An Assessment of Arizona's Intermittent Streams

By Jason Jones

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Introduction

This study is the first systematic assessment of intermittent streams in Arizona. Intermittent streams are defined in the Arizona Administrative Code as "streams that only flow during certain times of the year" (Arizona Administrative Code R18-11-101(25)). In contrast, perennial streams flow yearlong while ephemeral streams only flow in response to storm events. Ephemeral and intermittent stream systems comprise a large portion of southwestern watersheds, and contribute to the hydrological, biogeochemical, and ecological health of a watershed (EPA, 2008).

Monitoring efforts are typically focused on perennial streams because they are easier to sample and because of their importance to humans and wildlife. The Clean Water Act Assessment is the primary way states determine if streams can be used for various uses such as drinking water, agriculture, recreation, fish consumption and for wildlife. Arizona assessed 53% of perennial streams and just 5% of intermittent streams in the 2016 Clean Water Act Assessment (ADEQ, 2017).

This study will compare intermittent stream data to water quality standards using a probabilistic design, which allows statistical inferences to be made about all intermittent streams in the state. Arizona has 1,450 intermittent stream reaches (6,051 miles), which make up 4% of Arizona streams (Figure 1). A network of low cost time-lapse cameras were deployed to give unambiguous daily flow data for a full year at 32 random sites. In addition to flow data, chemistry, habitat, and macroinvertbrates were sampled from July 2015 to June 2017. The study design integrated multiple chemistry events in order to make impairment and assessment decisions for each designated use.

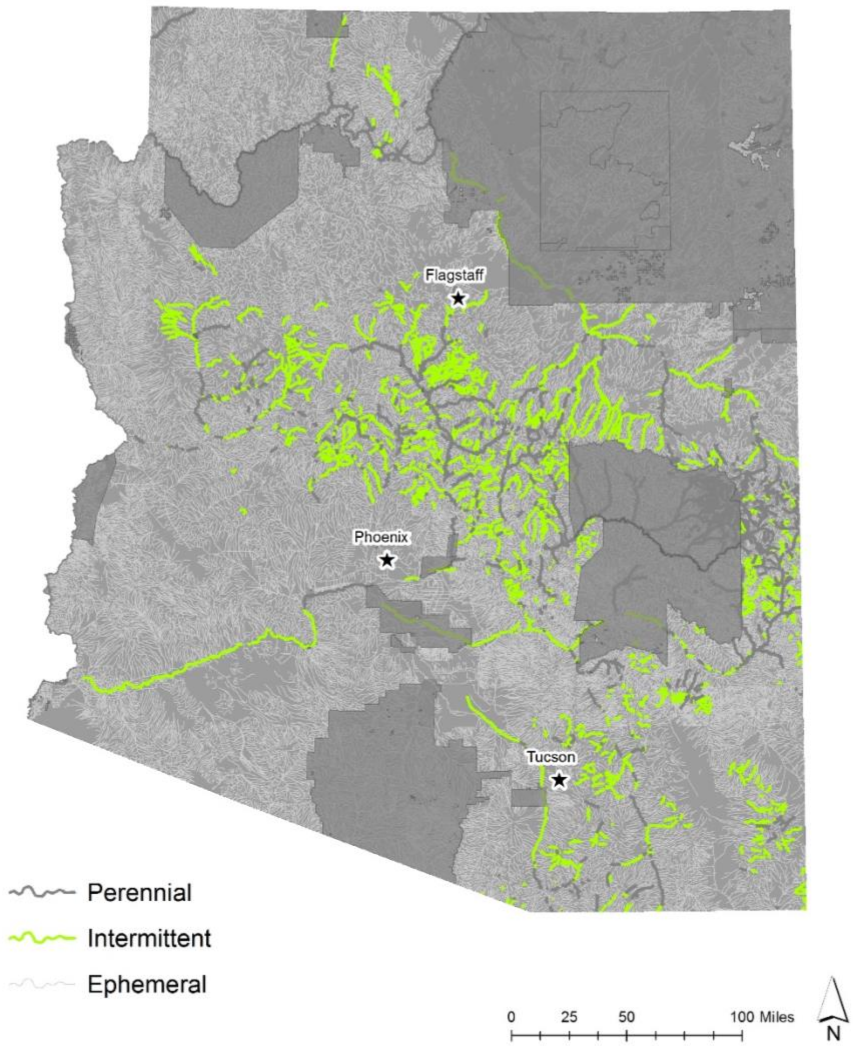

Figure 1. Arizona intermittent streams.

Importance of Intermittent Streams

Water is in the arid southwest is precious. It is a commodity that we literally cannot live without. The 6,051 miles of intermittent streams in Arizona provide critical habitat for plants and animals. They also increase the property values and recreational enjoyment for people.

When functioning properly intermittent streams provide numerous benefits to their watersheds (EPA, 2008) including:

- **Wildlife habitat and corridors**. Arizona has incredible biodiversity of birds, amphibians, reptiles and mammals (http://biodiversitymapping.org). Biodiversity is greater in intermittent stream riparian areas compared to areas surrounding them (Goodrich et al., 2004; Stromberg et al., 2005; Figure 2). Hunters and anglers spend almost a billion dollars per year in Arizona and support over 17,000 jobs (http://azgfd.gov/w_c/survey_results.shtml).
- **Fish refuge / food source**. The isolated pools can serve as refuges for fish to survive in intermittent streams during dry periods (Labbe and Fausch, 2000).

- **<u>Move water, nutrients and sediment throughout the watershed</u>**. The Walnut Gulch experimental station has shown sediment transport through an intermittent and ephemeral system to the San Pedro River (Levick et al., 2008).
- **<u>Hydrologic connections</u>**. Streams in Arizona are highly impacted by low frequency, low duration but high magnitude stream flows caused by flash floods. These larger floods reconnect stream networks (Alexander, 2015).
- **<u>Dissipate stream energy during high flows to reduce erosion</u>**. Vegetation in riparian areas along stream banks stabilizes the soil and prevents erosion (Groeneveld and Griepentrog, 1985)
- **<u>Surface and subsurface water storage</u>**. Riparian vegetation is supported by water in the alluvial aquifer and banks, which supports plants during dry periods (Dickinson et al., 2010)

Figure 2. A variety of wildlife use intermittent streams. Left to right, black bear, deer, mountain lion, javalina, and elk.

Hard to study water that sometimes isn't there

A probabilistic sampling design was used to randomly select 39 sites using the R statistical package spsurvey with no stratification (Olsen, 2015). The target population was intermittent streams in Arizona (excluding Indian Reservations). The Allstreams geodatabase filtering on intermittent streams was used. Allstreams was based on EPA's reachfile 3 map and was created in the 1990's. ADEQ and Arizona Game and Fish have added various attributes to the reachfile 3 map over the years including flow status (perennial, intermittent, ephemeral).

One hundred and seventy-three sites were evaluated and 39 of those were determined to be valid intermittent streams. Desktop indicators for intermittency included:

- Hydrology - Water present in Google Earth at any time. Presence on intermittent map.
- Vegetation – Noticeable riparian corridor. Riparian plants are generally a lighter green color and more dense than their upland counterparts.

Sites that could not be confirmed as intermittent streams through desktop reconnaissance were physically visited (Figure 3). Thirty-two of the 39 valid intermittent sites were sampled and photographed daily (82% assessed). The seven sites that were valid intermittent streams but not sampled included three sites where cameras were stolen, two sites where cameras were lost due to flooding and two sites where access was denied by the land owner (Figure 4 to 7).

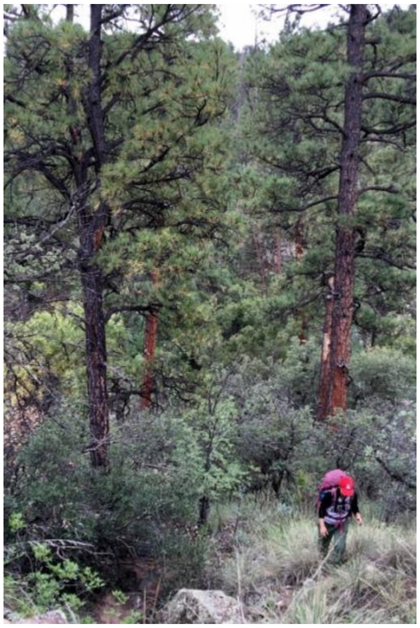

Figure 3. Intermittent stream reconnaissance.

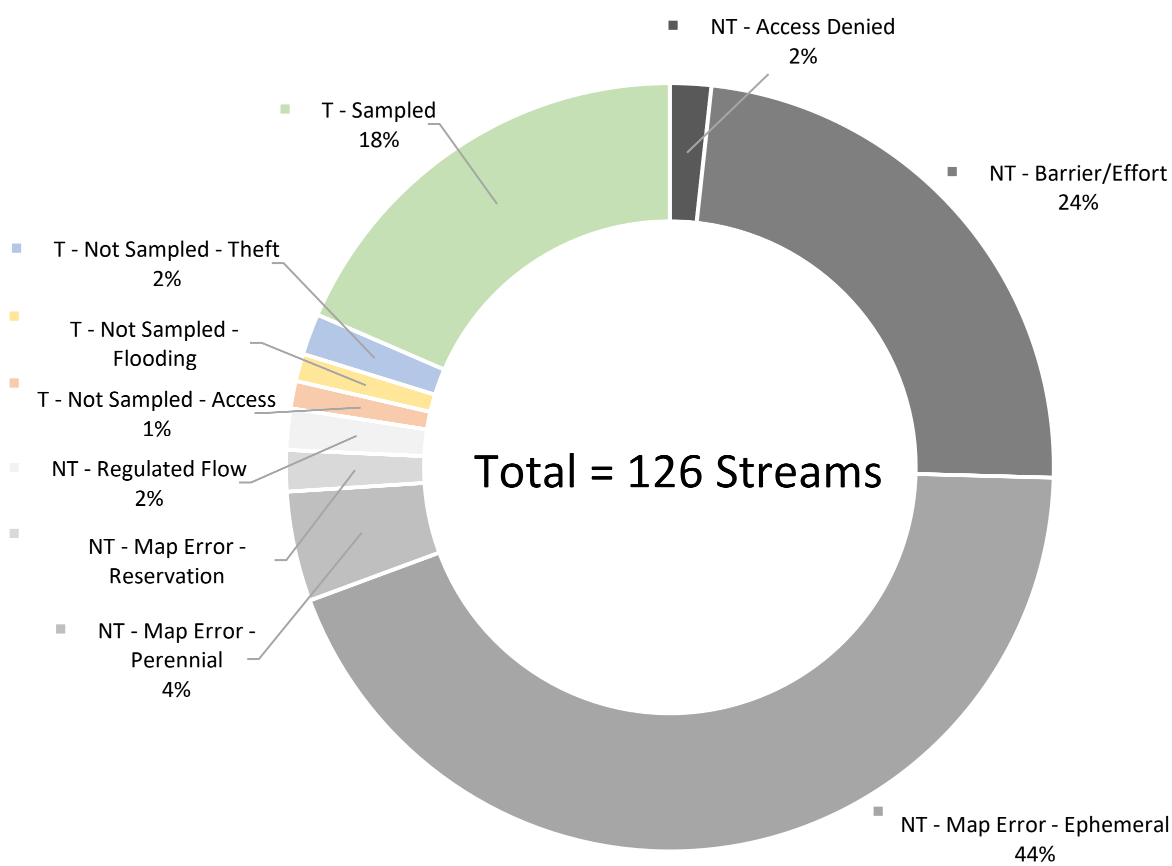

Figure 4. Reconnaissance results. T = Part of Target Population. NT = Not Target.

Eighty-seven sites were determined not to be intermittent streams even though they were on the intermittent stream map. Of the 87 sites, 76 were determined to actually be ephemeral, while eight were determined to be perennial. Forty-one sites were inaccessible either due to barriers such as canyons or would require too much effort to reach. Three sites had regulated flow such as being completely dominated by effluent or agriculture return flows. Data from desktop reconnaissance and the one time site visits are not used to make designated use decisions in rule. Designated use changes based on a daily flow data are included in the 'Designated Use Changes' section.

Figure 5. Intermittent camera set up. The time-lapse camera is powered by a solar panel and battery.

Figure 6. Camera loss due to fire.

Figure 7. Camera loss at Hinton Creek due to massive flooding after a fire.

Condition of Arizona's Intermittent Streams

The condition of all of Arizona's intermittent streams was determined by using a probabilistic monitoring design, which allows statistical inferences from the 39 targeted sites to be applied to all 1,450 intermittent stream reaches. Probabilistic designs work in much the same way as election polls, which use samples from a subset of a population in order to answer questions about the entire population. A targeted approach only provides information for sampled sites.

Forty-six percent (667 reaches) of Arizona's intermittent streams are either fully supporting all uses or partially supporting uses (Figure 8). Five percent of Arizona streams are impaired, which is equivalent to 73 impaired stream reaches. Thirty-one percent (450 reaches) of streams are inconclusive, which means that they could either also be impaired or supporting.

During the 2016 assessment only 5% of intermittent streams were assessed leaving 95% unassessed (1,378 reaches). The use of probabilistic monitoring reduced the uncertainty from 95% to 49% (18% for unassessed streams and 31% of inconclusive streams). Uncertainty could be further reduced if the study design followed each stream to a final assessment decision.

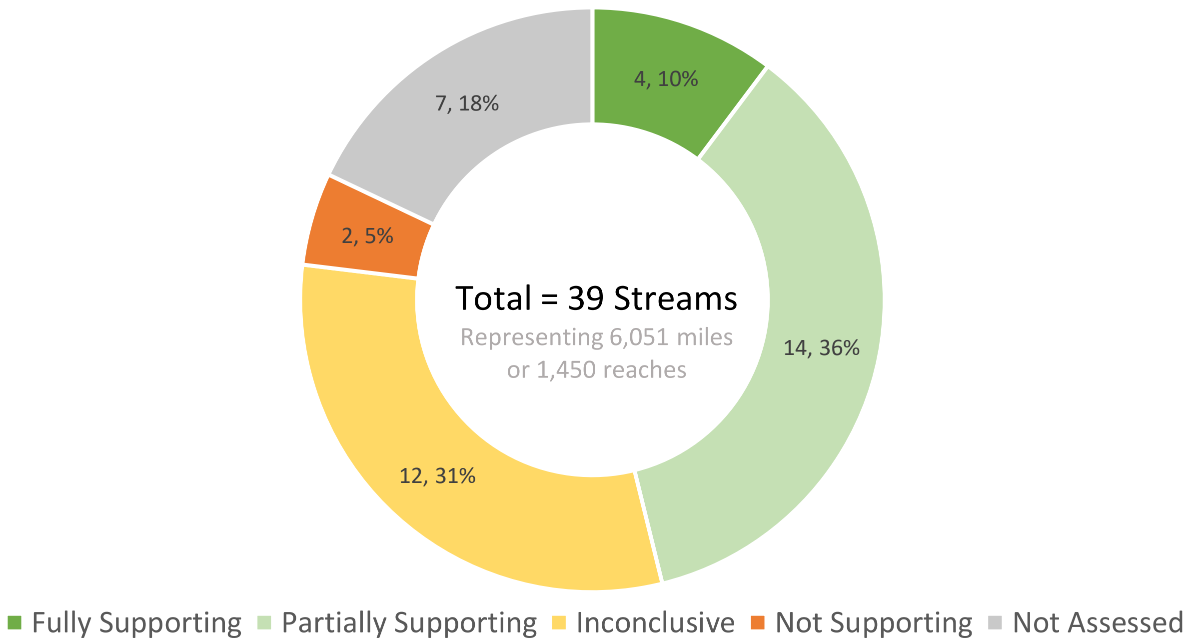

Figure 8. Assessments by Waterbody. Number of assessed waterbodies by category shown followed by percentage.

Each intermittent stream has multiple designated uses, which are assigned in the Arizona Administrative Code. Fish consumption and agricultural designated uses are generally supporting their use across Arizona for intermittent streams (Figure 9). The aquatic life use has the highest inconclusive percentage of any use.

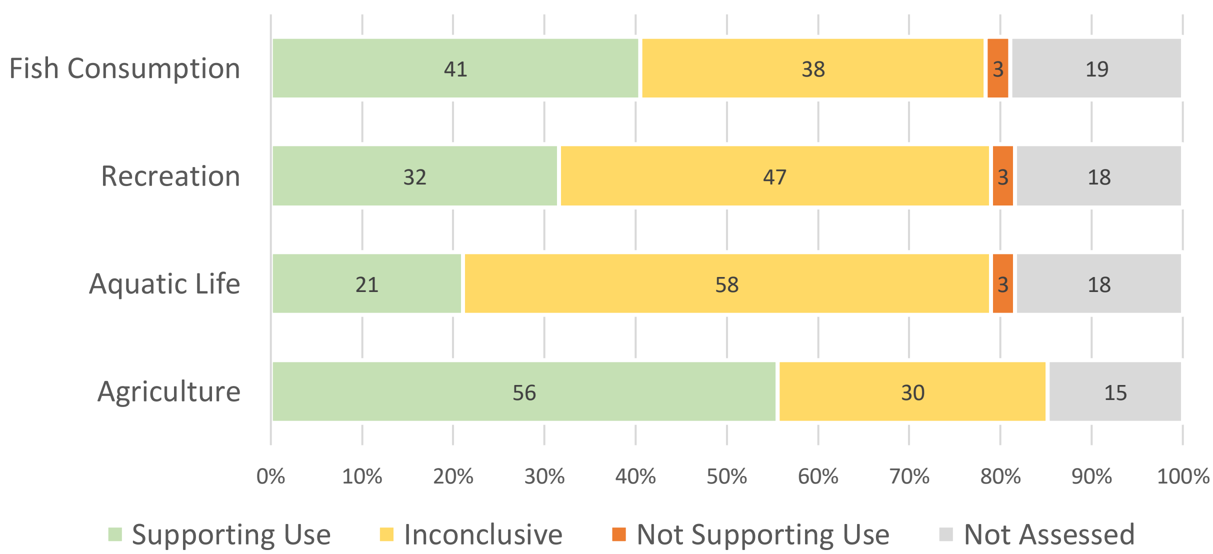

Figure 9. Intermittent stream assessment by designated use. Total = 39 stream reaches.

Inconclusive assessments are due to exceedances or missing data (Table 1). Inconclusive assessments due to missing data occurs when samplers were not able to sample a stream at least three times because the stream dried up. Exceedances of a water quality standard can also cause an inconclusive result. For example, a minimum of five samples is needed if there is a dissolved oxygen exceedance. A binomial distribution is used to determine how many samples are required before an attainment or impairment decision can be made for each parameter. One (or sometimes even several) exceedances do not mean a stream's use is impaired.

Table 1. Number of intermittent exceedances by use.

Use	Exceedance	Missing core/seasonal distribution	Total
Agriculture	1	7	8
Aquatic Life	16	6	22
Recreation	7	11	18
Fish Consumption	3	11	14

Exceedance / Impairment Summary

Parameters that exceed a water quality standard but are not impairing the use of the stream can be considered to be a potential threat. Additional data may show that a particular stream is actually impaired rather than inconclusive for a particular parameter. Alternatively, the data may show that although there is an exceedance of the standard, the overall use is attaining.

Dissolved oxygen is the most common exceedance. There were 19 different dissolved oxygen exceedances over the course of this study (Table 2). It is not unusual for low flow or pooled streams to have low dissolved oxygen values. None of these resulted in an impairment decision because dissolved oxygen requires more samples before an impairment decision can be made in accordance with the binomial rule (Table 3).

Table 2. Number of intermittent exceedances by parameter.

Sum of # of Exceedances	Inconclusive	Not Supporting	Total
DISSOLVED OXYGEN (DO)	19		19
ARSENIC	2	14	16
ESCHERICHIA COLI	8		8
COPPER	4	2	6
PH	4		4
LEAD	4		4
SELENIUM	1		1
MANGANESE	1		1
Grand Total	**43**	**16**	**59**

Table 3. Binomial Distribution

Samples Collected		Minimum Exceedances		Maximum Exceedances
FROM	TO	IMPAIRED (Binomial)	INCONCLUSIVE	ATTAINING
3	9	NA	NA	0
10	15	NA	3	2

Samples Collected		Minimum Exceedances		Maximum Exceedances
16	19	NA	4	3
20	23	5	4	3
24	32	6	5	4

A water quality sample was taken even if only a pool of at least 30 feet in length was present. Dissolved oxygen standards are based on elevation (above or below 5,000 feet). The aquatic and wildlife cold standard for dissolved oxygen is 6 mg/L and the standard for aquatic and wildlife warm is 7 mg/L. There was not a significant difference between flowing streams and pools for cold water streams (p value of 0.8929 using the Wilcoxin rank sum test). Only six cold water pool samples were taken and the variation between those six sites was large. There is a significant difference between flowing waters and pools for warm water sites (p value of 0.003694 using the Wilcoxin rank sum test). Again the sample size for pool samples is fairly low (Figure 10).

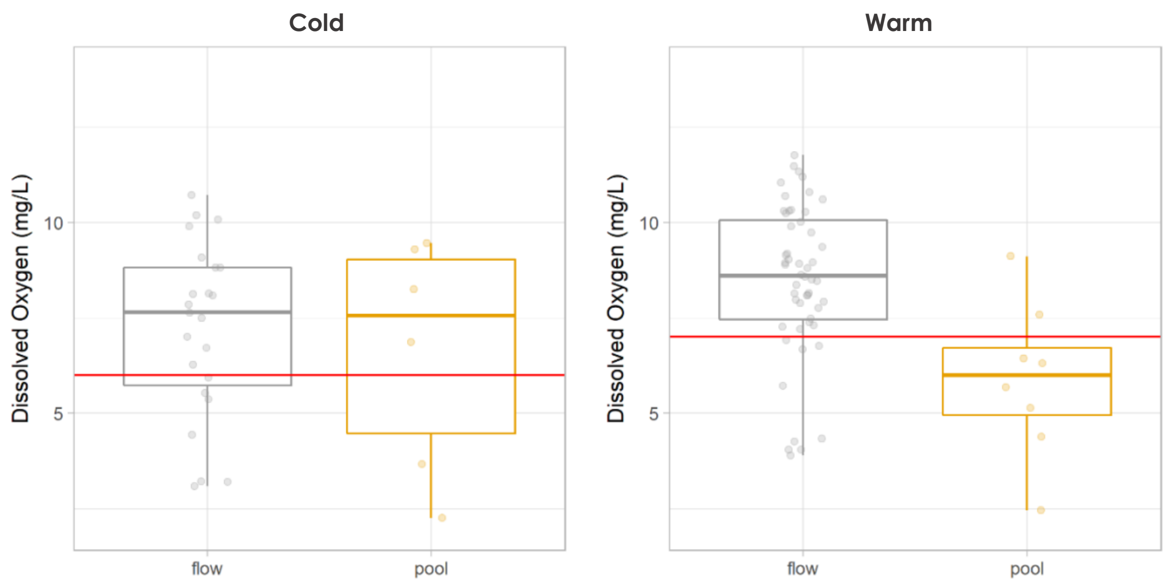

Figure 10. Dissolved oxygen for cold and warm water streams in flowing water and pools. The red line represents the water quality standard.

Flow Summary by Site

Fiscal year 2017 was significantly dryer than 2016 due to less precipitation (Figure 11). In 2016 there were 1,482 dry days and 3,291 wet days for all sites. In 2017 there were 3,251 dry days and 3,261 wet days for all sites. A Pearson's chi-squared test indicates there is a significant difference for stream flow between fiscal year 2016 and 2017 (p-value < 2.2e-16).

The significant difference in stream flow does not change the overall results of the data. The probabilistic design provides a snapshot of the condition of all of Arizona's intermittent streams for fiscal years 2016 and 2017. Knowing that fiscal year 2016 was more wet than 2017 helps interpret the data from this one probabilistic study. Additional probabilistic studies would need to be conducted to determine if days of flow impacts intermittent stream condition.

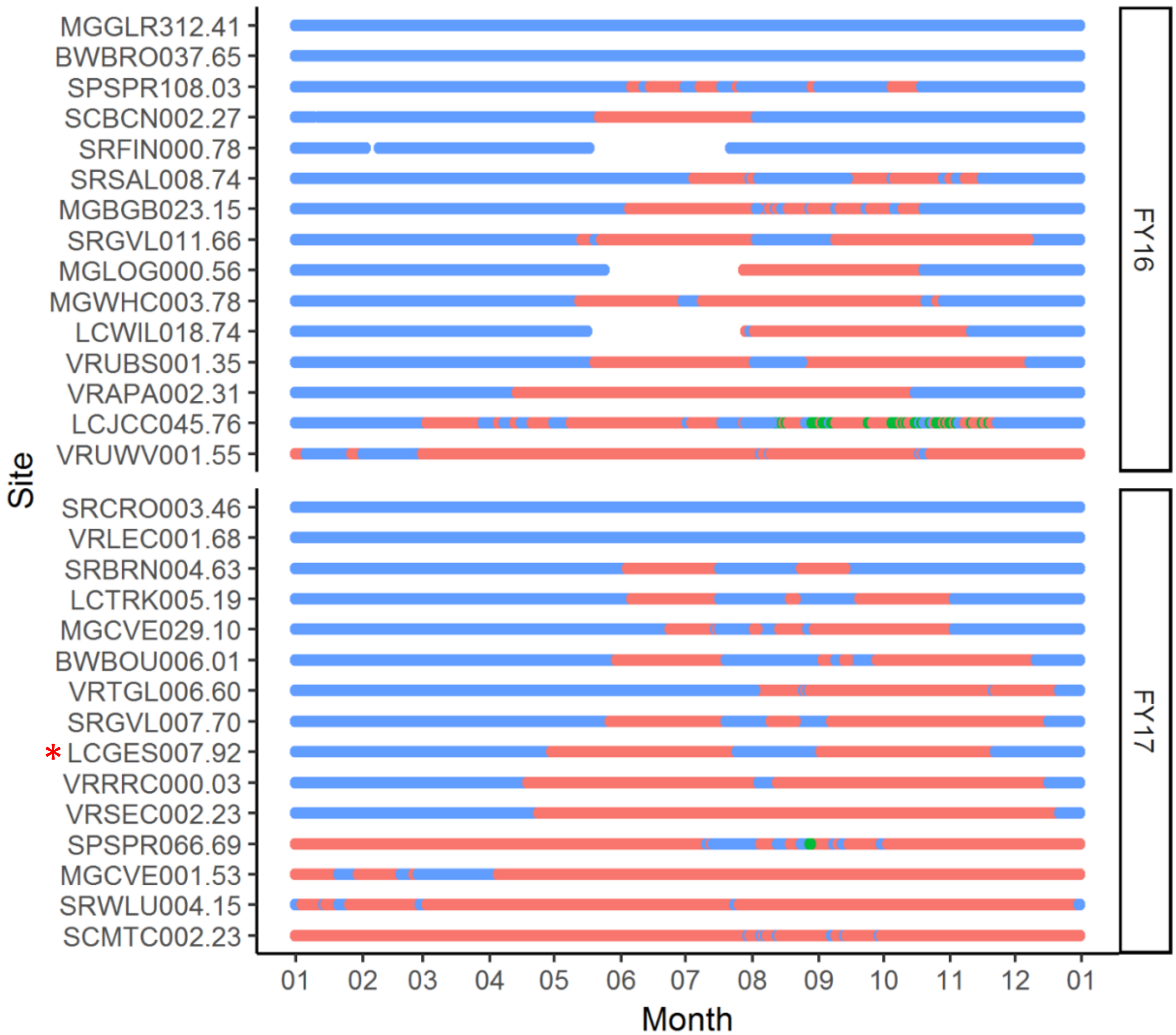

Figure 11. Days of flow for 30 sites. Wet. Dry. Missing. Gaps for SRFIN000.78, MGLOG000.56, LCWIL018.74 caused by flooding. See Appendix B for a list of site names.

General Springs (*LCGES007.92 Figure 12) shows the typical wet dry cycle coupled with daily precipitation data. The sustained winter rains correspond to the wet winter periods. The dry period in May was preceeded by a couple months of low precipitation. The dry cycle that began in September followed a period of precipitation in August where evaporation rates exceeded infiltration rates.

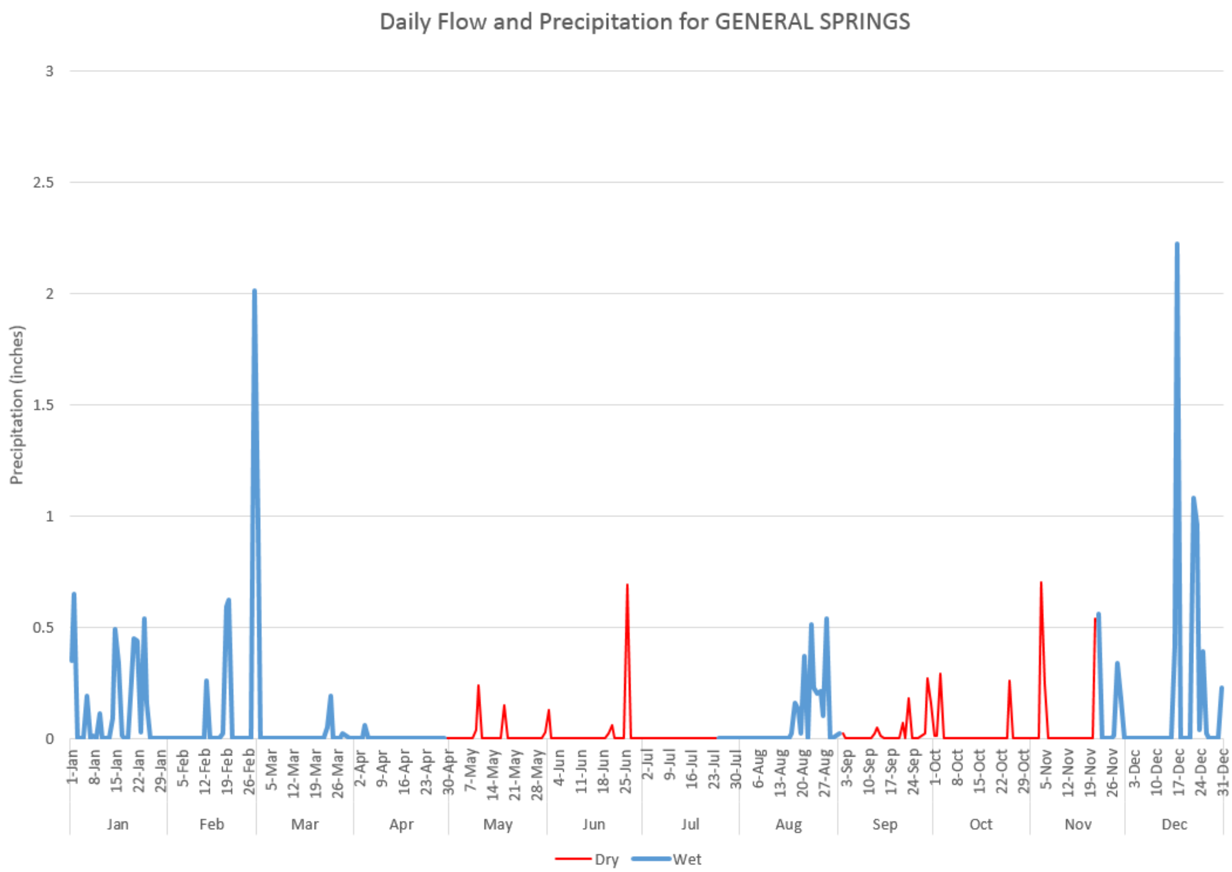

Figure 12. Daily flow and precipitation for General Springs.

Mattie Canyon (SCMTC002.23, FY17) did not follow the typical intermittent pattern and only flowed for eight days (Figure 13). Mattie Canyon passed the desktop reconnaissance as an intermittent stream due to water present in aerial photos. After a full year of flow analysis it was determined that Mattie Canyon is actually an ephemeral stream that only flows in response to storm events.

Figure 13. Brush fire at Mattie Canyon (SCMTC002.23) moved through the reach in April 2017. Flooding on July 23, 2017 followed by a dry event illustrates the ephemeral status of this stream.

Typical Stream Flow and Use

When considered as a whole, Arizona's intermittent streams typically flow from December to mid-May. They go dry in June (Figure 14). In August and September they are partially wet and then dry up again in October. Based on time-lapse camera data, people tend to frequent intermittent streams in the cooler months and avoid the streams during summer. Human visitation in October is three times that of July even though intermittent streams are dry, which implies that people are avoiding the summer heat rather than only visiting streams that have water. Wildlife follow the opposite trend. They tend to visit intermittent streams during the summer months even though the streams may not have water. The riparian vegetation provides good habitat and forage. Many intermittent streams have pools that make it through the hot summer. Animals take advantage of any water they can find.

Salome Creek would regularly flow only at night, possibly due to transpiration by plants (Figure 15). Salome Creek shows how intermittent stream how stream flow can differ by time of day as well as by month. High visitation by javelin and other wildlife at Salome Creek is probably due to the reliable water source and cooler temperatures in the riparian zone.

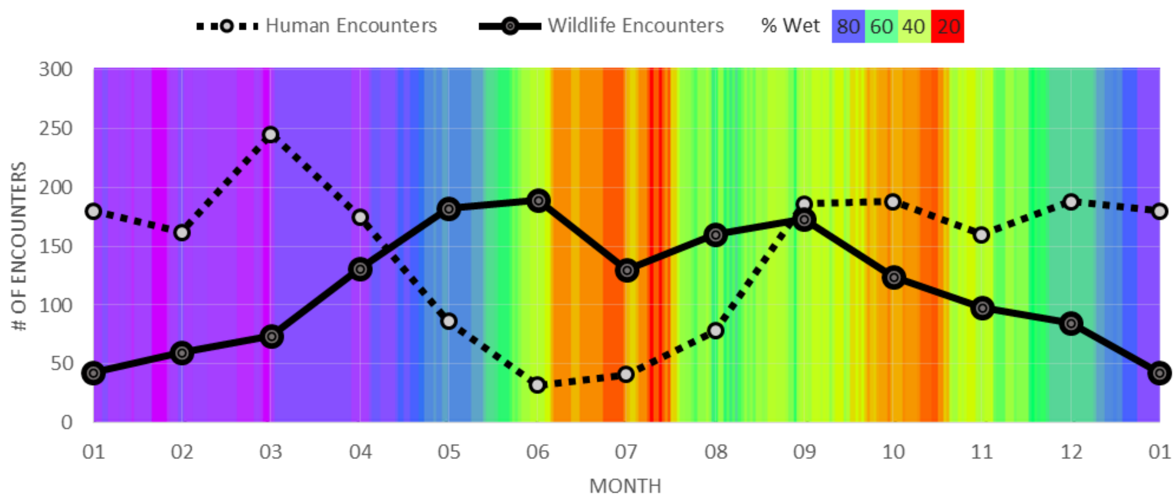

Figure 14. Typical stream flow by month and number of people and wildlife observed.

Figure 15. Time-lapse of flow at Salome likely caused by nightly transpiration by riparian plants.

Designated Use Changes

Appendix B of the Arizona Administrative Code identifies the designated uses for each waterbody in Arizona. Most of the streams in Arizona are not explicitly identified in Appendix B but rather identified using the Tributary Rule (A. A. C. R18-11-105). Table 4 itemizes recommended changes to Appendix B to ensure that designated uses are correctly identified.

Table 4. Changes in designated use

Name (Site)	Use Change	Reason
Mattie Canyon (SCMTC002.23)	Change from Aquatic and Wildlife Warm to Aquatic and Wildlife Ephemeral	Only 8 days of flow. Response to stormflow.

Name (Site)	Use Change	Reason
Whiteford Canyon (MGWHC003.78)	Change from Aquatic and Wildlife Ephemeral to Aquatic and Wildlife Warm Add to Appendix B and add Agriculture Livestock Use	213 days of flow in FY16. Response of flow not just due to storm events Cows regularly use stream
Long Gulch (MGLOG000.56)	Add to Appendix B and add Agriculture Livestock Use	Cows regularly use stream
SPSPR108.03 (San Pedro River)	Add to Appendix B and add Agriculture Livestock Use	Cows regularly use stream
Crouch Creek (SRCRO003.46)	Add to Appendix B and add Agriculture Livestock Use	Cows regularly use stream
Hinton Creek) SRFIN000.78	Add to Appendix B and add Agriculture Livestock Use	Cows regularly use stream
Green Valley Creek (SRGVL007.70 & SRGVL011.66)	Add to Appendix B and add Agriculture Livestock Use	Cows regularly use stream
Walnut Creek (SRWLU004.15)	Add to Appendix B and add Agriculture Livestock Use	Cows regularly use stream
Unnamed Tributary to Williamson Valley Wash (VRUWV001.55)	Add to Appendix B and add Agriculture Livestock Use	Cows regularly use stream

Intermittency and Macroinvertebrate Taxa Richness

Macroinvertebrate samples were collected at 21 of the 32 sites. Macroinvertebrates are excellent indicators of aquatic life health because they are direct measures of the aquatic community. Arizona has developed an Index of Biological Integrity for perennial streams and has developed standards for warm and cold streams (A.A.C. R18-11-108.01).

Arizona does not currently have standards for macroinvertebrates in intermittent streams. Developing macroinvertebrate standards for intermittent streams would need to take into account the gradient of flow, which affects macroinvertebrate diversity (Figure 16). Perennial systems flow year round and do not need to take into account days of flow. Days of flow had a significant effect on macroinvertebrate taxa richness in intermittent stream. Streams that only flowed 120 days per year only had around 10 different taxa present while streams that flowed year round had approximately 35 taxa.

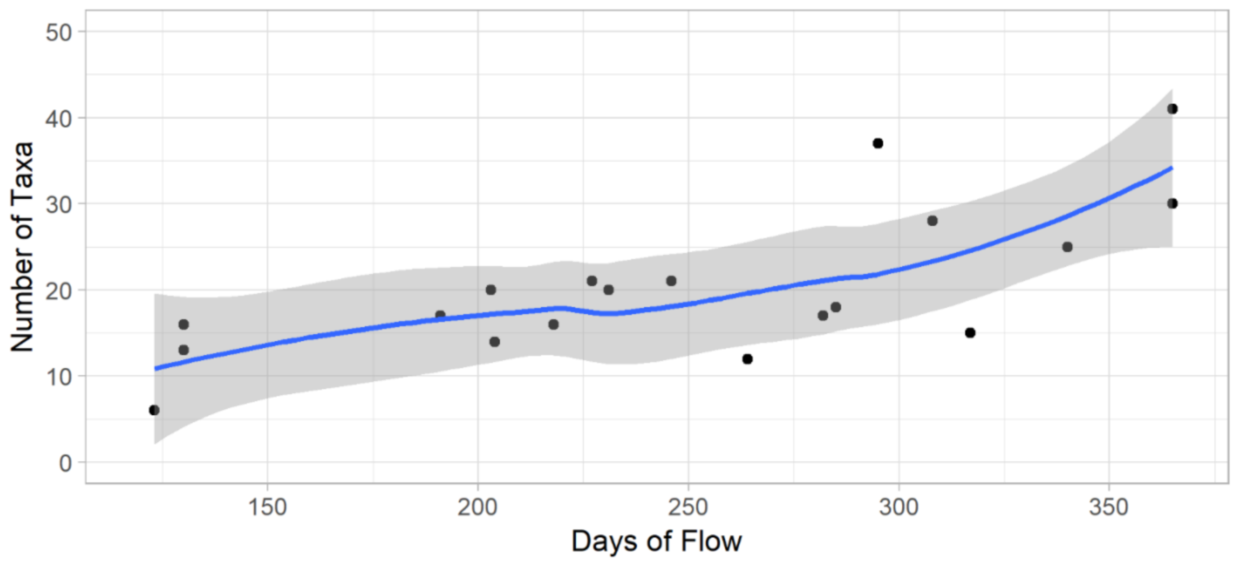

Figure 16. Taxa richness versus days of flow. The Blue line is a Lowess smooth curve. The Grey zone shows 90% confidence interval.

Figure 17. Intermittent stream macroinvertebrate sampling.

Future Study and Lessons Learned

This was the first statewide study of intermittent stream in Arizona. The following list has various items that can help tighten the data and make sampling and analysis easier.

- Continue sampling inconclusives until impairment or attainment decision made for each parameter and use. This means that samplers need to be empowered to look at the data they collect and be given the freedom to adjust sampling frequency to make impairment and attainment decisions.
- Macroinvertebrate sampling timeframe and methods should be adjusted to fit intermittent streams. Sampling should occur during the winter when flows are present in most streams. Six

of the 11 missed bug samples were sampled too late. Protocols should also handle large intermittent systems like the Gila River. Methods should use a protocol more similar to EPA's national aquatic resource survey, which use multiple transects within a reach covering all habitat types (pool, riffle, run).

- Sampling methodology should use a comprehensive longitudinal analysis of stream flow. Most of the focus of this study was on how streams changed at a specific point (where the camera was located). Incorporate wet dry mapping for every sample event to get a longitudinal picture of intermittency.
- Camera loss due to flooding was an issue. Install cameras higher on trees and use living trees.
- Co-locate precipitation measurements with camera installations.
- All forms must have the random site identifier and the ADEQ site ID. Significant effort was spent resolving ambiguous notes for streams with the same name like Walnut Creek. There were three different Walnut Creeks in different parts of Arizona. Random ID's and ADEQ site IDs are needed to ensure every site sampled in sequence.
- Use telemetry to send pictures daily to reduce possible loss and coordinate chemistry sampling events.
- Staff gage each site so flow can be quantified.

Conclusions / Recommendations

Based on current water quality standards, almost half of Arizona's intermittent streams are in good condition (46%). Five percent of Arizona intermittent streams are impaired. Copper and arsenic are the main pollutants causing impairment.

Arizona intermittent streams typically go dry in June and July and again in October. Wildlife visit intermittent streams more often during hot summer months, while humans tend to avoid intermittent streams during the same period. Duration of flow is particularly important for aquatic life. Macroinvertebrate taxa richness increases with days of flow. Any development of intermittent macroinvertebrate standards should take into account days of flow.

ADEQ recommends changing the designated uses of nine streams listed in Table 4 during the standards rule change. In addition, the standard for dissolved oxygen should exclude the naturally low levels of dissolved oxygen in intermittent pools.

Future studies should focus on resolving inconclusive results (Figures 8 and 9) by sampling until either an attainment or impairment decision is reached, which would decrease the number of inconclusive decisions and remove ambiguity from the data. The amount of effort to turn most inconclusive results into an attaining or impaired decision typically involves an additional two sampling trips at least seven days apart.

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Appendix A - Methods

The following methods were used to sample and assess intermittent streams.

- Sampling was conducted in accordance with ADEQ's 2018 Standard Operating Procedures for Surface Water Sampling – Chapter 8 http://static.azdeq.gov/wqd/sampling.pdf.
- Assessment methodology used the 2016 Arizona Clean Water Act Assessment Methodology – Chapter 2 http://static.azdeq.gov/wqd/wqa/2016_cwaa_final.pdf.
- Quality assurance and control procedures used the 2015 ADEQ quality assurance plan http://static.azdeq.gov/wqd/fish_advisory_SWS_QAPP.pdf.

These documents provide a detailed look at how intermittent streams were sampled. In general, the sampling methodology followed the following basic workflow.

1. **Select sites.** Randomly select an intermittent stream site.
2. **Perform a desktop reconnaissance.** Determine if a site visit is necessary.
3. **Reconnaissance site visit.** Perform a site visit, if needed, to confirm that a site is samplable. Intermittent indicators in the field include riparian vegetation, land owners, hydrology, fish and macroinvertebrates (if present).
4. **Install cameras.** Cameras were installed where water was likely to be present (like bedrock pinch points) and ideally facing at least two types of habitat if possible (riffle, pool, run). Cameras were set to take 2 pictures per day and if motion is present.
5. **Visit cameras quarterly and collect water quality samples.**
   A. Collect water quality chemistry samples quarterly if possible. Chemistry samples were taken if at least 30 feet of water was present. Nutrients, inorganics, total metals, dissolved metals, and suspended sediment concentration were collected from all sites. Quality control samples (blanks, duplicates, and splits) were taken at a rate of ten percent. All quality assurance samples for this project were within acceptable limits defined by ADEQ's QAPP.
   B. Download pictures. Adjust camera if needed.
   C. Collect habitat and macroinvertebrate data in the spring.
6. **Process pictures.** Identify flowing water and animals for each picture. Aggregate over 150,000 pictures into a daily log.
7. **Analyze the data.** Determine if standards were met for each designated use and if each use was attaining, inconclusive, or impaired.

Appendix B – Site Names

Site	Site Name	WBID	Assessment	Fiscal Year
MGGLR312.41	GILA RIVER	AZ15050100-007	Partially Supporting	FY16
BWBRO037.65	BURRO CREEK	AZ15030202-008	Fully Supporting	FY16
SPSPR108.03	SAN PEDRO RIVER	AZ15050201-299	Inconclusive	FY16
SCBCN002.27	BEAR CANYON CREEK	AZ15050302-018	Inconclusive	FY16
SRFIN000.78	FINTON CREEK	AZ15060103-797	Partially Supporting	FY16

Site	Site Name	WBID	Assessment	Fiscal Year
SRSAL008.74	SALOME CREEK	AZ15060103-022	Partially Supporting	FY16
MGBGB023.15	BIG BUG-BELOW PROVIDENCE MINE	AZ15070102-034B	Partially Supporting	FY16
SRGVL011.66	GREEN VALLEY CREEK	AZ15060105-023	Partially Supporting	FY16
MGLOG000.56	LONG GULCH	AZ15070102-591	Fully Supporting	FY16
MGWHC003.78	WHITEFORD CANYON	AZ15050302-294	Fully Supporting	FY16
LCWIL018.74	WILLOW CREEK	AZ15020008-011	Partially Supporting	FY16
VRUBS001.35	UNNAMED TRIB TO BIG SPRING CANYON - NORTH OF FS RD 14	AZ15060202-614	Partially Supporting	FY16
VRAPA002.31	APACHE CREEK	AZ15060201-019	Inconclusive	FY16
LCJCC045.76	JACKS CANYON	AZ15020008-004	Inconclusive	FY16
VRUWV001.55	UNNAMED TRIB TO WILLIAMSON VALLEY WASH	AZ15060201-486	Inconclusive	FY16
SRREY001.45	REYNOLDS CREEK	AZ15060103-202	Inconclusive	FY16
SRCRO003.46	CROUCH CREEK	AZ15060103-040	Partially Supporting	FY17
VRLEC001.68	LEE CANYON	AZ15060202-623	Partially Supporting	FY17
SRBRN004.63	BARNHARDT CANYON	AZ15060105-455B	Not Supporting	FY17
LCTRK005.19	TURKEY CREEK	AZ15020008-580	Inconclusive	FY17
MGCVE029.10	CAVE CREEK-SPUR CROSS	AZ15060106B-026A	Inconclusive	FY17
BWBOU006.01	BOULDER CREEK	AZ15030202-005B	Not Supporting	FY17
VRTGL006.60	TANGLE CREEK	AZ15060203-028	Fully Supporting	FY17
SRGVL007.70	GREEN VALLEY	AZ15060105-023	Partially Supporting	FY17
LCGES007.92	GENERAL SPRINGS CANYON	AZ15020008-521	Partially Supporting	FY17
VRRRC000.03	RARICK CANYON	AZ15060202-009	Partially Supporting	FY17
VRSEC002.23	SECRET CANYON	AZ15060202-499	Inconclusive	FY17
SPSPR066.69	SAN PEDRO	AZ15050202-003	Partially Supporting	FY17
MGCVE001.53	CAVE CREEK	AZ15060106B-026A	Inconclusive	FY17
SRWLU004.15	WALNUT CREEK	AZ15060105-183	Inconclusive	FY17
SCMTC002.23	MATTIE CANYON	AZ15050203-012	Inconclusive	FY17
LCMLK002.50	MILK CREEK	AZ15020001-309	Partially Supporting	FY17