

Oak Creek Project Report

2021

Oak Creek Watershed Council



Comprehensive Project Report Encompassing All Work Throughout the 2019–2021 Term

A collaborative effort between Arizona Department of Environmental Quality, United States Forest Service, National Forest Foundation, Friends of the Forest, Slide Rock State Park, City of Sedona, and the Sedona Chamber of Commerce and Tourism Bureau

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Executive Summary

The data in this report is a synopsis of the Ambassadors' work from 2019–2021. Included in this is detailed water quality findings primarily focused around the amount of *Escherichia coli* (*E. coli*) found within Oak Creek. Although this bacteria plays a critical role in all natural water bodies, Oak Creek is listed as impaired by the Arizona Department of Environmental Quality because it fails to meet water quality standards for *E. coli*. The maximum standard for a single sample of *E. coli* is 235 **colony forming units** (See definition in Appendix) per 100 milliliter sample. When a sample goes above this value it is an exceedance. Over the three years of water sampling by Oak Creek Watershed Council, there were 369 samples collected between two projects: baseline water sampling occurring on Tuesdays during the summer in Upper Oak Creek and major tributary, West Fork, and through the high impact recreation project occurring on Saturdays before, during and after holiday weekends in the summer. The baseline sampling project yielded one exceedance, across three years of sampling, on the last day of sampling in 2021. On the other hand, the high impact recreation project yielded 17 exceedances across two years of data collection. See data in Table 1.1 and 1.2, and tables in the Appendix (pg.29).

Other project work completed and worth highlighting during the 2019–2021 term include weekly canyon patrol, maintenance of pet waste stations and group cleanup events. This project work removed 2,949.99 lbs through canyon patrol, 4,293.5 lbs through pet waste station maintenance, and 5,750 lbs through group cleanup efforts. Altogether these three projects removed 12,993.49 lbs of trash, feces, and recyclables from the watershed. By simultaneously working to remove trash and potential contaminants from Oak Creek watershed, the overall water quality should have improved.

Also included in this report is detailed information, methods, results and discussion of all five main projects completed by OCWC staff, throughout the 2019–2021 term by Ambassadors Emma and Elise, and Executive Director, Kalai.

Introduction

The Oak Creek Watershed Council (OCWC) worked and collaborated on five main projects throughout the year of 2021. These projects include: a continuation of baseline water quality samples every Tuesday during the high use season, a high impact recreation project including water quality samples on high use weekends, social trail monitoring, and “canyon patrol” which involved OCWC’s ambassadors picking up trash throughout Oak Creek Canyon while providing resources and education to recreationists, a continuation and expansion of managing pet waste stations, education and outreach about municipal separate stormwater sewer systems (MS4), and public group cleanup events. All of these projects occurred within the Oak Creek watershed, a 465 sq. mile basin (Figure 1), with Oak Creek being a tributary of the Verde River, and contributing 61,600 acre-ft/year to the Verde River (Blasch et. al, 2006).

Since 2019, OCWC has collaborated with the Sedona Chamber of Commerce and Tourism Bureau and Slide Rock State Park to collect baseline water quality samples every Tuesday beginning in June and ending the Tuesday after Labor Day weekend. These samples are taken at four different sample sites, two retrieved from Oak Creek, and two from West Fork, a main

tributary into Oak Creek, including a rotating site duplicate sample, totalling five samples retrieved every Tuesday. Recognizing that there has seldom been water quality samples taken on Oak Creek north of Slide Rock State Park, it was crucial these sites were chosen in order to build a complete picture of the water quality in Oak Creek. Between June 1–September 7, 2021, 60 samples were retrieved by OCWC (including duplicates) with one exceedance. OCWC retrieved 64 Tuesday samples in 2020 and 56 samples in 2019. The difference in the number of samples collected between 2019 and 2021 is due to, firstly, the addition of a fourth sampling site near the end of the 2020 season, secondly, due to the forest closure on the Coconino National Forest between June 23–July 6, 2021 therefore, no samples were collected.

Starting in 2020, OCWC received grants from the Arizona Department of Environmental Quality (ADEQ) and the National Forest Foundation (NFF) to monitor high impact recreation (HIR). This includes water quality sampling before, during, and after predicted high use weekends like July 4th and Labor Day. OCWC was tasked to sample at seven different sites along Oak Creek within Oak Creek Canyon, including a duplicate sample at one of the sites.. These sites include: Oak Creek near Cave Springs campground, Gabion Pool, Bootlegger, Banjo Bill, Halfway, Grasshopper Point, and Midgley Bridge. Between March 20–October 17, 2021, OCWC collected 110 samples (including duplicates) and saw eight exceedances over 13 sampling days. In 2020, 79 samples were collected from May–September and nine exceedances were recorded.

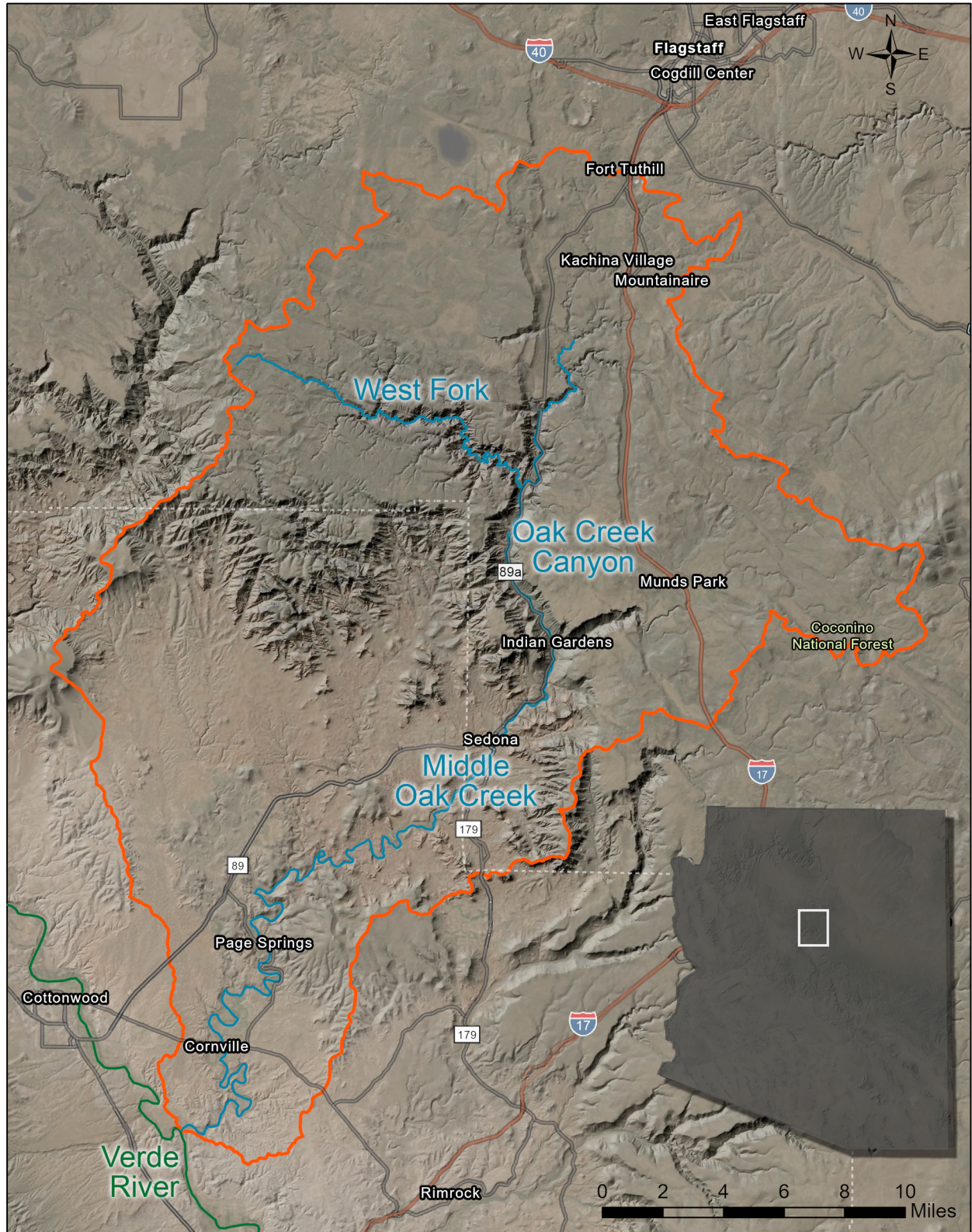


Figure 1. Map of Oak Creek watershed. The watershed boundary is shown in orange, Oak Creek is shown in blue, and Verde River is shown in green.

Coinciding with the HIR project, OCWC monitored pullout closures and improvements by doing a “canyon patrol” at these pullouts and day use sites located within Oak Creek Canyon. Monitoring included trash pick up and data collection by the Ambassadors of OCWC, education about leave no trace principles to recreationists, and passing out trash bags to recreationists who needed or wanted a trash bag. Ambassadors noted that in 2021 trash and overall use of the canyon was lower in comparison to the 2020 season. In 2021, Ambassadors have picked up 1,124.25 lbs of trash, feces, and recyclables from 37 sites.

The third and final piece of the HIR project includes the monitoring of social trail closures and improvements using photo point monitoring and public group cleanups. OCWC photo point monitored 14 different social trails within Oak Creek Canyon, seven naturalized and seven rehabilitated trails, from September 2020–September 2021. These sites were chosen based on treatment type and the timing of when the treatment was implemented.

Since 2013, OCWC has partnered with the United States Forest Service (USFS), the City of Sedona, and private stakeholders to reduce the amount of pet waste (pet fecal matter) in the watershed. In total, 28 pet waste stations have been maintained between 2014–2020, six of those maintained by OCWC, 13 maintained by private stakeholders, and nine maintained by the City of Sedona. In 2021, OCWC received funds from ADEQ to purchase and install an additional 37 partial and full pet waste stations as a part of the Oak Creek watershed restoration action plan (OCWRAP). OCWC now manages 14 partial and full pet waste stations, Slide Rock State Park manages three full stations, and Recreation Resource Management manages 17 partial and full stations. Four additional stations are to be installed once cleared by USFS for archeological reasons.

In the past, OCWC has worked with the City of Sedona to promote awareness about the municipal separate stormwater sewer system (MS4) that occurs in Sedona. This included helping install informational placards on city curbs above stormwater grates, canvassing businesses and private homes, and education and outreach through: newsletters, social media posts, tabling events, and presentations. During the year 2021, Ambassadors educated the public about the MS4 through tabling events, newsletters, and social media posts. It is crucial that residents and visitors alike understand the MS4 so that they can practice both best management practices on their property, such as sparingly using fertilizer and pesticides, and keeping a well maintained car. Or as a recreationist, practice leave no trace principles like packing out their trash and picking up their pet’s waste while on trail to reduce nonpoint source pollution into Oak Creek.

Lastly, OCWC has held at minimum, 10 cleanup . These cleanups have been an important tool for OCWC in order to remove trash, provide education to the public, and build land stewardship within the surrounding community. In the past year, some cleanup events were implemented at targeted areas within the watershed in order to further monitoring efforts. This included holding trash pickups at areas where photo point monitoring was taking place, and involved noting the amount of litter on both closed and improved social trails to the creek, an effort funded by the NFF.

Other cleanups included the extremely successful “Pickin’ up in the Pines” events, which during 2021, removed an estimated 2,400 lbs of trash, one in May and one in September, which included many makeshift toilets or “honeypots” near Pumphouse Wash, a tributary near the headwaters of Oak Creek. Cleanup events were also held within the City of Sedona to encourage MS4 education and cleanliness of the city.

Overall, OCWC saw a successful year in regards to current and new projects for 2021 concerning the health and integrity of the watershed. Moving forward, we will discuss the timelines of all projects between the years 2019–2021, and methods we used for each project concerning water quality, social trail monitoring, pet waste station data collection, and canyon patrol parameters. Furthermore, we will present the results and final numbers for water quality, pet waste, public cleanups, and canyon patrol, while comparing and discussing these results with previous years.

Timeline

The figures below depict timelines for the five main OCWC projects. Figure 2 shows the overall project timeline including MS4 outreach and education, Tuesday baseline water quality sampling and public cleanup event efforts. Figures 3–4 show the progress of the HIR project, and the PWS project. These timelines span from 2019–2021, and show how each project started, progressed, and were maintained during the past three years. It is worth it to note that these projects were impacted by the COVID-19 pandemic, and progress on these projects were delayed, but have since been completed.

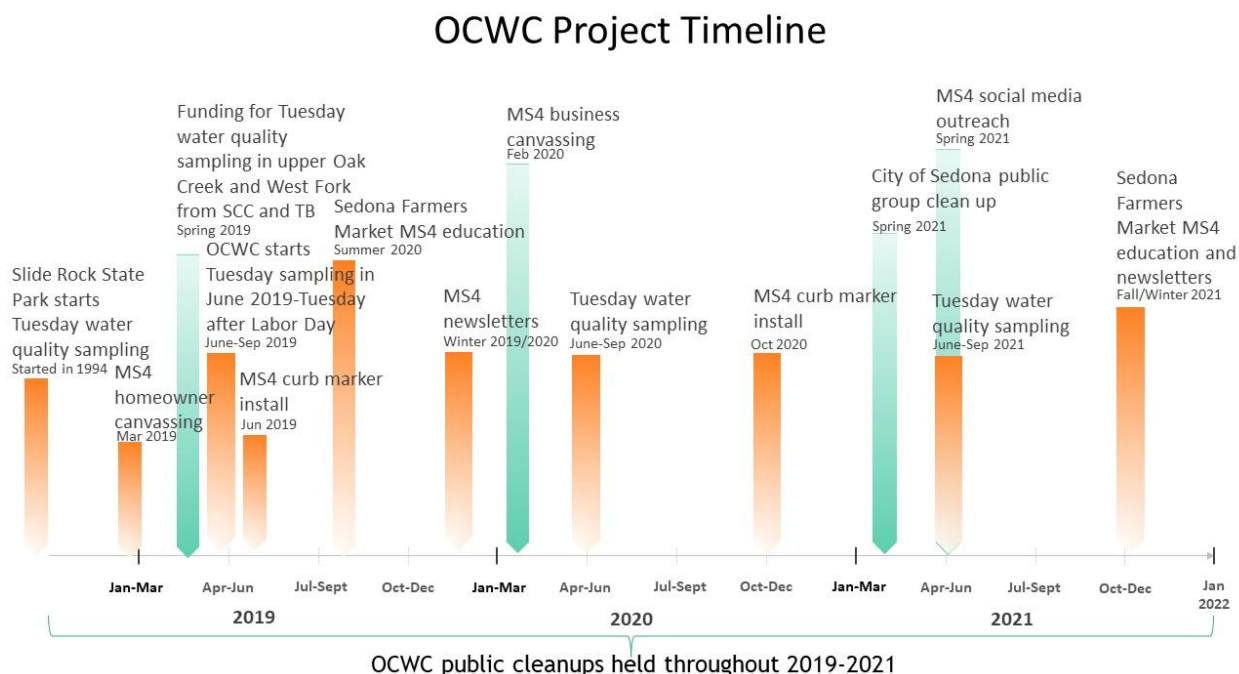


Figure 2. Oak Creek Watershed Council overall project timeline. Depicts the continuation of public cleanup events, MS4 outreach and education, and the start of baseline water quality sampling.

OCWC High Impact Recreation (HIR) Project Timeline

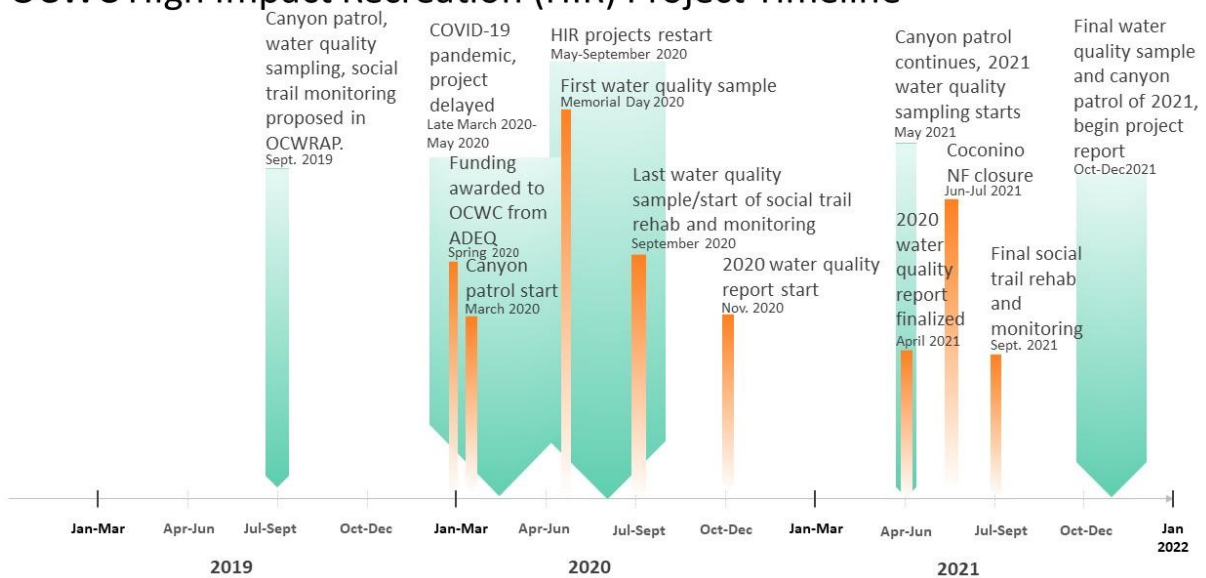


Figure 3. High impact recreation project timeline. Proposed in Fall of 2019 in the OCWRAP and progressed through both years 2020–2021.

OCWC Pet Waste Station Project Timeline

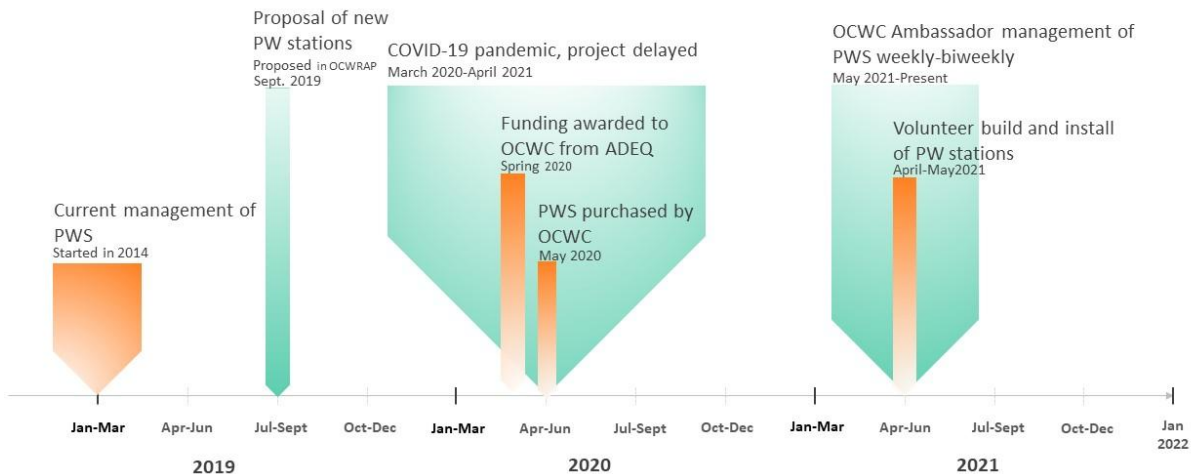


Figure 4. Pet waste station project timeline. An increase in pet waste stations around the watershed proposed in Fall of 2019 in the OCWRAP, paused in 2020 and finalized in 2021.

Methods

Tuesday Baseline Water Quality Samples:

Beginning in 2019, OCWC collected surface water samples for *E. coli* and **turbidity** (See definition in Appendix) in the upper part of Oak Creek Canyon and West Fork. Samples were collected in IDEXX 100 mL sample bottles each Tuesday morning from June 1–September 7 with the exception of a four-week hiatus from mid-June to mid-July due to the Coconino National Forest closure. The four sample sites were Pine Flats Subdivision (from the bridge), Oak Creek above the confluence with West Fork, West Fork above the confluence with Oak Creek, and West Fork at the second creek crossing (along the West Fork trail; Figure 5). Initially, in 2019 and most of the 2020 season, there were three sampling sites. The fourth site, Oak Creek above the confluence with West Fork, was added on the 12th week of sampling and only four samples were recorded for this site in 2020 (See tables A2–A5 in Appendix). Duplicate samples were collected for quality assurance each day of sampling. Turbidity samples were collected for each sample site and Ambassadors used a portable HACH turbidimeter in the field.

Samples were taken to SRSP to be processed in the State Park's facility. The data was recorded on paper and picked up by Ambassadors the following week where it was then recorded onto Google Sheets and entered into ADEQ's Data Portal.

HIR Water Quality Samples:

OCWC sampled over 13 dates from March to October 2021 before, during and after predicted high use weekends. In 2020, OCWC sampled over 11 dates from before Memorial Day Weekend to after Labor Day Weekend. All samples were collected on Saturdays or Sundays. High use weekends include Northern Arizona University's spring break, Memorial Day weekend, Fourth of July weekend, the weekend before school started in August, and Labor Day weekend. However, due to the forest closure in June and July of 2021, sampling dates were added in October to make up for the loss of data. Sampling sites are Cave Springs, Gabion Pool, Bootlegger, Banjo Bill, Halfway, Grasshopper Point, and Midgley Bridge (Figure 5). *E. coli* samples were collected in 100 mL IDEXX bottles. A turbidity sample was collected at each site and a duplicate collected each sampling day for quality assurance. Samples were placed on ice and brought to Natural Channel Designs Laboratory in Flagstaff where Ambassadors processed and analyzed *E. coli* bacteria concentrations using the IDEXX QuantiTray method. Samples were fed the **colilert-18 medium** (See definition in Appendix) and were counted 18 hours after incubation. Turbidity was found by using a HACH turbidimeter in the field.

One stormwater sample was collected at Cave Springs. To process the stormwater sample it went through three dilutions using DI water. First, it was processed as the original 100 mL sample. Then 10 mL of stormwater was added to 90 mL of DI water and processed. Then 1 mL of stormwater was added to 99 mL of DI water and finally 0.1 mL of the original sample was added to 99.9 mL of DI water.



Figure 5. Map of OCWC surface water quality sampling sites. Red stars indicate the Tuesday baseline sampling sites and yellow stars indicate the weekend sampling sites.

HIR Canyon Patrol:

Canyon patrol was conducted at 37 sites in Oak Creek Canyon including 11 day use areas and 26 open pullouts. During the high use season, Ambassadors focused on canyon patrol each weekend and targeted cleaning up areas throughout Oak Creek Canyon and where weekend water quality samples were taken. During the off season, Ambassadors patrolled 2 to 3 times per month. Ambassadors monitored the amount of recreators, dogs, and specific trash parameters such as number of diapers, glass bottles, and toilet areas found. The total weight of trash was recorded. Totals were entered into a spreadsheet and then submitted to the ADEQ Survey 123 portal.

HIR Photo Point Monitoring:

OCWC's role in the social trail closure and rehabilitation project was to monitor the effectiveness of the different treatments done to trails. This was conducted by doing repeat photography at 14 different social trails over six dates within a one year timespan. Monitoring also included holding cleanup events at these social trails to gauge the effectiveness of the rehabilitation and closures in relation to litter. The project began with monitoring social trails before receiving treatments in September 2020. The sites that were monitored were near Halfway, Gabion Pool, Cave Springs, and Pine Flats. By November 2020, most treatments were completed however, Halfway and Gabion Pool had not yet received treatments and were therefore no longer monitored after November. In the spring of 2021, four new treated social trails were added from near Manzanita Campground and monitoring continued throughout the summer until September 2021.

Pet Waste Stations:

Biweekly in the low use season and weekly in the high use season, Ambassadors visited the 14 different pet waste stations maintained by OCWC. Total weight and approximate percentage of contaminants from the receptacle was recorded into the ADEQ Survey 123 Pet Waste Portal. New bags were added to the dispenser when needed and recorded in the Pet Waste Portal. Transect walks were completed at four sites where an additional pet waste station may be added farther down the trail. Total number of bagged and unbagged dog feces were recorded as well as any trash seen on these trails within 500 feet from the trailhead.

MS4:

Outreach and education of Sedona's MS4 was conducted through canvassing homes and businesses, performing curb marker installations (See figure A4 in Appendix), tabling at the Sedona Community Farmers Market with the visual relief model (See figure A5 in Appendix), and by the creation of social media posts and newsletters.

Public Group Cleanup Events:

Outreach done in order to gain volunteers for cleanup events was done two different ways. The first was using the emailing list service Mailchimp, the second was using Instagram and Facebook posts to announce cleanups one to two weeks before a cleanup.

Once volunteers arrived for a cleanup, OCWC introduced themselves as a group, and went over safety matters that included: what to look out for, such as any suspicious items, drug

paraphernalia, areas with fecal matter, steep slopes with trash, and any items that looked to be over 50 years old. OCWC's number one concern for volunteers is their safety, and has been vigilant in preventing injury or exposure to illness through a cleanup event. Including this, per the Archeological Resources Protection Act of 1979, one is not allowed to remove any items occurring on federal or native land that is over 50 years old, even if it was clearly a piece of litter (ex. a rusty pop top can and rusty large metal cords). Due to this act, OCWC always informed volunteers to not remove anything rusty in accordance with this act.

Cleanups typically last for about two hours from the arrival to the departure of volunteers. Once most of the litter has been gathered, OCWC Ambassadors and Executive Director would sort and separate trash from recyclables, and fecal matter, and weigh each category separately, with an overall total weight recorded for litter collected during the cleanup.

Results

Tuesday Baseline Water Quality Samples:

Each Tuesday morning from June 1st through September 7th, both Oak Creek Watershed Council and Slide Rock State Park collected water quality samples. Altogether, there were 132 samples collected within 12 weeks in 2021. The percent of exceedances of *E. coli* bacteria found across all nine sites is 0.75% (See table A1 in Appendix). This indicates that 99.25% of the data points analyzed from this study show water quality below and within the State of Arizona's 235 most probable number (MPN) of colony forming units per 100 milliliter recreational water quality standard for *E. coli* in surface waters. Separately, OCWC captured one exceedance on 9/7/2021 at the West Fork at the Second Crossing site but SRSP did not capture any exceedances during the 2021 study period. These samples are not indicative of high recreation. Instead, they serve as a baseline for summertime water conditions near the headwaters of Oak Creek.

On June 15th, OCWC samples show a wide range from 4.1 to 155.3 MPN/100 mL, but SRSP samples only range from 15 to 46 MPN/100 mL (See table A1 in Appendix). Samples collected on July 27, 2021 show the highest consistent ranges of *E. coli* following monsoons on July 24th and 25th and stormflow throughout the day of the 26th (Figure 6). OCWC samples range from 128.1 to 218.7 MPN/100 mL and SRSP samples show a similar range from 108.1 to 172 MPN/100 mL on July 27th.



WFC sample site on Jul. 20, pre-flood.



Flood water seen at WFC on Jul. 24.
No samples were collected.



WFC sample site on Jul. 27 post-flood.
Notice vegetation cleared from flood.

Figure 6. West Fork at the confluence with Oak Creek sample site shown before, during and after flood event with flood waters seen on the 24th of July.

Throughout the month of August, both agencies' samples showed relatively low values of *E. coli* (See table A1 in Appendix). The maximum sample in August was on the third and showed 83 MPN/100 mL. The minimum value in August was 13.4 MPN/100 mL captured on August 10th. The average *E. coli* concentration in Oak Creek and West fork in August was 40.4 MPN/100 mL.

The last baseline sampling date for 2021 on September 7th shows a dramatic range between the two agencies' results (See table A1 in Appendix). OCWC samples range from 35 to 238.2 MPN/100 mL, showcasing a range of over 200 colony forming units, whereas SRSP samples only range from 40 to 72 MPN/100 mL.

In 2020, OCWC did not capture any exceedances but SRSP saw two exceedances on 9/8/2020 at two different but adjacent locations. Therefore, with 148 samples collected between the two agencies in 2020, the percent exceedances of *E. coli* bacteria found across all nine sites was 1%. In 2019, OCWC collected 56 samples across three of the same sites and did not see any exceedances, therefore provided 0% exceedances for baseline samples. Of all OCWC samples collected in the baseline data set, (180 samples), there was only one exceedance seen.

The **geometric mean analysis** (See definition in Appendix), of all sample sites shows that *E. coli* numbers stayed well below the 235 MPN/100 mL standard during this study (Table 1.1). Of the four baseline sample sites, West Fork at the Second Crossing (site WF2) had the highest geomean with a value of 40.6 MPN/100 mL. West Fork at the Second Crossing was the site of the single exceedance per the baseline dataset and the sampler's notes recorded that no one crossed the creek as the sample was collected. Oak Creek at the confluence with West Fork or "OCC" had the lowest geomean with a value of 24.3 MPN/100 mL. But in 2020, the same site had the highest geomean of the baseline data set with a value of 52.67 MPN/100 mL. Although,

only four weeks worth of data were collected for that site (see table A3 in Appendix). The site with the lowest geomean in 2020 was Pine Flats, “PF”, with a value of 13.83 MPN/100 mL.

In 2019, West Fork at the Confluence with Oak Creek had the lowest geomean with a value of 24.3 MPN/100 mL (Table 1.2). Pine Flats, the farthest upstream sample site, had a geomean of 30.6 MPN/100 mL. West Fork at the Second Crossing had the highest geomean in 2019 with a value of 37.3 MPN/100 mL.

Table 1.1 All Oak Creek samples taken by OCWC results, including *E. coli* minimums, maximums, and geometric means. Site names are in order as follows: Pine Flat, Cave Springs, Gabion Pool, Oak Creek above the confluence, West Fork above the confluence, West Fork at the second crossing, Bootlegger, Banjo Bill, Halfway, Grasshopper Point, and Midgley Bridge.

Site	2021 E. coli (MPN/100 mL)			2020 E. coli (MPN/100 mL)		
	Max	Min	Geomean	Max	Min	Geomean
PF	218.7	0	27.6	50.4	2	13.83
CS	>2,419.6	1	47.2	316.9	2	45.85
GP	214.3	4.1	32.3	193.5	6.3	44.16
OCC	128.1	2	24.3	93.3	33.1	52.67
WFC	214.2	12	37.2	96	9.8	32.2
WF2	238.2	5.2	40.6	116.2	11	34.26
BL	214.3	3.1	22	125.9	5.2	20.17
BB	193.5	2	18.1	>2,419.6	3.1	17.69
HW	325.5	0	33.4	499.6	5.1	44.28
GR	488.4	1	25.4	1,986.3	14.6	107.98
MB	260.3	3.1	24	307.6	9.6	46.94

Table 1.2 OCWC Baseline Data from 2019.

Site	2019 E. coli (MPN/100 mL)		
	Max	Min	Geomean
PF	224.7	1.1	30.6
WFC	104.6	5.2	24.3
WF2	127.4	10.9	37.3

HIR Water Quality Samples:

During the 2021 study, the percent of exceedances of *E. coli* bacteria found across all seven sites, 110 total samples, was 7.27%. That indicates that 92.73% of the data points analyzed from this study show water quality below and within the State of Arizona’s 235 MPN/100 mL

recreational water quality standard for *E. coli* in surface waters. This represents that the watershed, although highly utilized by human and wildlife traffic, measured *E. coli* bacteria exceedances 7.27% of the time between the 13 weekend sampling dates from March–October 2021.

There were eight exceedances captured by OCWC at four sites during the study in 2021. Those four sites are Cave Springs, Halfway, Grasshopper Point and Midgley Bridge. In 2020, nine exceedances were seen at five sites, the same four sites listed above with an additional single exceedance at Banjo Bill. Therefore, throughout the combined study periods (2020 and 2021) the percent exceedance is 8.99%. Indicating that over two years of high impact recreation data collection, water quality was in exceedance nearly 9% of the time according to the State of Arizona’s 235 MPN/100 mL recreational water quality standard for *E. coli* in surface waters.

The geometric mean analysis of all sample sites shows that *E. coli* numbers stayed well below the 235 MPN/100 mL standard during this study (Table 1.1). Cave Springs (site “CS”) had the highest geometric mean value during 2021 for *E. coli* with 47.2 MPN/100 mL. Cave Springs, with five exceedances over the sampling period, including one duplicate, one stormwater sample and the stormwater sample diluted to 10% of the original, had the most occurring number of exceedances (See table A6 in Appendix). The highest geomean in 2020 was Grasshopper Point with 107.98 MPN/100 mL. Grasshopper Point, with three exceedances, had the most number of exceedances in 2020 (See table A6 in Appendix).

Banjo Bill (site “BB” in Table 1.1) had the lowest geomean in 2021 and 2020 showing 18.1 and 17.69 MPN/100 mL, respectively. In 2020, it was the site with the single highest exceedance recorded at 2,419.6 MPN/100 mL. However, Banjo Bill is a site with consistently low values of *E. coli*, hence the lowest geomean for both years of sampling.

Results show that throughout the peak recreational season of May through September, 2020–2021, *E. coli* concentrations stayed below the State’s recreational water quality maximum of 235 MPN/100 mL 91% of the time (See table A6 in Appendix). Exceedances were seen in May, July, August, and September and often occurred over holiday weekends and during stormwater events but were not limited to either.

HIR Canyon Patrol:

Coinciding with weekend water quality sampling, OCWC Ambassadors continued canyon patrol efforts. In 2021, Ambassadors removed 1,124.25 lbs of trash, 65 diapers, and 233 glass bottles (Table 2). In comparison to 2020 (See table 2 and figure A1 in Appendix), there was less trash removed by 701.49 lbs, 101 diapers, and 180 glass bottles. 2020 totals include 1,825.74 lbs of trash, 166 diapers, and 413 glass bottles removed.

Table 2. Canyon Patrol Project Totals 2020–2021. Locations with asterisks are sampling sites and a double asterisk indicates a sampling site that was challenging to access for trash pick up efforts. A location without an asterisk was not sampled for water quality. Sites organized from upstream to downstream locations.

Location	Trash collected in pounds	2020	2021
Piped Spring		15.03	45.08
Pine Flat*		108.4	66.31
Cave Springs*		206.56	159.84
Gabion Pool**		45.42	42.88
West Fork**		23.75	22.13
Bootlegger*		59.91	42.66
Banjo Bill*		87.23	27.68
Halfway*		289.35	225.23
Manzanita		102.65	56.86
Encinoso		405.87	137.89
Oak Creek Visitor Center		277.1	86.19
Grasshopper Point**		118.4	147.48
Midgley Bridge**		86.07	64.02
	Total Trash Collected	1,825.74	1,124.25

HIR Photo Point Monitoring:

The four trails monitored near Manzanita Campground from April–September 2021, were closed social trails with treatments including rock dam, brush chute, and fence and signage (Figure 7). All four trails monitored at this site saw noticeable use, either with trash left behind or seeing people use the trail even with the treatments.



Figure 7. Social trail #90 near Manzanita Campground monitored four times from April–September 2021. In frame A, treatment was completed with the fence and signage but brush treatment was moved. Frames B and C show brush treatment was still in place but by September, frame D, brush was moved out of the way again.

The six sites monitored at Cave Springs from September 2020–September 2021 included three rehabilitated trails with log steps for stabilization, and three closed and naturalized trails with rocks and brush treatments. The three stabilized social trails were noted as frequently used trails to access the creek and were holding up well from the treatments (Figure 8). Two of the closed social trails remained effective and showed no signs of use whereas the third was not as effective and visitors were seen navigating around the log barrier treatment to access the social trail.



Social trail #42 made by recreators for creek access monitored before treatment on Sep. 23, 2020.



Social trail #42 shown rehabilitated with log steps for stabilization and continued access to creek on Jul. 29, 2021.

Figure 8. Social trail #42 near Cave Springs Campground left open for continued creek access.

The monitored sites at Pine Flats included three closed social trails. It was noted that the treatments at all trails were effective but at two sites new social trails were created for visitors to access the creek around the closures. These sites will require continued maintenance (Figure 9).



Figure 9. Social trail #28 near Pine Flats. Frame A shows the trail pre-treatment in September 2020. Frame B shows the trail recently after completion in Nov. 2020. Frame C shows the brush treatment is dead by August 2021 and frame D shows recent maintenance with more brush added in September 2021.

OCWC held three cleanup events at areas where social trail rehabilitation, closures, and monitoring occurred along pullouts within Oak Creek Canyon. These cleanup events were done in order to monitor the effectiveness of the social trail rehabilitation and closures in relation to trash left in the area. Over the three cleanup events, OCWC and volunteers removed 145 lbs of trash from these sites. These sites were also monitored by Ambassadors through canyon patrol, where Ambassadors removed 193.34 lbs of trash. In total 338.34 lbs of trash was removed from these sites.

Pet Waste Stations:

Since 2019, OCWC has removed 4,293.5 lbs of pet waste from USFS pet waste stations (See table A8 in Appendix). The amount of waste increased every year, particularly during 2021 with the addition of four new stations in May 2021, with a differential increase of 1,044.2 lbs between 2020 and 2021. In 2021 alone, 2,234.8 lbs of pet waste was collected from ten sites (See figure A2 in Appendix). It is important to note that these weights also include contamination that includes but is not limited to: food and beverage waste, diapers, glass bottles, paper waste, etc. This contamination was not pulled or weighed separately due to the nature of pet waste and the COVID-19 pandemic. However, percent contamination was estimated and recorded.

MS4:

Since 2019, OCWC has collaborated with the City of Sedona to educate and promote proper MS4 practices. OCWC did this by posting 11 social media outreach posts in 2021, six canva style posts for the fiscal year of 2020, four Instagram reels and one picture for the fiscal year of 2021. Including this, in 2019, ambassador, Emma and executive director, Kalai canvassed ~60 homes to inform residents of proper MS4 practices on one's property. In early 2020, Ambassadors canvassed ~10 businesses in the City of Sedona in order to gain permission to install "no dumping" placards (See figure A4 in Appendix) on the business' property where storm grates are located. Once permitted, Ambassadors and a City of Sedona employee installed these placards on local business properties, and in 2019 helped the City of Sedona employee replace any damaged or missing placards on city property.

In previous years, OCWC has tabled at events like the Sedona Community Farmers Market to promote education about the MS4 to residents and visitors. Educational tools like a shaded relief map (See figure A5 in Appendix) depicting storm drainages and washes draining into Oak Creek, along with Ambassadors explaining and informing people about why it is important to have strong MS4 ethics and practice leave no trace while living and visiting in Sedona. Tabling events occurred in 2019 and 2021, as the COVID-19 pandemic did not allow OCWC to table at events in 2020. In 2021, Ambassadors talked to 225 people for an estimated time of 915 minutes, or over 15 hours, about the MS4 to residents and visitors at the Sedona Community Farmers Market over the course of six Sundays.

Social media posts aimed to educate Instagram and Facebook users about Sedona's MS4 reached 2,385 accounts in 2021. Four of these social media posts were Instagram "Reels", which are short minute long videos that people watch. These reels were played 5,441 times as of 12/30/21 at 1:00 pm, and is continually growing as it is shared online. Out of the four posts so

far regarding MS4 in the fiscal year of 2021, OCWC has seen 174 “likes” in total. As mentioned previously, this number may grow as posts get shared and spread online. In the fiscal year of 2020, OCWC made six Canva posts to educate people about the MS4. For these six posts, OCWC saw a total of 109 “likes”.

Public Group Cleanup Events:

From 2019–2021, OCWC held 19 cleanup events throughout the watershed, collecting 5,750 lbs of trash, recyclables, and fecal matter (See table A9 in Appendix). In 2021 alone, OCWC group cleanup events removed 3,037 lbs of trash, recyclables, and fecal matter (See figure A3 in Appendix) over ten cleanup events. OCWC’s most successful group cleanup events during 2021 were the two “Pickin’ Up in the Pines” events held on Forest Roads 237 and 535 at designated dispersed campsites. These campsites occur near Pumphouse Wash, a major tributary near Oak Creek’s headwaters, and is a popular area for people to camp since it is a fee free campsite, and is close to Oak Creek Canyon, Sedona, and Flagstaff. Yet it is often left degraded by campers who leave trash and fecal matter, and build unauthorized fire pits and pit toilets (honeypots). With collaboration and help from the USFS and NFF, these two cleanup events removed an estimated amount of 2,400 lbs of trash over the course of just a few hours per cleanup. Including the eight other cleanup events during 2021, OCWC removed more than half of the total weight for all cleanup events that have occurred since 2019 in 2021.

Discussion

Tuesday Baseline Water Quality Samples:

The three year compilation of baseline data should be used to inform land managers of the water quality in the **inconclusive reach**, (See definition in Appendix), of West Fork and near headwaters of Oak Creek at Pine Flat. This data should be used to aid land managers in making a decision on Oak Creek’s impairment status in the future.

The USGS streamgage below (Figure 10) shows the water flow in Oak Creek decreasing throughout the month of June. June is the hottest and driest month of the year in Arizona so seeing water in Oak Creek range from 24-28 cubic feet per second (cfs) is normal. However, this June was exceptionally dry as fires broke out across the state and the Coconino National Forest closed from June 23rd through July 6th. By July 13th, monsoon rains flooded into Oak Creek and brought the stream up to 299 cfs at 5 p.m. Ambassadors sampled on the morning of the 13th while Oak Creek was still at 27 cfs and missed the stormflow when sampling.

The biggest flood of the summer was seen on July 24th when Oak Creek streamflow peaked at 1,530 cfs (Figure 10). By the 27th when the Ambassadors were back to sample, the creek was flowing at 47 cfs. This was higher than the near 30 cfs the creek is normally flowing at and explains the generally higher results in *E. coli* seen that day (See table A1 in Appendix).

As mentioned in the results section, the month of August showed low numbers of *E. coli* samples. Samples were collected on the 3rd, 10th, 17th, 24th, and 31st between 8 a.m. and noon of each week. The streamgage below shows an early peak in August but by the sampling day on the 3rd, the creek was near normal at 30 cfs and remained that way until the 17th. The

17th is another day of missed storm activity. In the morning during collection time, the creek was at 31 cfs but by 4:30 p.m., the creek reached 208 cfs and continued to increase to the second tallest peak in the figure at 911 cfs on August 18th at 6:07 p.m. When samples were collected on the 24th and 31st, the creek was back towards normal cfs. Thus, explaining a month of low E. coli numbers in terms of missed storm activity.

The single exceedance captured in this baseline study on September 7th at the West Fork at the second crossing site is unique. In the three years of baseline sampling this is the only exceedance seen. While the sampler's notes indicate that no one crossed the stream during collection, it is therefore unlikely that kicked up sediment caused an exceedance and the exceedance likely came from contaminated water from upstream from any source. Sources may include but are not limited to dog feces, human feces, and wild animal feces.

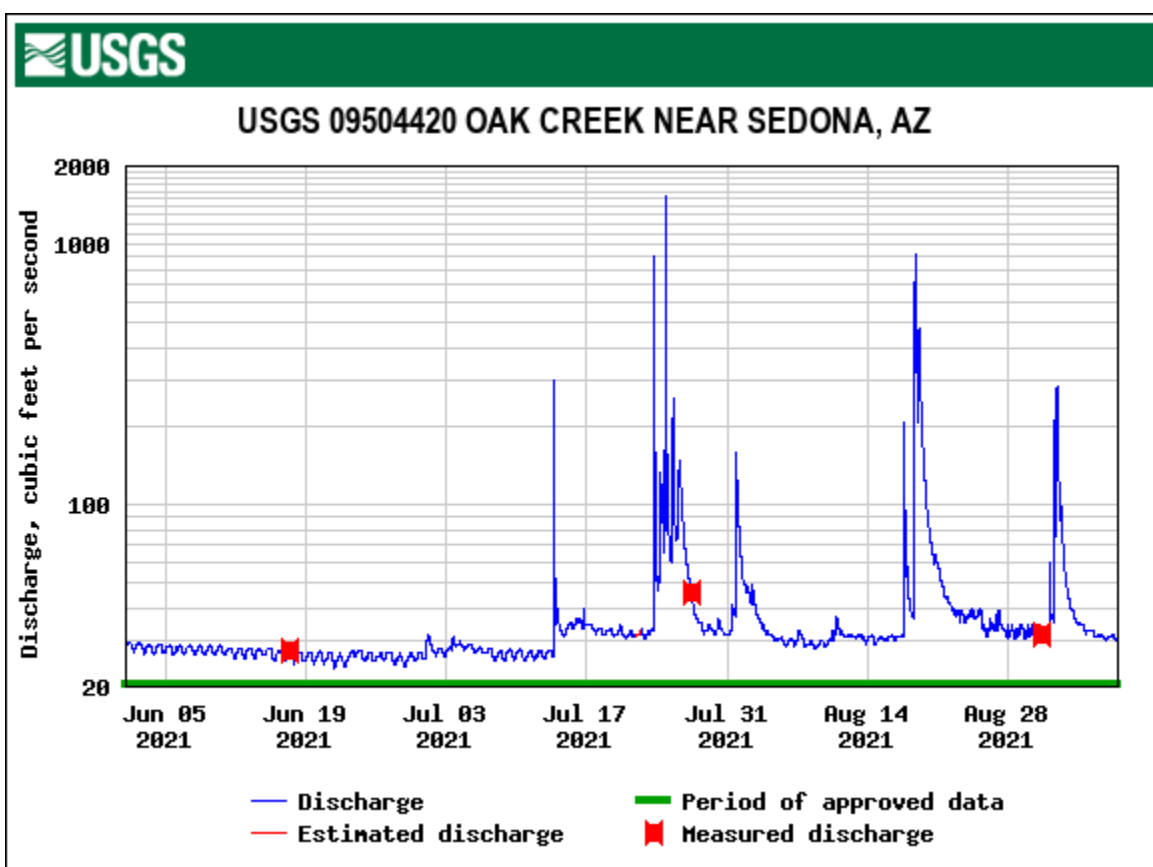


Figure 10. USGS streamgage data from Oak Creek near Sedona showing flow measurement in cubic feet per second (cfs) from June 1–September 7, 2021.

HIR Water Quality Samples:

Samples collected through the HIR project are to inform land managers of potential capacity issues and how high recreation affects water quality in Oak Creek Canyon. The data collected over the high use seasons from 2020 and 2021 are unique because the COVID-19 pandemic set recreation in Oak Creek Canyon to an all time high.

The USGS streamgage below (Figure 11), shows an early peak at 220 cfs on March 19th. OCWC's first HIR sampling day was the next day, March 20th, during NAU's spring break, however the rain and snowmelt didn't make for great spring break creekside activities. The creek was flowing at 110 cfs during sample collection on March 20th and while that is higher than normal, all samples showed low concentrations in *E. coli* bacteria ranging from 5.2 to 19.5 MPN/100 mL (See table A6 in Appendix). The low values in *E. coli* are likely because there was little human recreational activity in the water due to cold water temperatures in Oak Creek. Water temperatures ranged from 8.12 to 12.24 degrees Celsius (or 46.6 to 54 degrees Fahrenheit). Also, snowmelt is less rapid than rainwater. Higher water levels from snowmelt tends to be clear or slightly cloudy, while rainwater/stormwater is more **turbid** (See definition in Appendix), therefore bacteria is more likely to latch onto sediment particles suspended in the water column during stormwater events.

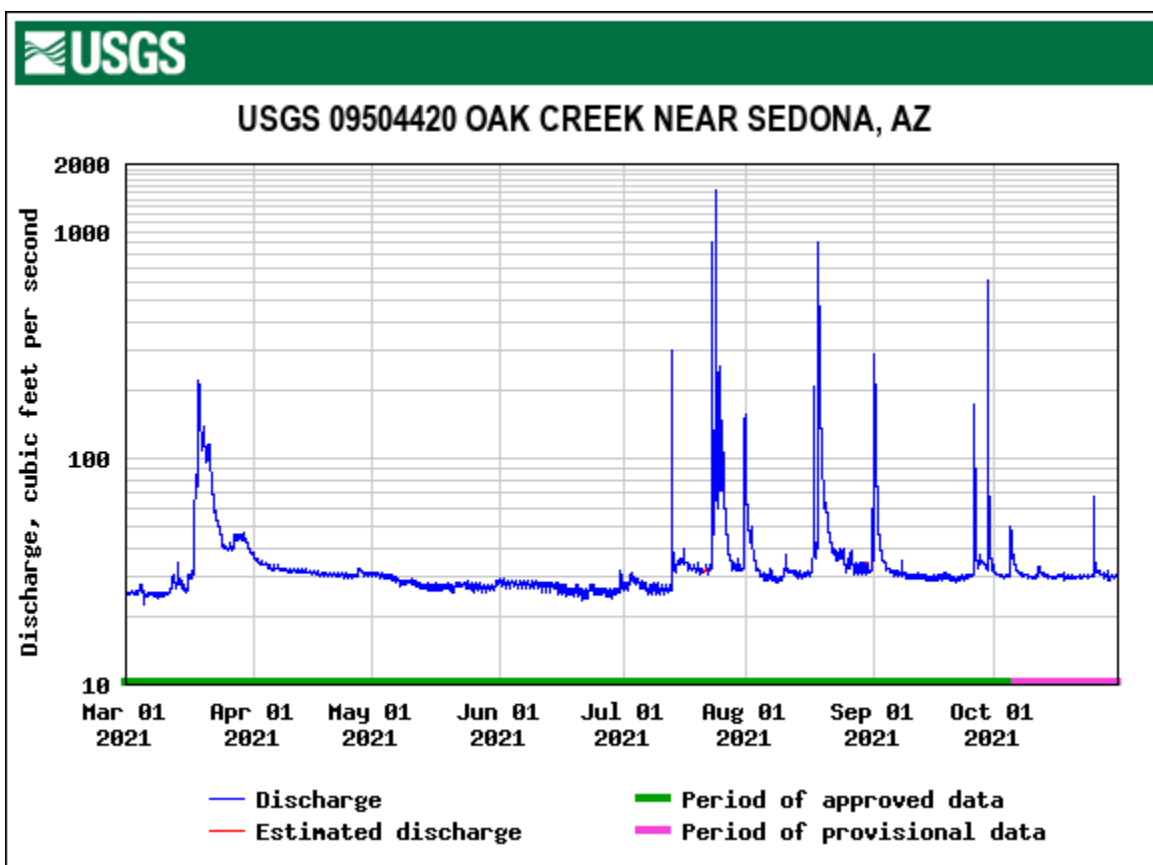


Figure 11. USGS streamgage data from Oak Creek near Sedona throughout the duration of HIR sampling project.

Sampling on July 31st began as a rainy day and the first samples collected included the duplicate at Cave Springs. Rain receded 20 minutes prior to sample collection and both the sample and duplicate from Cave Springs were exceedances showing 274.5 and 387.3 MPN/100 mL. As the sampling day continued no sign of stormwater caught up to us as we continued sampling downstream. We collected all our samples from the seven day use sites and added two additional sites, both upstream of the popular swimming holes at Grasshopper Point and

Midgley Bridge, then headed back to the Natural Channel Designs Laboratory in Flagstaff. While driving north, we saw stormwater raging at the Cave Springs sampling site and stopped to collect our first (and only) stormwater sample of the season. Figure 12 below shows the stormwater sample, stormwater, and stormwater sample next to a baseflow sample, both of which were exceedances, including the duplicate. The stormwater sample was processed four times in different concentrations. First, it was left as 100 mL and processed, then diluted to 10 mL and 90 mL DI water, then 1 mL of the stormwater and 99 mL of DI water and finally, 0.1 mL of the stormwater with 99.9 mL of DI water. Both the 100 mL sample and 10 mL sample were exceedances. The other exceedance of the day was from Grasshopper Point which can be attributed to high recreation because of the additional upstream of Grasshopper Point sample that was collected this day and did not show an exceedance (See table A6 in Appendix).



Figure 12. Stormwater flow on Oak Creek July 31, 2021.

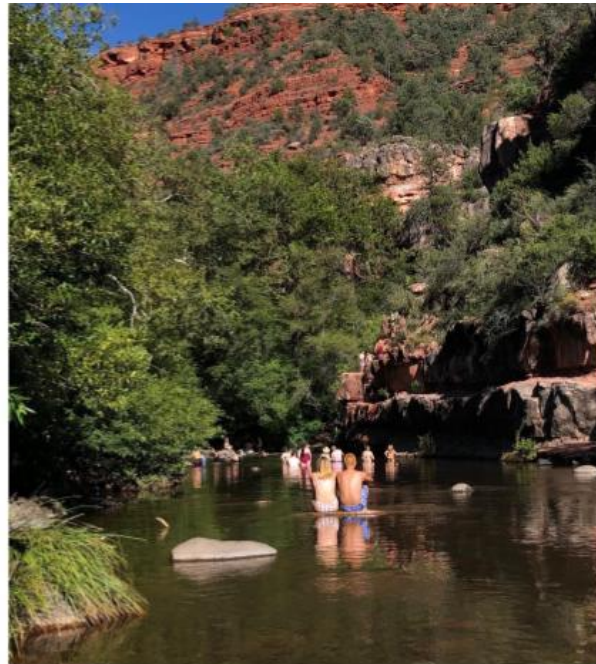
Figure 11 shows a peak at 911 cfs on August 18th and water levels stayed high through the 19th. When OCWC sampled again on the 21st, the water level was around 49 cfs. All samples from this day show *E. coli* concentrations at or near 200 MPN/100 mL, with one exceedance seen at Midgley Bridge showing 260.3 MPN/100 mL. This exceedance however is more likely due to recreation than residual stormwater because the sampler's notes say, "Sample site had 2 dogs and about 40 people. Many young kids (around 10 years old) were riding the water "slide" down and down again as the sample was being collected. Some college age adults on the beach and in the water also."

Although recreation is normal, good, and fun, high recreation can impact water quality as seen by sampling over the past two summers. 2020 showed exceptionally high recreation as can be seen in the figure below (Figure 13). Labor Day Weekend 2020 side by side to 2021 shows the density of people recreating in small swimming holes.

Along with this, exceedances were seen at five different day use sites over the past two seasons. Those sites being Cave Springs, Halfway, Grasshopper Point, Midgley Bridge and a singular exceedance at Banjo Bill in 2020. All of these day use sites have one thing in common: access to roadside pullout parking close by. Therefore, people can park outside of the designated day use area and walk in. Each day use site has limited parking spaces available to accommodate a recreational **carrying capacity** (See definition in Appendix) set by the Forest Service. When people park outside and walk into an already full day use area it affects visitor experience and ecological health.



Labor Day Weekend 2020 at Grasshopper Point, Over 200 people counted at the day use site.



Labor Day Weekend 2021 at Grasshopper Point, less than half as many people at day use site this year.

Figure 13. Crowding in Oak Creek Canyon in 2020 was more frequent than in 2021.

HIR Canyon Patrol:

Canyon patrol by Ambassadors saw another successful year in 2021, removing 1,124.25 lbs of trash from Oak Creek Canyon. There was less trash collected in comparison to 2020, where 1,825.74 lbs of trash was removed (table 2 and figure A1 in Appendix). It is important to note that Table 2 consolidates 37 sites visited by Ambassadors for canyon patrol into 13 generalized areas that are known sites within Oak Creek Canyon. The reduced amount of trash is likely attributed to the reopening of indoor spaces in 2021. Ambassadors also noticed a reduced amount of visitors and vehicles in the canyon. High use weekends like holidays were still very busy, and some areas with limited capacity or small parking lots like Grasshopper Point and Midgley Bridge during the summer, and West Fork, Gabion Pool, and Cave Springs pullouts during the fall, proved to be hard areas to access for Ambassadors during the high use season. It is very likely that there was more trash present than recorded due to the accessibility issues Ambassadors faced. Yet with only two to three people at a time picking up litter on the

weekends throughout Oak Creek Canyon, canyon patrol proves to be a very successful program in removing trash from pullouts and day use sites (Figure 14).



Figure 14. Just some of the trash Ambassadors removed while doing canyon patrol in 2020 and 2021.

HIR Photo Point Monitoring:

Based on OCWC's monitoring of both improved and closed social trails, some closed trails will require continued maintenance and rehabilitation due to recreationists "skirting" around the closure area. Including this, due to the high use of the improved social trails, and expected weathering and erosion that naturally occurs, these trails will also require continued maintenance in upcoming years. In order to know when, where, and how these trails should be maintained, rehabilitated, or closed, continued monitoring of these sites and others should be done in order to help inform land managers of problem areas along Oak Creek.

Although rehabilitation and closures improved overall soil erosion and appearance of the creekside access, the amount of trash was still major in areas monitored. Throughout 2021, OCWC held three public cleanup events geared toward the areas where social trail improvements, closures, and monitoring were implemented, and removed 145 lbs of trash. This does not include the trash removed by Ambassadors at these sites during canyon patrol, which totaled 193.34 lbs. The amount of trash found at these sites can be attributed to many variables.

With the presence of Highway 89A adjacent to the creek and recreation sites, highways are often littered, while it is unlawful and unethical to litter. Pullouts present along the 89A and these recreation sites make it convenient for travelers and recreationists alike to dump trash lightning fast without a second thought. Including this, many sites where people recreate do not have

trash bins readily available, and many see it as an inconvenience to hold on to one's trash until they arrive home, at a gas station, or day use site with a trash bin. Including this, many recreationists are uninformed about leave no trace ethics and principles, and the continued presence of litter promotes further littering as it portrays to people that if others have littered, then it is okay for them to litter as well.

Overall, at specific trails that were rehabilitated versus closed trails, there seemed to be no general localization of trash within these areas. Trash was still found widespread along the pullouts and creekside and would vary in the amount and type of trash from cleanup to cleanup, and from weekend to weekend.

Pet Waste Stations:

With the addition of four full pet waste stations managed by OCWC, there was a substantial increase in weight collected in 2021, with 2,234.8 lbs of pet waste collected versus 1,190.6 lbs of pet waste removed in 2020. Unfortunately these stations are often misused by recreationists who utilize these bins as a trash can rather than for pet waste alone. Often Ambassadors would find that the bin would not be full, yet the bin looked like it was overflowing due to trash being stuffed and stuck within the lid of the station. Soldiers Pass trailhead has been and still is a station that is often abused with trash, while Mescal trailhead saw previous misuse in the past during 2019 and 2020 (Figure 15), a substantial increase of misuse was seen in 2021. We assume this is due to the fact that the Mescal trailhead parking lot allows access to the Devil's Bridge trailhead, an extremely popular trail normally accessed from a parking lot off of Dry Creek Rd. From 2019–2021, Ambassadors witnessed the increased use of this area, with many recreationists parking along Dry Creek Rd. to access the Devil's Bridge trailhead from the Dry Creek trailhead parking lot.

With the addition of four new stations, it was expected that some or all of the new stations would have some misuse, but a substantial amount of misuse has been noted by Ambassadors at the Bell Rock and Cathedral Rock trailheads (Figure 16), both extremely popular trails within the Red Rock Ranger District. Including Bell Rock and Cathedral Rock, five out of the ten pet waste stations have accessible trash bins managed by the Forest Service, typically found near existing structures like a bathroom or informational boards. Including this, there is strong messaging (Figure 17) on the pet waste stations informing recreationists that these bins are for pet waste only. Although these stations are often misused by recreationists, overall these stations have prevented a substantial amount of pet waste and trash alike from entering local waterways, and proves to be a successful collaborative project.



Soldiers Pass misuse/overflow 2020



Mescal misuse/overflow 2019

Figure 15. Photos depicting misuse and overflow of Soldiers Pass and Mescal pet waste stations.



Bell Rock misuse/overflow 2021



Cathedral Rock misuse/overflow 2021

Figure 16. Photos depicting misuse and overflow of Bell Rock and Cathedral Rock pet waste stations.



Figure 17. Photo depicting pet waste station messaging and additional messaging reminding recreationists to pack out their trash.

MS4:

Since Ambassadors had not tabled since 2019/early 2020, OCWC was very excited to get back out and talk to the public at events. With over 15 hours of MS4 education talked about to residents and visitors of Sedona over six events, we found tabling to be a very successful and engaging way to speak to people about the MS4 in Sedona. These events also allowed for OCWC to put out a donation box in order to help continue OCWC's mission and work to protect Oak Creek and the watershed.

In relation to social media engagement, it is hard to gauge how effective the MS4 posts are. There are many sources reporting different "Reach Rates" that gauge a post to be successful or not. These reach rates vary from source to source, but also vary based on follower count and how large a page is. What we can conclude is that the reels have been one of the most engaging pieces of outreach and education OCWC has posted in terms of MS4 and all other social media posts. We have also noticed that although Instagram and Facebook are sister social media sites, there is much more engagement through Instagram versus Facebook.

Public Group Cleanup Events:

OCWC's group cleanup events saw an extremely successful year in 2021. With over 3,000 lbs of trash removed in 2021 alone, it was the most successful year for group cleanups since 2019. Group cleanups not only make the land cleaner and healthier, but also builds local land stewardship and provides a connection to one's community. It sets up connections for people to create new friendships and contacts with stakeholders, promotes a sense of giving back to the

land, and is also lots of fun! OCWC held its first **voluntourism** (See definition in Appendix), cleanup with the ALTURA Associates from California during their company retreat. This cleanup was the most successful in terms of the amount of trash removed from Carroll Canyon weighing in at 282 lbs. Group cleanups have allowed OCWC to clean areas outside the contracted area for canyon patrol, which in turn helps protect the entirety of the watershed.

Conclusion

In conclusion, although lower visitation was seen in 2021, high impact recreation can cause problems and issues in the long and short term. High impact recreation affects water quality, the overall scenic beauty of an area, lowers visitor experience, can cause harm to wildlife, and can impact and degrade the quality of life for people who live in the area. Although we had to play catchup on projects in 2021 due to delays in 2020, OCWC pushed forward and completed these projects with outstanding results.

A continuation of all of these projects will benefit the watershed. It helps land agencies and stakeholders concerned with the health and integrity of the watershed who may not have the resources to do the projects we have carried out. It helps the wildlife and people who call Oak Creek and its watershed home. It promotes conservation and land stewardship, and promotes a better visitor experience.

We would like to thank all of the stakeholders involved in these projects throughout the years: ADEQ, NFF, USFS, City of Sedona, Sedona Chamber of Commerce and Tourism Bureau for funding, and private stakeholders for donations. SRSP for being available to process the Tuesday water quality samples, Friends of the Forest for helping OCWC build the 37 new pet waste stations, Recreation Resource Management for maintaining many new pet waste stations, and allowing us into high use areas to collect water quality samples and trash when we wouldn't have been let in otherwise. Thanks to the volunteers who dedicated their time to cleanup litter at cleanup events and shout outs from people both on the creekside and the highway while Ambassadors collected litter. To USFS for allowing Ambassadors to use a USFS truck for pet waste in 202. To our board members and Executive Director, Kalai for working so hard to get and maintain funding to continue these projects and protect Oak Creek and its watershed.

We anticipate this report will be useful to many, and hope it helps continue the great work OCWC has done throughout the years, and allows for new and upcoming projects within the watershed to continue to protect and conserve the Oak Creek watershed.

Appendix

Table A1. Samples from OCWC and SRSP from 2021. Exceedance is highlighted in light red.

2021 OCWC Samples		<i>E. Coli</i> MPN	<i>E. Coli</i> MPN	2021 SRSP Samples	
6/1/2021	Pine Flats	5.2	2	Highway Bridge	6/1/2021
6/1/2021	Pine Flats Dup	0	1	Highway Bridge Dup	6/1/2021
6/1/2021	Oak Creek Conf.	2	19.9	Foot Bridge	6/1/2021
6/1/2021	West Fork Conf.	12	3.1	Large Pool	6/1/2021
6/1/2021	West Fork 2nd Crs.	5.2	9.1	MidSlide	6/1/2021
			11	Up Stream	6/1/2021
6/8/2021	Pine Flats	0	41	Highway Bridge	6/8/2021
6/8/2021	Oak Creek Conf.	15.6	26	Foot Bridge	6/8/2021
6/8/2021	Oak Creek Conf. Dup	15.6	28	Foot Bridge Dup	6/8/2021
6/8/2021	West Fork Conf.	12	39	Large Pool	6/8/2021
6/8/2021	West Fork 2nd Crs.	7.4	18	MidSlide	6/8/2021
			26	Up Stream	6/8/2021
6/15/2021	Pine Flats	4.1	24	Highway Bridge	6/15/2021
6/15/2021	Oak Creek Conf.	9.8	46	Foot Bridge	6/15/2021
6/15/2021	West Fork Conf.	48	31	Large Pool	6/15/2021
6/15/2021	West Fork Conf. Dup	40.4	22	Large Pool Dup	6/15/2021
6/15/2021	West Fork 2nd Crs.	155.3	15	MidSlide	6/15/2021
			23	Up Stream	6/15/2021
7/13/2021	Pine Flats	10.9	11	Highway Bridge	7/13/2021
7/13/2021	Oak Creek Conf.	24.6	17	Foot Bridge	7/13/2021
7/13/2021	Oak Creek Conf. Dup	23.8	17	Large Pool	7/13/2021
7/13/2021	West Fork Conf.	52.9	7.4	MidSlide	7/13/2021
7/13/2021	West Fork 2nd Crs.	60.2	12	MidSlide Dup	7/13/2021
			15	Up Stream	7/13/2021
7/20/2021	Pine Flats	13.5	18.5	Highway Bridge	7/20/2021
7/20/2021	Oak Creek Conf.	17.3	23	Foot Bridge	7/20/2021
7/20/2021	West Fork Conf.	57.1	16	Large Pool	7/20/2021
7/20/2021	West Fork 2nd Crs.	49.5	66	MidSlide	7/20/2021
7/20/2021	West Fork 2nd Crs. Dup	41.4	26	Up Stream	7/20/2021
			16	Up Stream Dup	7/20/2021
7/27/2021	Pine Flats	178.9	161.6	Highway Bridge	7/27/2021
7/27/2021	Pine Flats Dup	218.7	158.5	Highway Bridge Dup	7/27/2021
7/27/2021	Oak Creek Conf.	128.1	108.1	Foot Bridge	7/27/2021

7/27/2021	West Fork Conf.	214.2	129.6	Large Pool	7/27/2021
7/27/2021	West Fork 2nd Crs.	128.1	129.6	MidSlide	7/27/2021
			172	Up Stream	7/27/2021
8/3/2021	Pine Flats	31.8	83	Highway Bridge	8/3/2021
8/3/2021	Pine Flats Dup	27.2	69	Foot Bridge	8/3/2021
8/3/2021	Oak Creek Conf.	31.4	56	Foot Bridge Dup	8/3/2021
8/3/2021	West Fork Conf.	16.1	62	Large Pool	8/3/2021
8/3/2021	West Fork 2nd Crs.	19.7	68	MidSlide	8/3/2021
			77	Up Stream	8/3/2021
8/10/2021	Pine Flats	24.1	36	Highway Bridge	8/10/2021
8/10/2021	Oak Creek Conf.	22.8	46	Foot Bridge	8/10/2021
8/10/2021	Oak Creek Conf. Dup	13.4	60	Large Pool	8/10/2021
8/10/2021	West Fork Conf.	21.8	51	Large Pool Dup	8/10/2021
8/10/2021	West Fork 2nd Crs.	52.8	41	MidSlide	8/10/2021
			40	Up Stream	8/10/2021
8/17/2021	Pine Flats	48.7	45	Highway Bridge	8/17/2021
8/17/2021	Oak Creek Conf.	46.5	42	Foot Bridge	8/17/2021
8/17/2021	West Fork Conf.	26.2	47	Large Pool	8/17/2021
8/17/2021	West Fork Conf. Dup	23.8	61	MidSlide	8/17/2021
8/17/2021	West Fork 2nd Crs.	26.2	50	MidSlide Dup	8/17/2021
			65	Up Stream	8/17/2021
8/24/2021	Pine Flats	35	34	Highway Bridge	8/24/2021
8/24/2021	Oak Creek Conf.	45.5	39	Foot Bridge	8/24/2021
8/24/2021	West Fork Conf.	52.9	31	Large Pool	8/24/2021
8/24/2021	West Fork 2nd Crs.	21.3	33	MidSlide	8/24/2021
8/24/2021	West Fork 2nd Crs. Dup	18.9	23	Up Stream	8/24/2021
			40	Up Stream Dup	8/24/2021
8/31/2021	Pine Flats	29.9	22	Highway Bridge	8/31/2021
8/31/2021	Oak Creek Conf.	50.4	23	Highway Bridge Dup	8/31/2021
8/31/2021	West Fork Conf.	42.8	23	Foot Bridge	8/31/2021
8/31/2021	West Fork 2nd Crs.	73.8	26	Large Pool	8/31/2021
8/31/2021	West Fork 2nd Crs. Dup	74.9	25	MidSlide	8/31/2021
			29	Up Stream	8/31/2021
9/7/2021	Pine Flats	41.3	40	Highway Bridge	9/7/2021
9/7/2021	Oak Creek Conf.	65.7	53	Foot Bridge	9/7/2021
9/7/2021	Oak Creek Conf. Dup	35	61	Foot Bridge Dup	9/7/2021
9/7/2021	West Fork Conf.	107.1	53	Large Pool	9/7/2021

9/7/2021	West Fork 2nd Crs.	238.2	54	MidSlide	9/7/2021
			72	Up Stream	9/7/2021

Table A2. Pine Flats sample site data 2019-2021

Pine Flats					
2019	MPN	2020	MPN	2021	MPN
6/4/2019	3.1	6/2/2020	33.1	6/1/2021	5.2
6/4/2019	1.1	6/2/2020	27.8	6/1/2021	0
6/11/2019	8.6	6/9/2020	35.9	6/8/2021	0
6/18/2019	95.9	6/16/2020	7.4	6/15/2021	4.1
6/25/2019	116.9	6/23/2020	50.4	7/13/2021	10.9
6/25/2019	81.6	6/23/2020	39.9	7/20/2021	13.5
7/2/2019	20.1	6/30/2020	20.1	7/27/2021	178.9
7/9/2019	35	7/7/2020	6.3	7/27/2021	218.7
7/16/2019	224.7	7/14/2020	18.7	8/3/2021	31.8
7/16/2019	127.4	7/22/2020	29.5	8/3/2021	27.2
7/23/2019	53.7	2/28/2020	16	8/10/2021	24.1
7/30/2019	12	8/4/2020	8.6	8/17/2021	48.3
8/6/2019	131.3	8/11/2020	6.3	8/24/2021	35
8/6/2019	162.4	8/11/2020	7.4	8/31/2021	29.9
8/13/2019	16.1	8/18/2020	14.3	9/7/2021	41.3
8/20/2019	13.5	8/25/2020	2		
8/27/2019	23.1	8/25/2020	4.1		
8/27/2019	26.5	9/1/2020	29.1		
9/3/2019	17.3	9/8/2020	6.3		

Table A3. Oak Creek above confluence with West Fork sample site data 2020-2021

Oak Creek above Confluence with West Fork			
2020	MPN	2021	MPN
8/18/20	68.3	6/1/21	2
8/18/20	83.3	6/8/21	15.6
8/25/20	93.3	6/8/21	15.6
9/1/20	33.1	6/15/21	9.8
9/1/20	43.2	7/13/21	24.6
9/8/20	38.8	7/13/21	23.8
9/8/20	38.2	7/20/21	17.3
		7/27/21	128.1
		8/3/2021	31.4

		8/10/21	22.8
		8/10/21	13.4
		8/17/21	46.5
		8/24/21	45.5
		8/31/21	50.4
		9/7/21	65.7
		9/7/21	35

Table A4. West Fork above confluence with Oak Creek sample site data 2019-2021

West Fork above Confluence with Oak Creek					
2019	MPN	2020	MPN	2021	MPN
6/4/2019	104.6	6/2/2020	15.8	6/1/2021	12
6/11/2019	6.3	6/9/2020	43.2	6/8/2021	12
6/11/2019	5.2	6/9/2020	52.1	6/15/2021	48
6/18/2019	33.1	6/16/2020	23.3	6/15/2021	40.4
6/25/2019	31.3	6/23/2020	41.3	7/13/2021	52.9
7/2/2019	90	6/30/2020	44.1	7/20/2021	57.1
7/2/2019	22.3	6/30/2020	37.3	7/27/2021	214.2
7/9/2019	8.6	7/7/2020	22.8	8/3/2021	16.1
7/16/2019	24.3	7/14/2020	32.3	8/10/21	21.8
7/23/2019	13.4	7/14/2020	18.7	8/17/2021	26.2
7/23/2019	35.9	7/21/2020	96	8/17/2021	23.8
7/30/2019	39.3	7/21/2020	68.3	8/24/2021	52.9
8/6/2019	32.7	7/28/2020	12	8/31/2021	42.8
8/13/2019	8.5	8/4/2020	21.6	9/7/2021	107.1
8/13/2019	13.4	8/11/2020	33.1		
8/20/2019	21.6	8/18/2020	96		
8/27/2019	41.6	8/25/2020	44.8		
9/3/2019	47.1	9/1/2020	24.3		
9/3/2019	71.7	9/8/2020	9.8		

Table A5. West Fork at the second crossing sample site data 2019-2021

West Fork at the Second Crossing					
2019	MPN	2020	MPN	2021	MPN
6/4/2019	65.7	6/2/2020	116.2	6/1/2021	5.2
6/11/2019	10.9	6/9/2020	47.2	6/8/2021	7.4
6/18/2019	127.4	6/16/2020	36.9	6/15/2021	155.3
6/18/2019	121.1	6/16/2020	42.6	7/13/2021	60.2
6/25/2019	37.4	6/23/2020	36.9	7/20/2021	49.5

7/2/2019	42.8	6/30/2020	62.7	7/20/2021	41.4
7/9/2019	37.9	7/7/2020	19.9	7/27/2021	128.1
7/9/2019	16.1	7/7/2020	24.6	8/3/2021	19.7
7/16/2019	49.6	7/14/2020	26.2	8/10/2021	52.8
7/23/2019	16.8	7/21/2020	85.7	8/17/2021	26.2
7/30/2019	83	7/28/2020	20.1	8/24/2021	21.3
7/30/2019	57.3	7/28/2020	21.6	8/24/2021	18.9
8/6/2019	48	8/4/2020	21	8/31/2021	73.8
8/13/2019	32.3	8/4/2020	18.7	8/31/2021	74.9
8/20/2019	29.2	8/11/2020	55.7	9/7/2021	238.2
8/20/2019	19.9	8/18/2020	96		
8/27/2019	18.7	8/25/2020	30.9		
9/3/2019	14.6	9/1/2020	21.3		
		9/8/2020	11		

Table A6. OCWC HIR samples 2020 and 2021. Exceedances are highlighted in light red.

2021 HIR Samples		E. coli CFU	E. coli CFU	2020 HIR Samples	
3/20/2021	Cave Springs	19.5			
	Gabion Pool	8.4			
	Bootlegger	5.2			
	Bootlegger Dup.	5.2			
	Banjo Bill	14.6			
	Halfway	9.7			
	Grasshopper Point	17.1			
	Midgley Bridge	13.4	This section left blank on purpose		
4/10/2021	Cave Springs	1			
	Gabion Pool	49.8			
	Bootlegger	3.1			
	Banjo Bill	3.1			
	Halfway	0			
	Grasshopper Point	1			
	Grasshopper Point Dup.	2			
	Midgley Bridge	6.3			
5/22/2021	Cave Springs	3.1	8.6	Cave Springs	5/23/2020
	Gabion Pool	4.1	6.3	Gabion Pool	
	Bootlegger	14.6	22.5	Bootlegger	
	Banjo Bill	6.3	18.7	Banjo Bill	

	Halfway	21.3	20.1	Halfway	
	Grasshopper Point	11	n/a	Grasshopper Point	
	Grasshopper Point Dup.	9.8	81.3	Midgley Bridge	
	Midgley Bridge	3.1	83.3	Midgley Bridge Dup.	
5/29/2021	Cave Springs	14.4	19.9	Cave Springs	5/25/2020
	Gabion Pool	4.1	74.3	Gabion Pool	
	Bootlegger	4.1	70.3	Gabion Pool Dup.	
	Banjo Bill	2	5.2	Bootlegger	
	Halfway	2	7.4	Banjo Bill	
	Halfway Dup.	1	5.1	Halfway	
	Grasshopper Point	3.1	n/a	Grasshopper Point	
	Midgley Bridge	13.5	37.9	Midgley Bridge	
6/5/2021	Cave Springs	90.9	n/a	Cave Springs	5/30/2020
	Gabion Pool	45.7	n/a	Gabion Pool	
	Bootlegger	8.6	n/a	Bootlegger	
	Banjo Bill	4.1	n/a	Banjo Bill	
	Halfway	111.2	499.6	Halfway	
	Halfway Dup.	77.1	n/a	Grasshopper Point	
	Grasshopper Point	17.1	n/a	Midgley Bridge	
	Midgley Bridge	n/a	48.3	Cave Springs	6/13/2020
7/18/2021	Cave Springs	24.6	45.3	Cave Springs Dup.	
	Gabion Pool	25.3	35.4	Gabion Pool	
	Bootlegger	25.6	21.6	Bootlegger	
	Banjo Bill	31.8	17.1	Banjo Bill	
	Halfway	30.1	62.4	Halfway	
	Halfway Dup.	12.1	42.3	Grasshopper Point	
	Grasshopper Point	10.9	25.8	Midgley Bridge	
	Midgley Bridge	n/a	25.6	Cave Springs	7/4/2020
7/31/2021	Cave Springs	274.5	24.3	Gabion Pool	
	Cave Springs Dup.	387.3	23.1	Bootlegger	
	Gabion Pool	214.3	15.8	Banjo Bill	
	Bootlegger	113.4	133.4	Halfway	
	Banjo Bill	90.6	501.2	Grasshopper Point	
	Halfway	122.3	416.0	Grasshopper Point Dup.	
	Grasshopper Point	488.4	50.4	Midgley Bridge	

	Midgley Bridge	27.2	88.0	Cave Springs	7/5/2020
Upstream sample	Grasshopper Point	77.1	21.3	Gabion Pool	
Upstream sample	Midgley Bridge	42.8	18.1	Bootlegger	
Stormwater sample	Cave Springs	2419.6	3.1	Banjo Bill	
10 mL Dilution	Cave Springs	435.2	45.7	Halfway	
1 mL Dilution	Cave Springs	65	14.6	Grasshopper Point	
0.1 mL Dilution	Cave Springs	9.2	12.2	Midgley Bridge	
8/21/2021	Cave Springs	206.4	10.9	Midgley Bridge Dup.	
	Gabion Pool	193.5	308.8	Cave Springs	7/11/2020
	Bootlegger	214.3	316.9	Cave Springs Dup.	
	Banjo Bill	193.5	193.5	Gabion Pool	
	Halfway	214.3	39.9	Bootlegger	
	Halfway Dup.	201.4	17.1	Banjo Bill	
	Grasshopper Point	206.4	44.1	Halfway	
	Midgley Bridge	260.3	28.8	Grasshopper Point	
8/28/2021	Cave Springs	727	9.6	Midgley Bridge	
	Gabion Pool	101.4	90.8	Cave Springs	8/29/2020
	Bootlegger	90.8	133.3	Gabion Pool	
	Banjo Bill	14.4	98.8	Gabion Pool Dup.	
	Halfway	47.3	37.3	Bootlegger	
	Halfway Dup.	58.6	23.1	Banjo Bill	
	Grasshopper Point	33.6	30.9	Halfway	
	Midgley Bridge	30.1	201.4	Grasshopper Point	
9/4/2021	Cave Springs	13.5	307.6	Midgley Bridge	
	Gabion Pool	148.3	56.3	Cave Springs	9/5/2020
	Bootlegger	19.9	40.4	Gabion Pool	
	Banjo Bill	191.8	7.5	Bootlegger	
	Halfway	325.5	2419.6	Banjo Bill	
	Grasshopper Point	77.6	69.7	Halfway	
	Grasshopper Point Dup.	83.3	148.3	Grasshopper Point	
	Midgley Bridge	90.8	67.0	Midgley Bridge	
Upstream sample	Grasshopper Point	65	102.2	Cave Springs	9/6/2020
Upstream sample	Midgley Bridge	83.9	76.3	Gabion Pool	
9/11/2021	Cave Springs	11	81.3	Gabion Pool Dup.	
	Gabion Pool	13.4	125.9	Bootlegger	

	Bootlegger	55.6	5.2	Banjo Bill	
	Banjo Bill	13.5	70.8	Halfway	
	Banjo Bill Dup.	15.5	1986.3	Grasshopper Point	
	Halfway	29.2	248.1	Midgley Bridge	
	Grasshopper Point	36.4	2.0	Cave Springs	9/12/2020
	Midgley Bridge	218.7	6.3	Gabion Pool	
10/1/2021	Cave Springs	60.9	7.5	Bootlegger	
	Gabion Pool	42	5.2	Banjo Bill	
	Bootlegger	93.2	9.8	Halfway	
	Banjo Bill	75.4	31.3	Grasshopper Point	
	Halfway	58.3	31.3	Grasshopper Point Dup.	
	Halfway Dup.	81.3	12.2	Midgley Bridge	
	Grasshopper Point	191.8			
	Midgley Bridge	41			
10/17/2021	Cave Springs	7.5			
	Gabion Pool	14.8			
	Bootlegger	24.1	This section left blank on purpose		
	Banjo Bill	7.4			
	Halfway	3.1			
	Grasshopper Point	12.1			
	Midgley Bridge	3.1			
	Midgley Bridge Dup.	3.1			

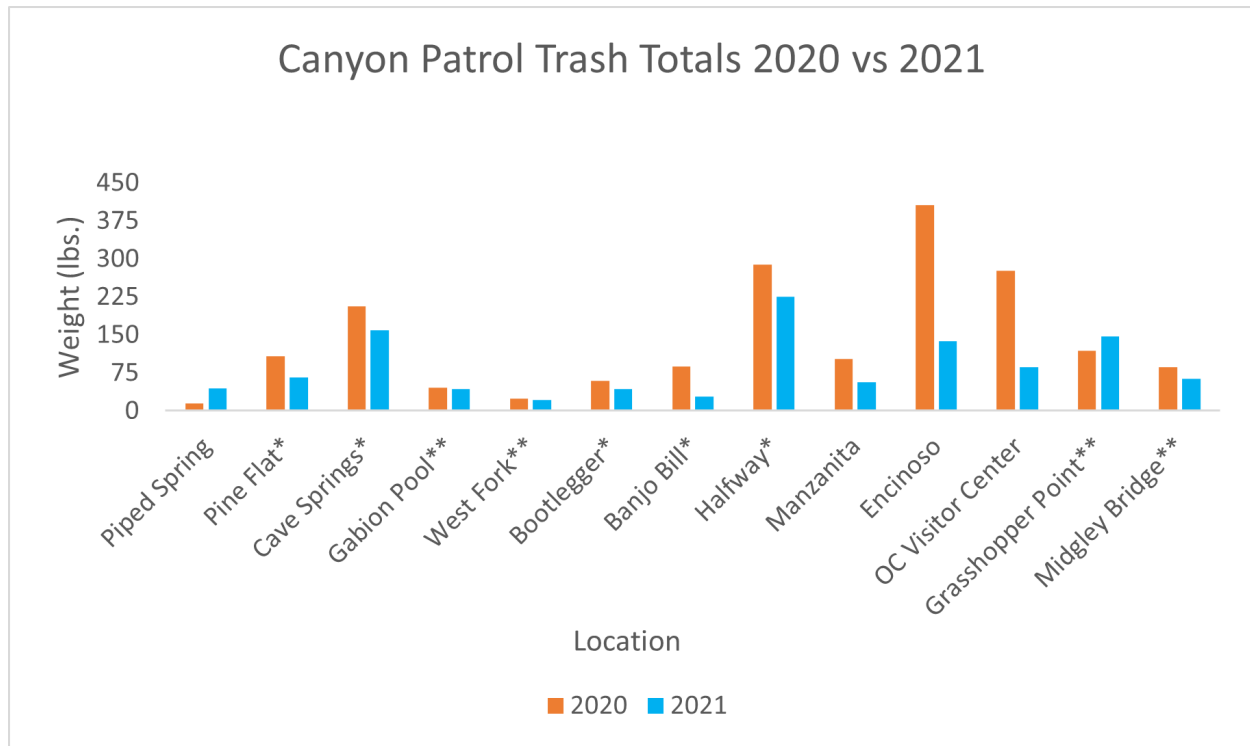


Figure A1. Canyon Patrol Project Totals 2020–2021. Locations with asterisks are sampling sites, a double asterisk indicates a sampling site that was challenging to access for trash pick up efforts. A location without an asterisk was not sampled for water quality. Sites organized from upstream to downstream locations. Although some sites like Grasshopper Point had more trash collected in 2021, overall there was less trash removed in 2021 in comparison to 2020.

Table A7. USFS trailhead pet waste station total weight (lbs). Trailheads marked with an asterisk indicate that these stations were installed in May 2021 and do not indicate an entire year's weight.

USFS Pet Waste Station Trailhead Totals (lbs.)			
	2019	2020	2021
Adobe Jack Trailhead	147	135.1	127.5
Turkey Creek Trailhead	33.5	64.1	62.8
Jim Thompson Trailhead	90.7	149.6	188.5
Mystic Trailhead	244.2	332.1	414.1
Soldiers Pass Trailhead	231	364.9	424.8
Mescal Trl/Long Cyn Trl	121.7	144.8	258
Huckaby Trailhead*	N/A	N/A	132.4
Cathedral Rock*	N/A	N/A	166.3
Bell Rock Trailhead*	N/A	N/A	304.4
Baldwin Trailhead*	N/A	N/A	156
Total weight collected/yr	868.1	1,190.6	2,234.8
Total weight 2019–2021	4,293.5		

USFS Pet Waste Station Trailhead Totals

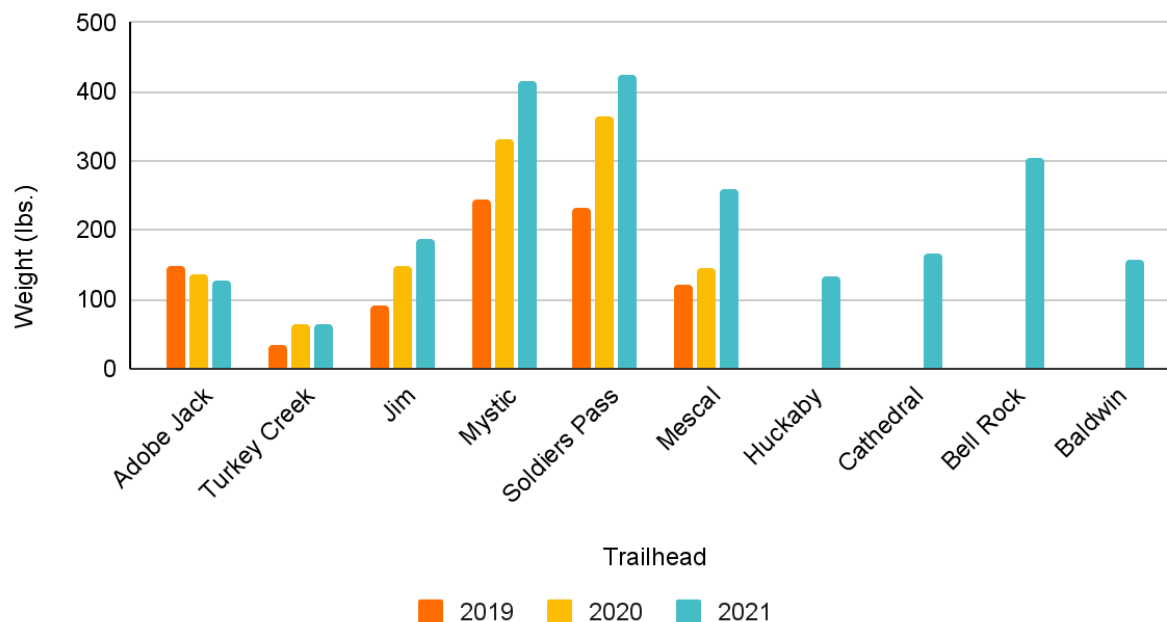


Figure A2. Bar graph depicting total weights for pet waste stations at different USFS trailheads. Note that Huckaby, Cathedral, Bell Rock, and Baldwin only have values occurring in 2021, as these stations were not installed until May 2021.

OCWC cleanup event total weights (lbs.) 2019-2021

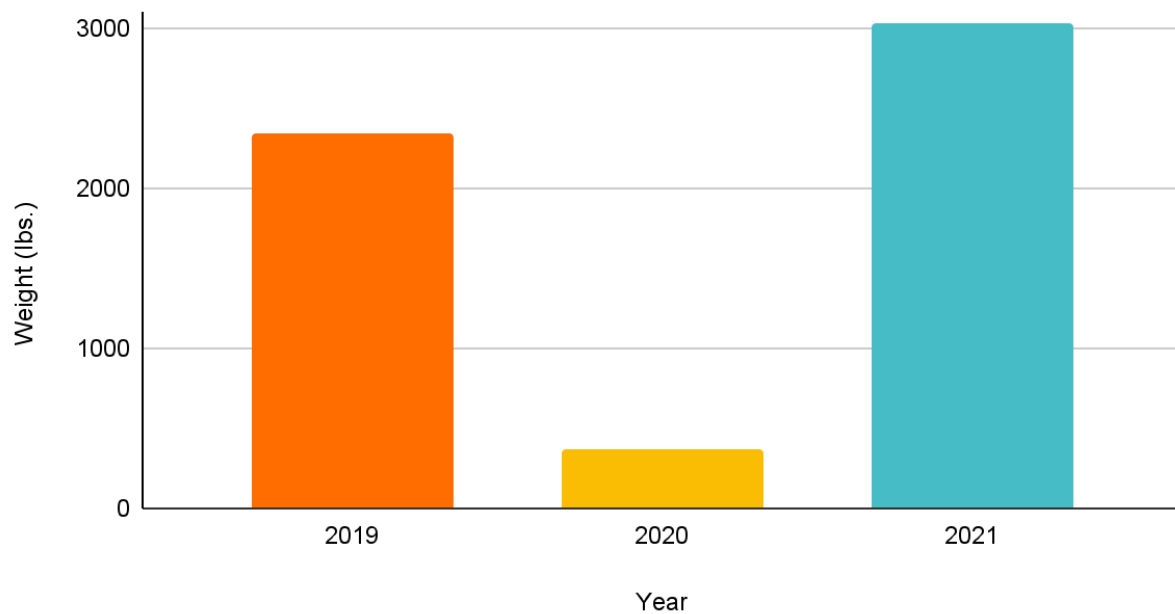


Figure A3. Bar graph depicting total weight for public cleanup events between years 2019–2021. Note that the total weight for 2020 is low due to the COVID-19 pandemic that did not allow OCWC to hold many group cleanup events.

Table A8. List of volunteer public cleanups held by OCWC from 2019–2021. The number of cleanups per year varies due to funding and the COVID-19 pandemic stay at home orders during 2020. An asterisk indicates an estimated weight.

2019 Volunteer Public Cleanups		2020 Volunteer Public Cleanups		2021 Volunteer Public Cleanups	
Site/Date	Weight (lbs.)	Site/Date	Weight (lbs.)	Site/Date	Weight (lbs.)
Spring Break cleanup @ Midgley Bridge	107	MLK Day cleanup with Friends of Verde River	220	Apr. Social Trail Mon. cleanup w/ Sedona Women	54
Earth Day in Oak Creek Canyon*	65	Labor Day RRC w/ VOC Rotary	40	May City of Sedona Bulk Trash Day/Neighborhood Cleanup	58
Red Rock Crossing April*	80	Public Lands Day	42	May Pickin**	1300
Midgley Bridge May 22	27	Carroll Canyon w/ Sedona Women	62	Labor Day RRC w/ VOC Rotary	29
July 4 Canyon Cleanup	625			Sept. Social Trail Mon. Cleanup w/ Sedona Women & City of Sedona	62
Landmark Pickin'	1260			Sept. Pickin**	1100
Labor Day RRC	55			Carroll Canyon, Sep. 30 w/ ALTURA	282
October Sedona Women & City of Sedona	130			Oct. 27 Fall cleanup	29
				OCS cleanup	37
				City of Sedona Cleanup	86
Totals	2,349		364		3,037
Three Year Total	5,750				



Figure A4. "No Dumping! Drains to Oak Creek" curbside placard installed near a storm grate in the City of Sedona.



Figure A5. Shaded relief model of basins and drainages within the City of Sedona showing where the MS4 flows into Oak Creek.

Definitions

Colony forming units: a unit commonly used to estimate the concentration of microorganisms in a test sample

Turbidity: the *quality* of being cloudy, opaque, or thick with suspended matter

Colilert-18: Colilert-18 is a liquid culture method that simultaneously detects both total coliforms and *Escherichia coli* in water, giving confirmed results in 18 hours.

Geometric mean analysis: In statistics, the geometric mean is calculated by raising the product of a series of numbers to the inverse of the total length of the series. The geometric mean is most useful when numbers in the series are not independent of each other or if numbers tend to make large fluctuations (Blokhin and Anderson 2021).

Why we use a geometric mean over an arithmetic mean: Due to the occasional large fluctuations seen for *E. coli* levels from water quality samples, a geometric mean shows a more realistic average in comparison to arithmetic mean. This way, we can use data points that would normally be considered outliers. If we used the arithmetic mean, large numbers (outliers) would skew the data in a large way, giving an unrealistic average for all samples.

Inconclusive reach: While Oak Creek is formally listed as an impaired waterway by ADEQ, the West Fork reach does not have a formal status due to inconclusive sampling.

Turbid: (of a liquid) cloudy, opaque, or thick with suspended matter

Recreational carrying capacity: the amount and type of use that an area can sustain over a given time period given goals to maintain the physical environment and experience of the visitor.

Voluntourism: a form of tourism in which travelers participate in voluntary work, typically for a charity or non-profit to give back to the place tourists visit

References

Blasch, K.W., Hoffmann, J.P., Graser, L.F., Bryson, J.R., and Flint, A.L., 2006. Hydrogeology of the upper and middle Verde River watersheds, central Arizona: U.S. Geological Survey Scientific Investigations Report 2005–5198, 102 p., 3 plates.

Blokhin, A. and Anderson S., 2021. When to Apply the Geometric Mean: Key Examples. Investopedia.com