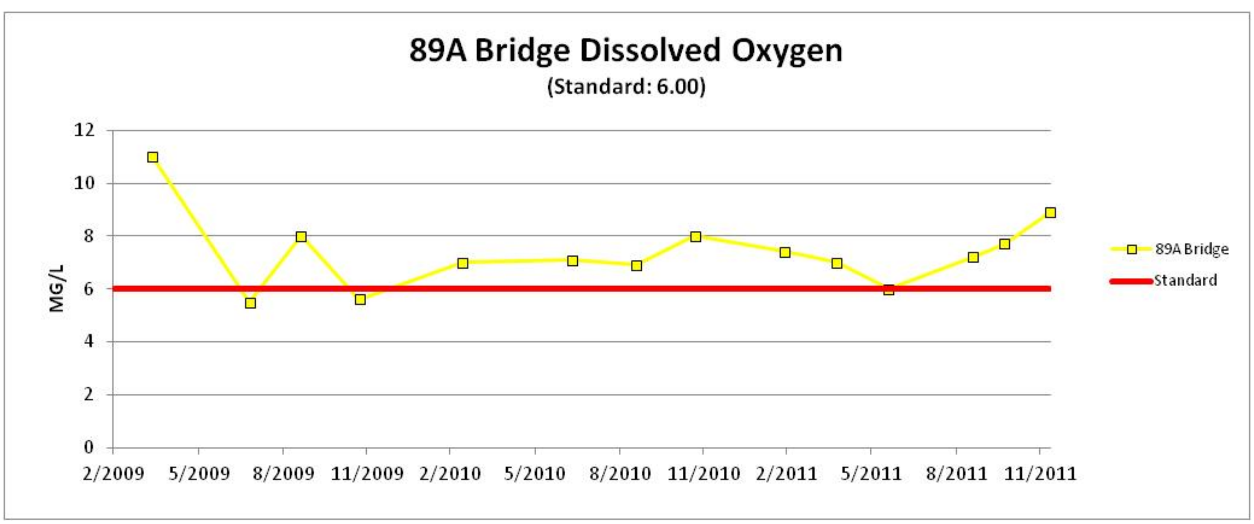

Chart 13. 89A Bridge dissolved oxygen

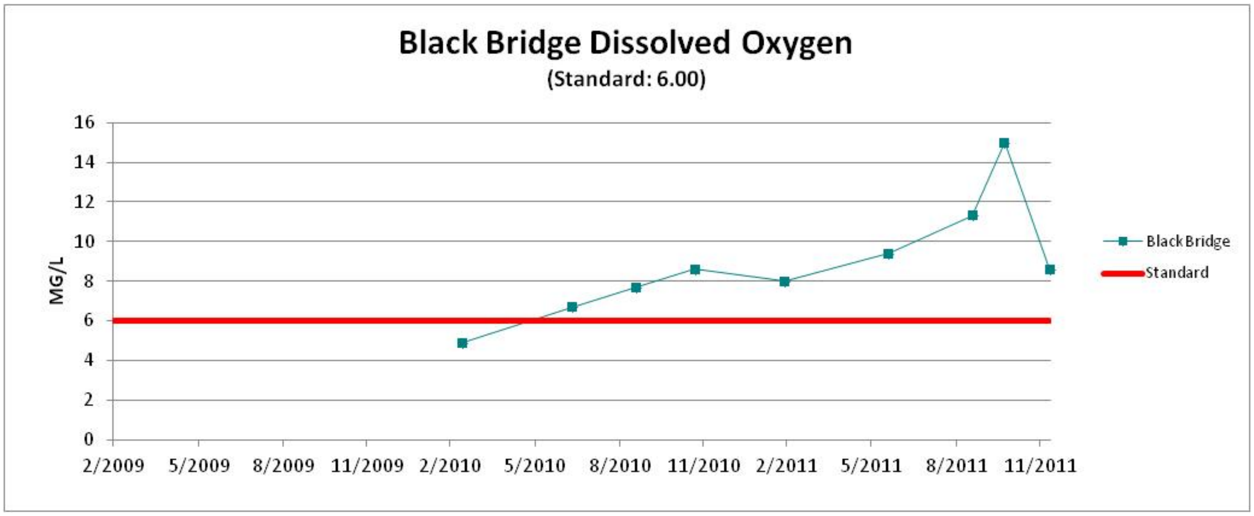

Chart 14. Black Bridge dissolved oxygen

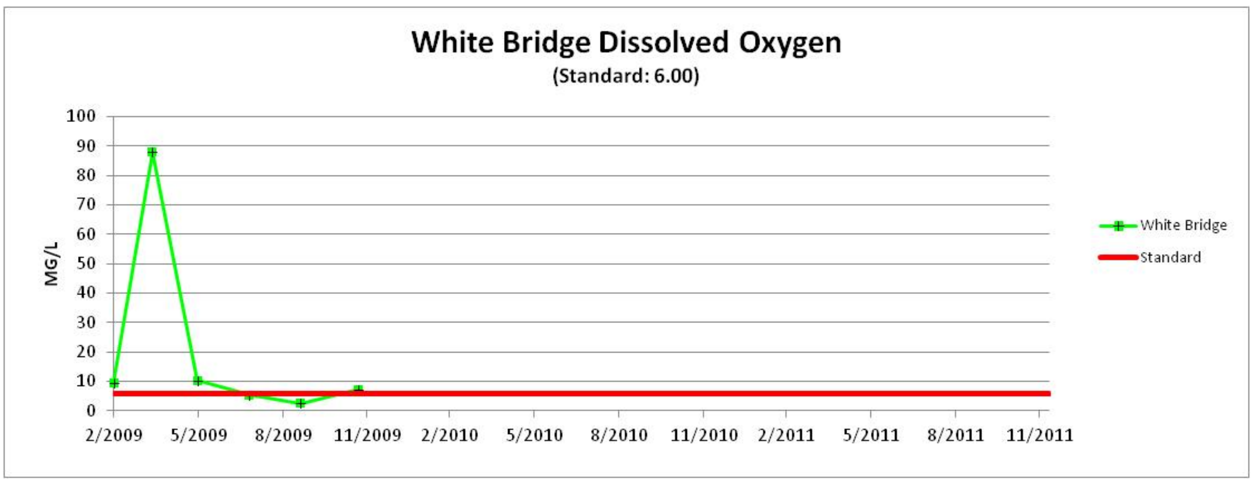

Chart 15. White Bridge dissolved oxygen

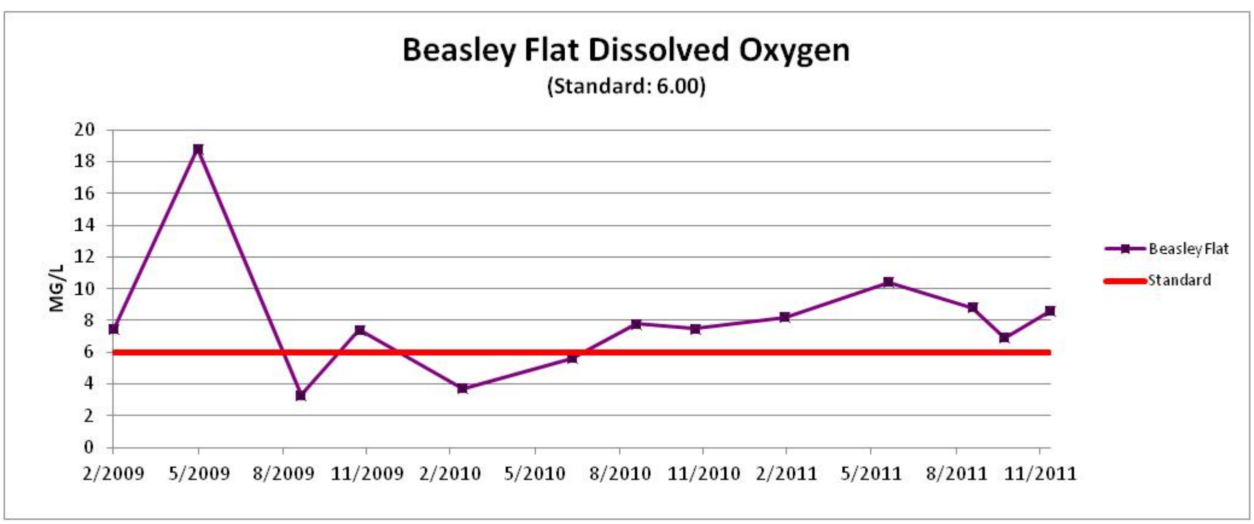

Chart 16. Beasley Flat dissolved oxygen

Table 11. Dissolved oxygen field measurements

Sampling Site	Date	DO Result (mg/L)
Above Verde Springs	02/28/2009	5.3
Bear Siding	02/28/2009	11.3
Perkinsville	02/28/2009	11.2
Reitz	02/28/2009	31.1
89A Bridge	02/28/2009	28.5
White Bridge	02/28/2009	9.6
Beasley Flat	02/28/2009	7.5
Above Verde Springs	04/11/2009	6.7
Bear Siding	04/11/2009	10.7
Perkinsville	04/11/2009	9.9
Reitz	04/11/2009	11
89A Bridge	04/11/2009	11
White Bridge	04/11/2009	88
Beasley Flat	04/11/2009	90
Above Verde Springs	05/30/2009	7.5
Bear Siding	05/30/2009	Not available
Perkinsville	05/30/2009	8.2
Reitz	05/30/2009	21.1
89A Bridge	05/30/2009	10. 4
White Bridge	05/30/2009	10.4
Beasley Flat	05/30/2009	18.8
Above Verde Springs	07/25/2009	5.1
Bear Siding	07/25/2009	6.2
Perkinsville	07/25/2009	7.5
Reitz	07/25/2009	7.1
89A Bridge	07/25/2009	5.5
White Bridge	07/25/2009	5.4
Beasley Flat	07/25/2009	63.0
Above Verde Springs	09/19/2009	4.0
Bear Siding	09/19/2009	7.9
Perkinsville	09/19/2009	7.6
Reitz	09/19/2009	8.3
89A Bridge	09/19/2009	8.01
White Bridge	09/19/2009	2.5
Beasley Flat	09/19/2009	3.3

Sampling Site	Date	DO Result (mg/L)
Above Verde Springs	11/21/2009	5.4
Bear Siding	11/21/2009	12.9
Perkinsville	11/21/2009	11.9
Reitz	11/21/2009	5.6
89A Bridge	11/21/2009	5.6
White Bridge	11/21/2009	7.2
Beasley Flat	11/21/2009	7.4
Above Verde Springs	03/13/2010	7.0
Bear Siding	03/13/2010	11.5
Perkinsville	03/13/2010	11.5
Reitz	03/13/2010	5.8
89A Bridge	03/13/2010	3.7
Black Bridge	03/13/2010	4.9
Beasley Flat	03/13/2010	11.5
Above Verde Springs	05/22/2010	4.9
Perkinsville	05/22/2010	8.1
Reitz	05/22/2010	Not available
89A Bridge	05/22/2010	Not available
Black Bridge	05/22/2010	Not available
Beasley Flat	05/22/2010	Not available
Above Verde Springs	07/10/2010	6.4
Perkinsville	07/10/2010	6.0
Reitz	07/10/2010	6.2
89A Bridge	07/10/2010	7.1
Black Bridge	07/10/2010	6.7
Beasley Flat	07/10/2010	5.6
Above Verde Springs	09/18/2010	Not available
Perkinsville	09/18/2010	Not available
Reitz	09/18/2010	7.9
89A Bridge	09/18/2010	6.9
Black Bridge	09/18/2010	7.7
Beasley Flat	09/18/2010	7.8

Sampling Site	**Date**	**DO Result (mg/L)**
Above Verde Springs	11/20/2010	6.8
Perkinsville	11/20/2010	8.0
Reitz	11/20/2010	7.6
89A Bridge	11/20/2010	8.0
Black Bridge	11/20/2010	8.6
Beasley Flat	11/20/2010	7.5
Above Verde Springs	02/26/2011	4.7
Perkinsville	02/26/2011	6.4
Reitz	02/26/2011	8.6
89A Bridge	02/26/2011	7.4
Black Bridge	02/26/2011	8.0
Beasley Flat	02/26/2011	8.2
Above Verde Springs	04/23/2011	6.7
Perkinsville	04/23/2011	6.7
Reitz	04/23/2011	7.9
89A Bridge	04/23/2011	7.0
Black Bridge	04/23/2011	Not available
Beasley Flat	04/23/2011	Not available
Above Verde Springs	06/18/2011	3.6
Perkinsville	06/18/2011	6.9
Reitz	06/18/2011	7.2
89A Bridge	06/18/2011	6.0
Black Bridge	06/18/2011	9.4
Beasley Flat	06/18/2011	10.4
Sampling Site	**Date**	**DO Result (mg/L)**
Above Verde Springs	09/17/2011	4.9
Perkinsville	09/17/2011	6.0
Reitz	09/17/2011	7.5
89A Bridge	09/17/2011	7.2
Black Bridge	09/17/2011	11.3
Beasley Flat	09/17/2011	8.8
Above Verde Springs	10/22/2011	Not available
Perkinsville	10/22/2011	9.2
Reitz	10/22/2011	8.9
89A Bridge	10/22/2011	7.7
Black Bridge	10/22/2011	15.0
Beasley Flat	10/22/2011	6.9

Sampling Site	Date	DO Result (mg/L)
Above Verde Springs	12/10/2011	3.7
Perkinsville	12/10/2011	8.4
Reitz	12/10/2011	8.5
89A Bridge	12/10/2011	8.9
Black Bridge	12/10/2011	8.6
Beasley Flat	12/10/2011	8.01

Total dissolved solids and electrical conductivity in the Verde River

Water has been described as the universal solvent because of its ability to dissolve substances with which it comes in contact. As water moves across the rocks and soils of the Verde River watershed, it picks up a variety of dissolved and particulate materials. The dissolved or soluble fraction of the material picked up is referred to as total dissolved solids (TDS). Most of the TDS in fresh water is comprised of inorganic compounds – (e.g., mineral compounds). Although there are traces of many elements comprising TDS, the majority of the TDS in freshwater is from four negative ions (bicarbonate, carbonate, chloride, and sulfate) and four positive ions (calcium, magnesium, sodium, and potassium). The unit of measurement for TDS is milligrams per liter (mg/L).

The field measurement of TDS is related to the measurement of the electrical conductivity (EC) of water. EC is a measure of the ability of freshwater to conduct an electric current. EC is directly related to the TDS content of water because TDS are comprised of positive and negative ions that conduct electrical current in proportion to the concentrations of the different ions in the water. Pure water, such as distilled water, has very low EC. By contrast, sea water has high concentrations of salts and other dissolved solids and thus has high EC. In general, high EC indicates a high TDS concentration and low EC is an indicator of low TDS concentrations.

TDS and water quality

The TDS concentration of water affects its suitability for domestic, industrial, and agricultural uses. At very high TDS levels, drinking water may have an unpleasant taste or odor and it may even cause gastrointestinal distress. For example, water with high TDS concentrations has been reported to have laxative effects, particularly when sulfate concentrations are high.

A concern associated with high TDS concentrations in water relates to the direct effects of increased salinity on the health of freshwater organisms. Freshwater organisms require a relatively constant concentration of dissolved ions in the water, much as humans require relatively constant concentrations of certain dissolved ions in our blood and other bodily fluids to maintain our health. TDS levels that are too high or too low can adversely affect the osmotic balance of the organisms and can limit their survival, growth, or reproduction. Also, water with high TDS concentrations may be too salty for some agricultural uses, particularly for irrigation of plants that are sensitive to salts (e.g., citrus).

There are no Arizona water quality standards for TDS

The Arizona Department of Environmental Quality has not adopted surface water quality standards for TDS in surface water. However, the EPA Safe Drinking Water Program has made recommendations for TDS that are advisory in nature. EPA has determined that high levels of TDS in drinking water do not present a significant human health risk and for this reason, EPA has not established a primary drinking water Maximum Contaminant Level (MCL) for TDS in its Safe Drinking Water Program. However, EPA does recommend a secondary MCL for TDS of 500 mg/L. This secondary MCL is intended to protect drinking water from the adverse effects of high TDS concentrations in water such as corrosion and scaling of pipes, fixtures, and appliances; water staining; discolored water; and unpleasant taste or odor. EPA's secondary MCL of 500 mg/L provides a useful reference point for comparison of Water Sentinels measurements of TDS in the Verde River and it provides a useful benchmark for assessing Verde River water quality.

How are TDS and EC measured?

To measure TDS in a laboratory, a known volume of a water sample is sucked through a fine filter that retains particulate matter. The remaining filtrate that has passed through the filter is then heated to evaporate the water, leaving behind a residue of dissolved solids. The laboratory analysis for TDS is relatively simple but requires an expensive drying oven, a very sensitive and expensive weighing scale (analytical balance), laboratory space, and a large amount of laboratory time.

The measurement of EC provides a simple, alternative way to *estimate* the TDS concentration of water. The Water Sentinels use an instrument called a Hanna combo tester to measure EC. EC is measured in microsiemens per centimeter (abbreviated µS/cm) by an electronic sensor consisting of two metal electrodes spaced exactly one centimeter apart. A constant voltage is applied across the electrodes. The electric current passes through the water and the Hanna combo tester measures the strength of the electrical current. The strength of the current is proportional to the concentration of dissolved ions in the water – the greater the concentration of dissolved ions in the water, the more conductive the water is. Very salty water has high conductivity. Conversely, distilled or de-ionized water has few dissolved ions, so there is almost no current flowing across the one centimeter gap (low EC).

EC is temperature-sensitive and increases with the increasing temperature of the water. Most instruments automatically correct for water temperature and standardize measurements to 25°Celsius. Temperature-corrected EC data are called specific ED, abbreviated EC25.

There is a known relationship between EC25 and the TDS concentration. One can estimate the TDS concentration of a water sample by multiplying the EC25 by a factor between 0.5 and 1.0 for rivers and streams. The value of the factor used depends upon the type and proportions of dissolved solids in the water. A widely accepted default factor to estimate the TDS concentration is 0.67. The equation to convert an electrical conductivity measurement to TDS is as follows:

$$\text{TDS (in mg/L or ppm)} = 0.67 \times \text{EC25 (in µS/cm or micromhos/cm)}$$

Water Sentinels do not submit Verde River samples to a laboratory for expensive and time-consuming TDS analyses. Instead, we obtain an estimated TDS concentration calculated from the measured EC of the Verde River. Conveniently, Water Sentinels don't have to do the math! We measure EC with the Hanna combo tester and the instrument automatically calculates and displays an *estimated* TDS concentration from the EC25 measurement.

How do the Arizona Water Sentinels measure TDS and EC?

Water Sentinels use a Hanna combo tester to measure EC and calculate TDS. The Hanna combo tester is called a "combo" tester because it measures TDS, EC, pH, and water temperature. The instrument is light, waterproof, and designed to float (a very useful feature when working in the Verde River!). Before a Water Sentinel makes an EC measurement, he or she must calibrate the Hanna combo tester. This is usually done the night before making the sampling trip to the river. To make an EC or TDS measurement in the field, a Water Sentinel simply selects either the EC or TDS mode on the Hanna combo tester (several different measurement modes can be selected). The sampler submerges the probe into the water and records the EC or TDS measurement by reading the value in the liquid crystal display on the instrument when the measurement stabilizes.

Arizona Water Sentinels Water Quality Data for TDS

Water Sentinels' field measurements show that TDS concentrations in the Verde River are typically in the 200 to 300 parts per million (ppm) range. With the exception of three measurements, all field measurements of TDS (n=168) over the last five years were below the EPA secondary MCL for drinking water of 500 mg/L. This means that more than 98 percent of the TDS measurements were less than 500 mg/L. Two of three measurements in excess of the EPA secondary MCL for TDS were measured at Beasley Flat (i.e, 525 ppm on June 18, 2011, and 634 ppm on July 10, 2010). The other TDS measurement above 500 ppm was measured at the 89A Highway Bridge site (594 ppm on April 26, 2008). The three measurements exceeding 500 ppm are highlighted in yellow in Table 13 below.

In general, TDS concentrations at the headwaters of the Verde River at Above Verde Springs are lower than TDS concentrations measured at other sampling sites farther downstream. The data show that TDS concentrations at the Above Verde Springs site range from a minimum of 124 ppm to a maximum of 250 ppm. The average TDS concentration at Above Verde Springs calculated from all Water Sentinels' measurements obtained at the site between February 2007 and December 2011 (n=27) is 222 ppm.

By contrast, measurements of TDS at the Beasley Flat site are, on average, almost 100 ppm greater than measured TDS concentrations at the Above Verde Springs site. TDS concentrations at Beasley Flat range from a minimum of 90 ppm to a maximum of 634 ppm. The average TDS concentration at Beasley Flat calculated from all measurements made between February 2007 and December 2011 is 339 ppm (n=24). In general, the dataset shows that TDS concentrations tend to increase as the Verde River flows downstream from its source above Verde Springs to Beasley Flat. While the average TDS concentration of 339 ppm at Beasley Flat is greater than the average TDS concentration at Above Verde Springs, both average values are still below the EPA secondary MCL of 500 mg/L for TDS in drinking water.

Water Sentinels' TDS data show that, in general, water quality of the Verde River with respect to TDS content is good. The dataset shows that TDS concentrations of the upper Verde River near its headwaters are approximately half the EPA secondary MCL for drinking water of 500 mg/L. Average TDS concentrations determined from field measurements for all sites range from 222 ppm to 339 ppm.

TDS concentrations tend to increase as the Verde River flows downstream from its source at Above Verde Springs to Beasley Flat below the Town of Camp Verde. However, the increase in average TDS concentration as the Verde River flows downstream is not uniform. Water Sentinels data show that average TDS concentrations are variable, increasing or decreasing in different reaches of the river. For example, the average TDS concentration increases between the Above Verde Springs and Perkinsville sites. The average TDS concentration is 222 ppm at Above Verde Springs and 264 ppm at Perkinsville, an increase of 42 ppm. The average TDS concentration *decreases* between the Perkinsville and Reitz sampling sites from 264 ppm at Perkinsville to 240 ppm at the Reitz site, a decrease in average TDS concentration of 24 ppm. The average TDS concentration increases again between the Reitz property site and the Highway 89A Bridge site from 240 ppm at Reitz to 271 ppm at Highway 89A Bridge, an increase of 31 ppm. The average TDS concentration increases again between the Highway 89A Bridge site (271 ppm) and the Black Bridge (293 ppm), an increase of 22 ppm. The average TDS concentration decreases between the Black Bridge and White Bridge sites (from 293 ppm at Black Bridge to 264 ppm at White Bridge, a decrease of 29 ppm). Finally, the average TDS concentration increases again between the White Bridge and Beasley Flat sites (293 ppm to 339 ppm, an increase of 46 ppm). This variability in average TDS concentrations at the various Water Sentinels' sampling sites may be explained by contributions of water from different tributaries with different TDS concentrations, possible irrigation return flows, or discharges from saline springs in different reaches of the Verde River.

Table 12. Range and average total dissolved solids concentrations by sampling site

Range and Average Total Dissolved Solids Concentrations by Sampling Site			
Sampling Site	**Minimum TDS**	**Maximum TDS**	**Average TDS**
Above Verde Springs	124	250	222 (n=27)
Perkinsville	71	310	264 (n=26)
Reitz	122	265	240 (n=23)
89A Bridge	144	395	271 (n=22)
Black Bridge	147	471	293 (n=8)
White Bridge	117	365	264 (n=16)
Beasley Flat	90	634	339 (n=24)

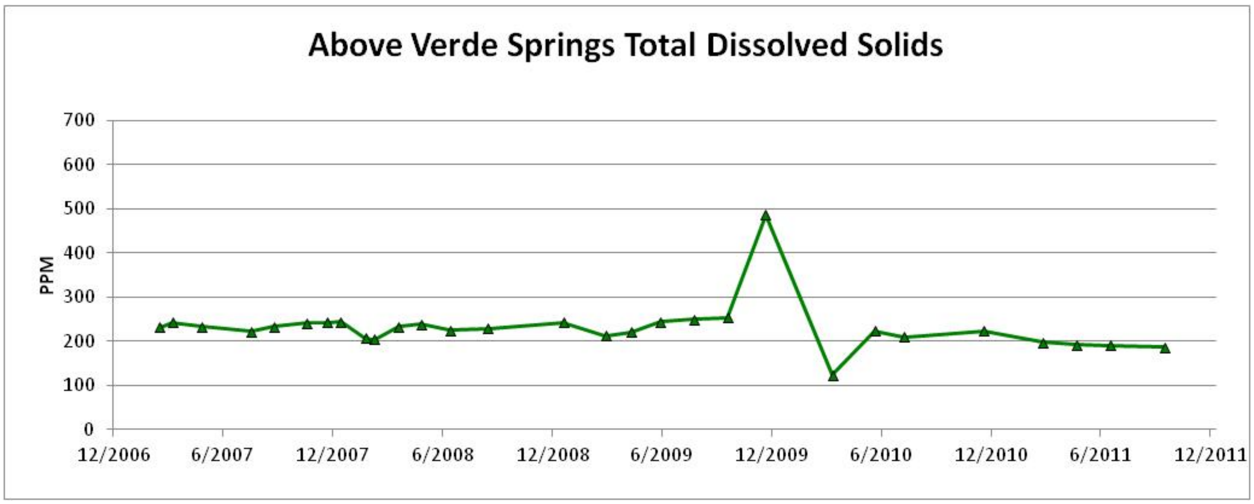

Chart 17. Above Verde Springs total dissolved solids

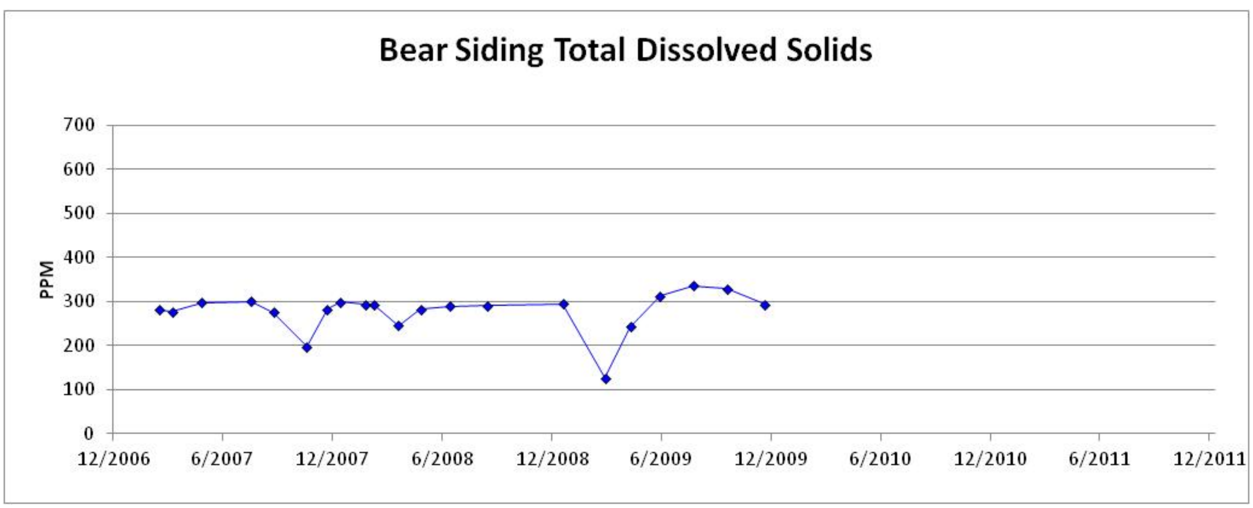

Chart 18. Bear Siding total dissolved solids

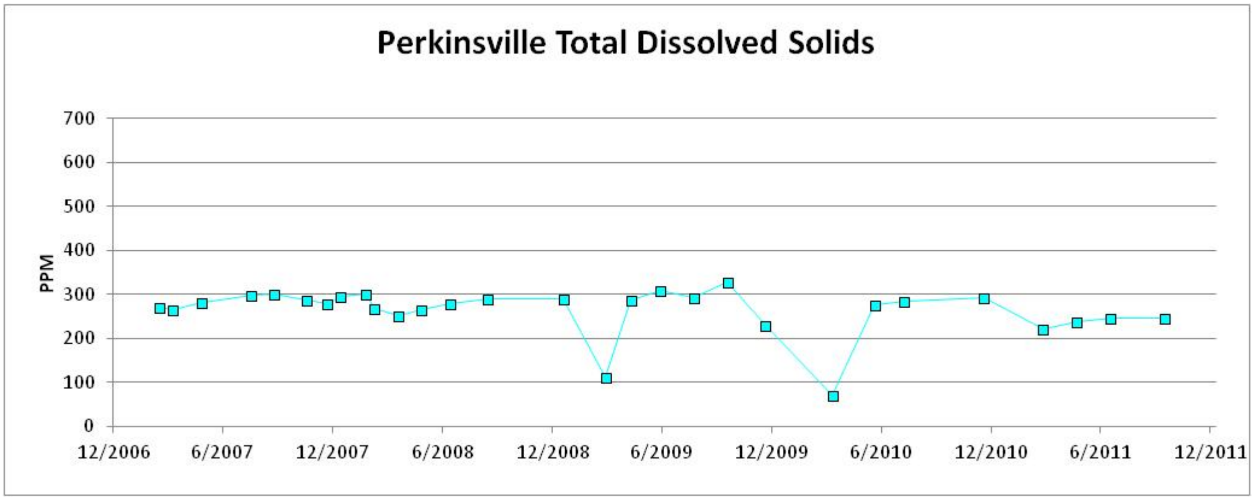

Chart 19. Perkinsville total dissolved solids

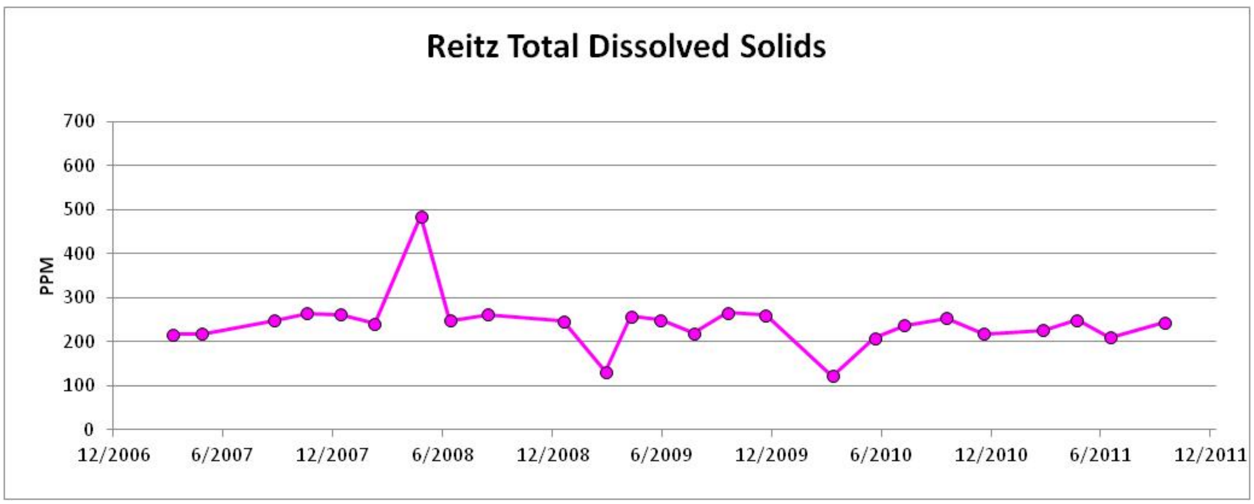

Chart 20. Reitz total dissolved solids

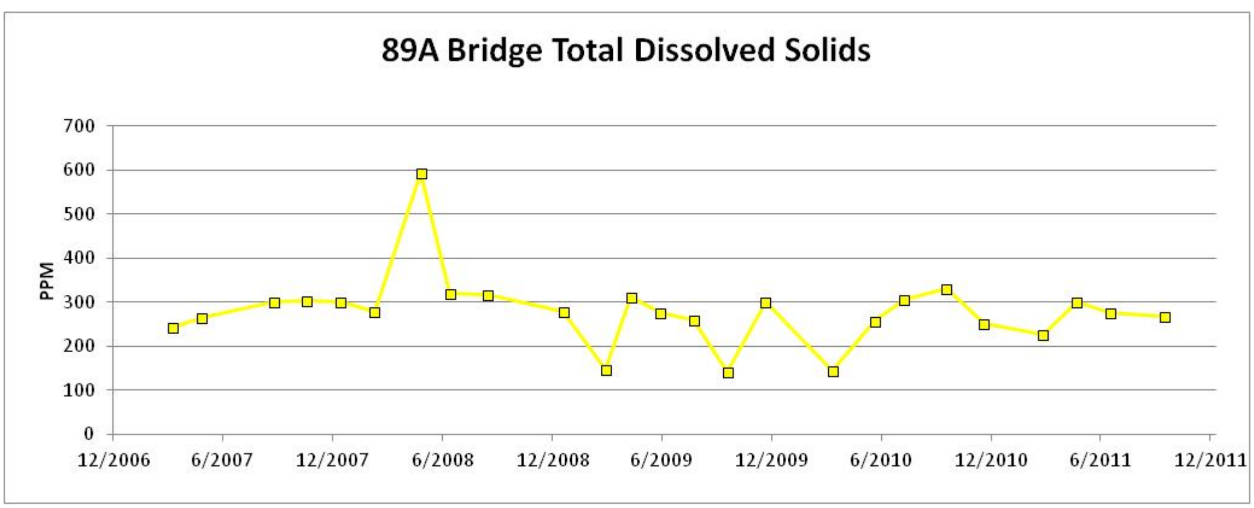

Chart 21. 89A Bridge total dissolved solids

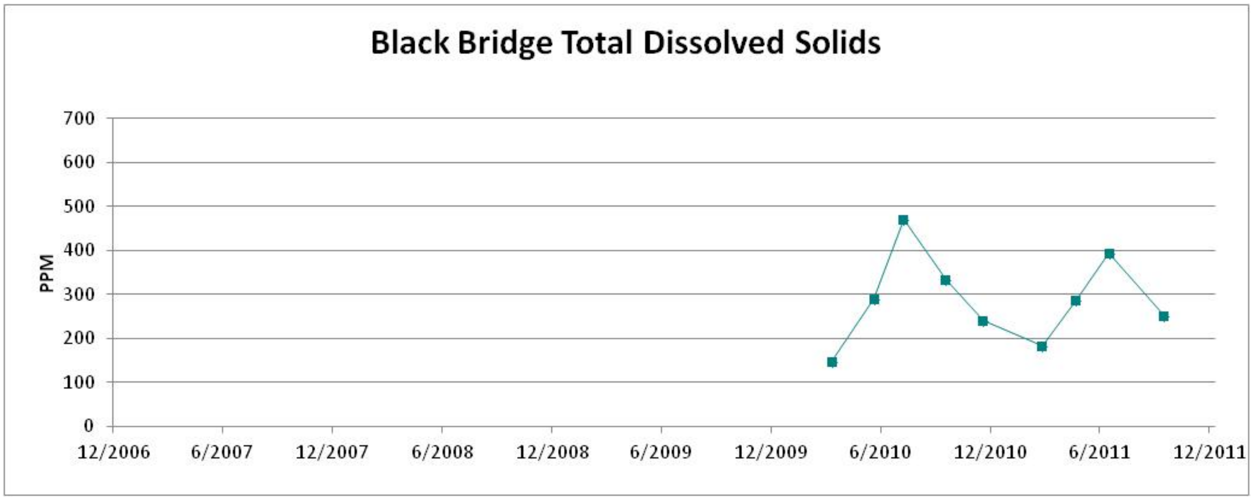

Chart 22. Black Bridge total dissolved solids

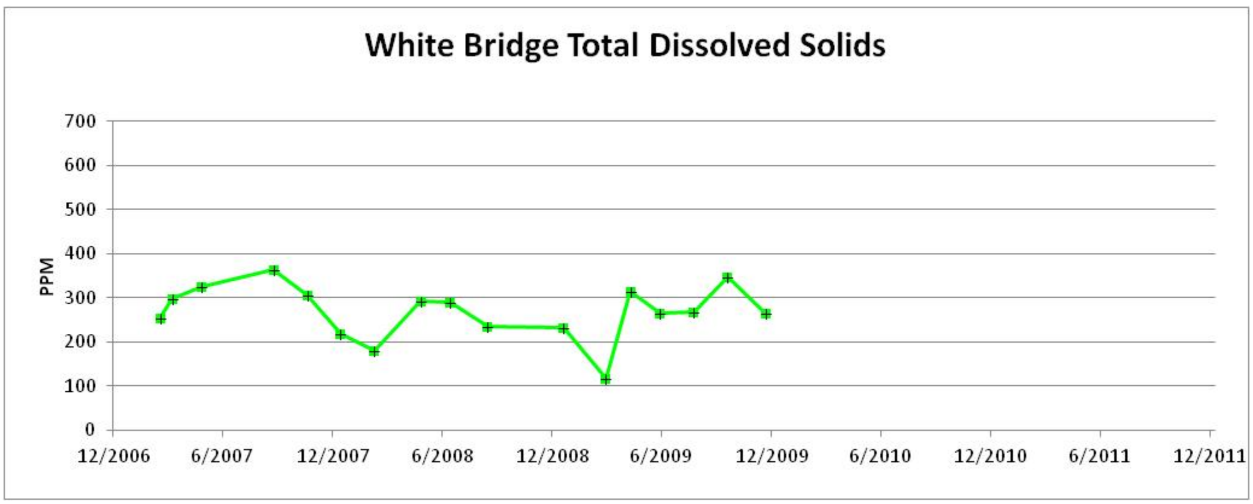

Chart 23. White Bridge total dissolved solids

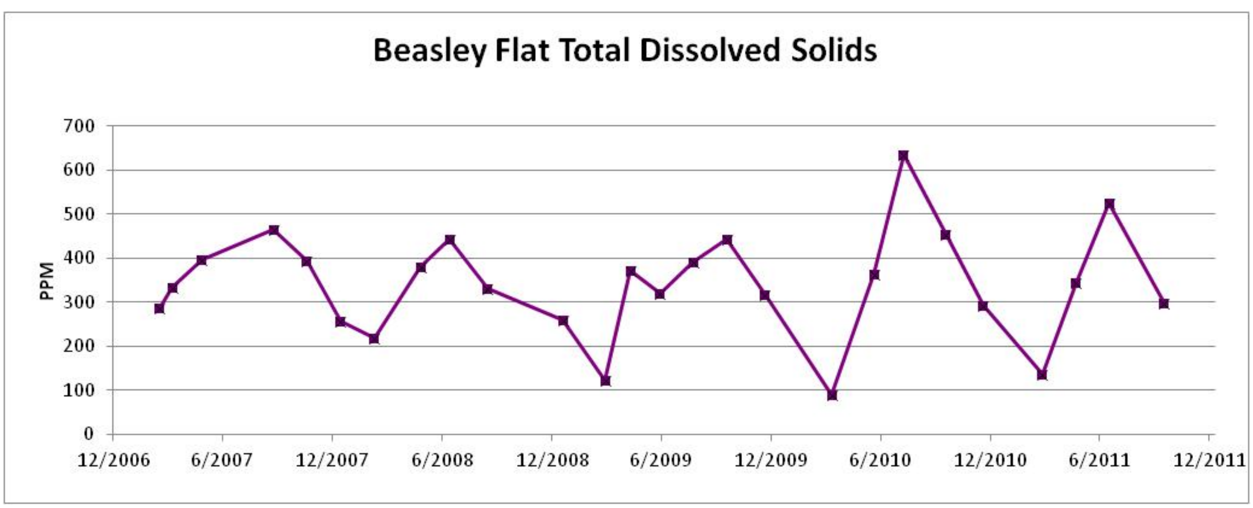

Chart 24. Beasley Flat total dissolved solids

Table 13. Total dissolved solids and electrical conductivity field measurements

Sampling Site	Date	TDS (in ppm)	EC (in µs/cm)
Above Verde Springs	02/17/2007	231	463
Bear Siding	02/17/2007	281	560
Perkinsville	02/17/2007	271	537
Reitz	02/17/2007	Not available	Not available
89A Bridge	02/17/2007	Not available	Not available
White Bridge	02/17/2007	253	506
Beasley Flat	02/17/2007	288	577
Above Verde Springs	03/10/2007	242	495
Bear Siding	03/10/2007	277	565
Perkinsville	03/10/2007	266	534
Reitz	03/10/2007	217	432
89A Bridge	03/10/2007	242	494
White Bridge	03/10/2007	297	596
Beasley Flats	03/10/2007	334	669
Above Verde Springs	04/28/2007	233	469
Bear Siding	04/28/2007	297	601
Perkinsville	04/28/2007	283	565
Reitz	04/28/2007	218	435
89A Bridge	04/28/2007	265	512
White Bridge	04/28/2007	325	658
Beasley Flat	04/28/2007	397	788
Above Verde Springs	07/19/2007	222	441
Bear Siding	07/19/2007	300	607
Perkinsville	07/19/2007	297	594
Above Verde Springs	08/25/2007	233	465
Bear Siding	08/25/2007	276	601
Perkinsville	08/25/2007	302	608
Reitz	08/25/2007	248	495
89A Bridge	08/25/2007	301	602
White Bridge	08/25/2007	365	728
Beasley Flat	08/25/2007	466	930
Above Verde Springs	10/20/2007	241	481
Bear Siding	10/20/2007	298	593
Perkinsville	10/20/2007	287	580
Reitz	10/20/2007	265	511
89A Bridge	10/20/2007	303	607
White Bridge	10/20/2007	305	613
Beasley Flat	10/20/2007	395	786
Above Verde Springs	11/23/2007	242	481
Bear Siding	11/23/2007	283	565
Perkinsville	11/23/2007	279	559

Sampling Site	Date	TDS (in ppm)	EC (in µs/cm)
Above Verde Springs	12/15/2007	244	490
Bear Siding	12/15/2007	299	596
Perkinsville	12/15/2007	295	591
Reitz	12/15/2007	262	519
89A Bridge	12/15/2007	301	599
White Bridge	12/15/2007	220	440
Beasley Flat	12/15/2007	256	513
Above Verde Springs	01/25/2008	207	426
Bear Siding	01/25/2008	294	594
Perkinsville	01/25/2008	301	612
Above Verde Springs	02/09/2008	204	412
Bear Siding	02/09/2008	292	583
Perkinsville	02/09/2008	267	535
Reitz	02/09/2008	241	486
89A Bridge	02/09/2008	278	560
White Bridge	02/09/2008	179	358
Beasley Flat	02/09/2008	220	435
Above Verde Springs	03/20/2008	233	468
Bear Siding	03/20/2008	245	496
Perkinsville	03/20/2008	252	504
Above Verde Springs	04/26/2008	239	478
Bear Siding	04/26/2008	283	568
Perkinsville	04/26/2008	266	532
Reitz	04/26/2008	241	485
89A Bridge	04/26/2008	594	693
White Bridge	04/26/2008	294	579
Beasley Flat	04/26/2008	380	658
Above Verde Springs	06/14/2008	225	445
Bear Siding	06/14/2008	289	579
Perkinsville	06/14/2008	279	559
Reitz	06/14/2008	248	494
89A Bridge	06/14/2008	321	638
White Bridge	06/14/2008	289	580
Beasley Flat	06/14/2008	443	871
Above Verde Springs	08/16/2008	229	458
Bear Siding	08/16/2008	291	583
Perkinsville	08/16/2008	291	583
Reitz	08/16/2008	262	525
89A Bridge	08/16/2008	316	629
White Bridge	08/16/2008	234	469
Beasley Flat	08/16/2008	331	678

Sampling Site	Date	TDS (in ppm)	EC (in µs/cm)
Above Verde Springs	12/20/2008	243	480
Bear Siding	12/20/2008	295	592
Perkinsville	12/20/2008	289	578
Reitz	12/20/2008	247	491
89A Bridge	12/20/2008	278	556
White Bridge	12/20/2008	231	461
Beasley Flat	12/20/2008	260	520
Above Verde Springs	02/28/2009	212	424
Bear Siding	02/28/2009	126	251
Perkinsville	02/28/2009	111	221
Reitz	02/28/2009	131	260
89A Bridge	02/28/2009	148	295
White Bridge	02/28/2009	117	234
Beasley Flat	02/28/2009	124	245
Above Verde Springs	04/11/2009	221	442
Bear Siding	04/11/2009	242	549
Perkinsville	04/11/2009	288	534
Reitz	04/11/2009	258	516
89A Bridge	04/11/2009	311	622
White Bridge	04/11/2009	315	630
Beasley Flat	04/11/2009	373	746
Above Verde Springs	05/30/2009	244	493
Bear Siding	05/30/2009	312	626
Perkinsville	05/30/2009	310	620
Reitz	05/30/2009	249	488
89A Bridge	05/30/2009	275	543
White Bridge	05/30/2009	265	530
Beasley Flat	05/30/2009	321	644
Above Verde Springs	07/25/2009	250	501
Bear Siding	07/25/2009	336	672
Perkinsville	07/25/2009	294	591
Reitz	07/25/2009	220	430
89A Bridge	07/25/2009	260	509
White Bridge	07/25/2009	269	538
Beasley Flat	07/25/2009	390	779
Above Verde Springs	11/21/2009	243	487
Bear Siding	11/21/2009	293	593
Perkinsville	11/21/2009	229	583
Reitz	11/21/2009	261	508
89A Bridge	11/21/2009	302	588
White Bridge	11/21/2009	265	530
Beasley Flat	11/21/2009	316	628

Sampling Site	Date	TDS (in ppm)	EC (in µs/cm)
Above Verde Springs	03/13/2010	124	249
Perkinsville	03/13/2010	71	142
Reitz	03/13/2010	122	244
89A Bridge	03/13/2010	144	288
Black Bridge	03/13/2010	147	290
Beasley Flat	03/13/2010	90	178
Above Verde Springs	05/22/2010	224	444
Perkinsville	05/22/2010	275	550
Reitz	05/22/2010	208	408
89A Bridge	05/22/2010	257	502
Black Bridge	05/22/2010	291	570
Beasley Flat	05/22/2010	364	711
Above Verde Springs	07/10/2010	210	423
Perkinsville	07/10/2010	285	570
Reitz	07/10/2010	237	467
89A Bridge	07/10/2010	306	599
Black Bridge	07/10/2010	471	943
Beasley Flat	07/10/2010	634	1267
Above Verde Springs	09/18/2010	Not available	Not available
Perkinsville	09/18/2010	Not available	Not available
Reitz	09/18/2010	253	495
89A Bridge	09/18/2010	330	646
Black Bridge	09/18/2010	333	666
Beasley Flat	09/18/2010	455	909
Above Verde Springs	11/20/2010	223	447
Perkinsville	11/20/2010	294	597
Reitz	11/20/2010	218	433
89A Bridge	11/20/2010	252	504
Black Bridge	11/20/2010	240	485
Beasley Flat	11/20/2010	292	581
Above Verde Springs	02/26/2011	198	396
Perkinsville	02/26/2011	221	442
Reitz	02/26/2011	226	445
89A Bridge	02/26/2011	266	518
Black Bridge	02/26/2011	182	367
Beasley Flat	02/26/2011	136	274

Sampling Site	Date	TDS (in ppm)	EC (in µs/cm)
Above Verde Springs	04/23/2011	192	386
Perkinsville	04/23/2011	238	476
Reitz	04/23/2011	250	490
89A Bridge	04/23/2011	302	593
Black Bridge	04/23/2011	288	579
Beasley Flat	04/23/2011	346	692
Above Verde Springs	06/18/2011	191	389
Perkinsville	06/18/2011	247	495
Reitz	06/18/2011	210	414
89A Bridge	06/18/2011	276	536
Black Bridge	06/18/2011	395	795
Beasley Flat	06/18/2011	525	1050
Above Verde Springs	09/17/2011	187	375
Perkinsville	09/17/2011	246	491
Reitz	09/17/2011	244	483
89A Bridge	09/17/2011	269	528
Black Bridge	09/17/2011	252	502
Beasley Flat	09/17/2011	298	598
Above Verde Springs	10/22/2011	185	369
Perkinsville	10/22/2011	243	485
Reitz	10/22/2011	256	501
89A Bridge	10/22/2011	311	610
Black Bridge	10/22/2011	288	578
Beasley Flat	10/22/2011	385	770
Above Verde Springs	12/10/2011	231	463
Perkinsville	12/10/2011	314	629
Reitz	12/10/2011	254	508
89A Bridge	12/10/2011	297	582
Black Bridge	12/10/2011	271	543
Beasley Flat	12/10/2011	319	637

The three estimated TDS measurements highlighted in yellow in Table 13 above represent the only TDS values greater than the EPA secondary MCL of 500 mg/L. In general, TDS concentrations of water in the Verde River range between 200 to 300 ppm.

The pH of the Verde River

When we measure pH, we measure how acidic or alkaline (i.e., basic) water is. The range for pH is from 0 to 14 standard units (abbreviated S.U). A pH of 7 S.U is neutral, a pH of less than 7 S.U. indicates acidic water, and a pH greater than 7 S.U indicates alkaline water. Standard units are logarithmic, like the Richter scale used to measure earthquakes. Each S.U. represents a 10-

fold change in the relative acidity or alkalinity of water. For example, water with a pH of 5 S.U. is 10 times more acidic than water with a pH of 6 S.U.

pH and water quality

Excessively high and low pH values adversely affect the suitability of water for aquatic life and human uses. High pH imparts a bitter taste to water and can cause water pipes and water fixtures to become encrusted with mineral deposits. Low pH or acidic water corrodes or dissolves metals and other substances.

The pH of water determines the solubility (i.e., the amount of a substance that can be dissolved in the water) and the biological availability (the amount that is used by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) or heavy metals (lead, copper, cadmium, etc.). In the case of heavy metals, the degree to which they are dissolved or made more soluble determines their toxicity to aquatic organisms. Heavy metals are more toxic in acidic water with low pH because the heavy metals are more soluble and are more biologically available to aquatic organisms living in the river. Water pollution can change the pH of a river which, in turn, harms animals and plants in the river. For example, acid mine drainage from an abandoned mine can have a pH of 2 S.U., which will kill fish in the stream. Using the logarithmic scale, acid mine-drainage with a pH of 2 S.U. is 100,000 times more acidic than neutral water with a pH of 7 S.U.

As the diagram below shows, pH ranges from 0 to 14 standard units (S.U.) with 7 S.U. being neutral. The pH values less than 7 S.U. are acidic while pH values greater than 7 S.U. are alkaline or basic. Battery acid has a pH of 1 S.U. Normal rainfall is slightly acidic and typically has a pH between 5 and 6 S.U. (rainfall tends to be slightly acidic because of carbon dioxide gas in the atmosphere). The normal range of pH in rivers and streams is between 6 and 8 S.U.

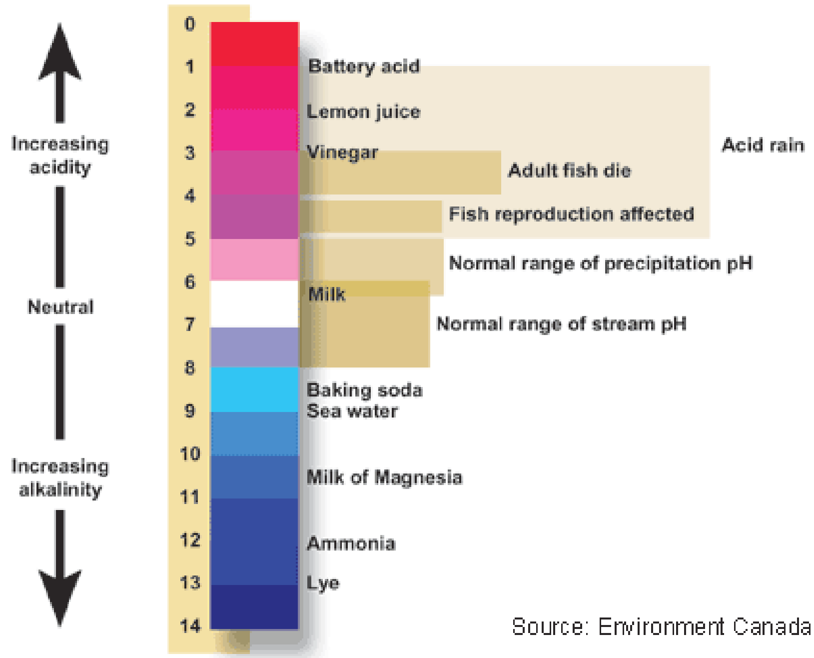

Figure 28. The pH scale
Source: Environment Canada

Measuring pH

Water Sentinels have been measuring the pH of the Verde River since December 2006. Water Sentinels use a Hanna combo tester to measure pH. It is called a "combo" tester because the instrument measures pH, EC, TDS, and water temperature.

To make a pH measurement, Water Sentinels select the pH mode with the SET/HOLD button on the Hanna combo tester. The sampler simply immerses the bottom of the Hanna combo tester with the pH sensor into the river and waits for the pH value in the instrument display to stop increasing or decreasing. Once the pH reading is relatively stable and stops changing, the Water Sentinel records the pH value on a field data sheet.

pH measurements of the Verde River

The charts below show pH measurements made by Water Sentinels at seven sites on the Verde River over the last five years. Water Sentinels made 194 field measurements of pH at Verde River sampling sites between February 17, 2007, and December 10, 2011. In general, water quality of the Verde River with respect to pH is good. As the following charts illustrate, the pH of the Verde River is relatively stable at all Water Sentinels' sampling sites with little variability between sites. Measured pH values usually fall within the 6.0 S.U to 9.0 S.U. range established by the Arizona water quality standard for pH to protect aquatic life and wildlife.

Measurements of pH in the Verde River show that the Verde River is alkaline. The minimum pH value measured over the last five years was 6.9 S.U at Beasley Flat, a field measurement that is only slightly below neutral at 7.0 S.U. Only two pH measurements in the last five years were below 7.0 S.U. Both measurements were only slightly below neutral with pH values of 6.9 and 6.99 S.U respectively.

The maximum pH was 9.57 S.U at Beasley Flat on February 17, 2009. The only other pH measurement above 9 S.U. in the Water Sentinels dataset was 9.4 S.U, measured on the same date at the White Bridge sampling site. These two field measurements represent the only violations of the pH water quality standard to protect aquatic life of the Verde River in five years of data collection.

Two measurements greater than 9 S.U out of 194 field measurements means that approximately 99 percent of pH measurements made by the Arizona Water Sentinels in the Verde River are between 6.0 S.U. and 9.0 S.U. and, thus, comply with state-adopted water quality standards for pH to protect aquatic life and wildlife. As the charts below illustrate, the pH dataset shows that there are no indications of any water quality problems related to the acidity of water in the river.

Figure 29. The Hanna combo tester
Photo credit: Mark Coryell

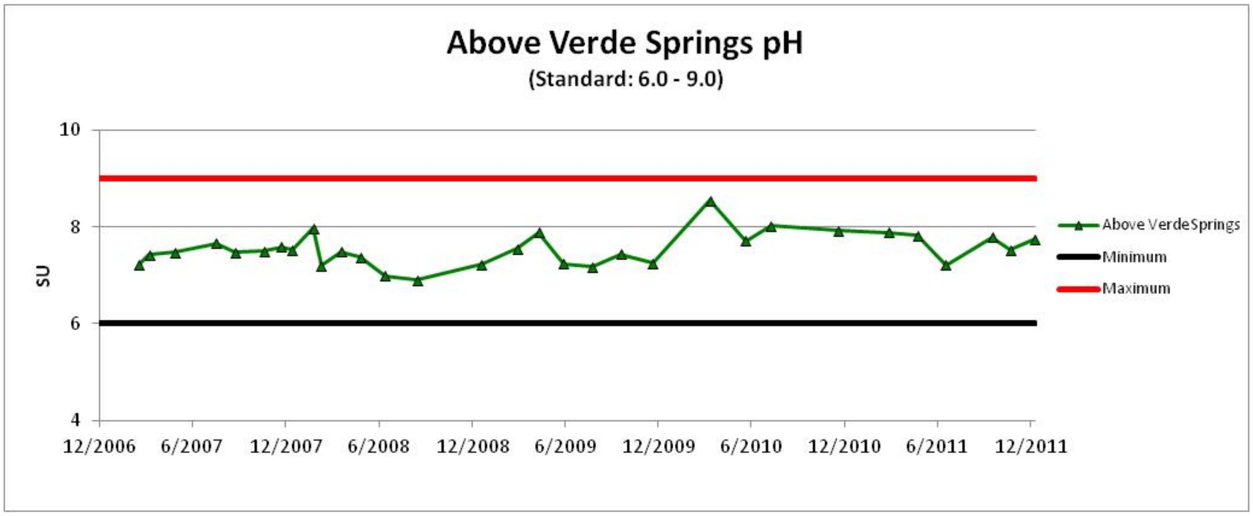

Chart 25. Above Verde Springs pH

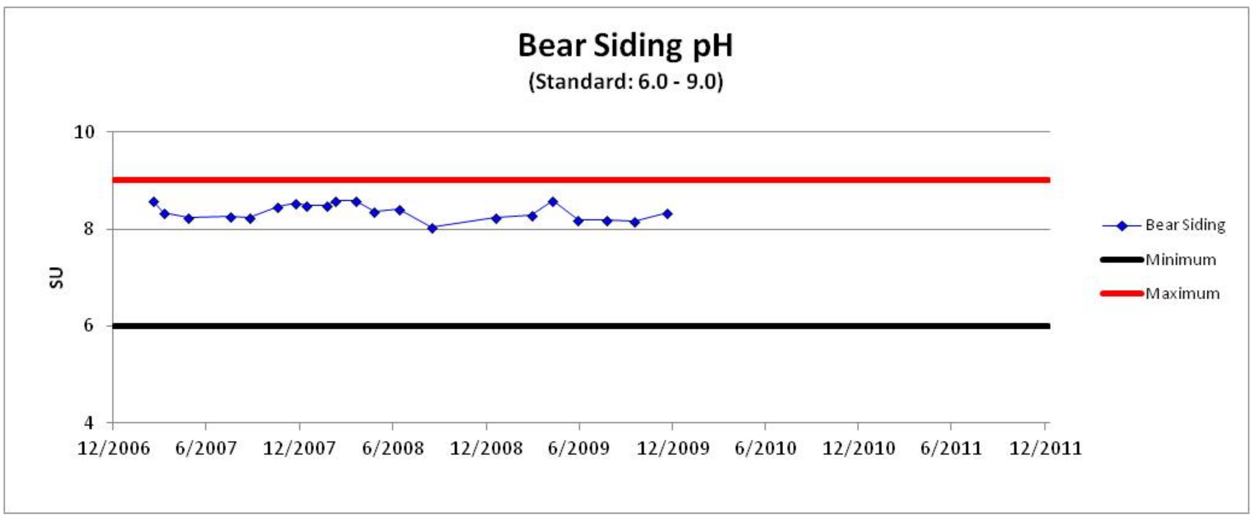

Chart 26. Bear Siding pH

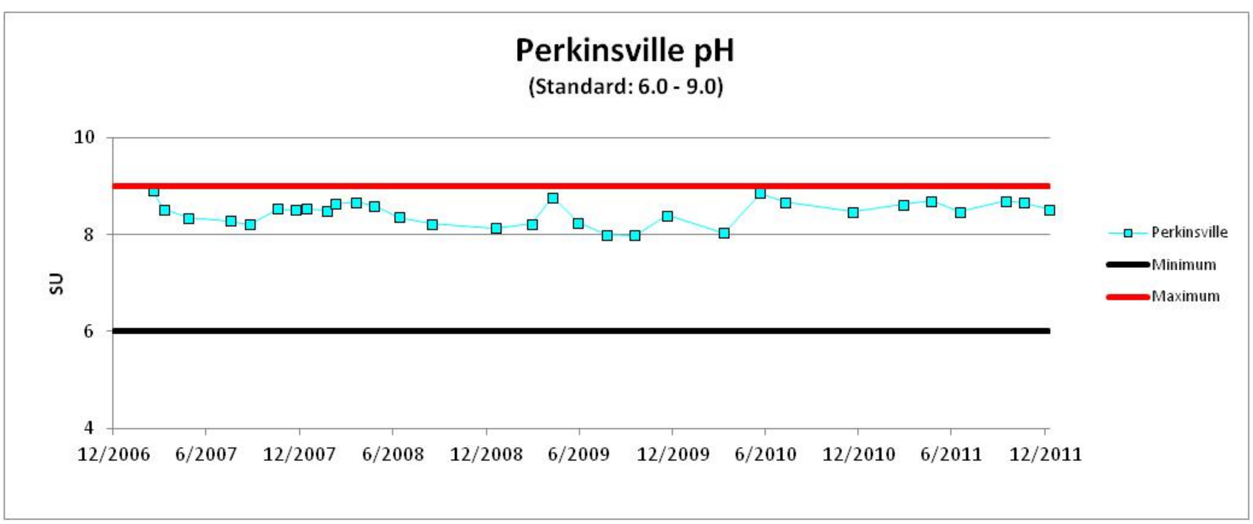

Chart 27. Perkinsville pH

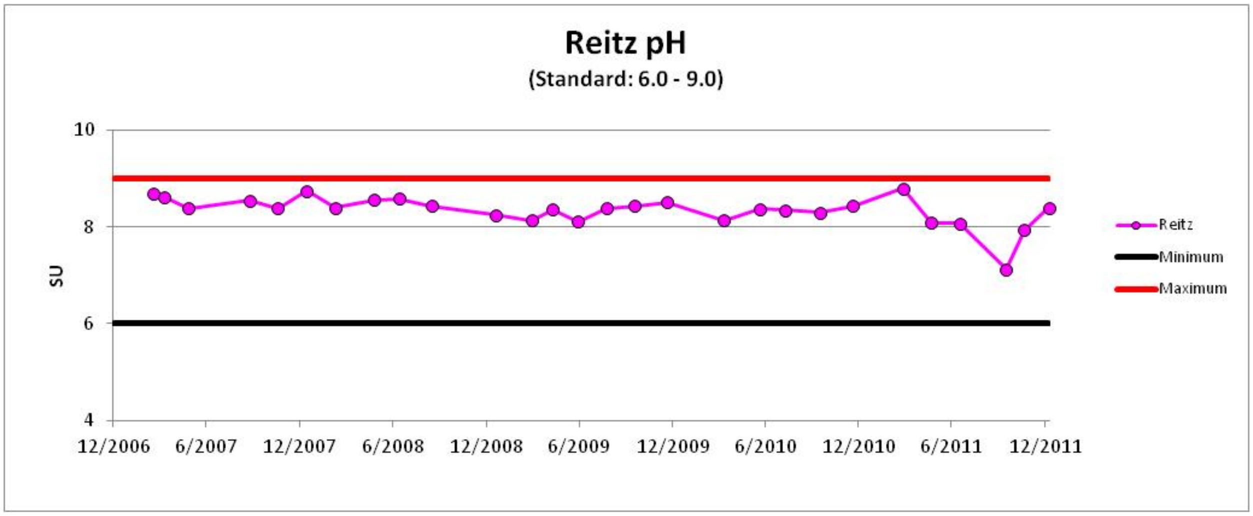

Chart 28. Reitz pH

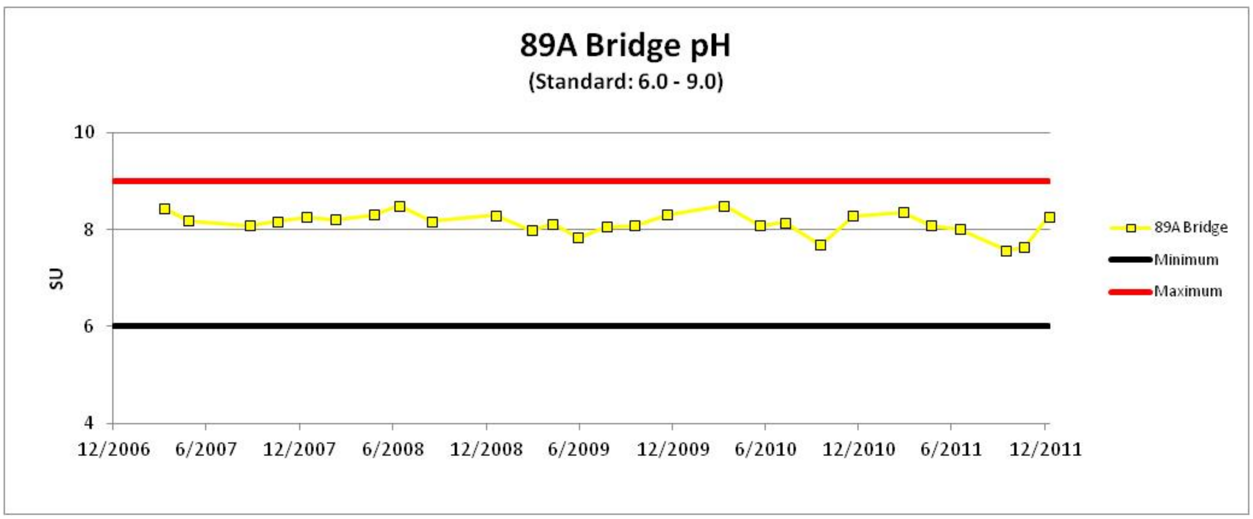

Chart 29. 89A Bridge pH

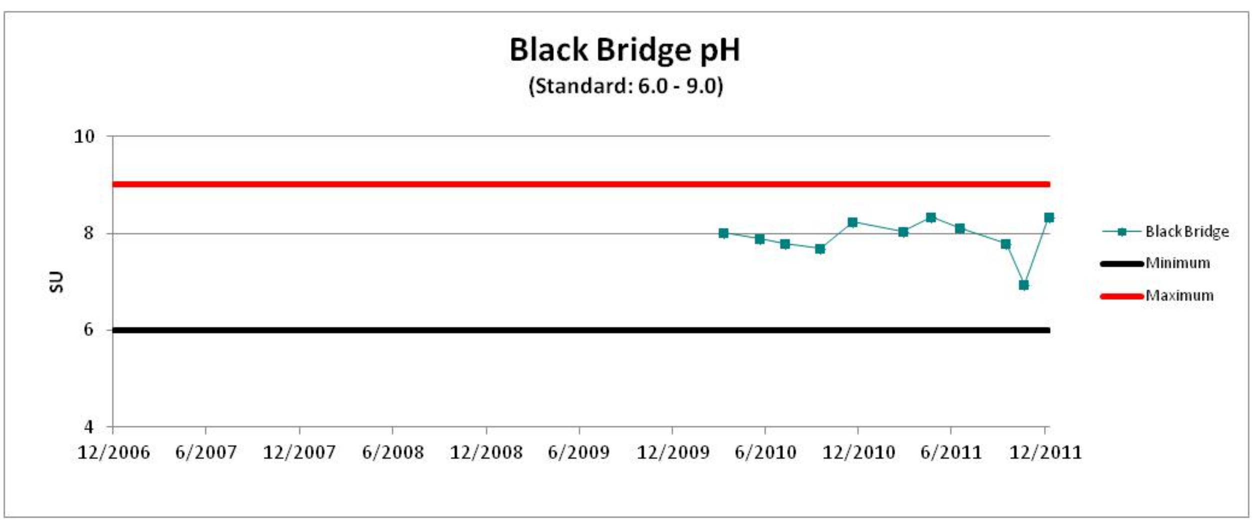

Chart 30. Black Bridge pH

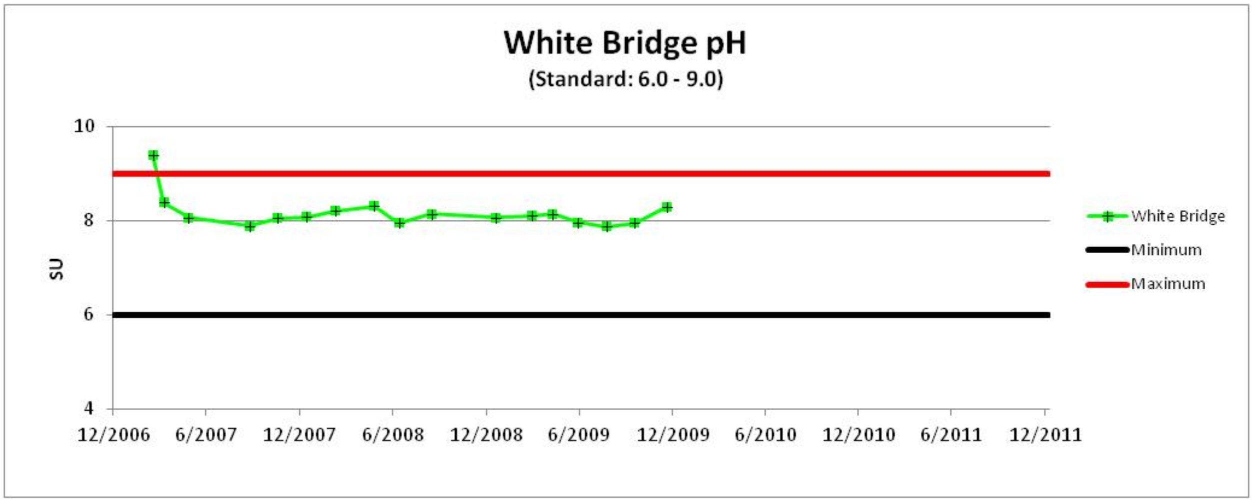

Chart 31. White Bridge pH

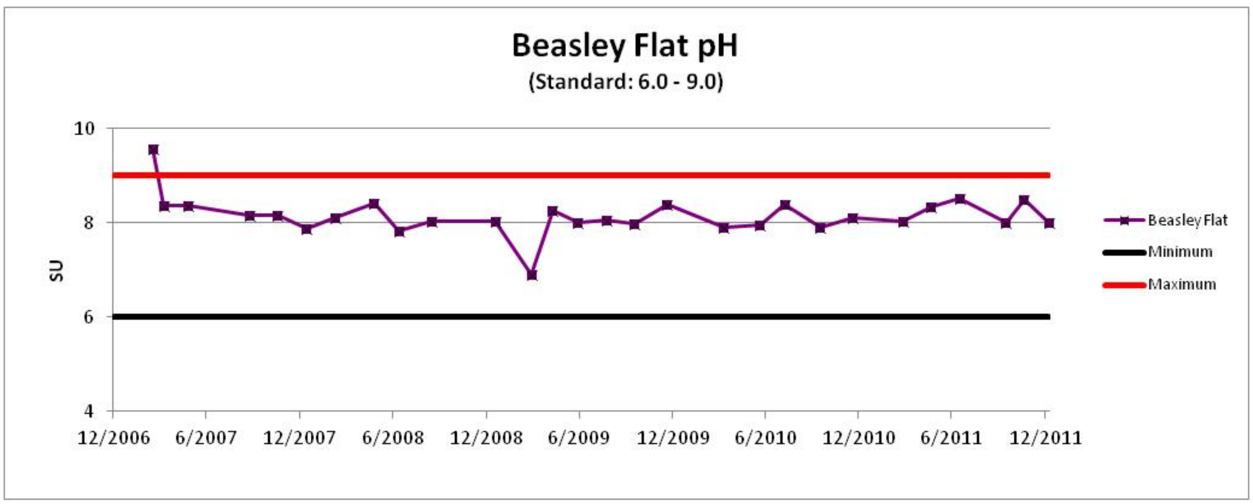

Chart 32. Beasley Flat pH

Table 14. pH field measurements

Sampling Site	Date	pH (in S.U)
Above Verde Springs	12/02/2006	Not available
Bear Siding	12/02/2006	Not available
Perkinsville	12/02/2006	Not available
Reitz	12/02/2006	Not available
89A Bridge	12/02/2006	Not available
White Bridge	12/02/2006	Not available
Beasley Flat	12/02/2006	Not available
Above Verde Springs	02/17/2007	7.22
Bear Siding	02/17/2007	8.6
Perkinsville	02/17/2007	8.9
Reitz	02/17/2007	8.68
89A Bridge	02/17/2007	Not available
White Bridge	02/17/2007	9.4
Beasley Flat	02/17/2007	9.57

Sampling Site	Date	pH (in S.U)
Above Verde Springs	03/10/2007	7.43
Bear Siding	03/10/2007	8.35
Perkinsville	03/10/2007	8.52
Reitz	03/10/2007	8.62
89A Bridge	03/10/2007	8.45
White Bridge	03/10/2007	8.39
Beasley Flat	03/10/2007	8.36
Above Verde Springs	04/28/2007	7.48
Bear Siding	04/28/2007	8.23
Perkinsville	04/28/2007	8.34
Reitz	04/28/2007	8.38
89A Bridge	04/28/2007	8.19
White Bridge	04/28/2007	8.07
Beasley Flat	04/28/2007	8.37
Above Verde Springs	07/19/07	7.66
Bear Siding	07/19/07	8.27
Perkinsville	07/19/07	8.28
Above Verde Springs	09/25/2007	7.48
Bear Siding	09/25/2007	8.25
Perkinsville	09/25/2007	8.21
Reitz	09/25/2007	8.55
89A Bridge	09/25/2007	8.09
White Bridge	09/25/2007	7.89
Beasley Flat	08/25/2007	8.16
Above Verde Springs	10/20/2007	7.50
Bear Siding	10/20/2007	8.47
Perkinsville	10/20/2007	8.53
Reitz	10/20/2007	8.38
89A Bridge	10/20/2007	8.17
White Bridge	10/20/2007	8.05
Beasley Flat	10/20/2007	8.16
Above Verde Springs	11/23/2007	7.59
Bear Siding	11/23/2007	8.53
Perkinsville	11/23/2007	8.51
Above Verde Springs	12/15/2007	7.52
Bear Siding	12/15/2007	8.48
Perkinsville	12/15/2007	8.53
Reitz	12/15/2007	8.74
89A Bridge	12/15/2007	8.26
White Bridge	12/15/2007	8.08
Beasley Flat	12/15/2007	7.89

Sampling Site	Date	pH (in S.U)
Above Verde Springs	01/25/2008	7.97
Bear Siding	01/25/2008	8.50
Perkinsville	01/25/2008	8.49
Above Verde Springs	02/09/2008	7.20
Bear Siding	02/09/2008	8.6
Perkinsville	02/09/2008	8.63
Reitz	02/09/2008	8.39
89A Bridge	02/09/2008	8.21
White Bridge	02/09/2008	8.21
Beasley Flat	02/09/2008	8.11
Above Verde Springs	03/20/2008	7.49
Bear Siding	03/20/2008	8.58
Perkinsville	03/20/2008	8.67
Above Verde Springs	04/26/2008	7.38
Bear Siding	04/26/2008	8.36
Perkinsville	04/26/2008	8.59
Reitz	04/26/2008	8.56
89A Bridge	04/26/2008	8.31
White Bridge	04/26/2008	8.31
Beasley Flat	04/26/2008	8.41
Above Verde Springs	06/14/2008	6.99
Bear Siding	06/14/2008	8.41
Perkinsville	06/14/2008	8.36
Reitz	06/14/2008	8.58
89A Bridge	06/14/2008	8.50
White Bridge	06/14/2008	7.95
Beasley Flat	06/14/2008	7.82
Above Verde Springs	08/16/2008	6.90
Bear Siding	08/16/2008	8.04
Perkinsville	08/16/2008	8.22
Reitz	08/16/2008	8.43
89A Bridge	08/16/2008	8.17
White Bridge	08/16/2008	8.14
Beasley Flat	08/16/2008	8.04
Above Verde Springs	12/20/2008	7.23
Bear Siding	12/20/2008	8.23
Perkinsville	12/20/2008	8.14
Reitz	12/20/2008	8.25
89A Bridge	12/20/2008	8.3
White Bridge	12/20/2008	8.07
Beasley Flat	12/20/2008	8.03

Sampling Site	Date	pH (in S.U)
Above Verde Springs	02/28/2009	7.55
Bear Siding	02/28/2009	8.3
Perkinsville	02/28/2009	8.22
Reitz	02/28/2009	8.14
89A Bridge	02/28/2009	7.99
White Bridge	02/28/2009	8.10
Beasley Flat	02/28/2009	6.9
Above Verde Springs	04/11/2009	7.88
Bear Siding	04/11/2009	8.59
Perkinsville	04/11/2009	8.77
Reitz	04/11/2009	8.36
89A Bridge	04/11/2009	8.12
White Bridge	04/11/2009	8.15
Beasley Flat	04/11/2009	8.26
Above Verde Springs	05/30/2009	7.24
Bear Siding	05/30/2009	8.20
Perkinsville	05/30/2009	8.24
Reitz	05/30/2009	8.11
89A Bridge	05/30/2009	7.83
White Bridge	05/30/2009	7.96
Beasley Flat	05/30/2009	8.00
Above Verde Springs	07/25/2009	7.17
Bear Siding	07/25/2009	8.18
Perkinsville	07/25/2009	8.0
Reitz	07/25/2009	8.38
89A Bridge	07/25/2009	8.06
White Bridge	07/25/2009	7.88
Beasley Flat	07/25/2009	8.05
Above Verde Springs	09/19/2009	7.44
Bear Siding	09/19/2009	8.16
Perkinsville	09/19/2009	7.99
Reitz	09/19/2009	8.43
89A Bridge	09/19/2009	8.09
White Bridge	09/19/2009	7.95
Beasley Flat	09/19/2009	7.99
Above Verde Springs	11/21/2009	7.25
Bear Siding	11/21/2009	8.34
Perkinsville	11/21/2009	8.4
Reitz	11/21/2009	8.51
89A Bridge	11/21/2009	8.31
White Bridge	11/21/2009	8.3
Beasley Flat	11/21/2009	8.4

Sampling Site	Date	pH (in S.U)
Above Verde Springs	03/13/2010	8.55
Perkinsville	03/13/2010	8.04
Reitz	03/13/2010	8.14
89A Bridge	03/13/2010	8.49
Black Bridge	03/13/2010	8.02
Beasley Flat	03/13/2010	7.91
Above Verde Springs	05/22/2010	7.71
Perkinsville	05/22/2010	8.85
Reitz	05/22/2010	8.37
89A Bridge	05/22/2010	8.08
Black Bridge	05/22/2010	7.90
Beasley Flat	05/22/2010	7.97
Above Verde Springs	07/10/2010	8.02
Perkinsville	07/10/2010	8.67
Reitz	07/10/2010	8.35
89A Bridge	07/10/2010	8.15
Black Bridge	07/10/2010	7.78
Beasley Flat	07/10/2010	8.4
Above Verde Springs	09/18/2010	Not available
Perkinsville	09/18/2010	Not available
Reitz	09/18/2010	8.3
89A Bridge	09/18/2010	7.69
Black Bridge	09/18/2010	7.68
Beasley Flat	09/18/2010	7.91
Above Verde Springs	11/20/2010	7.92
Perkinsville	11/20/2010	8.47
Reitz	11/20/2010	8.43
89A Bridge	11/20/2010	8.28
Black Bridge	11/20/2010	8.23
Beasley Flat	11/20/2010	8.10
Above Verde Springs	02/26/2011	7.88
Perkinsville	02/26/2011	8.62
Reitz	02/26/2011	8.8
89A Bridge	02/26/2011	8.36
Black Bridge	02/26/2011	8.05
Beasley Flat	02/26/2011	8.03
Above Verde Springs	04/23/2011	7.82
Perkinsville	04/23/2011	8.70
Reitz	04/23/2011	8.08
89A Bridge	04/23/2011	8.08
Black Bridge	04/23/2011	8.35
Beasley Flat	04/23/2011	8.35

Sampling Site	Date	pH (in S.U)
Above Verde Springs	06/18/2011	7.21
Perkinsville	06/18/2011	8.47
Reitz	06/18/2011	8.07
89A Bridge	06/18/2011	8.01
Black Bridge	06/18/2011	8.11
Beasley Flat	06/18/2011	8.51
Above Verde Springs	09/17/2011	7.78
Perkinsville	09/17/2011	8.70
Reitz	09/17/2011	7.13
89A Bridge	09/17/2011	7.57
Black Bridge	09/17/2011	7.78
Beasley Flat	09/17/2011	8.0
Above Verde Springs	10/22/2011	7.52
Perkinsville	10/22/2011	8.66
Reitz	10/22/2011	7.94
89A Bridge	10/22/2011	7.63
Black Bridge	10/22/2011	6.94
Beasley Flat	10/22/2011	8.5
Above Verde Springs	12/10/2011	7.75
Perkinsville	12/10/2011	8.52
Reitz	12/10/2011	8.4
89A Bridge	12/10/2011	8.27
Black Bridge	12/10/2011	8.35
Beasley Flat	12/10/2011	8.01

Arsenic in the Verde River

Arsenic occurs naturally in the Earth's crust. Due to the geology of the Verde Valley, arsenic is naturally present in Verde Valley soils and in local groundwater, often in concentrations that exceed the EPA MCL for drinking water for arsenic, established at 10 µg/L.

Water Sentinels have monitored total arsenic concentrations in the Verde River since December 2006, collecting 184 water samples for total arsenic analysis over a five-year time period. Total arsenic concentrations in samples obtained from the Verde River range from 8 µg/L to 32 µg/L. Most sample results obtained complied with the applicable water quality standard for arsenic of 30 µg/L for the Verde River to protect public health during recreational use of the river. We found four violations of the arsenic water quality standard above 30 µg/L over the last five years. This represents a noncompliance rate of only two percent of total samples collected. Put another way, Water Sentinels data show that 98 percent of water samples from the Verde River comply with applicable arsenic standards.

Although the dataset shows that the Verde River generally meets applicable surface water quality standards for arsenic, the reported arsenic concentrations in the Verde River routinely exceed the EPA National Primary Drinking Water MCL for drinking water. The EPA drinking water standard for total arsenic is established at 10 µg/L or 0.01 mg/L. Only 11 of 184 samples results (6 percent) complied with the 10 µg/L drinking water standard. Put another way, 94 percent of all sample results obtained by the Arizona Water Sentinels exceed the drinking water MCL for arsenic.

Arizona Water Sentinels' sample results for arsenic are consistent with sample results reported by other investigators such as the U.S. Geological Survey and Arizona State University researchers. Previous studies have documented elevated arsenic concentrations in the 15 to 25 µg/L range in the Verde River. Most of the Arizona Water Sentinels' sample results for total arsenic obtained from sites along the Verde River are in the same range.

The U.S. Geological Survey has studied the occurrence of arsenic in the Verde River watershed and found the following:

> "Natural sources of arsenic predominantly include volcanic and lacustrine deposits (Hem, 1985). Arsenic concentrations were lowest in the upper Verde River watershed, where they ranged from 1 to 20 µg/L in samples from Granite Creek. Concentrations steadily increase from near the mouth of Sycamore Creek to the downstream end of the study area near Camp Verde…. In the middle Verde River watershed, concentrations ranged from less than the detection limit to…27 µg/L. The source of arsenic likely is the oxidized sulfides of the Verde Formation and Tertiary volcanic deposits."[44]

Arizona State University researchers also have studied the fate and transport of arsenic in the Verde River. In a 1994 study titled *Sources and Fate of Arsenic in the Verde and Salt Rivers, Arizona*, the researchers stated the following:

> "In a study of the 12,900 square mile watershed of the Verde and Salt rivers in Arizona, we quantified watershed sources of arsenic…. Arsenic in river water was primarily in the soluble form. Arsenic concentrations decreased with increasing flow…highest concentrations (~25 µg/L) were found during low flow…. The major source of arsenic in the Verde River was the Verde Formation, a soft sedimentary deposit in the middle Verde River valley. This is supported by four facts: (1) arsenic concentrations of all streams increased when they entered the Verde Formation, 2) arsenic concentrations were highest during low flows, implicating a groundwater source, 3) arsenic could be leached from soils collected from this formation in laboratory experiments, and 4) aquifers in this formation have elevated arsenic concentrations. Although there has been extensive mining (gold, copper, silver) in several districts within the watersheds of these rivers, there is little evidence of contamination from tailings. Although we found

[44] Blasch, Kyle W., John P. Hoffmann, Leslie F. Graser, Jeannie R. Bryson and Alan L. Flint, 2006, *Hydrogeology of the Upper and Middle Verde River Watersheds, Central Arizona*, U.S. Geological Survey Scientific Investigations Report 2005–5198; (Prepared in cooperation with the Arizona Department of Water Resources and Yavapai County; Version 2, Updated 05/04/2007).

several tailings piles with high arsenic leaching potential, concentrations of arsenic in streams draining these areas were <10 µg/L during low flow."[45]

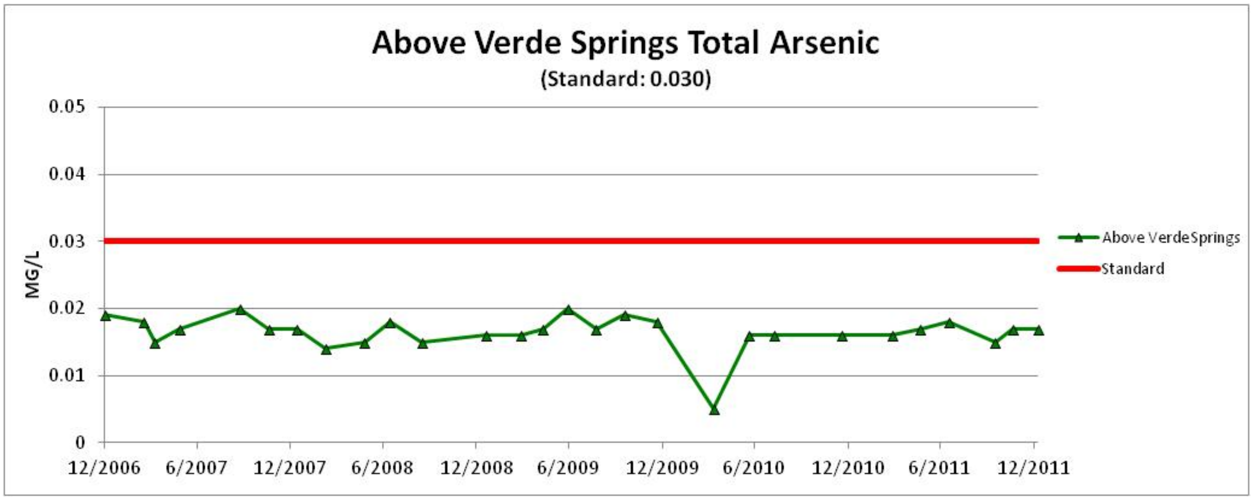

Chart 33. Above Verde Springs total arsenic

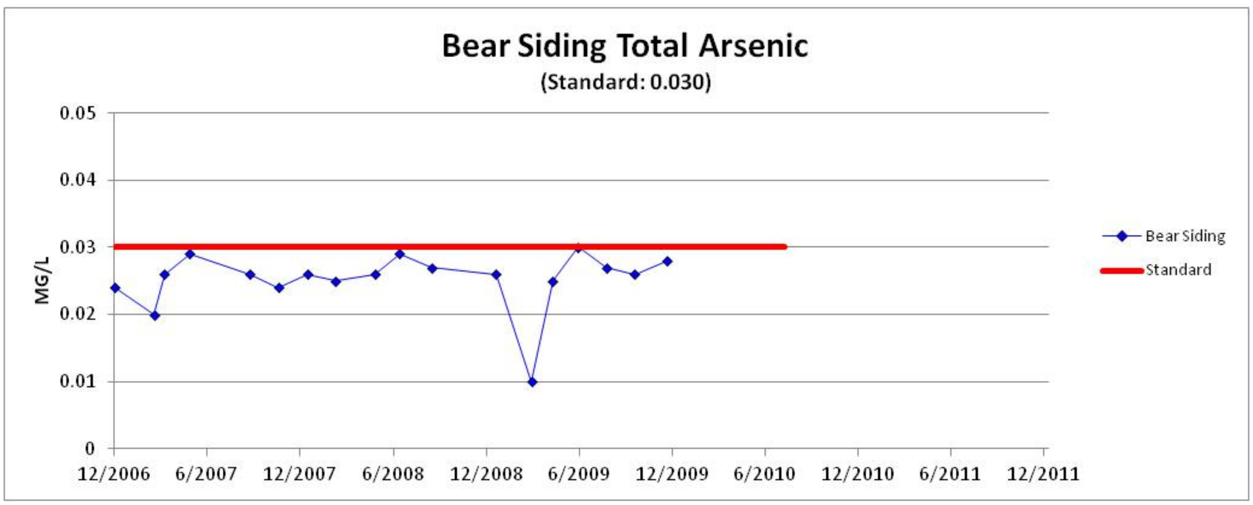

Chart 34. Bear Siding total arsenic

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[45] Lawrence A. Baker, Taqueer Qureshi, and Leslie Farnsworth, *Sources and Fate of Arsenic in the Verde and Salt Rivers, Arizona*, Department of Civil Engineering, Arizona State University. Paper presented at the Water Environment Federation Meeting, October 17, 1994, Chicago

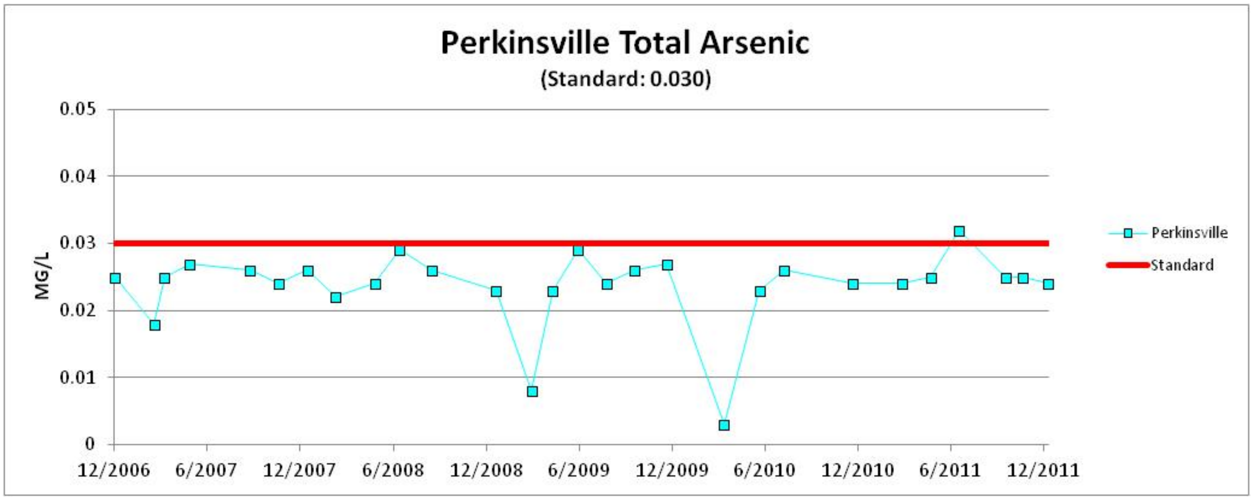

Chart 35. Perkinsville total arsenic

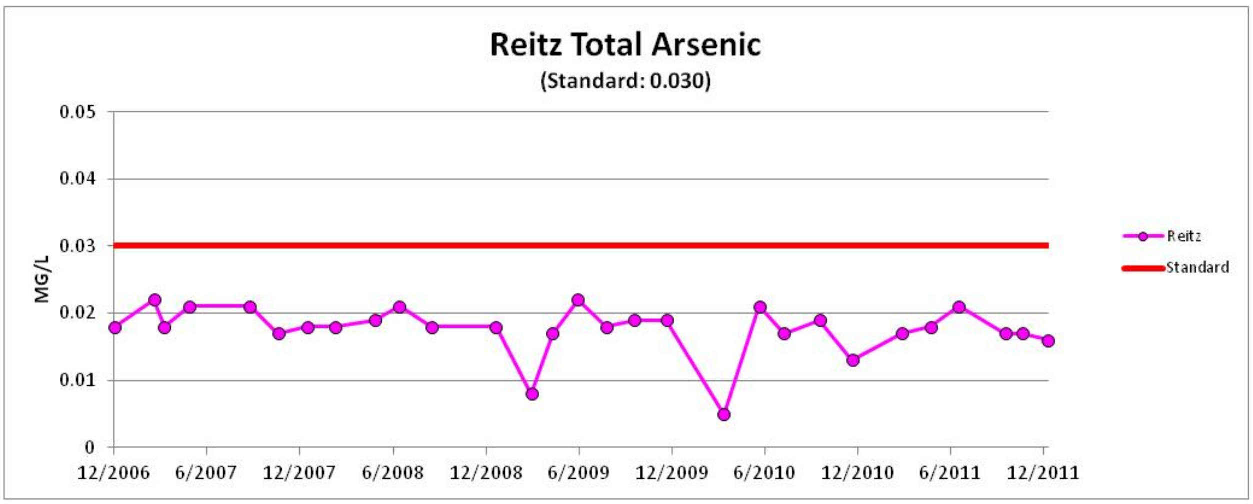

Chart 36. Reitz total arsenic

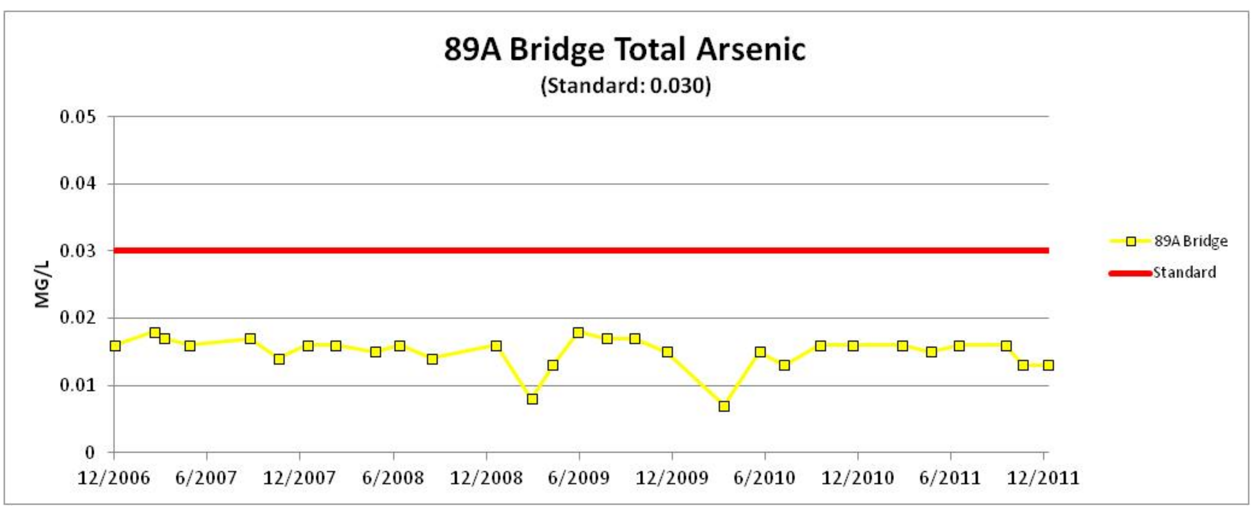

Chart 37. 89A Bridge total arsenic

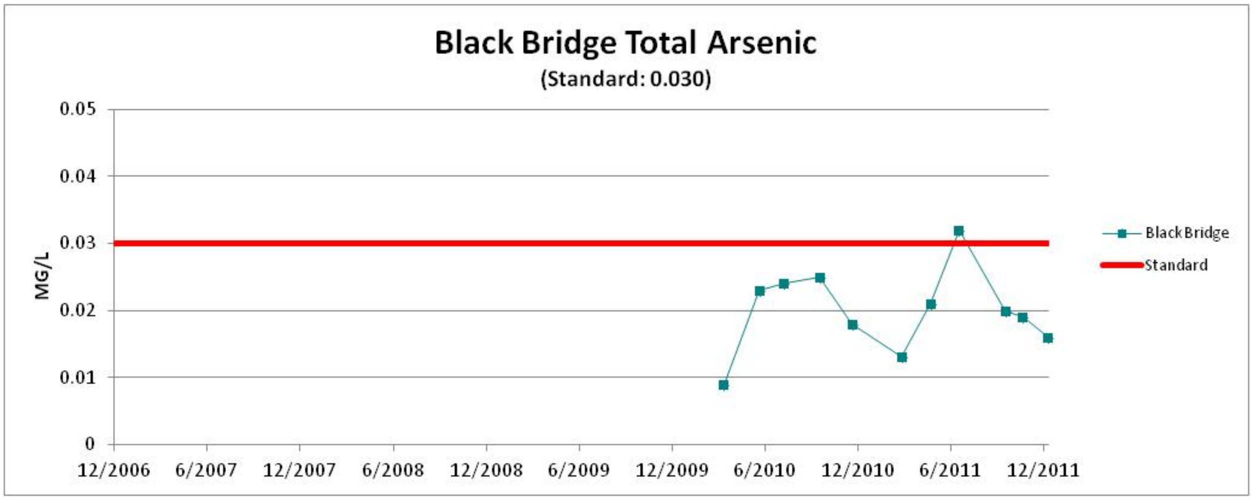

Chart 38. Black Bridge total arsenic

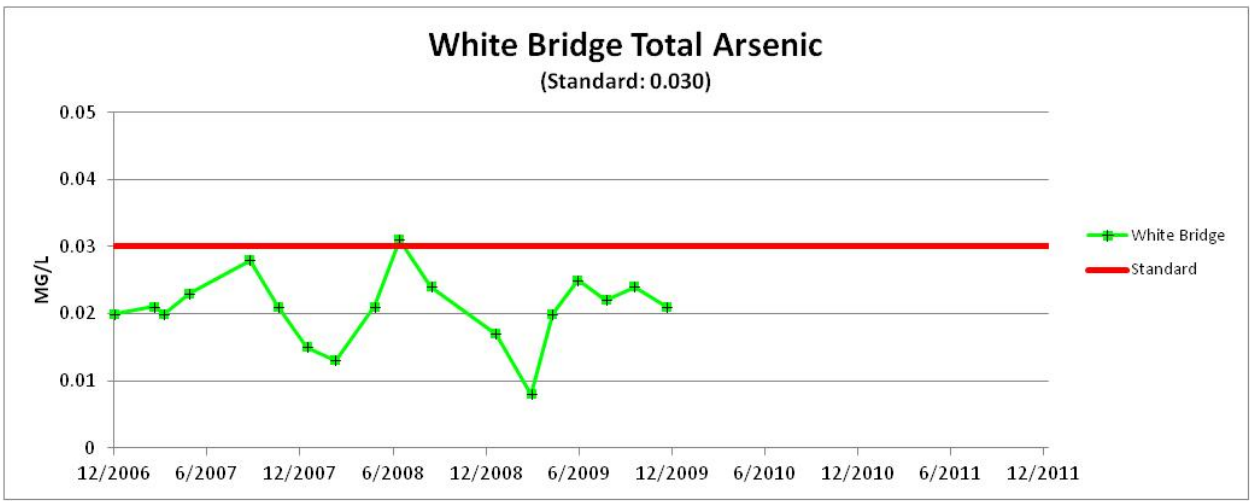

Chart 39. White Bridge total arsenic

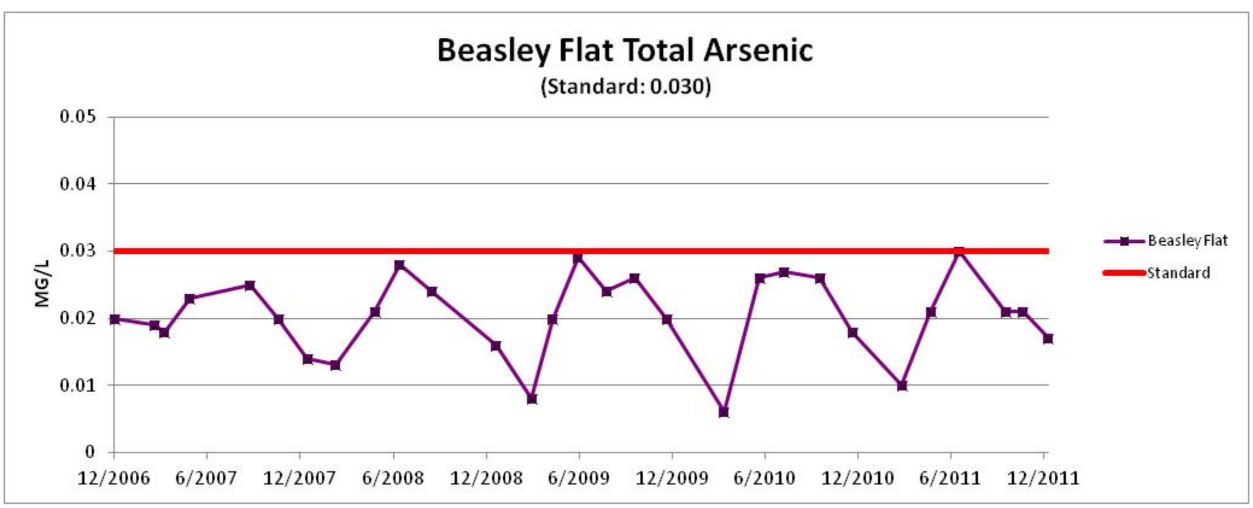

Chart 40. Beasley Flat total arsenic

Table 15. Total arsenic field measurements

Sampling Site	Date	Total Arsenic (in µg/L)
Above Verde Springs	12/02/2006	19
Bear Siding	12/02/2006	24
Perkinsville	12/02/2006	25
Reitz	12/02/2006	18
89A Bridge	12/02/2006	16
White Bridge	12/02/2006	20
Beasley Flat	12/02/2006	20
Above Verde Springs	02/17/2007	18
Bear Siding	02/17/2007	20
Perkinsville	02/17/2007	18
Reitz	02/17/2007	22
89A Bridge	02/17/2007	18
White Bridge	02/17/2007	21
Beasley Flat	02/17/2007	19
Above Verde Springs	03/10/2007	15
Bear Siding	03/10/2007	26
Perkinsville	03/10/2007	25
Reitz	03/10/2007	18
89A Bridge	03/10/2007	17
White Bridge	03/10/2007	20
Beasley Flat	03/10/2007	18
Above Verde Springs	04/28/2007	17
Bear Siding	04/28/2007	29
Perkinsville	04/28/2007	27
Reitz	04/28/2007	21
89A Bridge	04/28/2007	16
White Bridge	04/28/2007	23
Beasley Flat	04/28/2007	23
Above Verde Springs	08/25/2007	20
Bear Siding	08/25/2007	26
Perkinsville	08/25/2007	26
Reitz	08/25/2007	21
89A Bridge	08/25/2007	17
White Bridge	08/25/2007	28
Beasley Flat	08/25/2007	25
Above Verde Springs	10/20/2007	17
Bear Siding	10/20/2007	24
Perkinsville	10/20/2007	24
Reitz	10/20/2007	17
89A Bridge	10/20/2007	14
White Bridge	10/20/2007	21
Beasley Flat	10/20/2007	20

Sampling Site	Date	Total Arsenic (in µg/L)
Above Verde Springs	12/15/2007	17
Bear Siding	12/15/2007	26
Perkinsville	12/15/2007	26
Reitz	12/15/2007	18
89A Bridge	12/15/2007	16
White Bridge	12/15/2007	15
Beasley Flat	12/15/2007	14
Above Verde Springs	02/09/2008	14
Bear Siding	02/09/2008	25
Perkinsville	02/09/2008	22
Reitz	02/09/2008	18
89A Bridge	02/09/2008	16
White Bridge	02/09/2008	13
Beasley Flat	02/09/2008	13
Above Verde Springs	04/26/2008	15
Bear Siding	04/26/2008	26
Perkinsville	04/26/2008	24
Reitz	04/26/2008	19
89A Bridge	04/26/2008	15
White Bridge	04/26/2008	21
Beasley Flat	04/26/2008	21
Above Verde Springs	06/14/2008	18
Bear Siding	06/14/2008	29
Perkinsville	06/14/2008	29
Reitz	06/14/2008	21
89A Bridge	06/14/2008	16
White Bridge	06/14/2008	31
Beasley Flat	06/14/2008	28
Above Verde Springs	08/16/2008	15
Bear Siding	08/16/2008	27
Perkinsville	08/16/2008	26
Reitz	08/16/2008	18
89A Bridge	08/16/2008	14
White Bridge	08/16/2008	24
Beasley Flat	08/16/2008	24
Above Verde Springs	12/20/2008	16
Bear Siding	12/20/2008	26
Perkinsville	12/20/2008	23
Reitz	12/20/2008	18
89A Bridge	12/20/2008	16
White Bridge	12/20/2008	17
Beasley Flat	12/20/2008	16

Sampling Site	Date	Total Arsenic (in µg/L)
Above Verde Springs	02/28/2009	16
Bear Siding	02/28/2009	10
Perkinsville	02/28/2009	8
Reitz	02/28/2009	8
89A Bridge	02/28/2009	8
White Bridge	02/28/2009	8
Beasley Flat	02/28/2009	8
Above Verde Springs	04/11/2009	17
Bear Siding	04/11/2009	25
Perkinsville	04/11/2009	23
Reitz	04/11/2009	17
89A Bridge	04/11/2009	13
White Bridge	04/11/2009	20
Beasley Flat	04/11/2009	20
Above Verde Springs	05/30/2009	20
Bear Siding	05/30/2009	30
Perkinsville	05/30/2009	29
Reitz	05/30/2009	22
89A Bridge	05/30/2009	18
White Bridge	05/30/2009	25
Beasley Flat	05/30/2009	29
Above Verde Springs	07/25/2009	17
Bear Siding	07/25/2009	27
Perkinsville	07/25/2009	24
Reitz	07/25/2009	18
89A Bridge	07/25/2009	17
White Bridge	07/25/2009	22
Beasley Flat	07/25/2009	24
Above Verde Springs	09/19/2009	19
Bear Siding	09/19/2009	26
Perkinsville	09/19/2009	26
Reitz	09/19/2009	19
89A Bridge	09/19/2009	17
White Bridge	09/19/2009	24
Beasley Flat	09/19/2009	26
Above Verde Springs	11/21/2009	18
Bear Siding	11/21/2009	28
Perkinsville	11/21/2009	27
Reitz	11/21/2009	19
89A Bridge	11/21/2009	15
White Bridge	11/21/2009	21
Beasley Flat	11/21/2009	20

Sampling Site	Date	Total Arsenic (in µg/L)
Above Verde Springs	03/13/2010	5
Perkinsville	03/13/2010	3
Reitz	03/13/2010	5
89A Bridge	03/13/2010	7
Black Bridge	03/13/2010	9
Beasley Flat	03/13/2010	6
Above Verde Springs	05/22/2010	16
Perkinsville	05/22/2010	23
Reitz	05/22/2010	21
89A Bridge	05/22/2010	15
Black Bridge	05/22/2010	23
Beasley Flat	05/22/2010	26
Above Verde Springs	07/10/2010	16
Perkinsville	07/10/2010	26
Reitz	07/10/2010	14
89A Bridge	07/10/2010	13
Black Bridge	07/10/2010	24
Beasley Flat	07/10/2010	27
Above Verde Springs	09/18/2010	Not available
Perkinsville	09/18/2010	Not available
Reitz	09/18/2010	19
89A Bridge	09/18/2010	16
Black Bridge	09/18/2010	25
Beasley Flat	09/18/2010	26
Above Verde Springs	11/20/2010	16
Perkinsville	11/20/2010	24
Reitz	11/20/2010	13
89A Bridge	11/20/2010	16
Black Bridge	11/20/2010	18
Beasley Flat	11/20/2010	18
Above Verde Springs	02/26/2011	16
Perkinsville	02/26/2011	24
Reitz	02/26/2011	17
89A Bridge	02/26/2011	16
Black Bridge	02/26/2011	13
Beasley Flat	02/26/2011	10
Above Verde Springs	04/23/2011	17
Perkinsville	04/23/2011	25
Reitz	04/23/2011	18
89A Bridge	04/23/2011	15
Black Bridge	04/23/2011	21
Beasley Flat	04/23/2011	21

Sampling Site	Date	Total Arsenic (in µg/L)
Above Verde Springs	06/18/2011	18
Perkinsville	06/18/2011	32
Reitz	06/18/2011	21
89A Bridge	06/18/2011	16
Black Bridge	06/18/2011	32
Beasley Flat	06/18/2011	30
Above Verde Springs	09/17/2011	15
Perkinsville	09/17/2011	25
Reitz	09/17/2011	17
89A Bridge	09/17/2011	16
Black Bridge	09/17/2011	20
Beasley Flat	09/17/2011	21
Above Verde Springs	10/22/2011	17
Perkinsville	10/22/2011	25
Reitz	10/22/2011	17
89A Bridge	10/22/2011	13
Black Bridge	10/22/2011	21
Beasley Flat	10/22/2011	19
Above Verde Springs	12/10/2011	17
Perkinsville	12/10/2011	24
Reitz	12/10/2011	16
89A Bridge	12/10/2011	13
Black Bridge	12/10/2011	16
Beasley Flat	12/10/2011	17

Nutrients: Total nitrogen and total phosphorus

Total Nitrogen: Nitrogen is plentiful in the natural environment. Almost 80 percent of the earth's atmosphere consists of nitrogen gas (N_2). However, plants and animals need nitrogen in other chemical forms before they can use it. Just as water moves through the hydrological cycle and takes on different forms, there is also a nitrogen cycle in which nitrogen compounds change forms as they move through the nitrogen cycle.

Total nitrogen is the sum of organic and inorganic nitrogen compounds in a water sample. Total Kjeldahl Nitrogen (TKN) is the sum of organic nitrogen, ammonia (NH_3), and ammonium (NH_4^+) in the water samples from the Verde River. Total nitrogen can be calculated by monitoring for Total Kjeldahl Nitrogen (TKN) and nitrate-nitrite individually and adding the individual results. An acceptable range of total nitrogen in water is 2 to 6 mg/L. It is important to know how much total nitrogen is in the water. Too much nitrogen can lead to excessive plant growth, and nitrogen in certain forms (such as ammonia) can be harmful or toxic to aquatic life.

Arizona water quality standards for total nitrogen and total phosphorus

The State of Arizona has adopted surface water quality standards for nutrients (i.e., total nitrogen and total phosphorus) at R18-11-109(F)(1) of the Arizona Administrative Code (A.A.C.). These nutrient standards are site-specific and vary for different rivers within the state. The nutrient standards for the Verde River are expressed as total nitrogen and total phosphorus concentrations. The total nitrogen standards for the Verde River and its tributaries from the headwaters to Bartlett Lake are expressed as annual mean, 90^{th} percentile, and SSM values:

Table 16. Surface water quality standards for total nitrogen for the Verde River

	Annual Mean	**90^{th} Percentile***	**Single sample maximum**
Total nitrogen	1.00 mg/L	1.50 mg/L	3.00 mg/L

*A minimum of 10 samples, each taken at least 10 days apart in a consecutive 12-month period, are required to determine a 90^{th} percentile.

How does nitrogen get into the Verde River?

Nitrogen ends up in the water environment mainly through natural and agricultural processes**.** Nitrates are naturally present in soil and water. In the nitrogen cycle, bacteria in soils convert nitrogen to nitrate, which is taken up by plants and then consumed by animals. Nitrate is returned to the environment in animal feces, as well as through the decay of plants and animals after they die. Microorganisms convert nitrate or the ammonium ion to nitrite. This reaction occurs in the environment as well as within the digestive tract of humans and other animals. After bacteria convert (reduce) nitrate to nitrite in the environment, the nitrogen cycle is completed when the bacteria convert the nitrite to nitrogen gas and it returns to the atmosphere.

Normally, the natural nitrogen cycle does not allow excessive amounts of nitrates or nitrites to accumulate in the environment. However, human activities have increased environmental nitrate concentrations, with agriculture being the major source through increased use of fertilizers as well as manure from livestock and poultry farming. Nitrate and nitrite compounds are very soluble in water and are highly mobile. They have a high potential for entering rivers and streams in storm water runoff when it rains. They also have a high potential for entering groundwater through soil leaching.

A significant amount of nitrogen can be found in domestic wastewater from septic systems and in effluent from wastewater treatment plants. Usually about one-third of the total nitrogen in domestic wastewater is organic nitrogen compounds, mostly urea with the remainder being ammonium salts. .

What are the environmental effects of nitrogen in water?

Nitrogen compounds, with the exception of ammonia, which is toxic to fish, usually are not hazardous when present in water. The nitrates, nitrites, and other nitrogen compounds in water are actually nutrients for plankton, algae, and other aquatic plants. When nitrogen concentrations increase, plankton and algae production in rivers and lakes increases. This nutrient enrichment can lead to algal blooms and excessive plant growth in water bodies. Large amounts of nitrate may cause eutrophication in lakes, rivers ,and streams. Eutrophication is a condition in which there is an excess of nutrients in the water, which results in oxygen deficiency and fish mortality.

What are the human health effects of nitrogen in water?

The human body consists of approximately 2.6 percent nitrogen, which is a human dietary requirement. Nitrates are not generally considered toxic, but, at high concentrations, the human body may convert nitrate to nitrite. Nitrites are toxic because they can disrupt blood oxygen transport by methemoglobin conversion. This conversion is particularly dangerous to infants because it rapidly depletes levels of oxygen in the blood, which creates a condition known as methemoglobinemia (sometimes referred to as blue "baby syndrome") in which blood can't carry sufficient oxygen to the body's cells, causing the veins and skin to appear blue. EPA has established drinking water standards for nitrate and nitrite to protect infants this reason. The maximum EPA-recommended concentration for nitrate in water is 10 mg/L, and the maximum level for nitrite is 1 mg/L. These drinking water standards were established to protect the health of infants.[46]

What do Arizona Water Sentinels' data reveal about total nitrogen concentrations of the Verde River?

Water Sentinels have collected water quality data on nutrients, including TKN and nitrate-nitrite since the inception of the Verde River monitoring program. For the first three years of data collection, Water Sentinels collected water quality data on TKN concentrations of the Verde River. As noted previously, TKN is the organic component of total nitrogen and includes ammonia and the ammonium ion. However, the measurement of TKN concentrations does not include the measurement of nitrate or nitrite in the water sample. For this reason, it was not possible to calculate total nitrogen concentrations for water samples collected from the Verde River between December 2, 2006, and November 11, 2009. Table 17 below shows all TKN, nitrate-nitrite, and total nitrogen data obtained by the Water Sentinels. Table 17 indicates "na" meaning "not available" where the testing laboratory did not analyze the water samples for

[46] See http://www.water-research.net/nitrate.htm and http://www.ead.anl.gov/pub/doc/nitrate-ite.pdf. Argonne National Laboratory, Human Health Fact Sheet, August 2005.

nitrate and nitrite. Table 17 also includes a "nc" which means that a total nitrogen concentration was "not calculated" because of the absence of nitrate-nitrite sample results.

TKN concentrations at sampling sites range from a minimum concentration at the level of detection (<0.2 mg/L) to a maximum concentration of 0.7 mg/L. TKN results by themselves cannot be compared to Arizona's SSM water quality standard for total nitrogen in the Verde River that is established at 3 mg/L. However, because the observed TKN concentrations are low (i.e., all TKN concentration were less than 0.7 mg/L) and the small probability that nitrate plus nitrite concentrations exceeded 2 mg/L, it is likely that the Verde River complied with the applicable water quality standard for total nitrogen during the first three years of data collection. While we can only speculate about compliance with total nitrogen standards in the absence of nitrate-nitrite data, the speculation is supported by a more complete total nitrogen dataset for the Verde River from sample results obtained after January 2010. The more recent Water Sentinels' dataset shows that there were no violations of the SSM total nitrogen standard of 3 mg/L. The highest total nitrogen calculation in the dataset is 1.54 mg/L (obtained at the Above Verde Springs site on November 20, 2010), a concentration that is approximately half of the current total nitrogen standard for the Verde River.

Since 2010, Water Sentinels have collected water quality data for TKN and nitrate plus nitrite for sampling sites on the Verde River (n=54). TKN concentrations in Verde River samples range obtained after 2010 range from less than 0.2 mg/L (at the method level of detection) to 0.7 mg/L. Nitrate plus nitrite concentrations range between less than 0.01 mg/L to a maximum of 1.34 mg/L (the maximum nitrate plus nitrate sample result was obtained at Above Verde Springs on November 20, 2010). Only three out of 54 calculations for total nitrogen exceeded 1 mg/L, well below the 3 mg/L SSM standard for the Verde River. The three total nitrogen calculations in excess of 1 mg/L were obtained from samples collected at the Water Sentinels Above Verde Springs site.

The dataset shows that TKN concentrations of water samples from the Verde River have been consistent over the five-year period of record. The sample results indicate that water quality of the Verde River with respect to total nitrogen has complied with applicable water quality standards over the last five years.

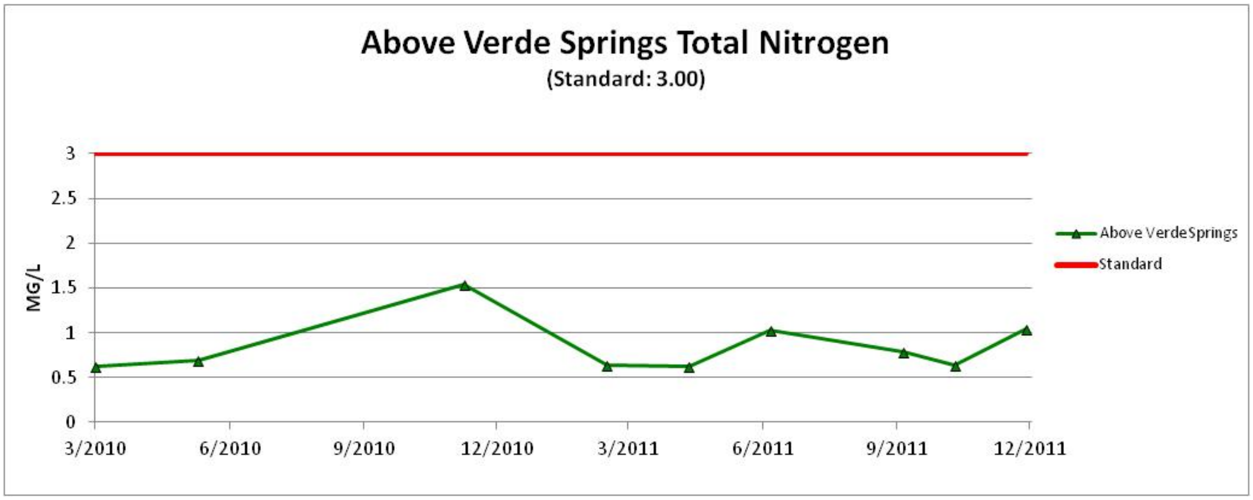

Chart 41. Above Verde Springs total nitrogen

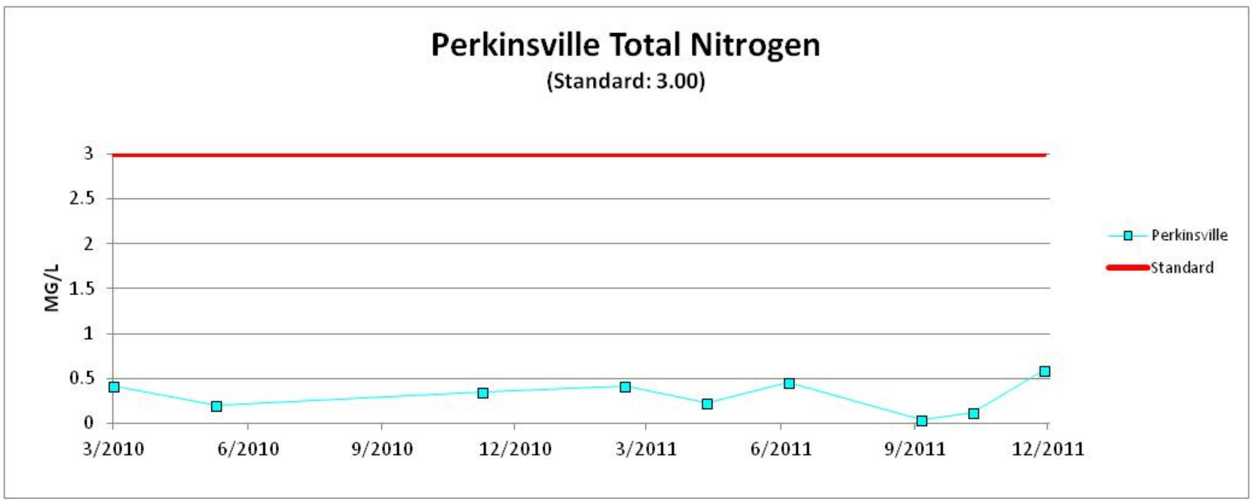

Chart 42. Perkinsville total nitrogen

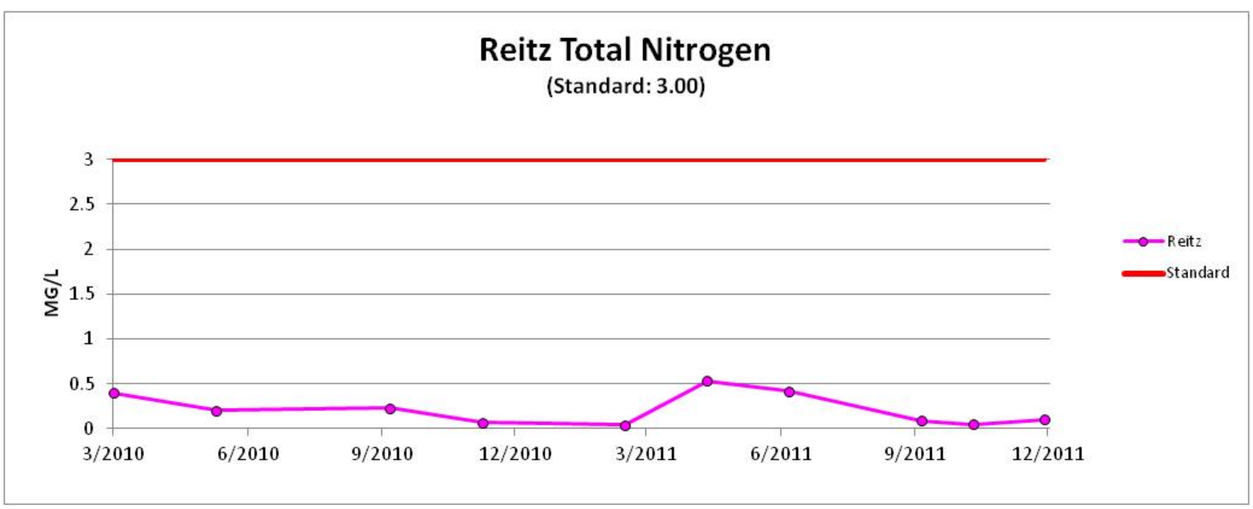

Chart 43. Reitz total nitrogen

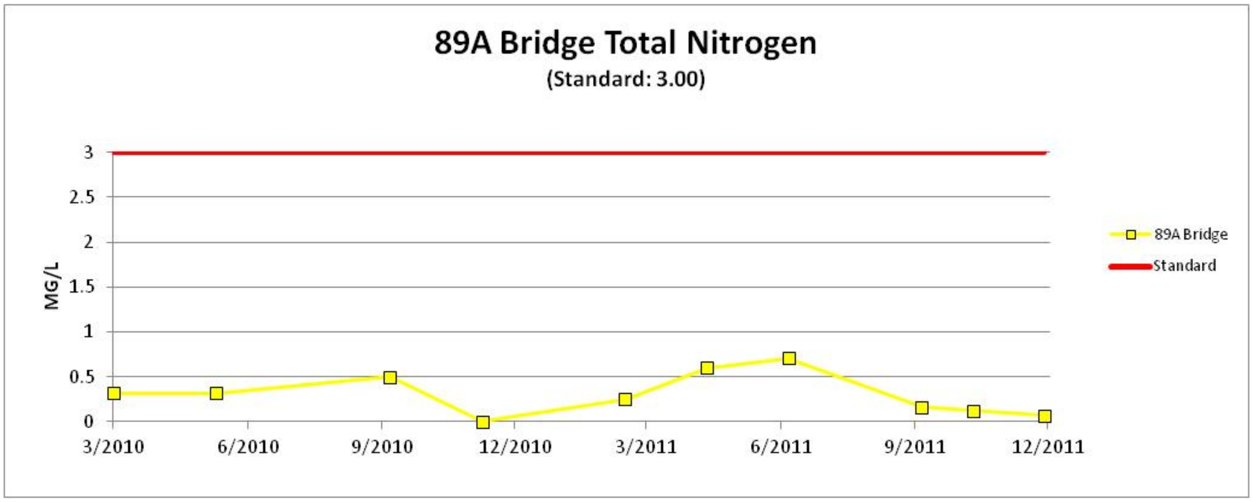

Chart 44. 89A Bridge total nitrogen

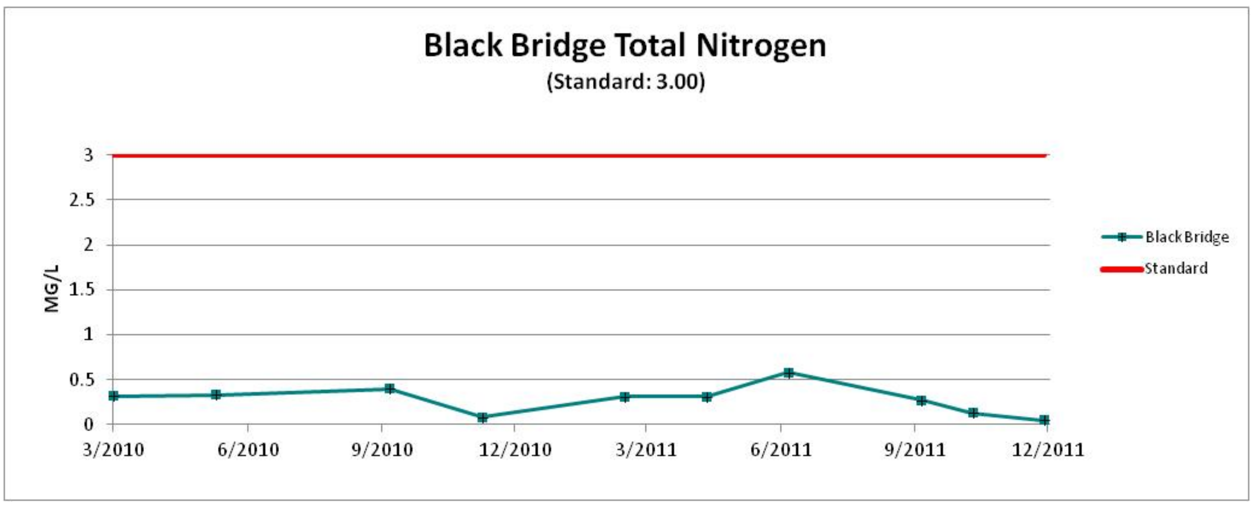

Chart 45. Black Bridge total nitrogen

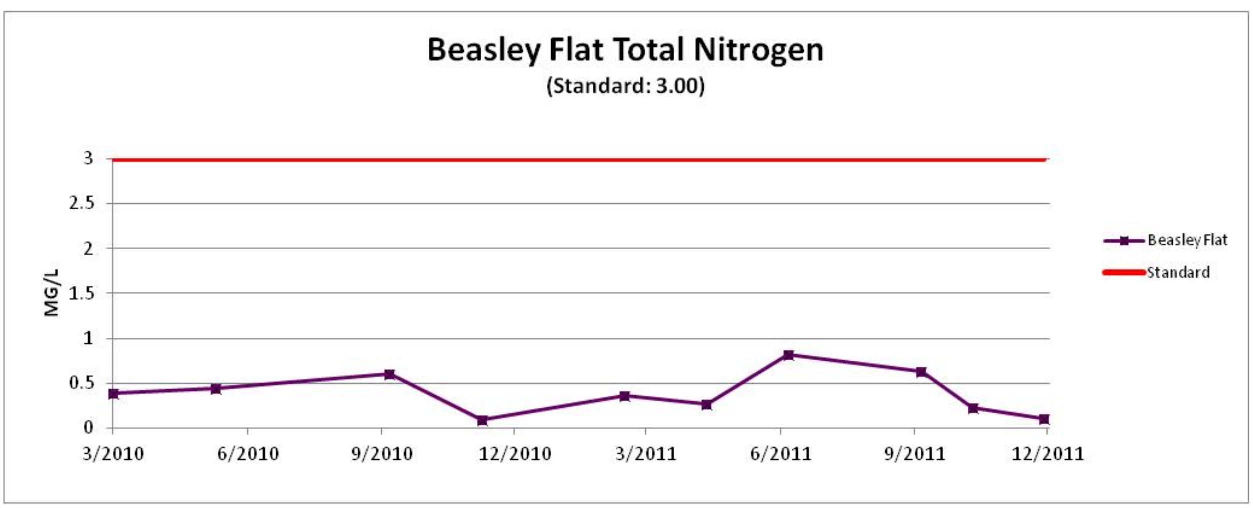

Chart 46. Beasley Flat total nitrogen

Table 17. Total nitrogen field measurements

Sampling Site	Date	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite	Total Nitrogen
Above Verde Springs	12/02/2006	0.39	NA	NC
Bear Siding	12/02/2006	0.46	NA	NC
Perkinsville	12/02/2006	0,53	NA	NC
Reitz	12/02/2006	0.36	NA	NC
Hwy 89A Bridge	12/02/2006	0.36	NA	NC
White Bridge	12/02/2006	0.50	NA	NC
Beasley Flat	12/02/2006	0.42	NA	NC
Above Verde Springs	02/17/2007	0.2	NA	NC
Bear Siding	02/17/2007	0.2	NA	NC
Perkinsville	02/17/2007	0.2	NA	NC
Reitz	02/17/2007	0.2	NA	NC
Hwy 89A Bridge	02/17/2007	0.2	NA	NC
White Bridge	02/17/2007	0.3	NA	NC
Beasley Flat	02/17/2007	0.3	NA	NC
Above Verde Springs	03/10/2007	0.3	NA	NC
Bear Siding	03/10/2007	<0.2	NA	NC
Perkinsville	03/10/2007	<0.2	NA	NC
Reitz	03/10/2007	0.2	NA	NC
Hwy 89A Bridge	03/10/2007	0.2	NA	NC
White Bridge	03/10/2007	<0.2	NA	NC
Beasley Flat	03/10/2007	0.2	NA	NC
Above Verde Springs	04/28/2007	0.4	NA	NC
Bear Siding	04/28/2007	<0.2	NA	NC
Perkinsville	04/28/2007	0.2	NA	NC
Reitz	04/28/2007	<0.2	NA	NC
Hwy 89A Bridge	04/28/2007	<0.2	NA	NC
White Bridge	04/28/2007	<0.2	NA	NC
Beasley Flat	04/28/2007	0.7	NA	NC
Above Verde Springs	08/25/2007	0.5	NA	NC
Bear Siding	08/25/2007	0.5	NA	NC
Perkinsville	08/25/2007	0.5	NA	NC
Reitz	08/25/2007	0.5	NA	NC
Hwy 89A Bridge	08/25/2007	0.6	NA	NC
White Bridge	08/25/2007	0.6	NA	NC
Beasley Flat	08/25/2007	0.7	NA	NC
Above Verde Springs	10/20/2007	<0.2	NA	NC
Bear Siding	10/20/2007	<0.2	NA	NC
Perkinsville	10/20/2007	<0.2	NA	NC
Reitz	10/20/2007	<0.2	NA	NC
Hwy 89A Bridge	10/20/2007	<0.2	NA	NC
White Bridge	10/20/2007	<0.2	NA	NC
Beasley Flat	10/20/2007	<0.2	NA	NC

Sampling Site	Date	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite	Total Nitrogen
Above Verde Springs	12/15/2007	0.3	NA	NC
Bear Siding	12/15/2007	0.2	NA	NC
Perkinsville	12/15/2007	0.2	NA	NC
Reitz	12/15/2007	0.2	NA	NC
Hwy 89A Bridge	12/15/2007	0.2	NA	NC
White Bridge	12/15/2007	0.2	NA	NC
Beasley Flat	12/15/2007	0.2	NA	NC
Above Verde Springs	02/09/2008	0.3	NA	NC
Bear Siding	02/09/2008	0.2	NA	NC
Perkinsville	02/09/2008	0.2	NA	NC
Reitz	02/09/2008	0.3	NA	NC
Hwy 89A Bridge	02/09/2008	0.2	NA	NC
White Bridge	02/09/2008	0.2	NA	NC
Beasley Flat	02/09/2008	0.2	NA	NC
Above Verde Springs	04/26/2008	0.2	NA	NC
Bear Siding	04/26/2008	<0.2	NA	NC
Perkinsville	04/26/2008	<0.2	NA	NC
Reitz	04/26/2008	<0.2	NA	NC
Hwy 89A Bridge	04/26/2008	0.3	NA	NC
White Bridge	04/26/2008	<0.2	NA	NC
Beasley Flat	04/26/2008	0.2	NA	NC
Above Verde Springs	06/14/2008	0.2	NA	NC
Bear Siding	06/14/2008	0.2	NA	NC
Perkinsville	06/14/2008	0.2	NA	NC
Reitz	06/14/2008	0.2	NA	NC
Hwy 89A Bridge	06/14/2008	<0.2	NA	NC
White Bridge	06/14/2008	<0.2	NA	NC
Beasley Flat	06/14/2008	0.2	NA	NC
Above Verde Springs	08/16/2008	0.5	NA	NC
Bear Siding	08/16/2008	0.4	NA	NC
Perkinsville	08/16/2008	0.5	NA	NC
Reitz	08/16/2008	0.5	NA	NC
Hwy 89A Bridge	08/16/2008	0.5	NA	NC
White Bridge	08/16/2008	1.0	NA	NC
Beasley Flat	08/16/2008	0.8	NA	NC
Above Verde Springs	12/20/2008	0.2	NA	NC
Bear Siding	12/20/2008	0.3	NA	NC
Perkinsville	12/20/2008	0.3	NA	NC
Reitz	12/20/2008	0.3	NA	NC
Hwy 89A Bridge	12/20/2008	0.3	NA	NC
White Bridge	12/20/2008	0.3	NA	NC
Beasley Flat	12/20/2008	0.3	NA	NC

Sampling Site	Date	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite	Total Nitrogen
Above Verde Springs	02/28/2009	0.2	NA	NC
Bear Siding	02/28/2009	0.2	NA	NC
Perkinsville	02/28/2009	<0.2	NA	NC
Reitz	02/28/2009	<0.2	NA	NC
Hwy 89A Bridge	02/28/2009	0.2	NA	NC
White Bridge	02/28/2009	0.2	NA	NC
Beasley Flat	02/28/2009	0.2	NA	NC
Above Verde Springs	04/11/2009	<0.2	NA	NC
Bear Siding	04/11/2009	<0.2	NA	NC
Perkinsville	04/11/2009	<0.2	NA	NC
Reitz	04/11/2009	<0.2	NA	NC
Hwy 89A Bridge	04/11/2009	<0.2	NA	NC
White Bridge	04/11/2009	<0.2	NA	NC
Beasley Flat	04/11/2009	<0.2	NA	NC
Above Verde Springs	05/30/2009	0.2	NA	NC
Bear Siding	05/30/2009	0.2	NA	NC
Perkinsville	05/30/2009	0.3	NA	NC
Reitz	05/30/2009	0.2	NA	NC
Hwy 89A Bridge	05/30/2009	0.2	NA	NC
White Bridge	05/30/2009	0.2	NA	NC
Beasley Flat	05/30/2009	0.2	NA	NC
Above Verde Springs	07/25/2009	0.2	NA	NC
Bear Siding	07/25/2009	0.2	NA	NC
Perkinsville	07/25/2009	<0.2	NA	NC
Reitz	07/25/2009	<0.2	NA	NC
Hwy 89A Bridge	07/25/2009	0.2	NA	NC
White Bridge	07/25/2009	0.7	NA	NC
Beasley Flat	07/25/2009	0.4	NA	NC
Above Verde Springs	09/19/2009	<0.2	NA	NC
Bear Siding	09/19/2009	<0.2	NA	NC
Perkinsville	09/19/2009	<0.2	NA	NC
Reitz	09/19/2009	<0.2	NA	NC
Hwy 89A Bridge	09/19/2009	<0.2	NA	NC
White Bridge	09/19/2009	<0.2	NA	NC
Beasley Flat	09/19/2009	<0.2	NA	NC
Above Verde Springs	11/21/2009	0.3	NA	NC
Bear Siding	11/21/2009	0.2	NA	NC
Perkinsville	11/21/2009	0.2	NA	NC
Reitz	11/21/2009	0.2	NA	NC
Hwy 89A Bridge	11/21/2009	<0.2	NA	NC
White Bridge	11/21/2009	<0.2	NA	NC
Beasley Flat	11/21/2009	<0.2	NA	NC

Sampling Site	Date	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite	Total Nitrogen
Above Verde Springs	03/13/2010	0.4	0.22	0.62
Perkinsville	03/13/2010	0.3	0.11	0.41
Reitz	03/13/2010	0.3	0.10	0.4
Hwy 89A Bridge	03/13/2010	0.2	0.12	0.32
Black Bridge	03/13/2010	0.2	0.12	0.32
Beasley Flat	03/13/2010	0.3	0.09	0.39
Above Verde Springs	05/22/2010	0.4	0.29	0.69
Perkinsville	05/22/2010	0.2	<0.01	0.21*
Reitz	05/22/2010	0.2	<0.01	0.21*
Hwy 89A Bridge	05/22/2010	0.2	0.12	0.32
Black Bridge	05/22/2010	0.2	0.13	0.33
Beasley Flat	05/22/2010	0.2	<0.01	0.21*
Above Verde Springs	07/10/2010	0.4	NA	NC
Perkinsville	07/10/2010	0.3	NA	NC
Reitz	07/10/2010	0.2	NA	NC
Hwy 89A Bridge	07/10/2010	0.2	NA	NC
Black Bridge	07/10/2010	0.2	NA	NC
Beasley Flat	07/10/2010	0.3	NA	NC
Above Verde Springs	09/18/2010	NA	NA	NC
Perkinsville	09/18/2010	NA	NA	NC
Reitz	09/18/2010	0.2	0.03	0.23
Hwy 89A Bridge	09/18/2010	0.2	0.30	0.50
Black Bridge	09/18/2010	0.2	0.20	0.40
Beasley Flat	09/18/2010	0.3	0.30	0.60
Above Verde Springs	11/20/2010	0.2	1.34	1.54
Perkinsville	11/20/2010	<0.2	0.35	<0.55*
Reitz	11/20/2010	<0.2	0.07	<0.27*
Hwy 89A Bridge	11/20/2010	<0.2	<0.01	<0.21*
Black Bridge	11/20/2010	<0.2	0.08	<0.28*
Beasley Flat	11/20/2010	<0.2	0.09	<0.29*
Above Verde Springs	02/26/2011	0.2	0.44	0.64
Perkinsville	02/26/2011	0.2	0.22	0.44
Reitz	02/26/2011	<0.2	0.04	<0.24
Hwy 89A Bridge	02/26/2011	0.2	0.05	0.25
Black Bridge	02/26/2011	0.2	0.11	0.31
Beasley Flat	02/26/2011	0.3	0.06	0.36
Above Verde Springs	04/23/2011	0.3	0.32	0.62
Perkinsville	04/23/2011	0.2	0.02	0.22
Reitz	04/23/2011	<0.2	0.53	<0.73
Hwy 89A Bridge	04/23/2011	0.2	0.40	0.60
Black Bridge	04/23/2011	0.2	0.11	0.31
Beasley Flat	04/23/2011	0.2	0.07	0.27

Sampling Site	Date	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite	Total Nitrogen
Above Verde Springs	06/18/2011	0.7	0.33	1.03
Perkinsville	06/18/2011	0.4	0.06	0.46
Reitz	06/18/2011	0.4	0.02	0.42
Hwy 89A Bridge	06/18/2011	0.5	0.21	0.71
Black Bridge	06/18/2011	0.3	0.28	0.58
Beasley Flat	06/18/2011	0.4	0.42	0.82
Above Verde Springs	09/17/2011	0.2	0.58	0.78
Perkinsville	09/17/2011	<0.2	0.04	<0.24
Reitz	09/17/2011	<0.2	0.09	<0.29
Hwy 89A Bridge	09/17/2011	<0.2	0.16	<0.36
Black Bridge	09/17/2011	0.2	0.43	0.63
Beasley Flat	09/17/2011	<0.2	0.27	<0.47
Above Verde Springs	10/22/2011	<0.2	0.64	<0.84
Perkinsville	10/22/2011	<0.2	0.12	<0.32
Reitz	10/22/2011	<0.2	0.05	<0.25
Hwy 89A Bridge	10/22/2011	<0.2	0.12	<0.32
Black Bridge	10/22/2011	<0.2	0.13	<0.33
Beasley Flat	10/22/2011	<0.2	0.22	<0.42
Above Verde Springs	12/10/2011	0.2	0.84	1.04
Perkinsville	12/10/2011	<0.2	0.59	<0.79
Reitz	12/10/2011	<0.2	0.10	<0.30
Hwy 89A Bridge	12/10/2011	<0.2	0.07	<0.27
Black Bridge	12/10/2011	<0.2	0. 05	<0.25
Beasley Flat	12/10/2011	<0.2	0.11	<0.31

Total Phosphorus

Phosphorus is an essential nutrient for plant and animal life in the Verde River. However, like nitrogen, too much phosphorus in the water column can cause excessive growth of algae and aquatic plants, leading to eutrophication and a reduction in the quality of aquatic habitats. Elevated phosphorus concentrations can accelerate and cause excessive plant growth and cause a reduction of the amount of DO in the river. Also like nitrogen, phosphorus can take on many chemical forms and is constantly changing. Total phosphorus is a measurement of all forms of phosphorus in a water sample.[47]

Arizona Water Quality Standard for Total Phosphorus

The Arizona water quality standards for total phosphorus for the Verde River are prescribed at Arizona Administrative Code R18-11-109(F)(1). Like total nitrogen, the water quality standards for total phosphorus are expressed as annual mean, 90th percentile, and SSM values. Because

[47] See http://www.tristatecouncil.org/programs/taterms.html

the Arizona Water Sentinels collect samples at sites approximately once every two months, the sample results should be compared to the SSM of 1.00 mg/L**.**

Table 18. Surface water quality standards for total phosphorus for the Verde River

	Annual Mean	90th Percentile*	Single sample maximum
Total phosphorus	0.10 mg/L	0.30 mg/L	1.00 mg/L

Arizona Water Sentinels collected 192 water samples for total phosphorus analysis from December 2, 2006, to December 10, 2011. There were no violations of the SSM total phosphorus water quality standard over this five-year period of record. The maximum concentration of total phosphorus reported was 0.644 mg/L from a sample obtained at the White Bridge sampling site on August 16, 2008. The following charts present the sample results for total phosphorus by sampling site. Water Sentinels discontinued sampling for total phosphorus for all sampling sites in 2012 because the dataset established an adequate baseline to support a conclusion that Verde River water quality with respect to total phosphorus is very good and consistently complies with the applicable SSM water quality standard.

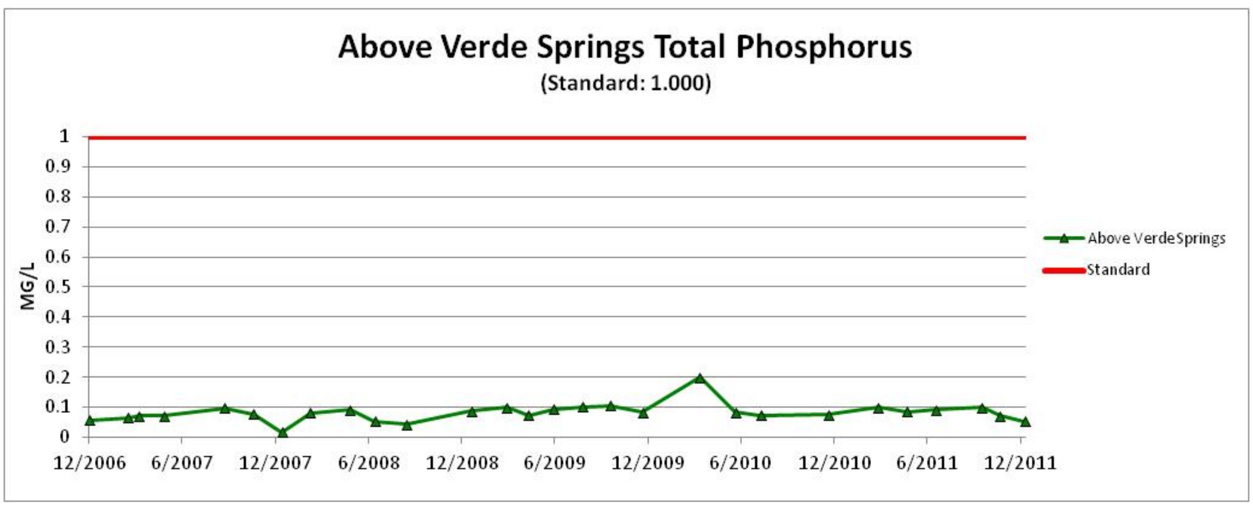

Chart 47. Above Verde Springs total phosphorus

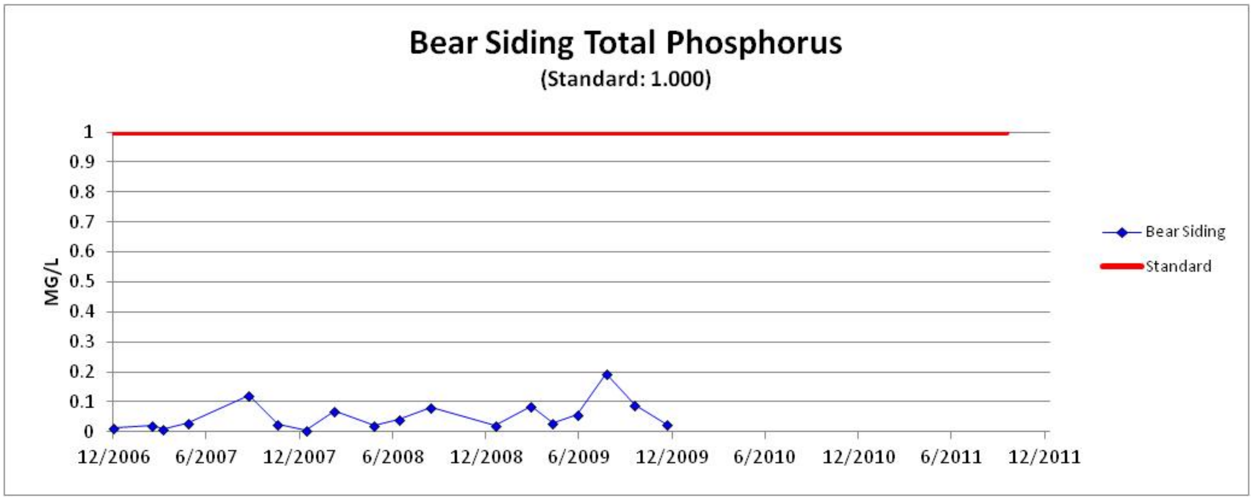

Chart 48. Bear Siding total phosphorus

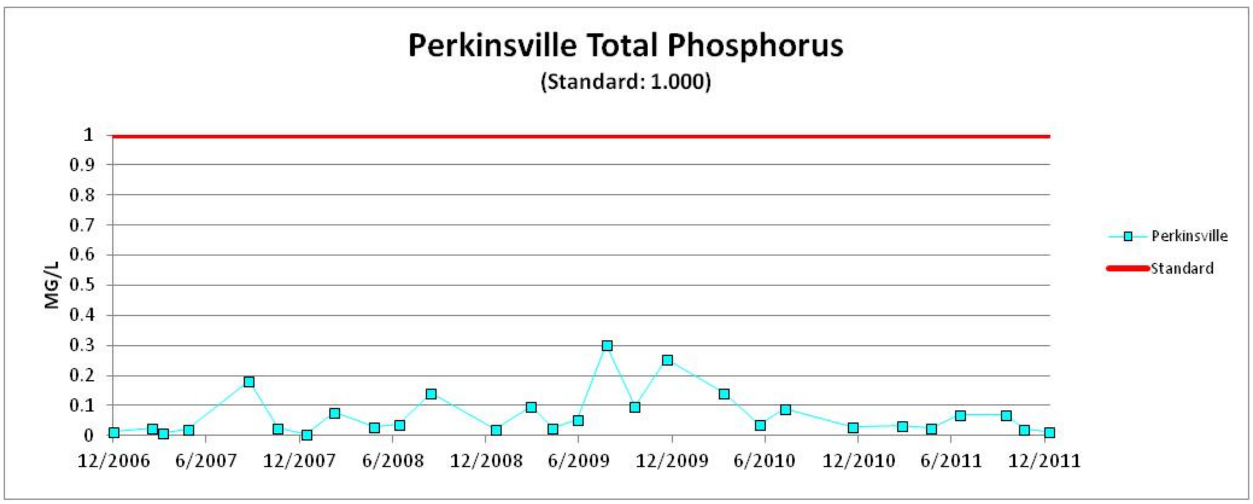

Chart 49. Perkinsville total phosphorus

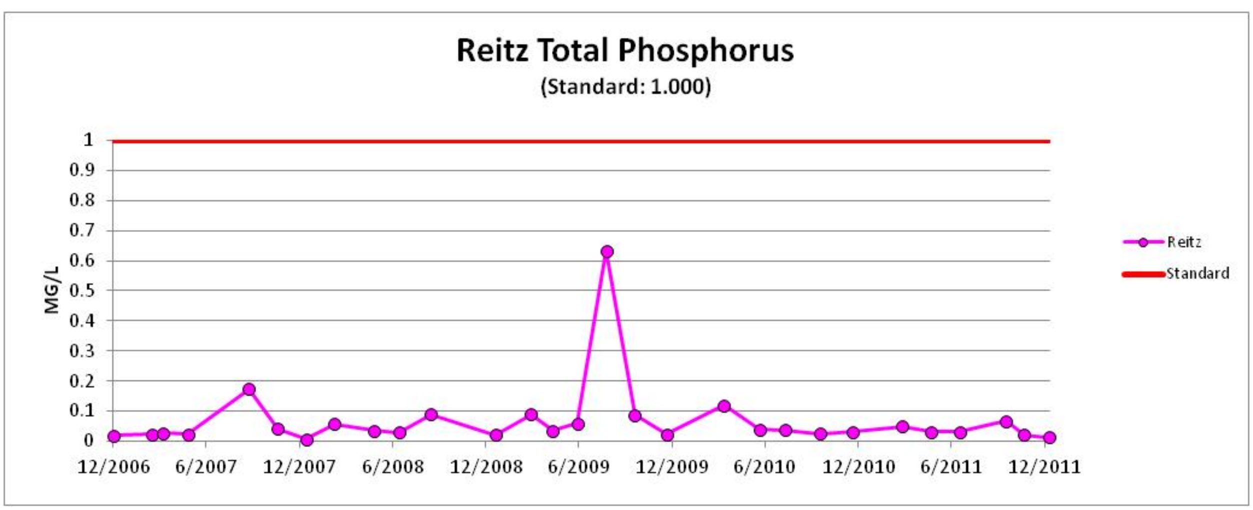

Chart 50. Reitz total phosphorus

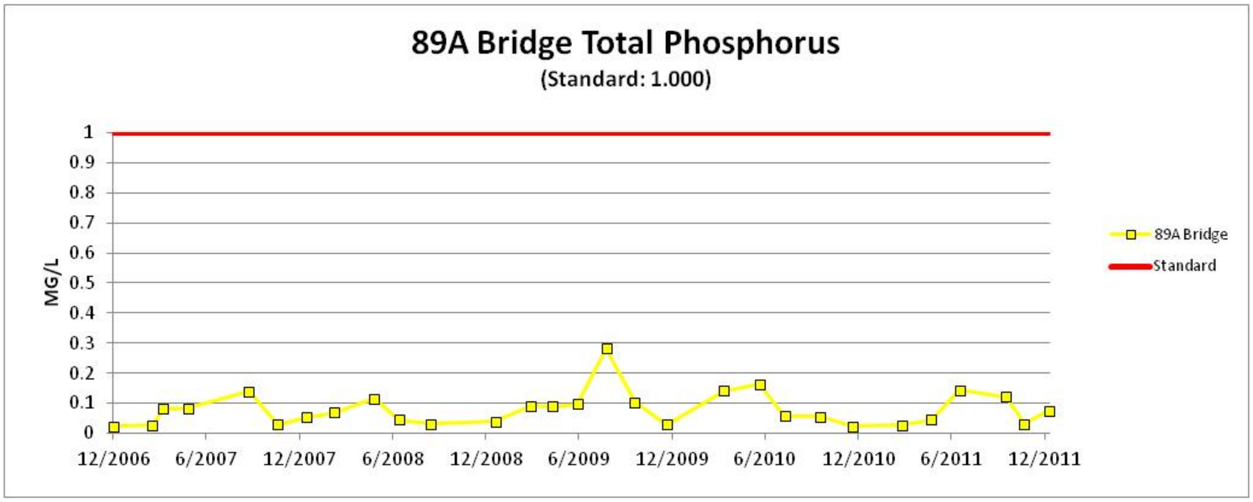

Chart 51. 89A Bridge total phosphorus

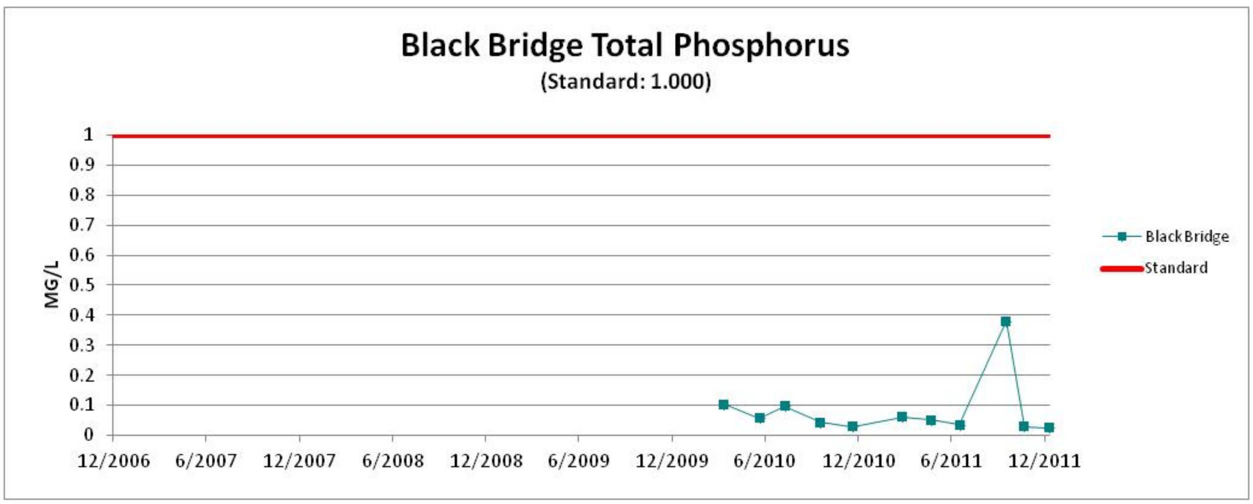

Chart 52. Black Bridge total phosphorus

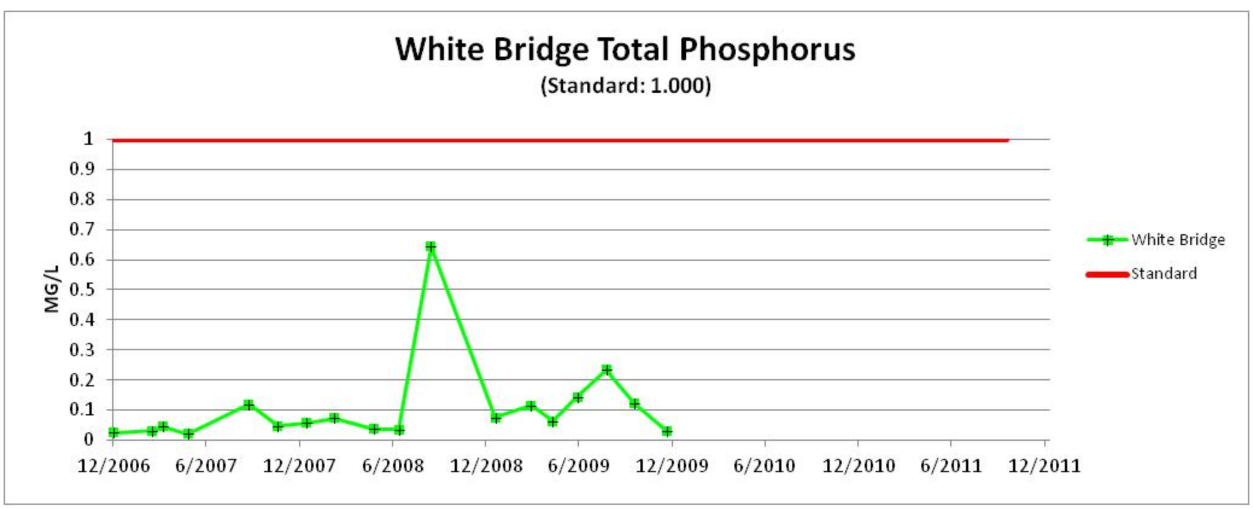

Chart 53. White Bridge total phosphorus

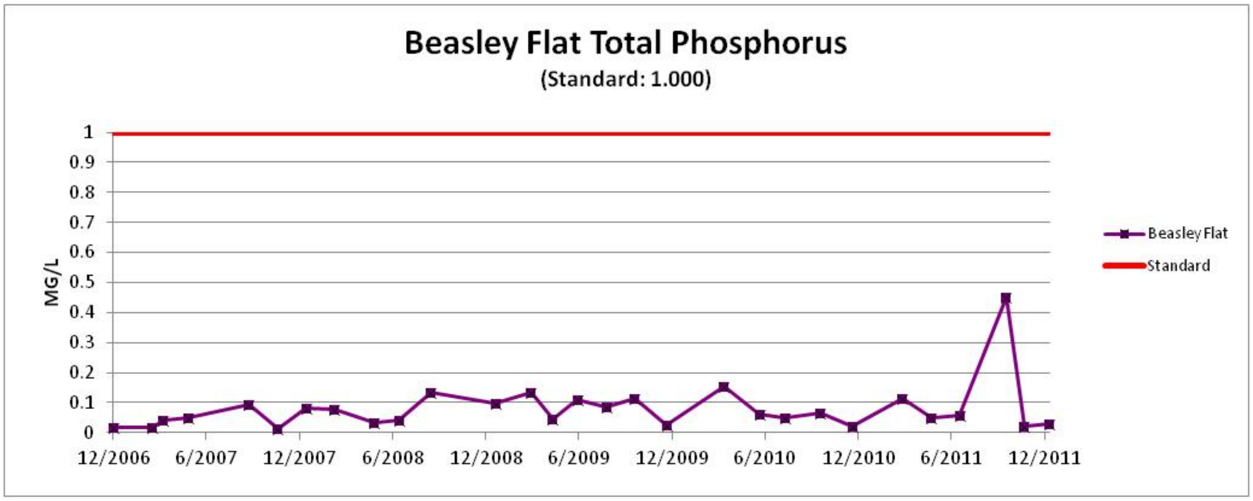

Chart 54. Beasley Flat total phosphorus

Table 19. Total phosphorus field measurements

Sampling Site	Date	Total Phosphorus (in mg/L as P)
Above Verde Springs	12/02/2006	0.056
Bear Siding	12/02/2006	0.014
Perkinsville	12/02/2006	0.012
Reitz	12/02/2006	0.018
Hwy 89A Bridge	12/02/2006	0.022
White Bridge	12/02/2006	0.025
Beasley Flat	12/02/2006	0.018
Above Verde Springs	02/17/2007	0.064
Bear Siding	02/17/2007	0.020
Perkinsville	02/17/2007	0.027
Reitz	02/17/2007	0.022
Hwy 89A Bridge	02/17/2007	0.027
White Bridge	02/17/2007	0.030
Beasley Flat	02/17/2007	0.017
Above Verde Springs	03/10/2007	0.070
Bear Siding	03/10/2007	0.010
Perkinsville	03/10/2007	0.009
Reitz	03/10/2007	0.026
Hwy 89A Bridge	03/10/2007	0.080
White Bridge	03/10/2007	0.045
Beasley Flat	03/10/2007	0.043

Sampling Site	Date	Total Phosphorus (in mg/L as P)
Above Verde Springs	04/28/2007	0.070
Bear Siding	04/28/2007	0.031
Perkinsville	04/28/2007	0.022
Reitz	04/28/2007	0.022
Hwy 89A Bridge	04/28/2007	0.082
White Bridge	04/28/2007	0.020
Beasley Flat	04/28/2007	0.050
Above Verde Springs	08/25/2007	0.096
Bear Siding	08/25/2007	0.123
Perkinsville	08/25/2007	0.183
Reitz	08/25/2007	0.174
Hwy 89A Bridge	08/25/2007	0.140
White Bridge	08/25/2007	0.119
Beasley Flat	08/25/2007	0.093
Above Verde Springs	10/20/2007	0.077
Bear Siding	10/20/2007	0.027
Perkinsville	10/20/2007	0.024
Reitz	10/20/2007	0.041
Hwy 89A Bridge	10/20/2007	0.029
White Bridge	10/20/2007	0.047
Beasley Flat	10/20/2007	0.015
Above Verde Springs	12/15/2007	0.017
Bear Siding	12/15/2007	0.007
Perkinsville	12/15/2007	0.006
Reitz	12/15/2007	0.006
Hwy 89A Bridge	12/15/2007	0.053
White Bridge	12/15/2007	0.056
Beasley Flat	12/15/2007	0.083
Above Verde Springs	02/09/2008	0.080
Bear Siding	02/09/2008	0.068
Perkinsville	02/09/2008	0.076
Reitz	02/09/2008	0.057
Hwy 89A Bridge	02/09/2008	0.068
White Bridge	02/09/2008	0.073
Beasley Flat	02/09/2008	0.079
Above Verde Springs	04/26/2008	0.091
Bear Siding	04/26/2008	0.022
Perkinsville	04/26/2008	0.031
Reitz	04/26/2008	0.034
Hwy 89A Bridge	04/26/2008	0.115
White Bridge	04/26/2008	0.036
Beasley Flat	04/26/2008	0.033

Sampling Site	Date	Total Phosphorus (in mg/L as P)
Above Verde Springs	06/14/2008	0.053
Bear Siding	06/14/2008	0.042
Perkinsville	06/14/2008	0.038
Reitz	06/14/2008	0.029
Hwy 89A Bridge	06/14/2008	0.045
White Bridge	06/14/2008	0.035
Beasley Flat	06/14/2008	0.042
Above Verde Springs	08/16/2008	0.043
Bear Siding	08/16/2008	0.082
Perkinsville	08/16/2008	0.143
Reitz	08/16/2008	0.088
Hwy 89A Bridge	08/16/2008	0.031
White Bridge	08/16/2008	0.644
Beasley Flat	08/16/2008	0.133
Above Verde Springs	12/20/2008	0.086
Bear Siding	12/20/2008	0.021
Perkinsville	12/20/2008	0.021
Reitz	12/20/2008	0.021
Hwy 89A Bridge	12/20/2008	0.038
White Bridge	12/20/2008	0.075
Beasley Flat	12/20/2008	0.098
Above Verde Springs	02/28/2009	0.099
Bear Siding	02/28/2009	0.087
Perkinsville	02/28/2009	0.096
Reitz	02/28/2009	0.088
Hwy 89A Bridge	02/28/2009	0.090
White Bridge	02/28/2009	0.115
Beasley Flat	02/28/2009	0.133
Above Verde Springs	04/11/2009	0.073
Bear Siding	04/11/2009	0.030
Perkinsville	04/11/2009	0.025
Reitz	04/11/2009	0.035
Hwy 89A Bridge	04/11/2009	0.089
White Bridge	04/11/2009	0.063
Beasley Flat	04/11/2009	0.047
Above Verde Springs	05/30/2009	0.092
Bear Siding	05/30/2009	0.059
Perkinsville	05/30/2009	0.054
Reitz	05/30/2009	0.058
Hwy 89A Bridge	05/30/2009	0.097
White Bridge	05/30/2009	0.144
Beasley Flat	05/30/2009	0.109

Sampling Site	Date	Total Phosphorus (in mg/L as P)
Above Verde Springs	07/25/2009	0.100
Bear Siding	07/25/2009	0.193
Perkinsville	07/25/2009	0.303
Reitz	07/25/2009	0.633
Hwy 89A Bridge	07/25/2009	0.281
White Bridge	07/25/2009	0.234
Beasley Flat	07/25/2009	0.087
Above Verde Springs	09/19/2009	0.105
Bear Siding	09/19/2009	0.089
Perkinsville	09/19/2009	0.099
Reitz	09/19/2009	0.086
Hwy 89A Bridge	09/19/2009	0.102
White Bridge	09/19/2009	0.121
Beasley Flat	09/19/2009	0.113
Above Verde Springs	11/21/2009	0.083
Bear Siding	11/21/2009	0.027
Perkinsville	11/21/2009	0.254
Reitz	11/21/2009	0.022
Hwy 89A Bridge	11/21/2009	0.028
White Bridge	11/21/2009	0.030
Beasley Flat	11/21/2009	0.027
Above Verde Springs	03/13/2010	0.199
Perkinsville	03/13/2010	0.143
Reitz	03/13/2010	0.119
Hwy 89A Bridge	03/13/2010	0.141
Black Bridge	03/13/2010	0.102
Beasley Flat	03/13/2010	0.155
Above Verde Springs	05/22/2010	0.083
Perkinsville	05/22/2010	0.039
Reitz	05/22/2010	0.038
Hwy 89A Bridge	05/22/2010	0.163
Black Bridge	05/22/2010	0.057
Beasley Flat	05/22/2010	0.062
Above Verde Springs	07/10/2010	0.072
Perkinsville	07/10/2010	0.090
Reitz	07/10/2010	0.036
Hwy 89A Bridge	07/10/2010	0.056
Black Bridge	07/10/2010	0.096
Beasley Flat	07/10/2010	0.050

Sampling Site	Date	Total Phosphorus (in mg/L as P)
Above Verde Springs	09/18/2010	Not available
Perkinsville	09/18/2010	Not available
Reitz	09/18/2010	0.025
Hwy 89A Bridge	09/18/2010	0.054
Black Bridge	09/18/2010	0.043
Beasley Flat	09/18/2010	0.065
Above Verde Springs	11/20/2010	0.075
Perkinsville	11/20/2010	0.028
Reitz	11/20/2010	0.031
Hwy 89A Bridge	11/20/2010	0.023
Black Bridge	11/20/2010	0.028
Beasley Flat	11/20/2010	0.023
Above Verde Springs	02/26/2011	0.099
Perkinsville	02/26/2011	0.032
Reitz	02/26/2011	0.048
Hwy 89A Bridge	02/26/2011	0.027
Black Bridge	02/26/2011	0.061
Beasley Flat	02/26/2011	0.115
Above Verde Springs	04/23/2011	0.084
Perkinsville	04/23/2011	0.027
Reitz	04/23/2011	0.031
Hwy 89A Bridge	04/23/2011	0.045
Black Bridge	04/23/2011	0.051
Beasley Flat	04/23/2011	0.050
Above Verde Springs	06/18/2011	0.091
Perkinsville	06/18/2011	0.069
Reitz	06/18/2011	0.030
Hwy 89A Bridge	06/18/2011	0.144
Black Bridge	06/18/2011	0.034
Beasley Flat	06/18/2011	0.057
Above Verde Springs	09/17/2011	0.098
Perkinsville	09/17/2011	0.068
Reitz	09/17/2011	0.066
Hwy 89A Bridge	09/17/2011	0.121
Black Bridge	09/17/2011	0.380
Beasley Flat	09/17/2011	0.451
Above Verde Springs	10/22/2011	0.070
Perkinsville	10/22/2011	0.020
Reitz	10/22/2011	0.020
Hwy 89A Bridge	10/22/2011	0.031
Black Bridge	10/22/2011	0.029
Beasley Flat	10/22/2011	0.021

Sampling Site	Date	Total Phosphorus (in mg/L as P)
Above Verde Springs	12/10/2011	0.052
Perkinsville	12/10/2011	0.013
Reitz	12/10/2011	0.012
Hwy 89A Bridge	12/10/2011	0.074
Black Bridge	12/10/2011	0.025
Beasley Flat	12/10/2011	0.028

Suspended Sediment Concentration (SSC)

Water Sentinels began collecting suspended sediment concentration (SSC) samples from the Verde River in March 2010 and collected 64 samples at six different sampling sites over the last two years. Sample results show that total suspended sediment concentrations range from a minimum SSC of 0.99 mg/L to a maximum SSC of 236.64 mg/L. Both the minimum and the maximum SSC concentrations were obtained at the Black Bridge sampling site.

Arizona Water Quality Standard for Suspended Sediment Concentration

Arizona has adopted a water quality standard for SSC. The standard is prescribed at Arizona Administrative Code R18-11-109(D). The water quality standard is expressed as a median value to be determined from a minimum of four samples collected at least seven days apart. The SSC water quality standard limits the use of sample results from samples collected during or within 48 hours after a local storm event. Arizona's water quality standard for SSC is intended to apply during base flow conditions and **not** during or soon after a storm event when the river may be responding directly to storm water runoff. Arizona's current water quality standard for SSC is a "base flow" standard, not a "wet weather" standard.

Also, the water quality standard is expressed as a median value. The standard is expressed as a median value because it is intended to regulate "average" SSC in rivers and streams. The applicable water quality standard for average SSC in a warm water river like the Verde River is 80 mg/L. This means that the "average" or median concentration of suspended sediment in the Verde River should be below 80 mg/L.

Arizona Water Sentinels' Sample Results for Suspended Sediment Concentration

Arizona Water Sentinels collected 64 grab samples for SSC analysis between March 13, 2010, and December 10, 2011. Sixty-two out of 64 sample results for total SSC, or 97 percent of all sample results, were below 80 mg/L. Two sample results were greater than 80 mg/L and both were obtained on the same day, September 17, 2011. The two sample results in excess of 80 mg/L were obtained at Black Bridge (236.64 mg/L) and Beasley Flat (203.86 mg/L); they are the two highest SSC sample results in the dataset. Neither sample result can be considered a violation of the Arizona water quality standard for SSC because they are not median values.

The median SSC determined from 64 sample results is 8.25 mg/L. The arithmetic average SSC concentration (n=64) calculated for the Verde River is 23.46 mg/L. Both expressions of the “average” SSC of the Verde River are below the current water quality standard of 80 mg/L (four-sample minimum median value).

The Water Sentinels’ dataset indicates that SSC for the upper Verde River at its headwaters are lower than SSC for the middle Verde River obtained at the sampling sites in the more developed Verde River corridor from the Town of Clarkdale to below the Town of Camp Verde. For example, the median SSC value for 10 samples collected at the Above Verde Springs site at the headwaters of the Verde River is 8.49 mg/L. The median SSC for samples collected at Perkinsville on the upper Verde River is 8.37 mg/L. Finally, the median SSC at the Reitz property sampling site located upstream of the Town of Clarkdale is 4.68 mg/L. The median SSC values for these sampling sites on the upper Verde River are below 10 mg/L. By contrast, the median SSC values for sampling sites located in the more developed river corridor adjacent to the towns of Clarkdale, Cottonwood, and Camp Verde are higher. For example, the median SSC value for samples collected at the Highway 89A Bridge is 11.11 mg/L, the median SSC value at Black Bridge near the Town of Camp Verde is 7.62 mg/L, and the median SSC value for 11 samples obtained at Beasley Flat is 22.26 mg/L. While median SSC values tend to be relatively higher in the more developed reaches of the middle Verde River, the “average” SSC reported at all Water Sentinels are still well below the Arizona water quality standard of 80 mg/L.

Table 20. Median suspended sediment concentration values by sampling site

Sampling Site	Median SSC value in mg/L
Above Verde Springs	8.49
Perkinsville	8.37
Reitz	4.68
Highway 89A Bridge	11.11
Black Bridge	7.62
Beasley Flat	22.26

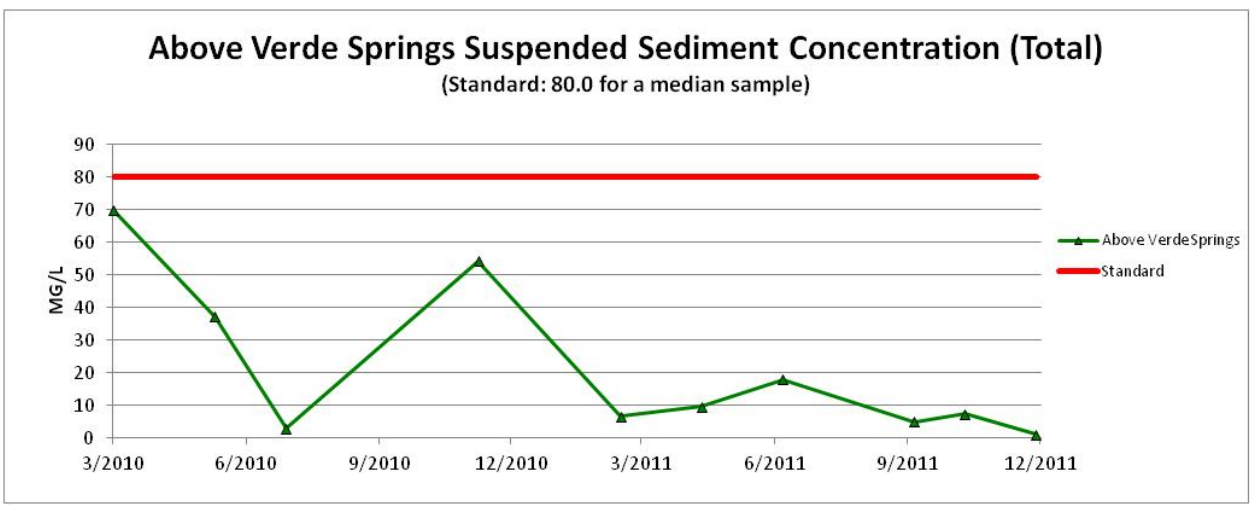

Chart 55. Above Verde Springs suspended sediment concentration

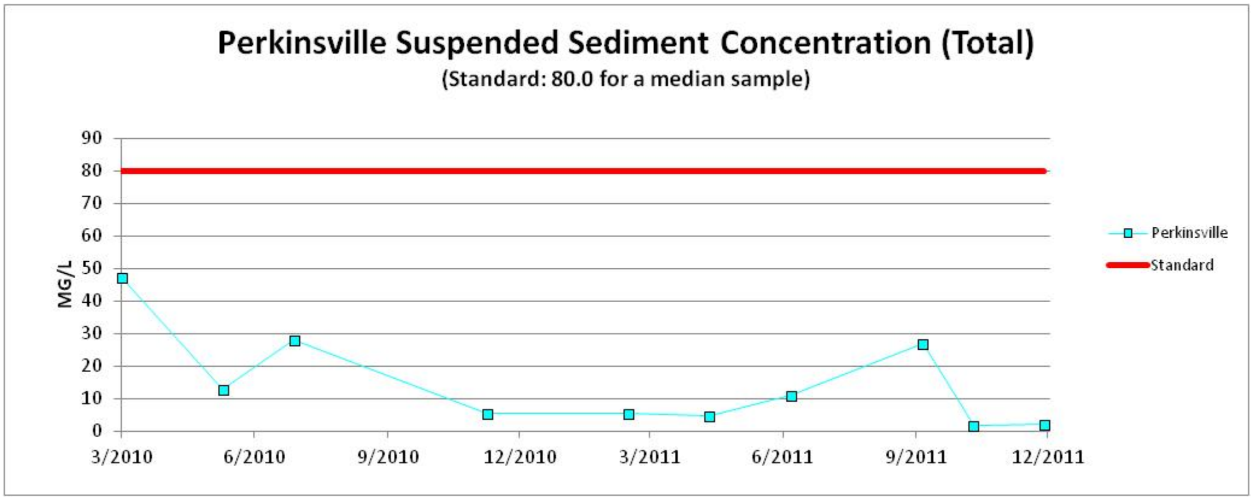

Chart 56. Perkinsville suspended sediment concentration

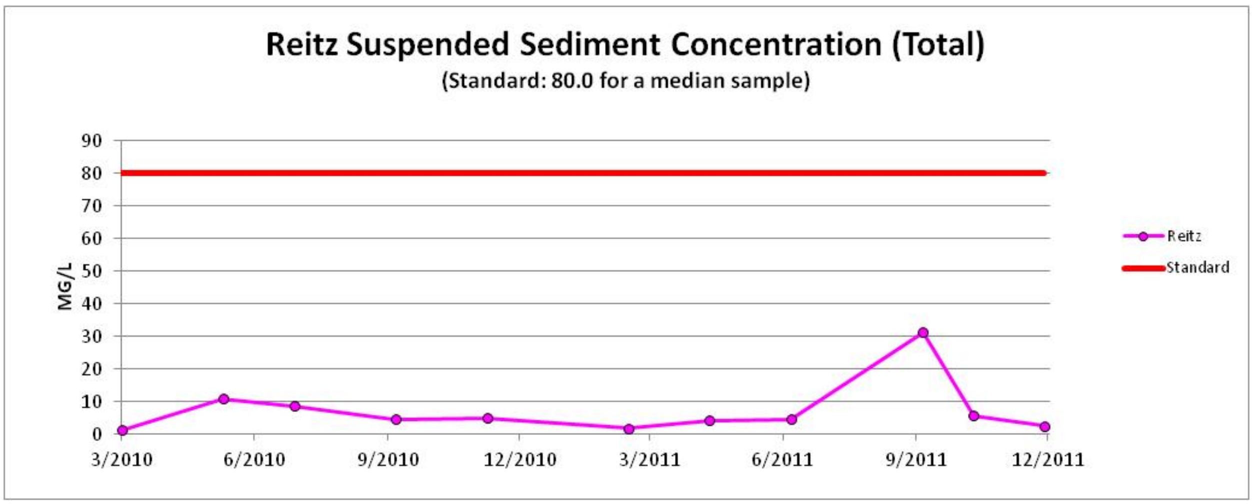

Chart 57. Reitz suspended sediment concentration

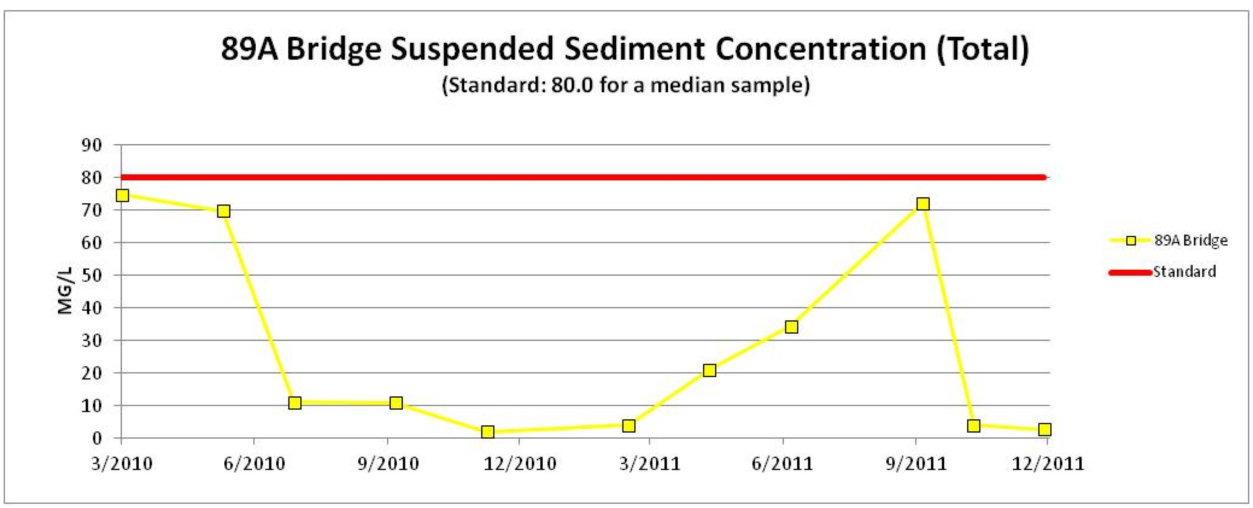

Chart 58. 89A Bridge suspended sediment concentration

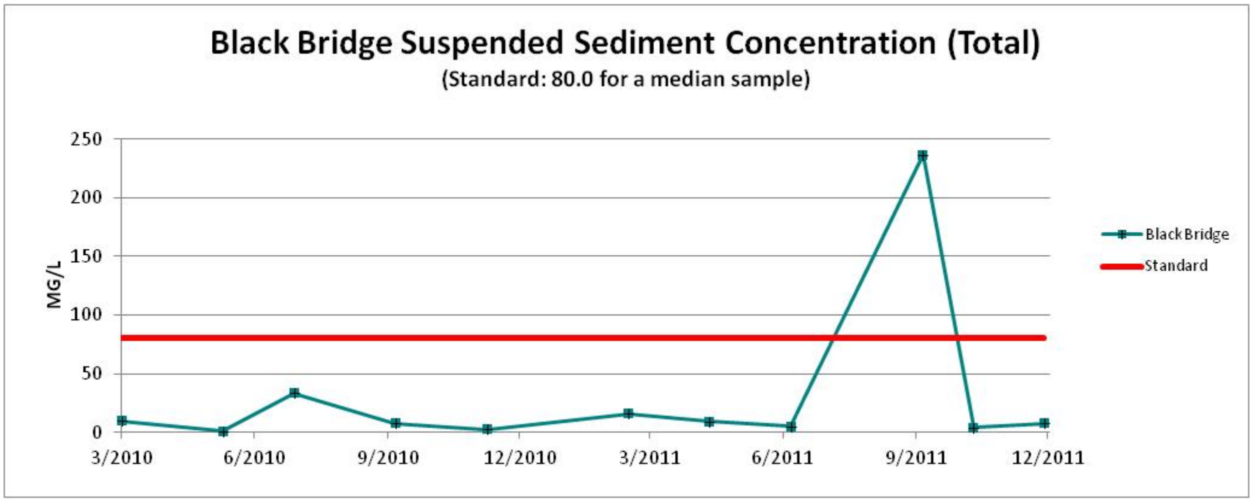

Chart 59. Black Bridge suspended sediment concentration

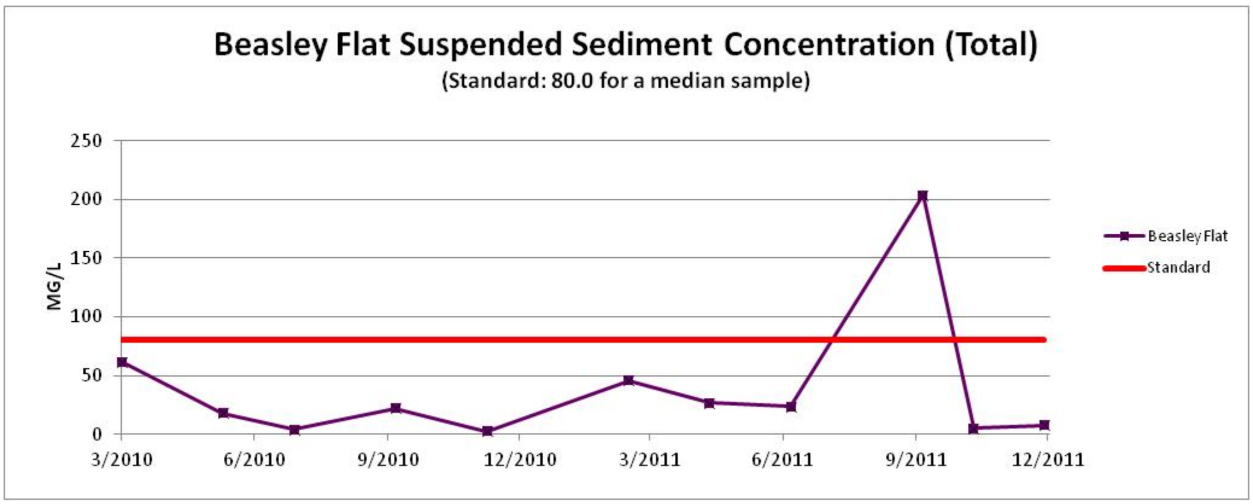

Chart 60. Beasley Flat suspended sediment concentration

Table 21. Suspended sediment concentration field measurements

Sampling Site	Date	Suspended Sediment Concentration (in mg/L)		
		Fine	Coarse	Total
Above Verde Springs	03/13/2010	59.9	10.0	**69.9**
Perkinsville	03/13/2010	43.3	3.94	**47.24**
Reitz	03/13/2010	<0.10	1.30	**<1.40**
89A Bridge	03/13/2010	73.6	1.20	**74.8**
Black Bridge	03/13/2010	9.42	0.17	**9.59**
Beasley Flat	03/13/2010	60.60	1.28	**61.88**

Sampling Site	Date	Suspended Sediment Concentration (in mg/L)		
		Fine	**Coarse**	**Total**
Above Verde Springs	05/22/2010	1.61	35.7	**37.31**
Perkinsville	05/22/2010	5.63	7.18	**12.81**
Reitz	05/22/2010	9.95	0.96	**10.91**
Highway 89A Bridge	05/22/2010	40.7	29.2	**69.9**
Black Bridge	05/22/2010	0.28	0.71	**0.99**
Beasley Flat	05/22/2010	5.27	12.6	**17.87**
Above Verde Springs	07/10/2010	1.00	2.01	**3.01**
Perkinsville	07/10/2010	27.8	0.21	**28.01**
Reitz	07/10/2010	7.75	0.93	**8.68**
89A Bridge	07/10/2010	9.34	1.77	**11.11**
Black Bridge	07/10/2010	30.6	2.67	**33.27**
Beasley Flat	07/10/2010	3.16	0.70	**3.86**
Reitz	09/18/2010	4.57	0.11	**4.68**
89A Bridge	09/18/2010	10.6	0.36	**10.96**
Black Bridge	09/18/2010	7.65	0.10	**7.75**
Beasley Flat	09/18/2010	21.80	0.46	**22.26**
Above Verde Springs	11/20/2010	29.9	24.4	**54.3**
Perkinsville	11/20/2010	2.58	2.86	**5.44**
Reitz	11/20/2010	3.11	1.85	**4.96**
Hwy 89A Bridge	11/20/2010	0.22	1.73	**1.95**
Black Bridge	11/20/2010	2.47	0.14	**2.61**
Beasley Flat	11/20/2010	1.86	0.59	**2.45**
Above Verde Springs	02/26/2011	3.81	2.92	**6.73**
Perkinsville	02/26/2011	5.55	<0.10	**<5.65**
Reitz	02/26/2011	1.75	<0.10	**<1.85**
Hwy 89A Bridge	02/26/2011	3.70	0.39	**4.09**
Black Bridge	02/26/2011	16.0	<0.10	**<16.1**
Beasley Flat	02/26/2011	45.0	0.64	**45.64**
Above Verde Springs	04/23/2011	4.06	5.51	**9.57**
Perkinsville	04/23/2011	0.31	4.45	**4.76**
Reitz	04/23/2011	0.39	3.88	**4.27**
Hwy 89A Bridge	04/23/2011	12.5	8.54	**21.04**
Black Bridge	04/23/2011	<0.10	9.35	**<9.45**
Beasley Flat	04/23/2011	6.88	20.00	**26.88**
Above Verde Springs	06/18/2011	0.59	17.4	**17.99**
Perkinsville	06/18/2011	5.88	5.21	**11.09**
Reitz	06/18/2011	<0.10	4.58	**<4.68**
Hwy 89A Bridge	06/18/2011	8.69	25.8	**34.49**
Black Bridge	06/18/2011	0.49	4.60	**5.09**
Beasley Flat	06/18/2011	0.40	23.3	**23.70**

Sampling Site	Date	Suspended Sediment Concentration (in mg/L)		
		Fine	**Coarse**	**Total**
Above Verde Springs	09/17/2011	4.61	0.33	**4.94**
Perkinsville	09/17/2011	26.80	<0.10	**26.90**
Reitz	09/17/2011	30.10	1.28	**31.38**
Hwy 89A Bridge	09/17/2011	71.40	0.84	**72.24**
Black Bridge	09/17/2011	235.0	1.64	**236.64**
Beasley Flat	09/17/2011	203. 00	0.86	**203.86**
Above Verde Springs	10/22/2011	5.31	2.10	**7.41**
Perkinsville	10/22/2011	1.56	0.27	**1.83**
Reitz	10/22/2011	3.95	1.82	**5.77**
Hwy 89A Bridge	10/22/2011	2.05	2.06	**4.11**
Black Bridge	10/22/2011	3.83	0.29	**4.12**
Beasley Flat	10/22/2011	4.13	0.90	**5.03**
Above Verde Springs	12/10/2011	0.14	1.03	**1.17**
Perkinsville	12/10/2011	<0.10	2.04	**<2.14**
Reitz	12/10/2011	1.15	1.37	**2.52**
Hwy 89A Bridge	12/10/2011	<0.10	2.82	**<2.92**
Black Bridge	12/10/2011	0.30	7.32	**7.62**
Beasley Flat	12/10/2011	1.51	6.30	**7.81**

Summary

Arizona Water Sentinels collected data for selected water quality parameters for five years between December 2, 2006, and December 10, 2011. The suite of water quality parameters included *E. coli* bacteria, total arsenic, total nitrogen, total phosphorus, and suspended sediment concentration. Water Sentinels also made field measurements of DO concentration, pH, EC, TDS, and air and water temperature. Water Sentinels collected hundreds of water samples at six to eight sampling sites along the upper and middle reaches of the Verde River during all seasons in the five-year period, visiting sampling sites on the Verde River five or six times each calendar year.

Although the Water Sentinels' five-year data collection effort was somewhat limited in scope because of laboratory budget and staffing constraints, our datasets provide enough data to reasonably draw several conclusions about water quality of the Verde River for the selected parameters we studied. In general, the dataset indicates that the water quality of the Verde River is good with respect to the parameters summarized in this report.

Microbiological water quality: The *E. coli* bacteria dataset indicates that the Verde River is safe for swimming and water-based recreation such as kayaking, canoeing, and tubing. The dataset shows that the upper Verde River is very clean with only a few, isolated violations of Arizona's bacteria standards to protect human health and recreational use. In five years of data collection, the Water Sentinels obtained 13 sample results out of 194 samples that exceeded the SSM water quality standard for *E. coli* bacteria adopted by the State of Arizona. Over 95 percent of the sample results obtained over the last five years complied with applicable water quality standards for bacteria to maintain and protect water quality for recreation, including full body contact recreational uses such as swimming. The highest number of violations of the *E. coli* bacteria standard was found at the Highway 89A Bridge site near downtown Cottonwood. Our dataset suggests that there may be sources of fecal contamination of the Verde River in the more developed river corridor in the area between Clarkdale and Cottonwood. More frequent monitoring at more sampling sites in this middle reach of the Verde River is recommended to determine possible source[s] of fecal contamination in the area.

Total arsenic: The Arizona Water Sentinels' dataset for total arsenic in the Verde River confirms the findings of previous investigators that total arsenic concentrations in the Verde River are elevated above drinking water standards. Water Sentinels collected 184 water samples for total arsenic analysis over a five-year period. Ninety-eight percent of sample results met the applicable surface water quality standard designed to protect human health from arsenic exposure during recreational use of the Verde River (30 µg/L). Water Sentinels found four violations of the total arsenic surface water quality standard (30 µg/L) over the last five years. In contrast, total arsenic concentrations in samples collected from the Verde River routinely exceed the EPA MCL for arsenic in drinking water (10 µg/L). The dataset shows that only 11 of 184 sample results complied with the 10 µg/L drinking water standard, whereas 94 percent exceeded this standard. Elevated arsenic concentrations in the Verde River are thought to be due to natural causes relating to the geology of the Verde River watershed, caused by the leaching of water infiltrating through the arsenic-bearing soils of the Verde Formation to groundwater, which ultimately is discharged to the Verde River. Our dataset shows that total arsenic concentrations above 10 µg/L in water samples from the Verde River are widespread. We recommend that residents of the Verde Valley who rely on wells for their drinking water have their well water tested for arsenic to determine whether it meets drinking water standards. Water from the Verde River used by public water systems for drinking water supply should be blended or treated to reduce total arsenic concentrations in finished drinking water to less than 10 µg/L.

Nutrients – Total Nitrogen and Total Phosphorus: The Verde River does not appear to have water quality problems associated with excessive nutrient concentrations. The Water Sentinels' dataset documents that TKN concentrations of water samples from the Verde River have been consistently low over the five-year period of record with TKN concentrations ranging from less than 0.2 mg/L to 0.7 mg/L. Nitrate plus nitrite concentrations ranged from less than 0.01 mg/L to a maximum of 1.34 mg/L. These sample results show that water quality of the Verde River with respect to total nitrogen complies with the applicable SSM water quality standard of 3.0 mg/L for total nitrogen. There were no violations of the current SSM standard over the two-year period of time that the Water Sentinels conducted more complete nutrient sampling to permit calculation of total nitrogen concentrations.

Water Sentinels collected 192 water samples for total phosphorus analysis from December 2, 2006, to December 10, 2011. There were no violations of the SSM total phosphorus water quality standard over five years of sampling. The maximum concentration of total phosphorus was 0.644 mg/L from a sample obtained at the White Bridge sampling site on August 16, 2008. This sample result is well below the SSM standard of 1.0 mg/L for total phosphorus. The dataset demonstrates that Verde River water quality with respect to total phosphorus is excellent and consistently complies with the SSM total phosphorus water quality standard.

Suspended Sediment Concentration (SSC): Water Sentinels collected 64 SSC samples on the Verde River over a two-year period (2010 and 2011). We, therefore, have only a limited SSC dataset to interpret. However, this limited dataset indicates that water quality with respect to suspended sediment in the Verde River appears to be good when the river is at base flow. The limited dataset indicates that there were no violations of the Arizona water quality standard of 80 mg/L (a median value based on a minimum of four samples) that applies to the Verde River. Median SSC values ranged from a low of 4.68 mg/L at the Reitz property sampling site to a high of 22.26 mg/L at Beasley Flat. In general, it appears that SSC are, on average, higher in the more developed, middle reaches of the Verde River near the towns of Clarkdale, Cottonwood, and Camp Verde than the average SSC found in the upper Verde River.

Dissolved Oxygen (DO): In general, DO concentrations of the Verde River adequately support healthy populations of aquatic organisms. The total number of DO measurements in the Water Sentinels dataset equals 74 field measurements and DO field measurements range from a low of 2.5 mg/L (White Bridge site on September 19, 2009) to 12.9 mg/L (Bear Siding sampling site on November 21, 2009). The average DO concentration calculated from all valid DO field measurements from the Verde River over the last two years is 7.5 mg/L.

Water Sentinels made 18 field measurements of DO in the Verde River that were less than Arizona's minimum DO water quality standard of 6.0 mg/L that has been adopted to protect aquatic life in the Verde River. Eighteen violations represent approximately 24 percent of all DO field measurements. Eight of the 18 violations of the DO standard were measured at the Above Verde Springs sampling site, which may be due to natural causes relating to low DO concentrations in groundwater discharged to create the base flow of the Verde River at Above Verde Springs.

The other field measurements violating the 6 mg/L water quality standard for DO were scattered among the following sites: Reitz property (2 violations), 89A Bridge (3 violations), Black Bridge (1 violation), White Bridge (2 violations), and Beasley Flat (2 violations). Ten violations out of 74 field measurements represent approximately 13 percent of all of the field measurements. Put another way, 87 percent of the measurements of DO in the Verde River obtained at sites other than Above Verde Springs (almost 9 out of 10 field measurements) complied with applicable water quality standards for DO. Also, it should be noted that six of the 10 violations reported by the Water Sentinels are relatively minor violations of the SSM DO standard with field measurements falling between 5 mg/L and 6 mg/L.

pH: Arizona Water Sentinels' measurements of pH show that the Verde River is slightly alkaline. The minimum pH value measured over the last 5 years was 6.9 S.U at Beasley Flat, a field measurement that is only slightly below neutral at 7.0 S.U. Only two pH measurements in the last five years were below 7.0 S.U. Both field measurements were only slightly below neutral with pH values of 6.9 and 6.99 S.U. Measurements made by Water Sentinels at seven sites on the Verde River over the last five years show that, in general, water quality of the Verde River with respect to pH is good and there is little variability in pH between sampling sites. Measured pH values usually fall within the 6.0 S.U to 9.0 S.U. range established by the Arizona water quality standard for pH to protect aquatic life and wildlife. The vast majority of pH measurements (99 percent) made by the Arizona Water Sentinels in the Verde River were between 6.0 S.U. and 9.0 S.U.

Total dissolved solids (TDS): Water Sentinels' field measurements show that TDS concentrations in the Verde River are typically in the 200 to 300 ppm range. With the exception of three measurements, all Water Sentinels field measurements of TDS (n=168) over the last five years were below the EPA secondary MCL for drinking water of 500 mg/L. More than 98 percent of the Water Sentinels TDS measurements were less than 500 mg/L.

In general, TDS concentrations tend to increase as the Verde River flows downstream from its source at Above Verde Springs to Beasley Flat. However, the increase in average TDS concentration as the Verde River flows downstream is not uniform. Data show that average TDS concentrations are variable, increasing or decreasing in different reaches of the river. This variability in average TDS concentrations at Water Sentinels' sampling sites may be explained by contributions of water from different tributaries with different TDS concentrations, possible irrigation return flows, or discharges from springs with different salinities in different reaches of the Verde River.

Abbreviations and Acronyms

ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
BLM	Bureau of Land Management
cfs	Cubic feet per second
cfu	Colony forming units
DO	Dissolved oxygen
EC	Electrical conductivity
EPA	U.S. Environmental Protection Agency
MCL	Maximum contaminant level
mg/L	Milligrams per liter
µg/L	Micrograms per liter
mL	Milliliter
MPN	Most probable number
SPRNCA	San Pedro Riparian National Conservation Area
SRP	Salt River Project
SSC	Suspended Sediment Concentration
SSM	Single sample maximum
S.U.	Standard Units (a unit of measurement for pH)
TDS	Total dissolved solids
TKN	Total Kjeldahl Nitrogen
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish & Wildlife Service
USGS	U.S. Geological Survey