

CIENEGA CREEK NATURAL PRESERVE

Hydrologic Monitoring & Analysis

July 2016 to June 2017

Prepared by
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Cover photos: Cienega Creek (CC2) flow monitoring, June 2017 (top left); Davidson Spring 1 flow monitoring, June 2017 (bottom left); Cienega Well, July 2015 (top center); Empirita CCI Well, July 2015 (bottom center); USGS Stream Gauge 09484600 and District ALERT Gauge 4250, April 2017 (right)

Executive Summary

Overview

The Water Resources Division of the Pima County Regional Flood Control District (District) conducts hydrologic monitoring within the Cienega Creek Natural Preserve (Preserve) and vicinity, with evaluation and reporting performed annually after the end of the fiscal year (June 30). The Preserve covers over 4,000 acres along a 15-mile stretch of Cienega Creek (Creek) and a 1.75-mile stretch of Davidson Canyon Wash in eastern Pima County, Arizona. In addition, the study area includes about 310 acres of land along Davidson Canyon Wash owned by Pima County (County) as part of the Bar V Ranch acquisition (**Figure 1-1**). Stream flows within the Preserve support rare and endangered fish and frogs as well as dense areas of cottonwood/willow and mesquite woodland forests that provide shelter and foraging habitat for a wide variety of native wildlife. Land use and natural changes, including climate change, can threaten these unique natural resources throughout the region. Both Cienega Creek and Davidson Canyon Wash are designated “Outstanding Arizona Waters” due to the presence of surface water that meets or exceeds the State’s standards for warm water aquatic and wildlife species. In addition, the Preserve is mitigation land to help offset development and other activities that may affect federally threatened and endangered species throughout Pima County. Hydrologic monitoring activities include surface flow extent (wet/dry mapping), base and storm flow measurements, groundwater level monitoring, precipitation and water quality sampling. Flow volume, extent and depth to water have recovered some the past 2-3 years after a drought dating back to the late 1990s. However, 20- year trends are still downward.

Streamflow Volume

Base creek flows are field measured by District staff at two sites: downstream of Tilted Beds and near Marsh Station Road Bridge (**Figure 2-1**). Monitoring of the site downstream of Tilted Beds began in October 2016 due to no flow at the Tilted Beds site since May 2009. Average quarterly flow at the new site from October 2016 to June 2017 was 0.05 cfs, similar to the monthly average flow of 0.04 cfs at the Tilted Beds site from July 1994 to May 2009. However, the peak of 0.14 cfs at the new site in January 2017 was less than half of the highest peak (0.36 cfs) at the Tilted Beds site in April 1995. The site close to Marsh Station Road has been monitored since August 1993, with a maximum discharge of 3.24 cfs in March 1994 and a minimum discharge of 0.013 cfs in June 2015. Peak discharge near Marsh Station Road was 0.99 cfs in January 2017 and a low of 0.21 cfs was measured in June 2017. Peak base flows at this site have not reached 2 cfs since September 2006 and 1.5 cfs since February 2009. The yearly low in June 2017 is the highest pre-monsoon discharge since 0.21 cfs in June 2009.

Base flows are also field measured by District staff along Davidson Canyon at two known spring sites: Davidson Spring #1 and Davidson Spring #2 (**Figure 2-1**). Quarterly monitoring of these two sites recently began in February 2016, with only a few measurements taken prior during water

quality sampling events. Flows at Davidson Spring #1 ranged from 0.013 cfs in October 2016 to 0.49 cfs in February 2017. Flows at Davidson Spring #2 ranged from 0.007 cfs in March 2017 to 0.043 cfs in February 2016. Recorded flows at these two springs have been infrequent, with many observations showing dry conditions between March 2007 and August 2015. However, flows at Davidson Spring #1 were recorded almost monthly since October 2016.

Automated records are available from four stream gauges along Cienega Creek from The Narrows to about one mile downstream of Pantano Dam and at one gauge along Davidson Canyon just upstream of Interstate 10 (**Figure 2-1**). Two gauges operated by the United States Geologic Survey (USGS), at The Narrows and Pantano Dam, provide continuous base flow records along perennial stream reaches. The Narrows gauge, operated since 2002, represents daily flows coming into the Lower Cienega Creek Basin near the southern upstream edge of the Preserve. Flow volume recorded over the last year (1,037 acre-feet) was below the 15-year average of 1,239 acre-feet, but above the median flow volume of 879 acre-feet. The average volume shows a composite of wet years (2006-2008, 2010 and 2014-2016) surrounded by much drier years (2002-2005, 2009 and 2011-2013). The gauge at Pantano Dam, having a much longer period of record, provides daily flows leaving the watershed. Flow volume over the last year was about one-half the 20-year average of 3,631 acre-feet, also consisting of a few wet years surrounded by very dry years. Daily base flows at this gauge have been steadily trending upward since they reached a low of 0.13 cfs in 2010; time will tell if this trend continues or if it is cyclic as in previous years. The District operates the other three gauges in the study area that monitor storm flows along ephemeral reaches. The gauge at Davidson Canyon has indicated mostly drier conditions over the last ten years, with volumes in 2006, 2008 and 2011 exceeding the average of 525 acre-feet. The other two gauges along Cienega Creek, upstream of I-10 and downstream of Pantano Dam, began operation in July 2014 and July 2016 respectively, and no trends are available at this time.

Surface Flow Extent

Pima Association of Governments (PAG) maps the extent of base (perennial) flow, or wet/dry mapping, during the months of March, June, September and December. Pre-monsoon base flow in June shows worst case watershed conditions in the Preserve, and was observed over a 9.5-mile stretch of Cienega Creek from I-10 to Pantano Dam since 1985 (**Figure 3-1**). The 1.44 miles observed by PAG in June 2017 represents only 15 percent of the original extent. This is the third consecutive year extent of base flow has increased since a low of 0.86 miles in June 2014. However, a significant downward trend has been observed since 2001 when over 5 miles of flow was recorded.

Along Davidson Canyon upstream of I-10, base flow extent has typically begun near Davidson Spring #1 since records were first established in 2006 (**Figure 3-1**). Although annual maximum base flow has been recorded on a yearly basis, ranging from 0.002 to 1.6 miles, pre-monsoon base flow has only been observed in six of the twelve years. The 0.12-mile extent observed in June 2017 is the second highest since 0.22 miles was observed in 2009, and is the second consecutive year flow was observed during this month after three consecutive years of no flow.

Along Davidson Canyon downstream of I-10, base flow generally begins near Davidson Spring #2 and heads towards the confluence with Cienega Creek (**Figure 3-1**). The full extent of flow, covering a distance of 0.21 miles (1,100 feet), was recorded during a few months in both 1999 and 2001. District staff recorded small surface flow extents from Davidson Spring #2 in January and March of 2017, covering 0.02 miles and 0.004 miles respectively. This is the first time flow has been observed at this site since September 2010, and only the second time since March 2004.

Groundwater Conditions

The District regularly measures groundwater levels in ten wells distributed throughout the Preserve (**Figure 4-1**). With over 20 years of data available, many of the wells show distinct seasonal trends in groundwater levels with peaks occurring during or after the summer monsoon period (July-September) and troughs at the end of spring (May-June). Yearly trends, evaluated using data collected in January, indicate the groundwater table has been in decline since 1995 with an average annual rate of decline of 0.46 feet for four monitoring wells with available data. However, the recent groundwater level trend shows a recovery rate of 0.24 feet per year since 2006, based upon seven monitoring wells with available data. The 10-year recovery in groundwater levels has continued despite water levels dropping over the last year in most of the monitoring wells. As of June 2017, depths to groundwater have ranged from about 20 feet below land surface (bls) near the middle of the Preserve to 220 feet bls at the downstream end near Colossal Cave Road. Based on the monitoring wells and existing stream flow, an area of shallow groundwater (depth above 50 feet below land surface) exists along Cienega Creek from Pantano Jungle to Pantano Dam and along Davidson Canyon Wash about one-third of a mile upstream of I-10 to the confluence with Cienega Creek.

Water Quality and Geochemistry

Water quality monitoring has been conducted semi-annually along Cienega Creek since 2010 and along Davidson Canyon since 2008 (**Figure 5-1**). The Davidson Canyon site was dry during a number of site visits, with no samples collected during Calendar Years 2011 and 2013. Along with the most recent results, average water quality within the Preserve has been very good over the last ten years or so, with only secondary drinking water standards of sulfate, total dissolved solids, and manganese exceeded. Secondary exceedances slightly affect the taste of the water, but are not harmful to human or aquatic health. Based upon cation/anion analyses, the surface water along Cienega Creek is classified a calcium-sulfate bicarbonate type, while the surface water along Davidson Canyon is more of a calcium bicarbonate type.

Precipitation

The District operates eight automated precipitation gauges within and surrounding the Preserve that collect data in real time and transmit the data to a database for tabulation (**Figure 6-1**). In 2016, annual precipitation from these gauges ranged from 5.75 inches at Rancho Del Lago (northwest of Preserve) to 17.27 inches at Davidson Canyon Wash upstream of I-10 (**Table 6-1**).

The amount at Rancho Del Lago was almost half of the 22-year average for this location. Precipitation amounts in the other gauges were generally greater than the average from 1994-2016, with differences ranging from -0.42 inches at Haystack Mountain (southeast of Preserve) to +4.44 inches along Mescal Arroyo (~6 miles East of Preserve). Annual flow volumes and groundwater levels generally appear to be reflective in the precipitation amounts, with highs occurring after wet years (1998, 2000, 2006-2008, 2011 and 2015) and lows occurring after drier years (2001-2005, 2009-2010 and 2012-2013). Due to watershed size and many tributary watercourses from different mountain ranges, precipitation records are not all consistent with flows and water levels throughout the period of record.

Recommendations

Based on this hydrologic evaluation, the following recommendations are needed to enhance the watershed monitoring program for the Preserve:

- Continued maintenance and operation of the water level data loggers in six of the wells along Cienega Creek and Davidson Canyon
- Continued cooperation with Arizona Department of Water Resources to maintain and operate the dataloggers located in the two wells downstream of Pantano Dam
- Continued maintenance and operation of the District's automated stream gauges at Cienega Creek near I-10, Davidson Canyon and Pantano at Schist sites to measure flows for evaluating the overall water balance for the Preserve
- Install gauges to capture stream flows coming into Cienega Creek from Mescal Arroyo and Agua Verde to help evaluate or assess inputs that are not captured by the current gauging system
- Modifying the water quality sampling protocol to include analyses of dissolved metals as well as total metals for water collected along Cienega Creek and Davidson Canyon Wash to match the "Outstanding Arizona Waters" warm water aquatic and wildlife standards.

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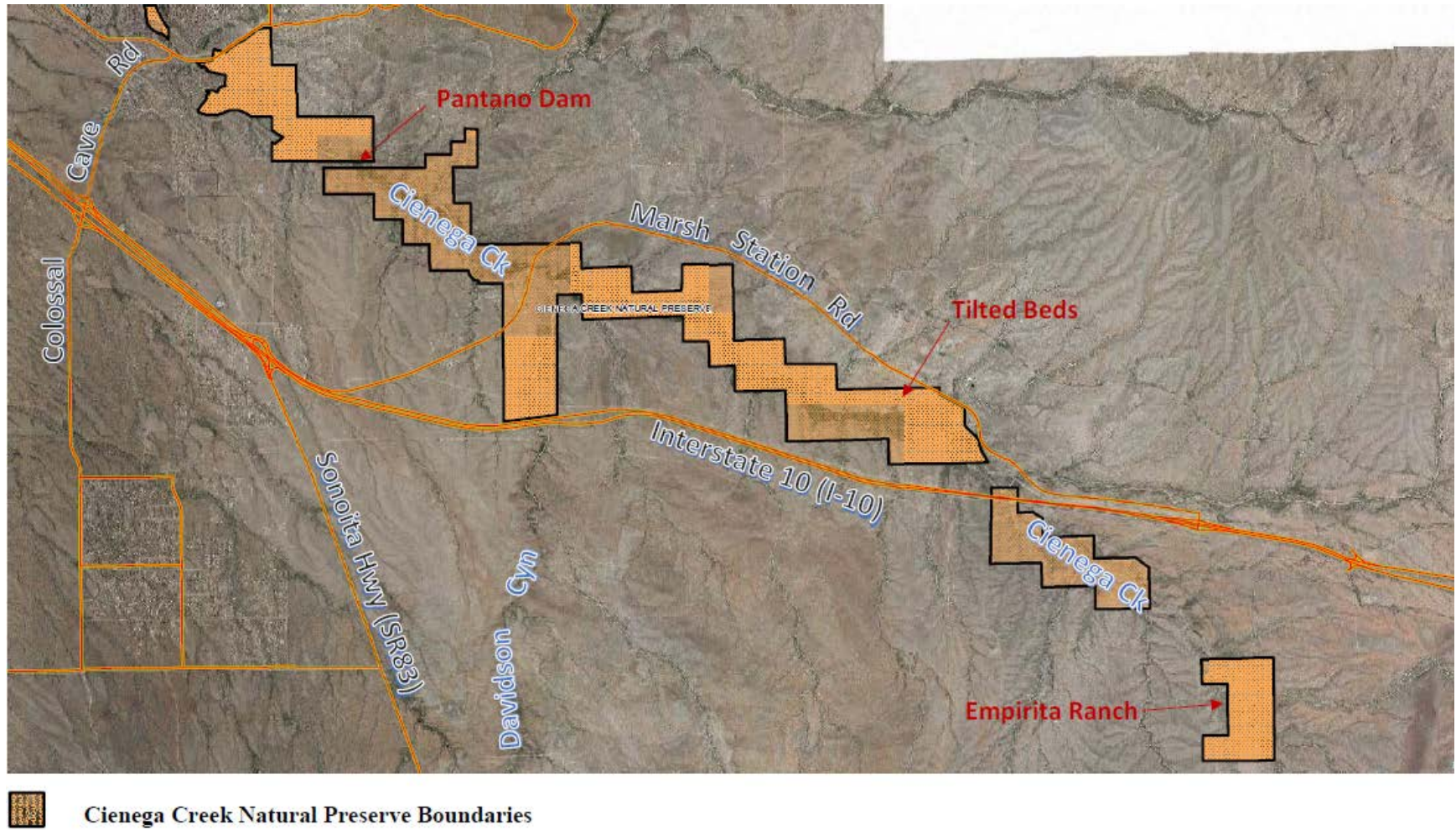
1.0 Introduction

With the purchase of its lands in 1986, the Pima County Regional Flood Control District (District) established the Cienega Creek Natural Preserve (Preserve) in order to protect one of the few remaining low elevation perennial streams and associated riparian habitats in southeastern Arizona. Stream flows along Cienega Creek help support rare and endangered fish and frogs as well as dense areas of riparian vegetation that provide shelter and forage to a wide variety of native wildlife. Encompassing over 4,000 acres (**Figure 1-1**), the Preserve is also an important human resource due to its scenic, cultural and recreational values. Through efforts by the District, the State of Arizona designated Cienega Creek and Davidson Canyon Wash as Outstanding Arizona Waters throughout the extent of the Preserve system. Preserve lands have also been designated as mitigation land under Pima County's Multi-species Conservation Plan to help offset impacts to threatened and endangered species by development and other "covered activities" throughout the County. Protecting water resources is one of the key elements to help maintain this area as a valuable piece to conservation in Pima County.

Hydrologic monitoring has been ongoing in the Preserve since 1984, starting with a program developed by Errol L. Montgomery and Associates to monitor groundwater levels, surface flows, water quality and extent of surface flows for evaluation of potential water developments in the Empirita Ranch area. After purchasing the lands and preparing a management plan for the Preserve, the District coordinated with Pima Association of Governments to continue monitoring surface flows, groundwater levels and stream flow extent to establish baseline conditions for comparison to possible future groundwater developments or land use changes within the Cienega Creek watershed. More recent efforts include periodic water quality data collection since 2008 and repeat photography since 2006. In addition to field monitoring, the District operates and maintains a network of automated precipitation and stream gauges utilized for water balance monitoring within the watershed as well as their intended purpose for flood warning to downstream areas. Coupled with water monitoring efforts by the U. S. Geological Survey (USGS), Bureau of Land Management, and Arizona Department of Environmental Quality, a multifaceted monitoring program has been established as a regional indicator for drought assessment and overall health within the Cienega Creek watershed.

As of July 2015, the District has taken over monitoring of stream flow volumes, groundwater levels and water quality data collection. PAG continues to monitor the extent of perennial flow through the Preserve on a quarterly basis as well as maintain repeat photography along much of the stream length (**Attachment A**).

Figure 1-1. Cienega Creek Natural Preserve Boundary Map



2.0 Streamflow Volume

2.1 Methods

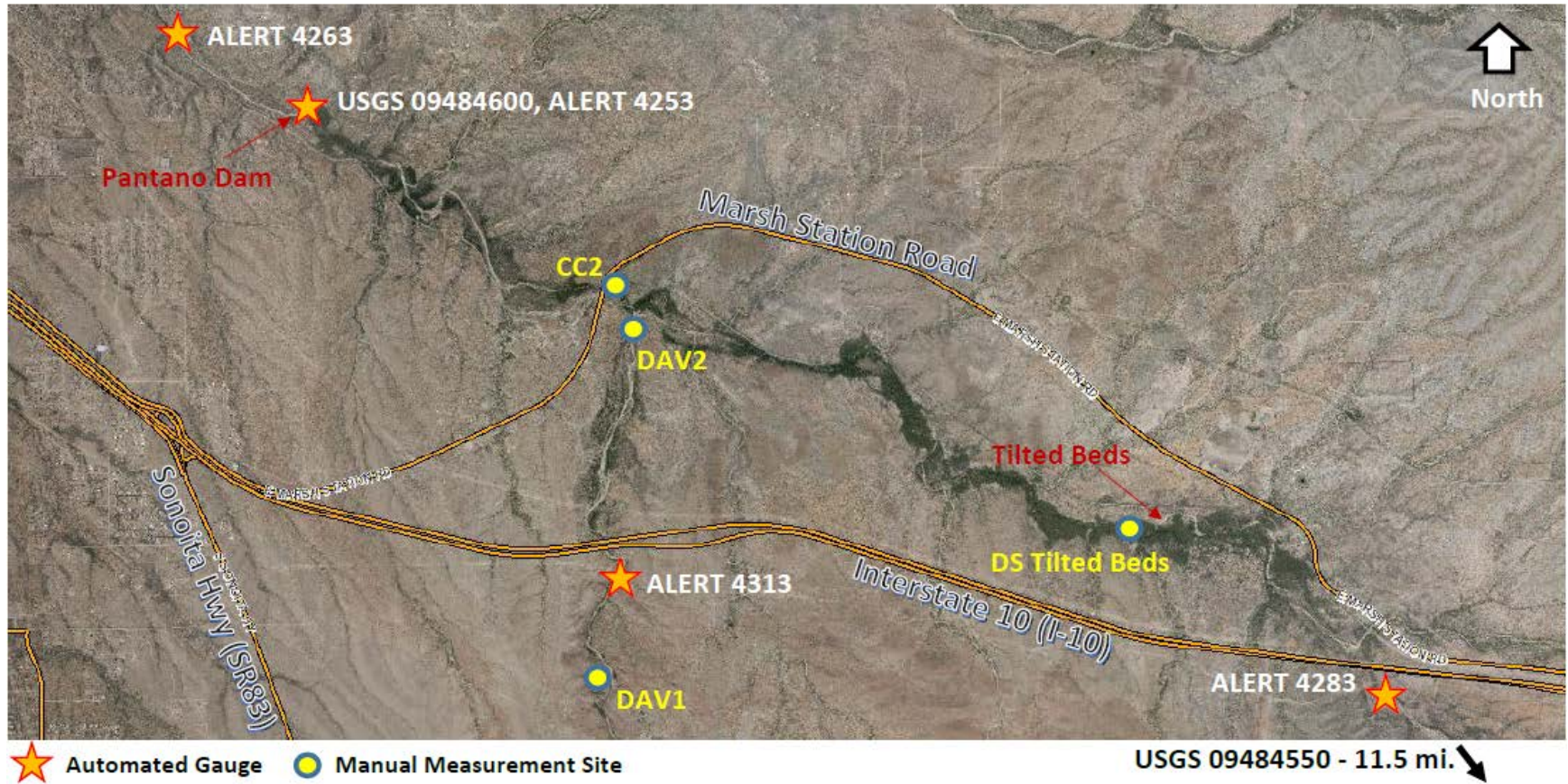
The District collects quarterly streamflow measurements along Cienega Creek near Marsh Station Road Bridge, downstream of Cienega Creek-Davidson Canyon Wash confluence, and at a point downstream from Tilted Beds, several miles upstream from Marsh Station Road Bridge (**Figure 2-1**). The District also collects streamflow measurements along Davidson Canyon Wash at Davidson Spring #1, upstream of Interstate 10 (I-10), and at Davidson Spring #2, upstream of Cienega Creek-Davidson Canyon Wash confluence (**Figure 2-1**). Measurements are made primarily using a Global Flow Probe, with discharge (Q) calculated in cubic feet per second (cfs). For flows too low to measure with the probe, measurements are either estimated using average channel geometry and flow rate or measured using the bucket method, flow volume through a weir or pipe over a set time. As defined within PAG's monitoring program (1998), the District continues to monitor streamflow only during baseflow conditions. For this evaluation, baseflow condition is discharge from the shallow aquifer into the stream channel without direct influence from surface runoff.

Within the Preserve, the following automated stream gauges collect surface flows in real time and transmit the data to databases for tabulation (**Figure 2-1**):

- ALERT 4283, along Cienega Creek upstream of I-10 Bridge
- ALERT 4313, along Davidson Canyon Wash upstream of I-10 Bridge, and
- Pantano @ Vail (USGS 09484600), downstream of Marsh Station Road at Pantano Dam.
- ALERT 4263, about one mile downstream of Pantano Dam at schist outcrop

ALERT 4253 is also at Pantano Dam and can be used to supplement the USGS gauge data if needed, however it is not at the typical base flow level. In addition, the District reviews data at one other stream gauge near The Narrows (USGS 09484550), about 11.5 miles upstream of Empirita Ranch. Voltages are measured using a pressure transducer or bubbler and the raw data is transmitted to an office database, which converts the data to streamflow based on established rating curves. Note that all of the sensors (except ALERT 4253) are at baseflow levels, but may not measure all flow due to changes in channel geometry. The gauges at The Narrows and Pantano @ Vail are at perennial stream flow sites, thus recording both base flow and stormwater runoff. ALERT 4283, 4263 and 4313 are along ephemeral reaches, thus primarily recording storm flows.

Figure 2-1. Stream flow monitoring sites within the Cienega Creek Natural Preserve



2.2 Results

Table 2-1 displays quarterly streamflow volumes at the field measurement sites from June 2016-June 2017. Using the typically low volume month of June as an indicator, streamflow within the Preserve slightly improved over the last year near Marsh Station Road and at Davidson Spring #1. The site downstream of Tilted Beds was not measured in June 2016, but more flow was measured at this site in June 2017 than in October 2016. Davidson Spring #2 was dry in June 2016 and in June 2017, but flow was recorded in January and March of 2017.

The overall flow trend along Cienega Creek has been downward since 1993, when regular monitoring within the Preserve began (**Figure 2-2**). The yearly seasonal pattern typically indicates the highest base level stream flows occur during the winter months (December through March) while the lowest level stream flows occur during the late spring (May through June). The lowest level recorded at Marsh Station Road was 0.013 cfs in June 2015. Peak base flows at this site have not reached over 2 cfs since September 2006 and over 1.5 cfs since February 2009. No flows have been observed or recorded at the Tilted Beds site since May 2009. Due to the recent dry trend, District staff started monitoring a site downstream of the Tilted Beds in October 2016 to obtain data for the most upstream extent of perennial flow within the Preserve.

Table 2-2 displays monthly stream flow volumes recorded by the automated stream gauges over the last fiscal year. Storm water runoff occurred only during the summer months in 2016. Base flows were recorded at The Narrows and Pantano @ Vail from October 2016 through June 2017, while the ALERT gauges recorded no flows during the same period. Flow volumes recorded at The Narrows, Pantano @ Vail and ALERT 4313 in 2016 were well below the respective averages over the last ten years. However, ALERT 4283 was not in operation much of this time due to work on the Cienega Creek/I-10 Bridge. ALERT 4263, which began operations in July

Table 2-1. Quarterly Streamflow Volumes from Field Measurements Taken June 2016-June 2017

Date	Flow (cfs) Marsh Station Rd.	Flow (cfs) DS Tilted Beds	Flow (cfs) Davidson Spg. #1	Flow (cfs) Davidson Spg. #2
June 2016	0.15	NM	0.0	0.0
October 2016	0.47	0.003	0.013	0.0
January 2017	0.99	0.018	0.05	0.01
February 2017	NM	NM	0.49	NM
March 2017	NM	NM	0.005	0.007
June 2017	0.21	0.014	0.002	0.0

NM = Not measured

Figure 2-2. Monthly Streamflow Volume at Tilted Beds and Marsh Station Sites (1993-2017)

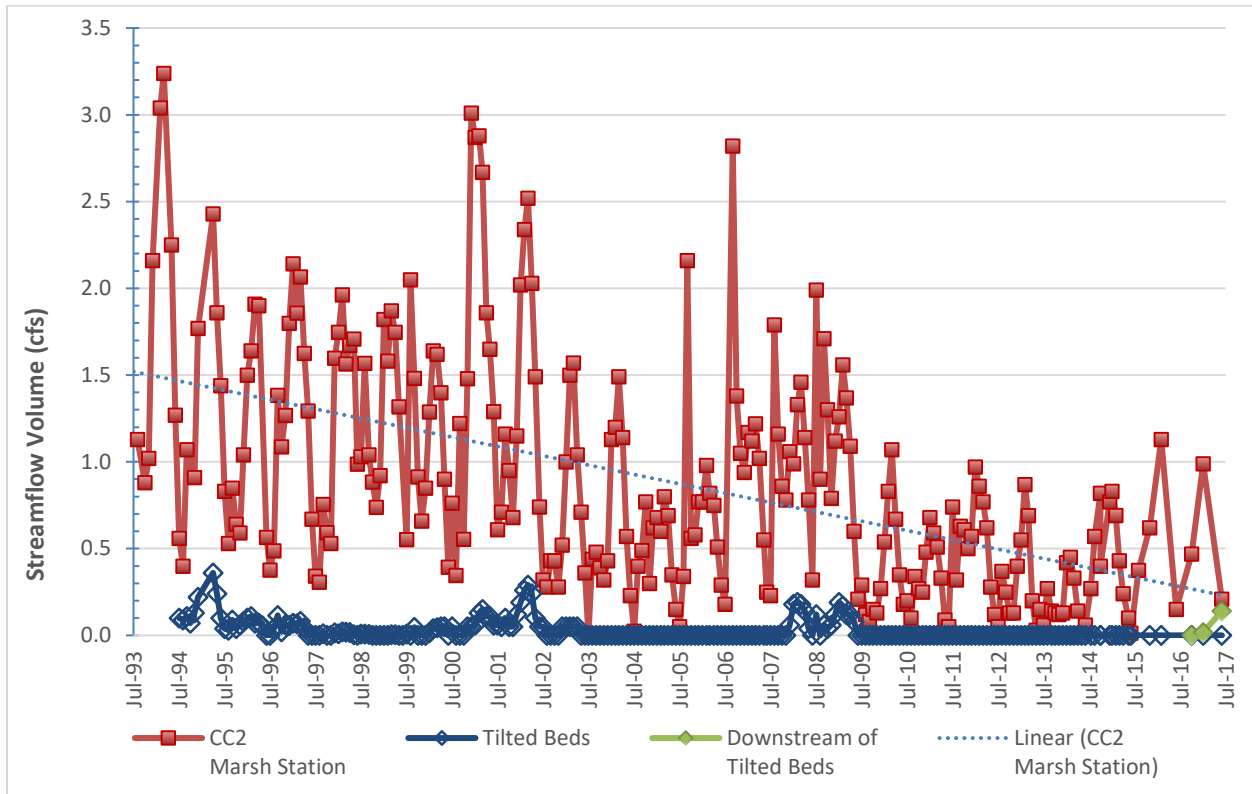


Table 2-2. Monthly Streamflow Volumes Recorded by Automated Sensors from June 2016-June 2017

Date	USGS 09484550 Cienega Creek @ The Narrows (acre-feet)	ALERT 4283 Cienega Creek (acre-feet)	ALERT 4313 Davidson Canyon (acre-feet)	USGS 09484600 Pantano @ Vail (acre-feet)	ALERT 4263 Pantano @ Schist Outcrop (acre-feet)
Jun '16	39.2	150.1	3.0	217.8	178.4
Jul '16	42.4	137.2	0.0	128.2	164.5
Aug '16	73.2	180.1	319.0	878.9	1023.8
Sep '16	482.2	409.6	0.0	249.8	566.9
Oct '16	35.8	0.0	0.0	65.3	0.0
Nov '16	44.8	0.0	0.0	53.3	0.0
Dec '16	60.0	0.0	0.0	54.7	0.0
Jan '17	71.0	0.0	0.0	42.7	0.0
Feb '17	64.7	0.0	0.0	12.7	0.0
Mar '17	64.3	0.0	0.0	18.6	0.0
Apr '17	41.7	0.0	0.0	20.4	0.0
May '17	28.8	0.0	0.0	38.7	0.0
Jun '17	14.7	0.0	0.0	16.8	0.0

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2013, has recorded more flow than Pantano @ Vail over the last few years. This could be due to added flow from one or both of the large tributaries between the two gauges or from slight differences between existing channel conditions and the established rating curve for the ALERT 4263 gauge. Note that USGS regularly calibrates its gauges and makes changes to rating curves for calculating flows after storm water events, while the District does not regularly modify its rating curves. With a longer period of record available, the Pantano @ Vail gauge shows that Calendar Year 2016 was particularly dry, about half the average over the last twenty years (Table 2-3).

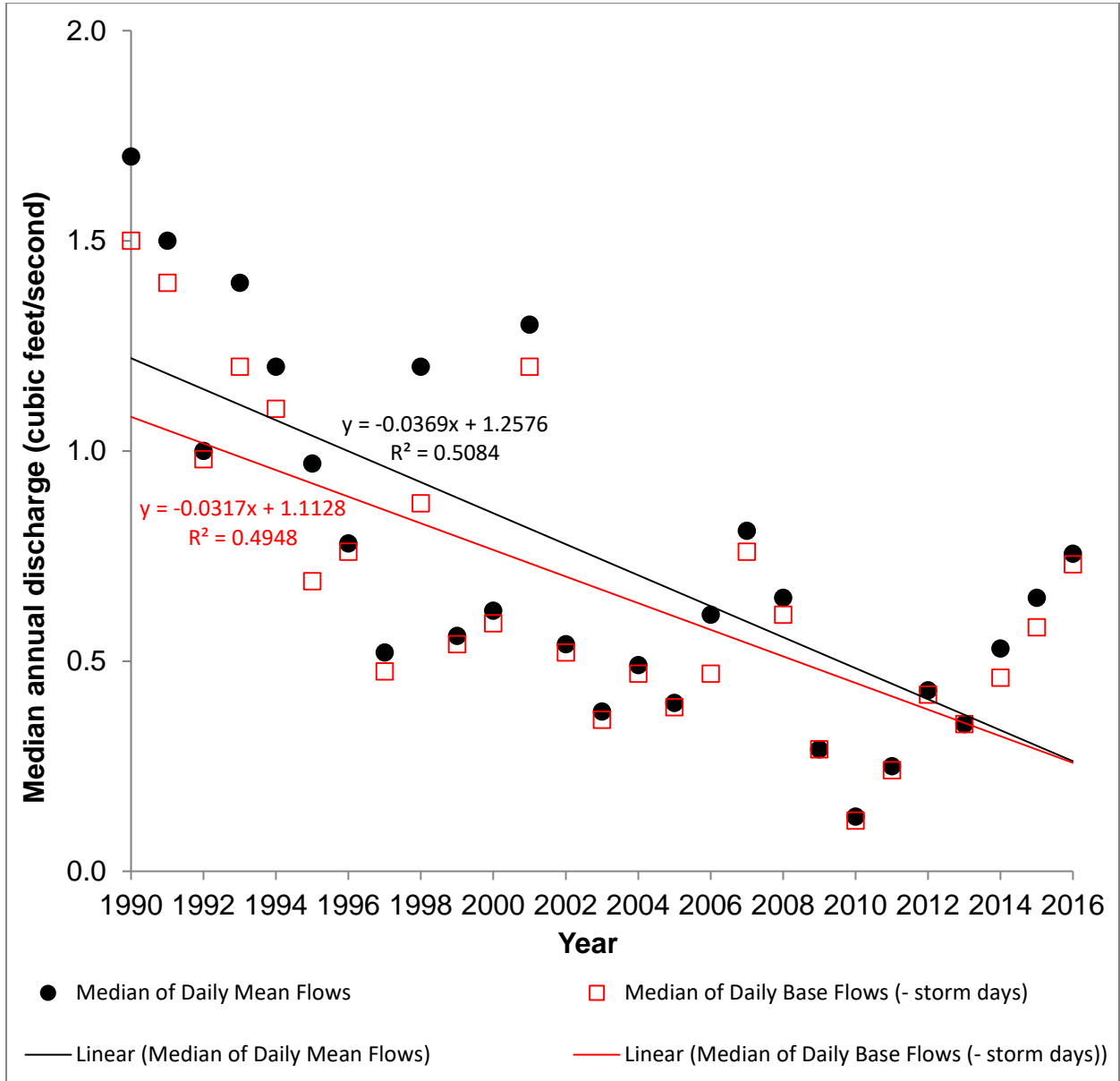
Figure 2-3 shows the median base flow trends since 1990 for the USGS gage at Pantano Dam. The gage is at the downstream end of the Cienega Creek watershed and is an indicator of watershed health by showing the amount of daily water draining from the watershed. In 1990, the median daily flow was around 1.5 cfs. The trend has been steadily downward, reaching a low in 2010 of around 0.13 cfs. The recent recovery of median flows up to 0.75 cfs in 2016 has been encouraging, but may only be cyclic like 2006-2008.

Table 2-3. Annual Streamflow Volumes Recorded by Automated Sensors from 1995-2016

Year	USGS 09484550 Cienega Creek @ The Narrows (acre-feet)	ALERT 4283 Cienega Creek (acre-feet)	ALERT 4313 Davidson Canyon (acre-feet)	USGS 09484600 Pantano @ Vail (acre-feet)	ALERT 4263 Pantano @ Schist Outcrop (acre-feet)
1995				2881	
1996				2794	
1997				1,176	
1998				11,170	
1999				3,477	
2000				8,271	
2001				2,599	
2002	636			1,424	
2003	678			1,749	
2004	596			1,967	
2005	860			2,589	
2006	2,773		976	8,095	
2007	2,789		145	7,687	
2008	2,581		1908	5,685	
2009	611		0	430	
2010	1,629		341	2,848	
2011	879		1025	3,806	
2012	532		331	1,265	
2013	447		0	1,019	
2014	1,275		705	3,622	4,619
2015	1,268		471	1,868	4,295
2016	1,037	877	322	1,875	2,097
Average 2007-2016	1,305	--	525	3,011	--
Average 1997-2016	1,239 (2002-2016)	--	--	3,631	--

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Figure 2-3. Base Flow Trends at Pantano Dam USGS Gage 09484600



3.0 Extent of Surface Flow (Wet/Dry Mapping)

3.1 Methods

PAG conducts wet/dry mapping through the typically perennial portions of Cienega Creek on a quarterly basis during the months of September, December, March and June. Total length of the creek channel monitored through the Preserve is about 9.5 miles, which extends from I-10 to Pantano Dam (**Figure 3-1**). Extent of surface flow is mapped by walking the length of the creek channel and marking the beginning and end of surface flow segments using a Global Positioning System (GPS) unit. Total length of surface flow for each wet/dry mapping event is calculated by totaling the extent of each flowing segment. Wet and dry segments along the creek vary in length from year to year and season to season based upon precipitation and storm water runoff along the creek.

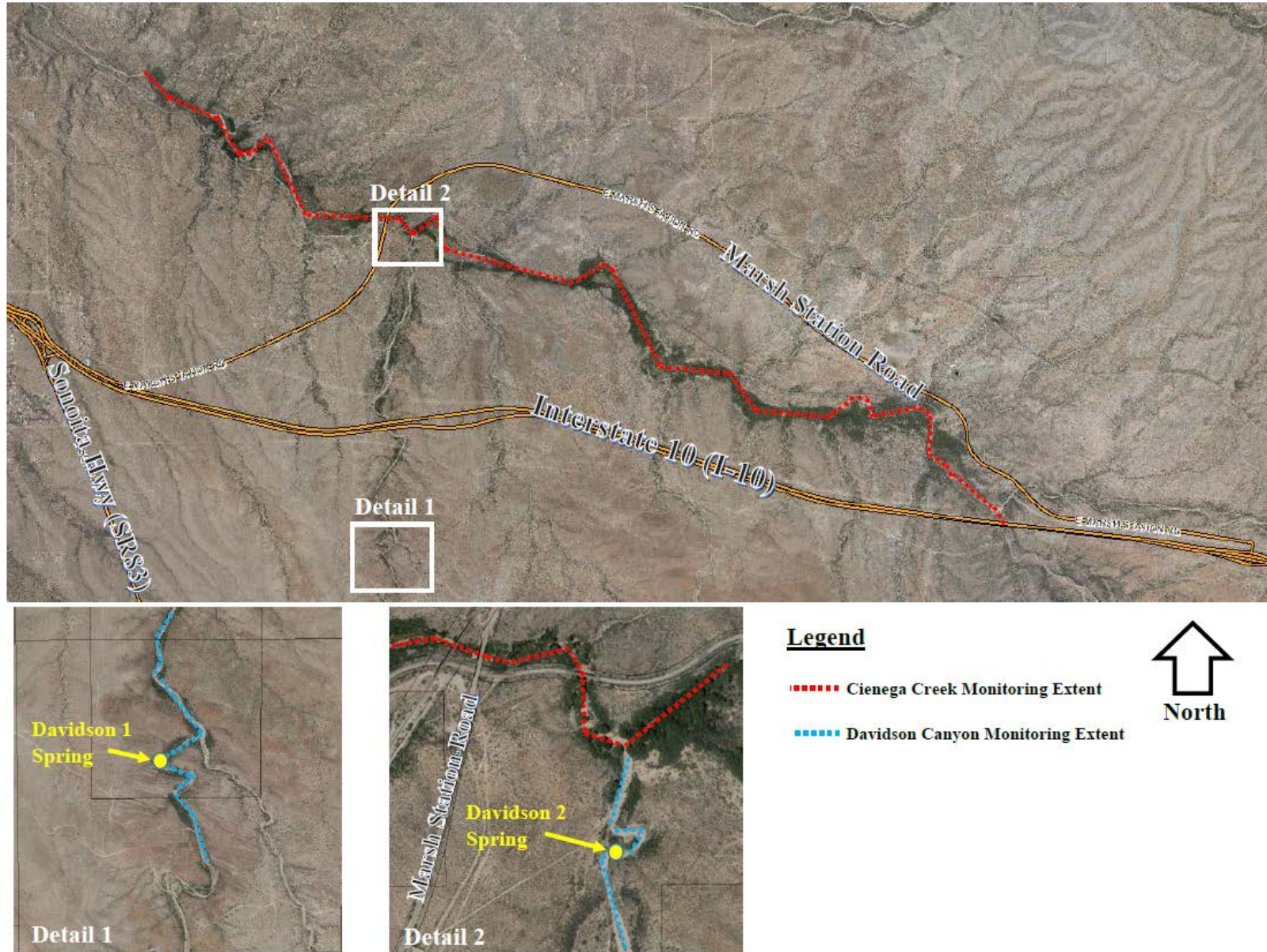
Both PAG and the District conduct wet/dry mapping through the flowing reaches of Davidson Canyon Wash: at a spring next to a bedrock outcrop south of the 1-10 Bridge crossing and at another spring next to shallow bedrock south of the confluence with Cienega Creek (**Figure 3-1**). PAG has conducted quarterly monitoring at the upper spring (Davidson 1 Spring) for the last eleven years. District staff has marked the extent of flows at both the upper and lower springs during base flow and water quality monitoring events at the Preserve since July 2015.

3.2 Results

Table 3-1 lists the results from the quarterly wet/dry mapping from June 2016 through June 2017. Typical for the area, the longest extent of surface flow occurred in March 2017 while the smallest extent occurred in June 2017. The higher extent in March is due to a combination of winter rainfall and the lack of water uptake by riparian vegetation (mostly trees) during the non-growing season (October through March). Spring (May-June) is typically the driest time of the year and is well within the growing season for vegetation, hence surface water is scarcer. This pattern has been more prominent since the beginning of the current drought in 1996.

PAG has been monitoring flow extent along Cienega Creek throughout the Preserve since 1999 and along Davidson Canyon since 2006. A description and graphic presentation of this year's observations in relation to previous years is provided in PAG's Riparian Health Assessment, 2017 (**Attachment A**). The 1.44 miles of surface flow recorded in June 2017 represents about 15 percent of the once 9.5 mile extent of surface flow along lower Cienega Creek in 1984-1985. This continues the long-term downward trend of surface flow extent, but does show some improvement since record lows were recorded from 2011 through 2015. The lowest extent on record was 0.86 miles, observed in June 2014.

Figure 3-1. Wet/Dry Mapping Extent within the Cienega Creek Natural Preserve



**Table 3-1. Quarterly Streamflow Extent from Field Measurements Taken
June 2016-June 2017**

Date	Flow Extent (miles)		
	Cienega Creek	Davidson 1 Spring	Davidson 2 Spring
June 2016	1.9	0.03	0.00
September 2016	2.53	0.63	NM
October 2016	NM	NM	0.00
December 2016	2.86	0.49	NM
January 2017	NM	NM	0.02
March 2017	3.44	0.64	0.004 ^a
June 2017	1.44	0.12	0.00

NM = Flow was not measured

^a Flow was from an off-channel spring source

PAG recorded flow extent from Davidson Spring #1 during each quarter over the last year, with a high of 0.63 mile in September 2016 and a low of 0.12 mile in June 2017. This is the second consecutive year that flow extent has been measured during each quarterly wet/dry mapping event. Apart from one record in December 2011, flow extent was only measured during the post-monsoon month of September over the previous six years (2009-2014). Surface flow in this area has ranged from 0.0 mile to just over 1.4 miles since 2006.

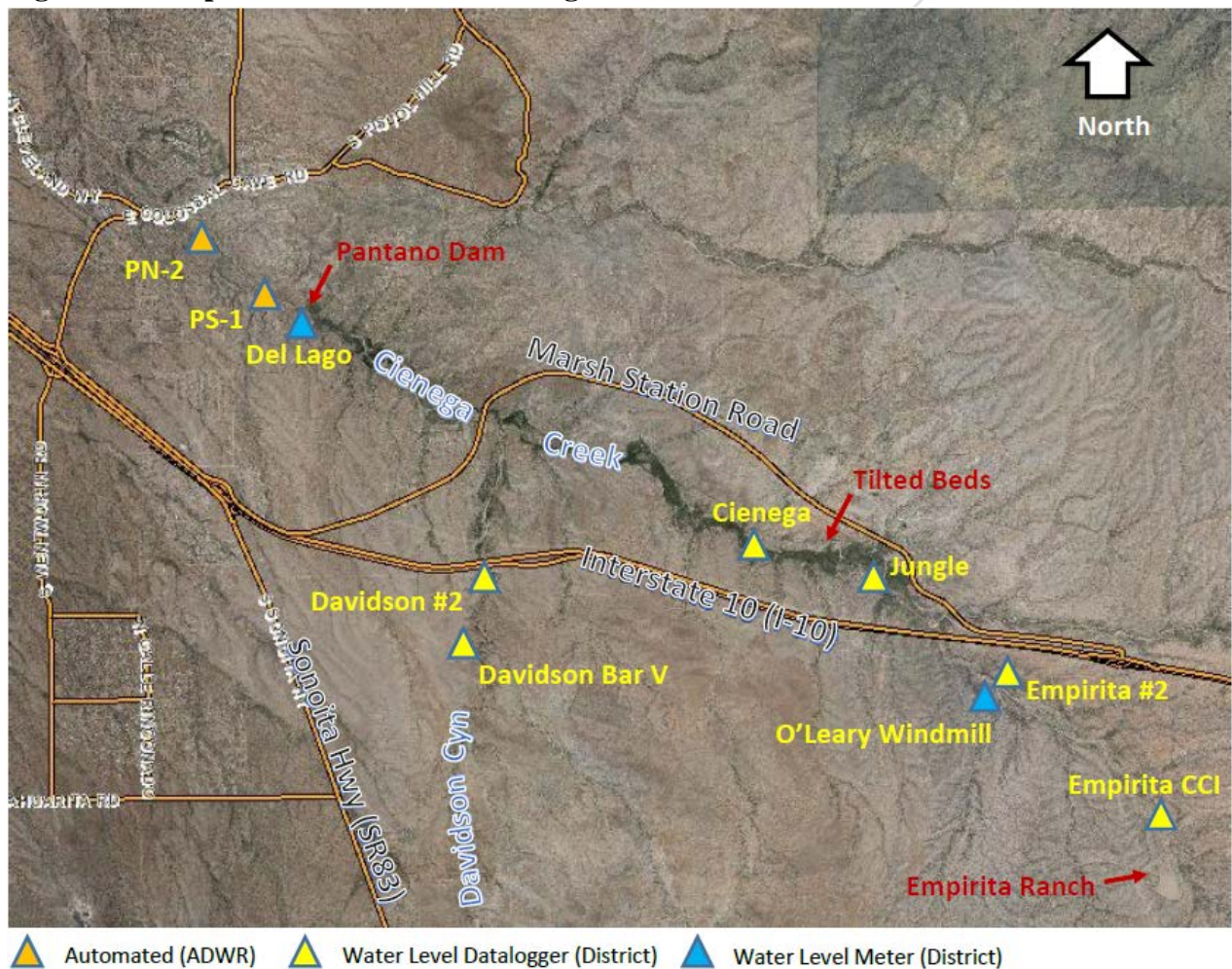
District staff recorded small surface flow extents from Davidson Spring #2 in January and March of 2017 (**Table 3-1**). This is the first time flow has been observed at this site since September 2010, and only the second time since March 2004. Note that surface flow in March 2017 was from a spring source off the main channel of Davidson Canyon, approximately 120 feet northeast of the usual spring site.

4.0 Groundwater Levels

4.1 Methods

Depths to groundwater are measured in ten wells distributed throughout the length of the Preserve along Cienega Creek and Davidson Canyon (**Figure 4-1**). Six of the wells are equipped with In-Situ Rugged Troll 200 data loggers, measuring and recording water levels at 6-hour intervals. This allows for analyses of daily fluctuations based on evapotranspiration losses from vegetation and for sudden spikes in water levels from surface runoff events. Two other wells (PS-1 and PN-2) are equipped with data loggers maintained by the Arizona Department of Water Resources (ADWR), with water levels measured every six hours and data provided online via ADWR's GWSI database. The remaining two wells (Del Lago, O'Leary) are manually measured twice a year (January and June) using a Powers Electric Portable Water Level Meter.

Figure 4-1. Map of Wells within the Cienega Creek Natural Preserve



4.2 Results

Groundwater levels predominantly declined over the last fiscal year, except along Davidson Canyon Wash and at one well near the upstream end of the Preserve (**Table 4-1**). The largest decline was observed at Cienega Well, which is along a perennial stream reach near the center of the Preserve. Other large declines occurred at and just downstream of Pantano Dam, which could be the result of a second straight year when stream flows were below average in this area. Increased water levels along Davidson Canyon Wash occurred despite very little flows recorded at the ALERT 4313 stream gauge. Note that surface flows were identified and measured at Davidson Spring #1 through a good part of the fiscal year (**Table 2-1**), which indicates the water table has risen a little in this area either from mountain front recharge or from snowmelt. Note that snow pack information was not evaluated for this report.

Figure 4-2 displays groundwater levels in relation to stream flows from June 2016 to June 2017. Three of the wells (Davidson #2, PS-1 and PN-2) showed significant water level recoveries with the onset of summer monsoon runoff from August through September 2016. Despite flows recorded along Cienega Creek near I-10 (ALERT 4283), neither the Jungle nor Cienega Wells showed any rise in groundwater levels during this period. After a brief decline from October through December 2016, water levels in the shallow wells recovered slightly through March 2017 without any significant flow recorded in the area. The deep well near the downstream end of the Preserve (PN-2) declined about six feet from December 2016 to June 2017, while the deep well along Davidson Canyon Wash (Davidson Bar V) remained stable throughout the fiscal year.

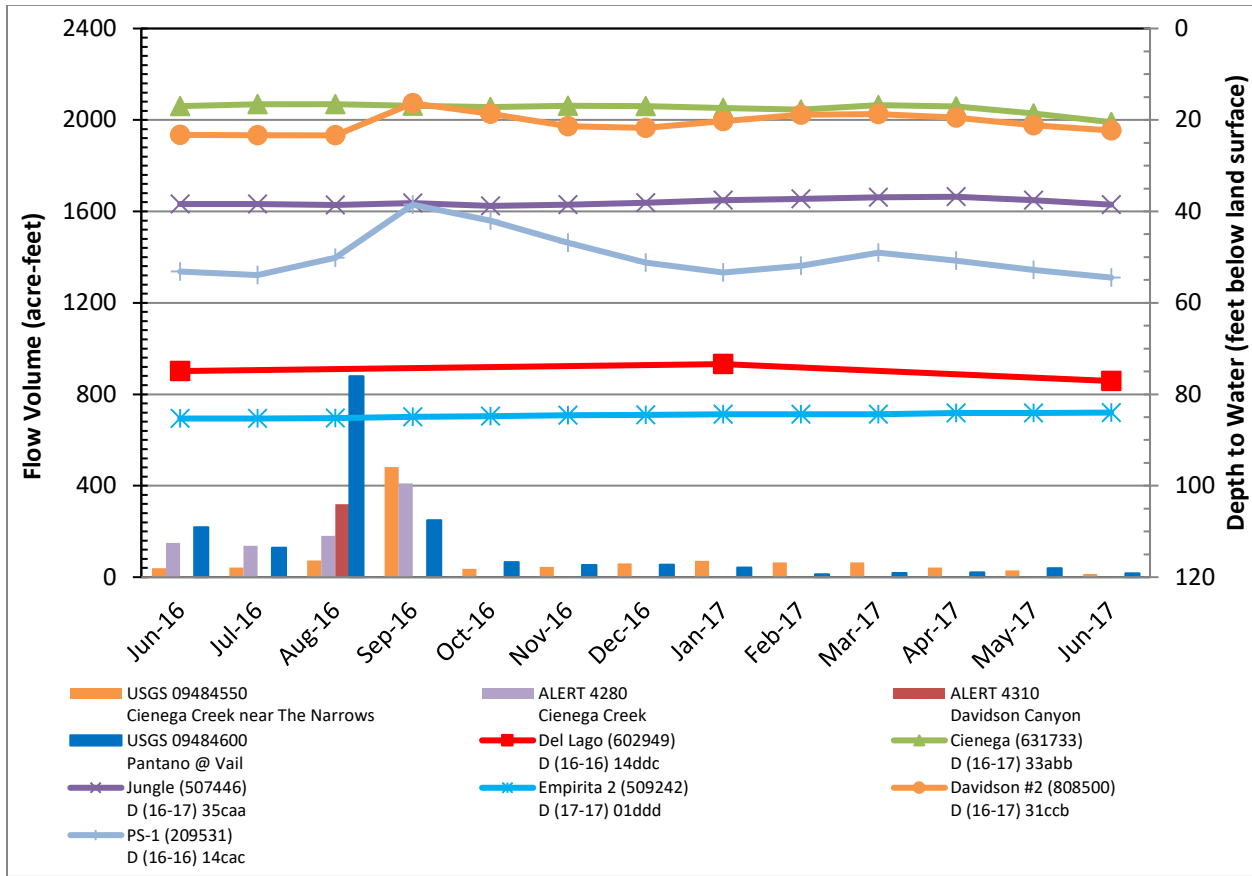
With over twenty years of monitoring data available, a number of wells show a distinct seasonal trend in groundwater levels (**Figure 4-3**). Peaks typically occur during or just after the summer monsoon period (August and September) and lows near the end of spring (May and June). The annual rise and fall of groundwater levels, generally measured and reported in January when regional pumping is lowest, predominantly correlate with stream flow volume along Cienega Creek and Davidson Canyon Wash (**Figure 4-4**). Groundwater levels in the downstream wells appear to be more impacted by stream flow than those upstream. Reasons for this could be the lack of perennial flow due to surface water diversions by Del Lago Golf LLC at Pantano Dam, less vegetation along the stream banks to intercept groundwater, and the addition of flows from major tributaries such as Davidson Canyon Wash and Aqua Verde Creek that intersect Cienega Creek downstream of Cienega Well. Pumping from nearby municipal wells may also have an influence in the downstream area, especially at PN-2 Well, with recent recoveries attributed to a significant reduction in groundwater withdrawals in the area near Colossal Cave Road (**Figure 4-5**). The groundwater withdrawals displayed in **Figure 4-5** represent all pumping, exempt and non-exempt wells, within the Lower Cienega Creek Basin - starting at The Narrows and ending approximately 1.5 miles downstream of Colossal Cave Road Bridge.

Table 4-1. Depth to Groundwater at Cienega Creek Natural Preserve Monitor Well Sites, Monthly Monitoring from July 2016-June 2017

Date	Empirita CCI	Empirita #2	Jungle	Cienega	Davidson Bar V	Davidson #2	Del Lago	PS-1	PN-2
June 2016	60.3	85.3	38.4	17.0	146.2	23.3	74.9	53.2	219.2
July 2016	60.6	85.3	38.4	16.6	146.1	23.3		54.0	220.1
August 2016	60.7	85.2	38.6	16.6	146.1	23.4		50.2	222.3
September 2016	60.1	84.9	38.2	16.9	146.0	16.4		38.5	220.1
October 2016	59.0	84.8	38.8	17.2	146.0	18.7		42	211.8
November 2016	58.2	84.6	38.5	16.9	145.9	21.4		46.8	207.0
December 2016	57.7	84.5	38.1	17.0	145.9	21.8		51.2	206.0
January 2017	57.6	84.4	37.6	17.4	145.8	20.3	73.4	53.4	207.3
February 2017	58.1	84.4	37.3	17.7	145.8	18.9		51.9	209.8
March 2017	59.0	84.4	37.0	16.8	145.8	18.8		49.0	212.5
April 2017	60.0	84.1	36.8	17.0	145.7	19.5		50.8	215.4
May 2017	60.7	84.1	37.6	18.6	145.6	21.2		52.8	217.9
June 2017	61.1	84.0	38.5	20.5	145.6	22.3	77.1	54.5	220.1
Annual Diff.	-0.8	+1.3	-0.1	-3.5	+0.6	+1.0	-2.2	-1.3	-0.9

Figure 4-2. Monthly Flow Volumes vs. Groundwater Levels at Cienega Creek Natural Preserve, June 2016 - June 2017

Shallow Wells



Deep Wells

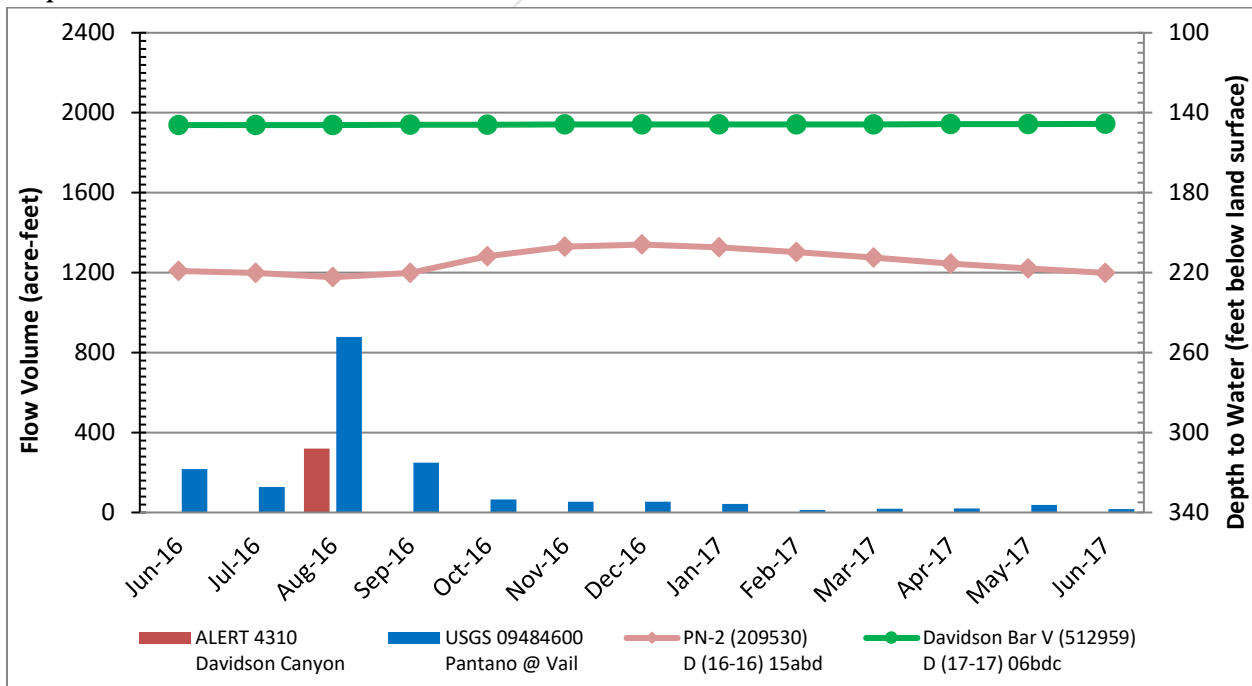
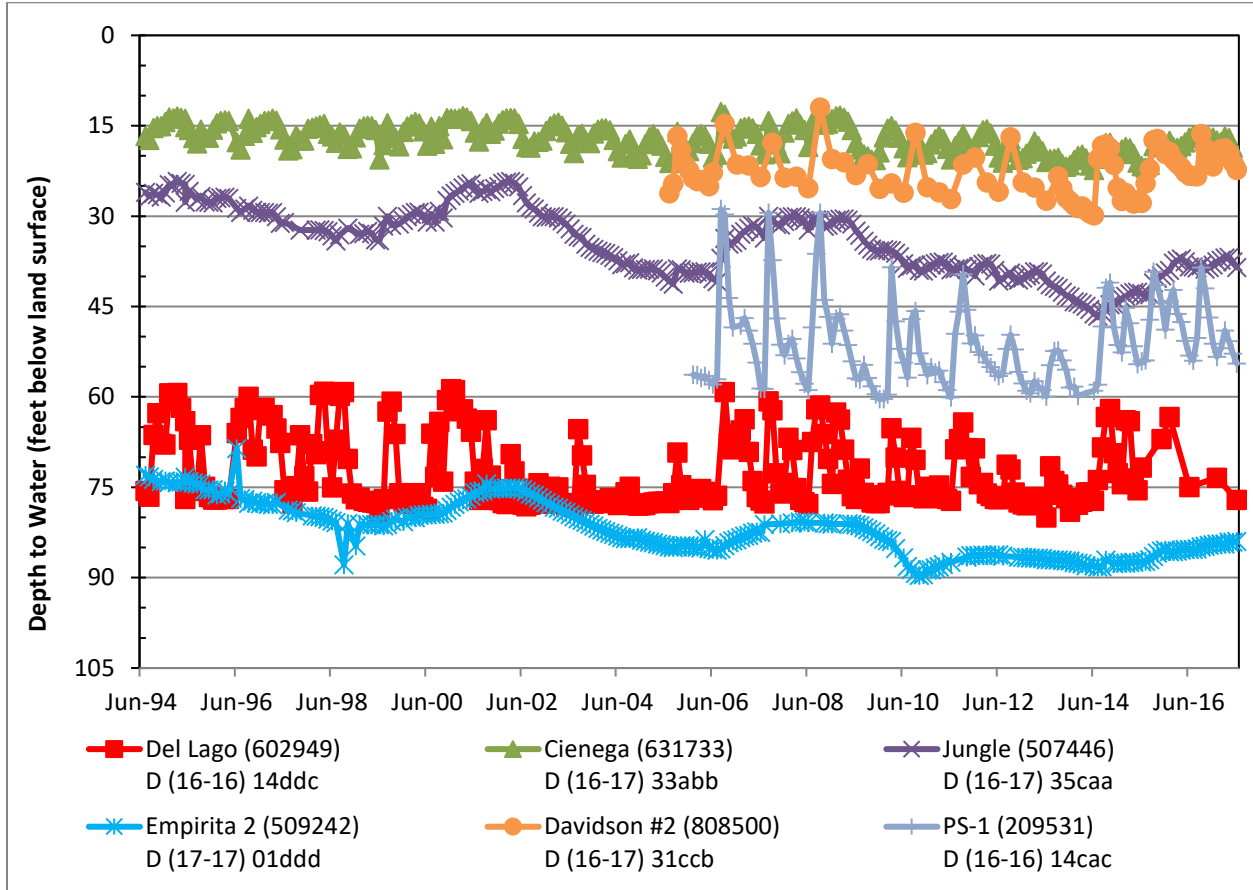


Figure 4-3. Monthly Groundwater Levels at Cienega Creek Natural Preserve, June 1994 - June 2017

Shallow Wells



Deep Wells

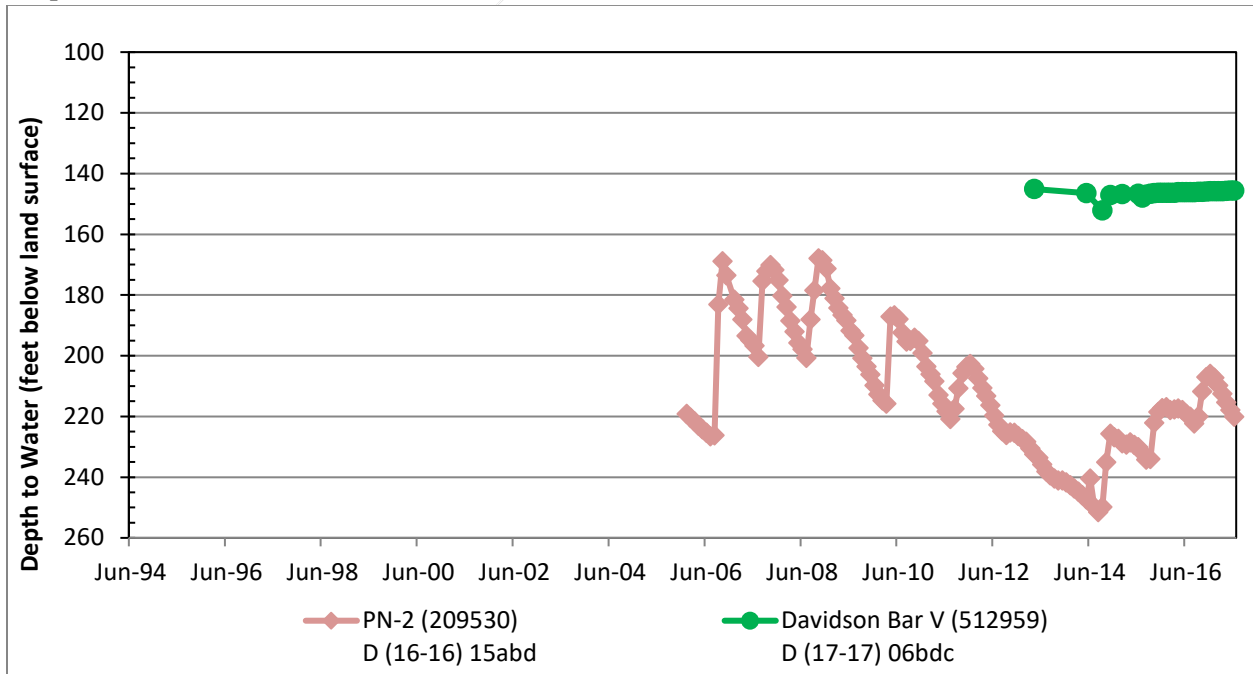
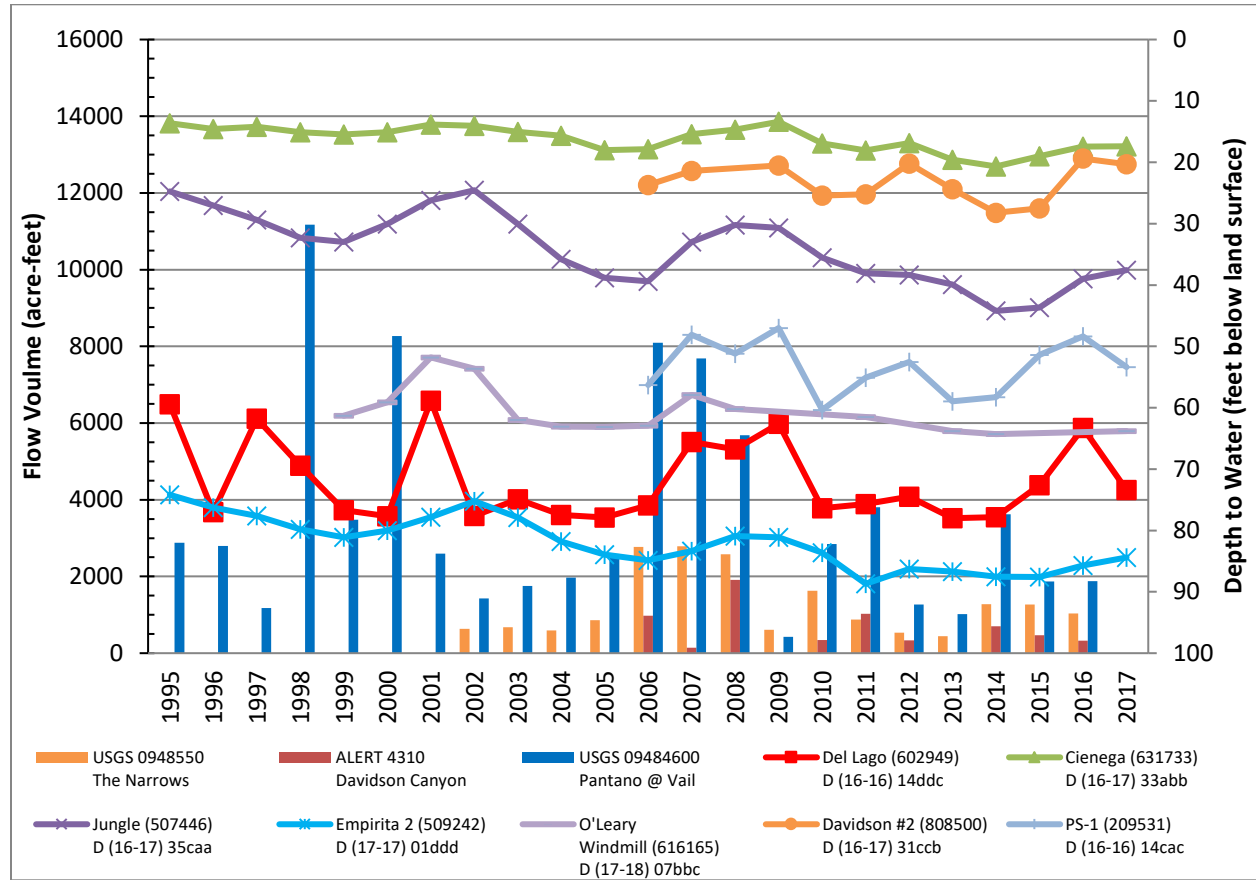


Figure 4-4. Annual Flow Volumes vs. Shallow Groundwater Levels at Cienega Creek Natural Preserve: 1995-2017

Shallow Wells



Deep Wells

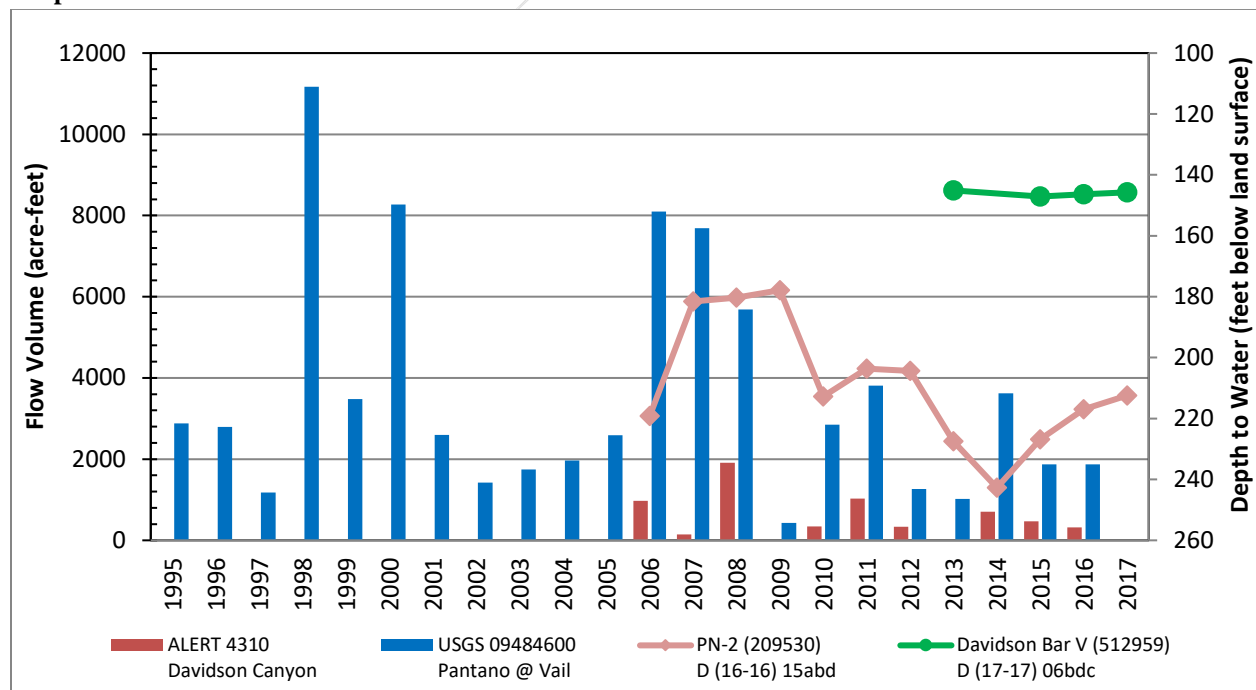
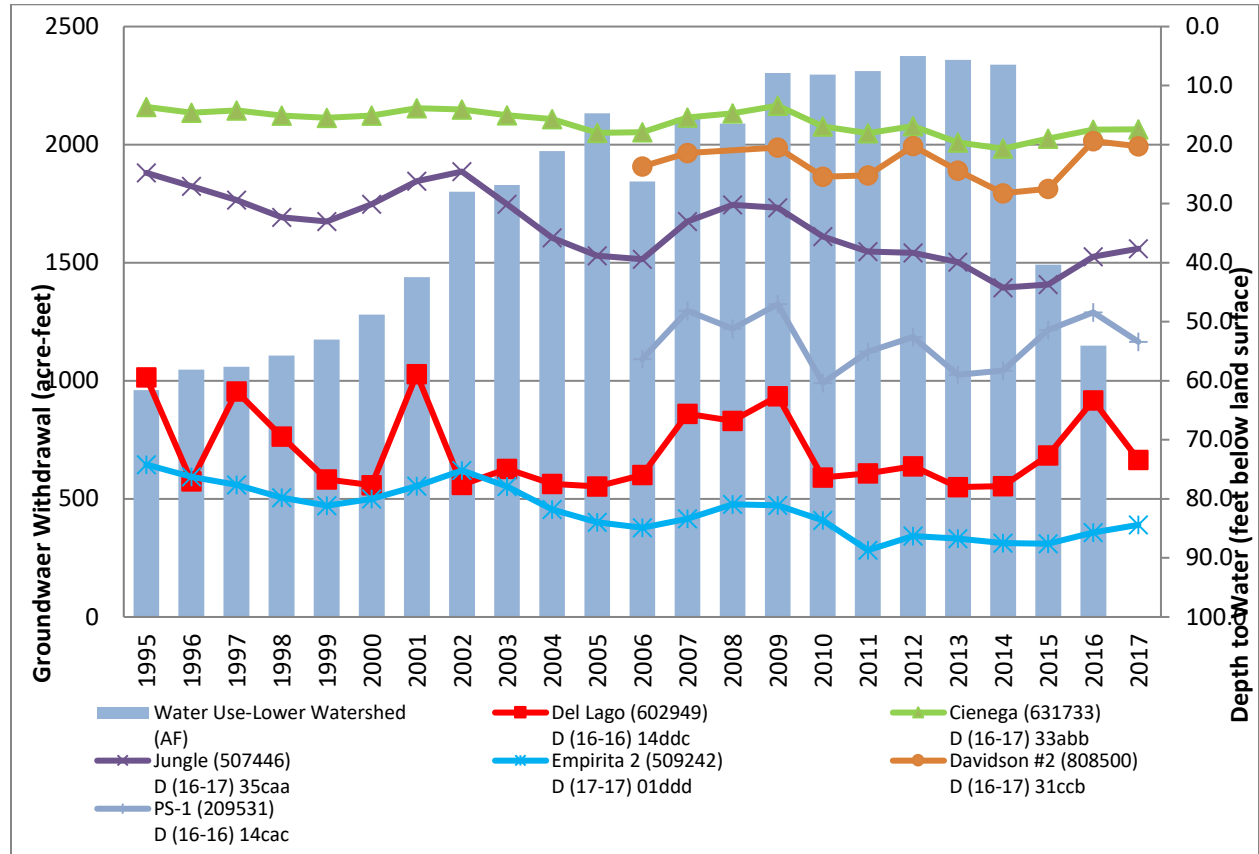
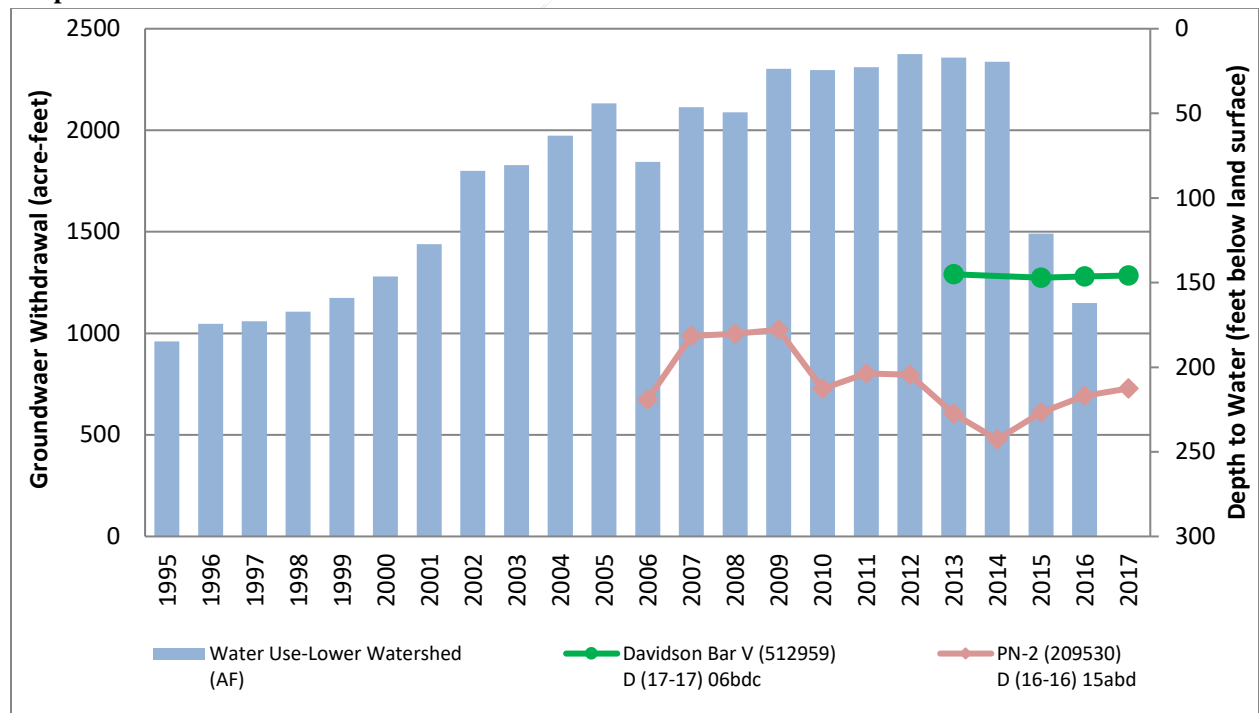


Figure 4-5. Annual Groundwater Withdrawals (Pumping) vs. Shallow Groundwater Levels at Cienega Creek Natural Preserve: 1995-2016

Shallow Wells



Deep Wells



Groundwater levels within the Preserve have been trending downward since 1995, as depicted in in **Figure 4-4**, with an average annual rate of decline of 0.46 feet for four of the monitoring wells (**Table 4-2**). However, water levels have been recovering at an average rising rate of 0.24 feet per year since 2006, based upon seven monitoring wells. The average rate of recovery has been highly influenced by wells in the downstream area. The decline in water levels over the last year indicates that the most recent ten-year trend may only be temporary if drier conditions continue to prevail.

Table 4-2. Water Level Changes along Cienega Creek and Davidson Canyon Wash within the Cienega Creek Natural Preserve

Wells55-Registry Well Name	Well Location	Dates Total Change, Change/Year (22-Year Record)	Dates Total Change, Change/Year (11-Year Record)
509242 (Empirita 2)	D-17-17-01DDD	1995-2017 (22 yr.) -10.21 ft., -0.46 ft./yr.	2006-2017 (11 yr.) +0.50 ft., +0.05 ft./yr.
507446 (Jungle)	D-16-17-35CAA	1995-2017 (22 yr.) -12.84 ft., -0.58 ft./yr.	2006-2017 (11 yr.) +1.80 ft., +0.16 ft./yr.
631733 (Cienega)	D-16-17-33ABB	1995-2017 (22 yr.) -3.78 ft., -0.17 ft./yr.	2006-2017 (11 yr.) +0.50 ft., +0.05 ft./yr.
808500 (Davidson #2)	D-16-17-31CCB		2006-2017 (11 yr.) +3.40 ft., +0.31 ft./yr.
602949 (Del Lago)	D-16-16-14DDC	1995-2017 (22 yr.) -14.00 ft., -0.63 ft./yr.	2006-2017 (11 yr.) +2.50 ft., +0.23 ft./yr.
209531 (PS-1)	D-16-16-14CAC		2006-2017 (11 yr.) +2.90 ft., +0.26 ft./yr.
209530 (PN-2)	D-16-16-15ABD		2006-2017 (11 yr.) +6.70 ft., +0.61 ft./yr.
AVERAGE		Number of Years = 22 Change/Year = -0.46 ft.	Number of Years = 11 Change/Year = +0.24 ft.

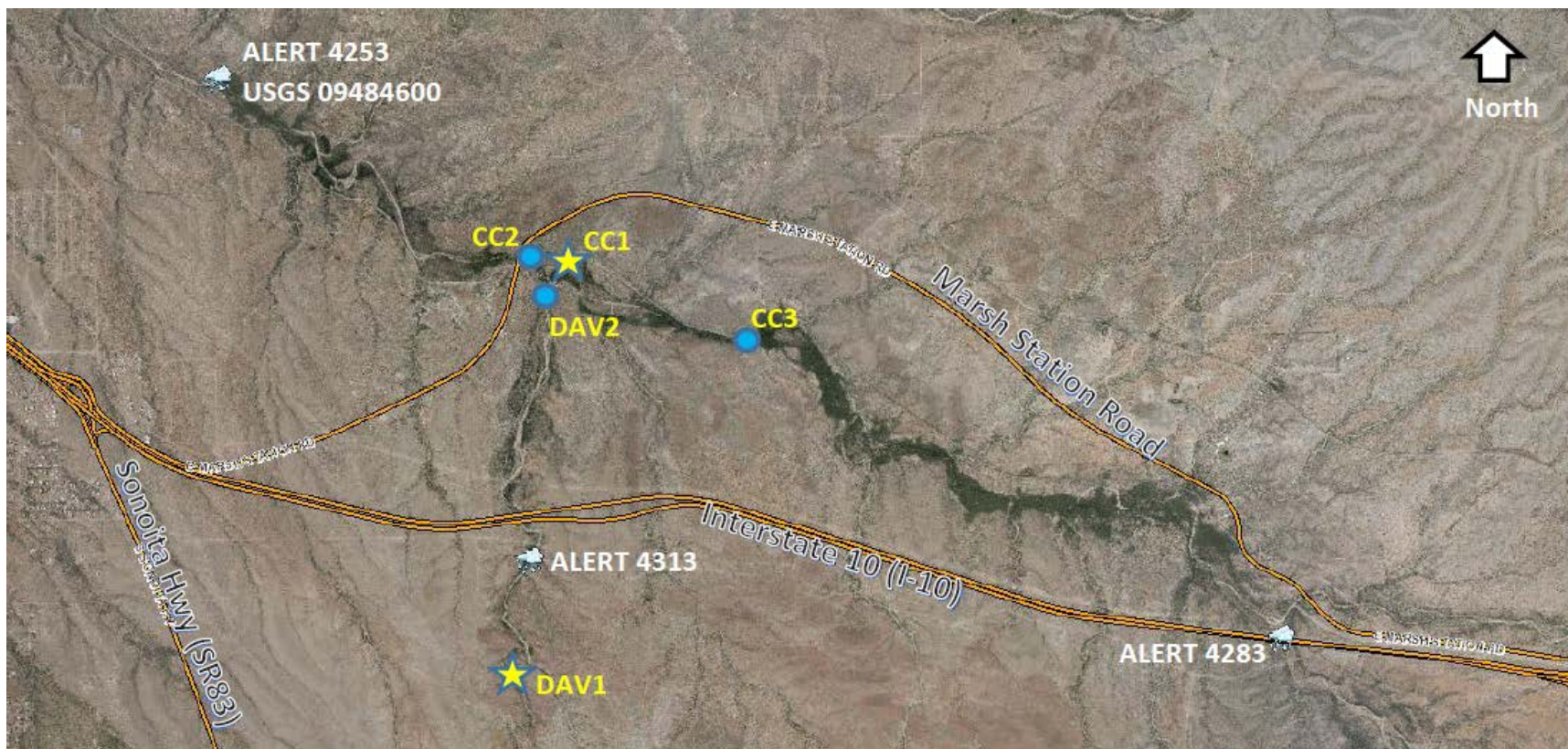
5.0 Water Quality

5.1 Methods

The District performs water quality monitoring within the Preserve to determine if there is any degradation of the two designated Outstanding Arizona Waters (OAW's) due to land use changes in the surrounding areas. The two OAW's within the Preserve are Cienega Creek from Empirita Ranch to Pantano Dam and Davidson Canyon Wash from Davidson #1 Spring to its confluence with Cienega Creek. The primary collection sites are Davidson #1 Spring in Davidson Canyon and along Cienega Creek just upstream of its confluence with Davidson Canyon Wash (**Figure 5-1**). Secondary collection sites are identified in case one or both of the primary sites are dry. Water samples are typically collected in February and September, when base flows are available at both sites. Arizona Department of Environmental Quality will periodically collect and test samples to evaluate water quality degradation of surface flow sites. The results from their analyses are included in the overall summary of water quality data for the Preserve.

Prior to sample collection, flow volume is measured using a Global Flow Probe (or alternate method for very low flows) and field parameters (i.e., temperature, pH, conductivity) are collected using a YSI Professional Plus Water Parameter Meter. Grab samples are then collected into bottles supplied by an Arizona State certified laboratory, which include preservatives required for the testing methods of each analyte. The bottles are placed in a cooler with ice and dropped off with a courier who delivers the bottles directly to the laboratory. A chain of custody is completed and submitted with the bottles to insure proper handling of the samples.

Figure 5-1. Water Quality Collection Sites along Cienega Creek and Davidson Canyon Wash



- ★ Primary Sample Collection Site
- Secondary Sample Collection Site: CC3 – Collection site if CC1 is dry
DAV2 – Collection site if DAV1 is dry
CC2 – Collection site if DAV 1 and DAV2 are dry

5.2 Results

Table 5-1 lists the results from water quality samples collected in October 2016 and February 2017, including federal standards for drinking water and state standards for warm water aquatic and wildlife use (A&Www). The samples collected over the last year meet all of the federal standards for drinking water, except for the secondary standards for sulfate (at CC1), total dissolved solids (both CC1 and DAV1) and on one occasion for manganese (DAV1). Note that these exceedances slightly affect the taste of the water, but would not be harmful to human health. The samples also meet most of the State standards for aquatic and wildlife use, although there are a number of standards based on dissolved metals in water and only total metals have been analyzed to date.

Water quality monitoring has been conducted semi-annually along Cienega Creek since 2010 and along Davidson Canyon Wash since 2008 to establish baseline conditions. The Davidson Canyon site was dry during a number of site visits, with no samples collected during Calendar Years 2011 and 2013. Similar to the most recent results, average water quality within the Preserve has been very good over the last seven to nine years with only the secondary drinking water standards of sulfate, total dissolved solids, and manganese being exceeded (**Table 5-2**). Based upon analyses of cations (calcium, magnesium, and sodium + potassium) and anions (sulfate, alkalinity and chloride + fluoride), the surface water along Cienega Creek can be classified as a calcium-sulfate bicarbonate type, while the surface water along Davidson Canyon Wash is more of a calcium bicarbonate type (**Figure 5-2**).

Table 5-1. Results from Water Quality Monitoring and Testing along Cienega Creek and Davidson Canyon Wash for Fiscal Year 2016-17.

Analyte	Unit	DWS (MCL)	A&Www	Cienega Creek (CC1)		Davidson Canyon (DAV1)	
				10/13/16	2/22/17	10/13/16	2/22/17
METALS							
Aluminum	mg/l	0.5-2.0 ^a	NA	< 0.1	< 0.1	< 0.1	< 0.1
Antimony	mg/l	0.006	0.088D	< 0.001	< 0.001	< 0.001	< 0.001
Arsenic	mg/l	0.01	0.34D	0.0031	0.0027	0.0021	0.0015
Barium	mg/l	2.0	NA	0.094	0.055	0.19	0.19
Beryllium	mg/l	0.004	0.065D	< 0.001	< 0.001	< 0.001	< 0.001
Cadmium	mg/l	0.005	NA	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Calcium	mg/l	NA	NA	190	190	130	140
Chromium	mg/l	0.1	1.773	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Copper	mg/l	1.3	0.0496	0.00053	< 0.0005	0.00051	0.00054
Iron	mg/l	0.3 ^a	NA	< 0.1	< 0.1	< 0.1	< 0.1
Lead	mg/l	0.015	0.281	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Magnesium	mg/l	NA	NA	56	56	25	27
Manganese	mg/l	0.05 ^a	NA	0.046	0.012	0.16	0.026
Mercury	mg/l	0.002	0.0024D	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Molybdenum	mg/l	NA	NA	< 0.01	< 0.01	< 0.01	< 0.01
Nickel	mg/l	NA	1.513	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Potassium	mg/l	NA	NA	5.0	4.8	3.2	2.3
Selenium	mg/l	0.05	NA	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Silver	mg/l	0.1 ^a	0.0349	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Sodium	mg/l	NA	NA	82	72	32	42
Thallium	mg/l	0.002	0.7D	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Zinc	mg/l	5.0 ^a	0.379	< 0.05	0.014	< 0.05	< 0.013
WET CHEMISTRY							
Alkalinity	mg/l	NA	NA	330	400	360	370
Chloride	mg/l	250 ^a	NA	14	12	12	18
Cyanide	mg/l	0.2	0.041	< 0.05	< 0.05	< 0.05	< 0.05
Fluoride	mg/l	4.0	NA	0.66	0.58	0.46	0.43
Kjeldahl Nitrogen	mg/l	NA	NA	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate-Nitrite as N	mg/l	10.0	NA	< 0.5	< 0.5	< 0.5	< 0.5
Sulfate	mg/l	250 ^a	NA	570	470	97	110
TDS	mg/l	500 ^a	NA	1200	1000	580	610
Turbidity	NTU	0.5-1.0	NA	0.31	0.29	0.31	0.25
FIELD PARAMETERS							
Conductivity	µS/cm	NA	NA	1046	1197	685	400.1
Cross-sectional Area	ft ²	NA	NA	0.25	0.75	No Sample	1.4
Dissolved Oxygen	mg/l	NA	NA	No Sample	5.74	No Sample	4.02
Dissolved Oxygen	%	NA	NA	No Sample	61.3	No Sample	43
Flow	cfs	NA	NA	0.31	0.35	0.013	0.49
pH		NA	NA	7.21	7.33	7.00	7.37
Stream Depth (avg.)	ft	NA	NA	.125	1.91	No Sample	0.18
Stream Width	ft	NA	NA	2.0	5.0	No Sample	0.69
Temperature	°F	NA	NA	64.9	64.6	75.5	65.6
TDS	mg/l	NA	NA	780	897	455	300.3

Table 5-1. Results from Water Quality Monitoring and Testing along Cienega Creek and Davidson Canyon Wash for Fiscal Year 2016-17 (continued)

DWS = Drinking Water Standards (Environmental Protection Agency)

MCL = Maximum Contaminant Level

A&Www = Aquatic and Wildlife for warm waters standard (State of Arizona)

NA = Not Available (no standard set for the analyte)

No Sample = Samples were not collected for the parameter or analyte

D = Dissolved metal

^a Secondary Maximum Contaminant Level – does not affect health, but does create taste, odor or visual problems with the water

< = No detection of analyte based on minimum detection limit (#)

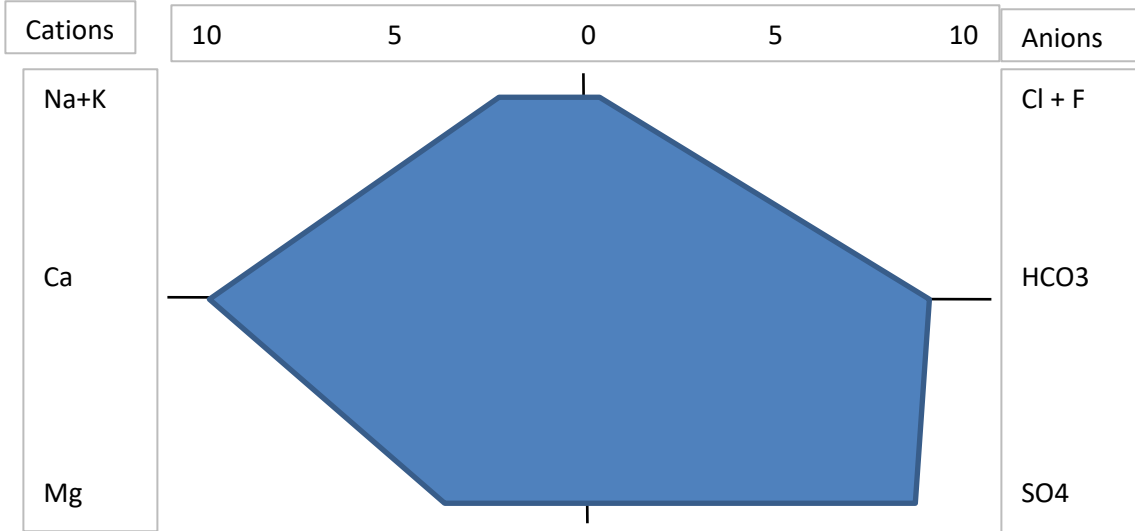
Table 5-2. Average water quality of samples collected within the Preserve since 2008

Analyte	Unit	DWS (MCL)	A&Www	Cienega Creek (CC1)	Davidson Canyon (DAV1)
METALS					
Aluminum	mg/l	0.5-2.0 ^a	NA	ND	ND
Antimony	mg/l	0.006	0.088D	ND	ND
Arsenic	mg/l	0.01	0.34D	0.0034	0.0025
Barium	mg/l	2.0	NA	0.10	0.18
Beryllium	mg/l	0.004	0.065D	ND	ND
Cadmium	mg/l	0.005	NA	ND	ND
Calcium	mg/l	NA	NA	160.8	102.5
Chromium	mg/l	0.1	1.773	ND	ND
Copper	mg/l	1.3	0.0496	ND	0.0014
Iron	mg/l	0.3 ^a	NA	0.07	ND
Lead	mg/l	0.015	0.281	ND	ND
Magnesium	mg/l	NA	NA	48.2	19
Manganese	mg/l	0.05 ^a	NA	0.069	0.135
Mercury	mg/l	0.002	0.0024D	ND	ND
Molybdenum	mg/l	NA	NA	ND	ND
Nickel	mg/l	NA	1.513	0.0047	0.0026
Potassium	mg/l	NA	NA	4.9	3.5
Selenium	mg/l	0.05	NA	ND	ND
Silver	mg/l	0.1 ^a	0.0349	ND	ND
Sodium	mg/l	NA	NA	63.8	30.6
Thallium	mg/l	0.002	0.7D	ND	ND
Zinc	mg/l	5.0 ^a	0.379	ND	ND
WET CHEMISTRY					
Alkalinity	mg/l	NA	NA	319	323
Chloride	mg/l	250 ^a	NA	10.8	7.7
Cyanide	mg/l	0.2	0.041	ND	ND
Fluoride	mg/l	4.0	NA	0.61	0.56
Kjeldahl Nitrogen	mg/l	NA	NA	ND	ND
Nitrate-Nitrite as N	mg/l	10.0	NA	ND	ND
Sulfate	mg/l	250 ^a	NA	457.7	64.9
TDS	mg/l	500 ^a	NA	1006.7	502
Turbidity	NTU	0.5-1.0	NA	0.54	0.41

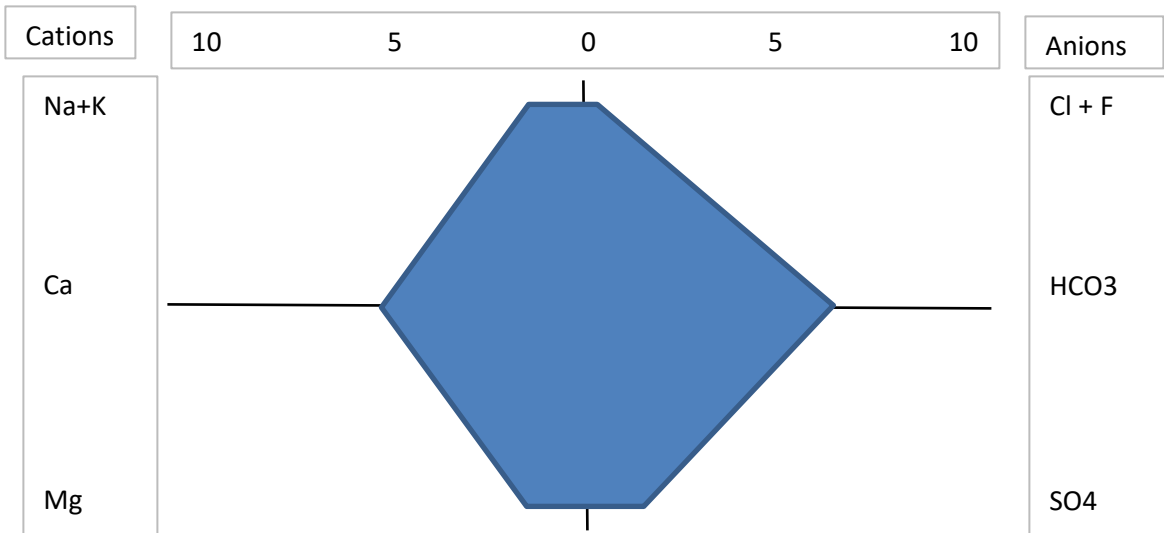
See legend from Table 8 above

Figure 5-2. Stiff Diagrams for Cienega Creek and Davidson Canyon Wash (average results)

Cienega Creek (CC1)



Davidson Canyon (DAV1)



6.0 Precipitation

6.1 Methods

Eight automated precipitation gauges, within the vicinity of the Preserve, collect data in real time and transmit the data to a database for tabulation (**Figure 6-1**):

ALERT 4220, Rancho Del Lago: approximately 2.35 miles northwest of Colossal Cave Road Bridge

ALERT 4250, Pantano at Vail: along Cienega Creek (Pantano Wash) at Pantano Dam

ALERT 4310, Davidson Canyon: along Davison Canyon approximately 0.33 mile upstream of the I-10 Bridge crossing

ALERT 4320, Empire Peak: in the Empire Mountains east of the confluence of Davidson Canyon Wash and Mulberry Canyon

ALERT 4280, Cienega Creek: along Cienega Creek approximately 0.33 mile upstream of the I-10 Bridge crossing

ALERT 4270, Salcido Place: in the Rincon Mountain foothills north of Agua Verde Creek headwaters

ALERT 4290, Mescal: along Mescal Arroyo approximately 6 miles upstream of its confluence with Cienega Creek

ALERT 4410, Haystack Mountain: in the Whetstone Mountain foothills southeast of Empirita Ranch

6.2 Results

In 2016, annual precipitation in the vicinity of the Preserve ranged from 5.75 inches at Rancho Del Lago to 17.27 inches at Davidson Canyon Wash near I-10 (**Table 6-1**). The amount at Rancho Del Lago was almost half of the 22-year average for this location. Precipitation amounts in the other gauges were generally greater than the average from 1994-2016, with differences ranging from -0.42 inches at Haystack Mountain to +4.44 inches along Mescal Arroyo (East of the Preserve). Annual streamflow volumes and groundwater levels generally appear to be reflective of the precipitation amounts, with highs occurring after wet years (1998, 2000, 2006-2008, 2011 and 2015) and lows occurring after drier years (2001-2005, 2009-2010 and 2012-2013). However, due to the size of the watershed and the many tributary watercourses from different mountain ranges, the precipitation records are not all consistent with flows and water levels throughout the period of record.

Figure 6-1. Automated Precipitation Gauges in the Vicinity of the Preserve

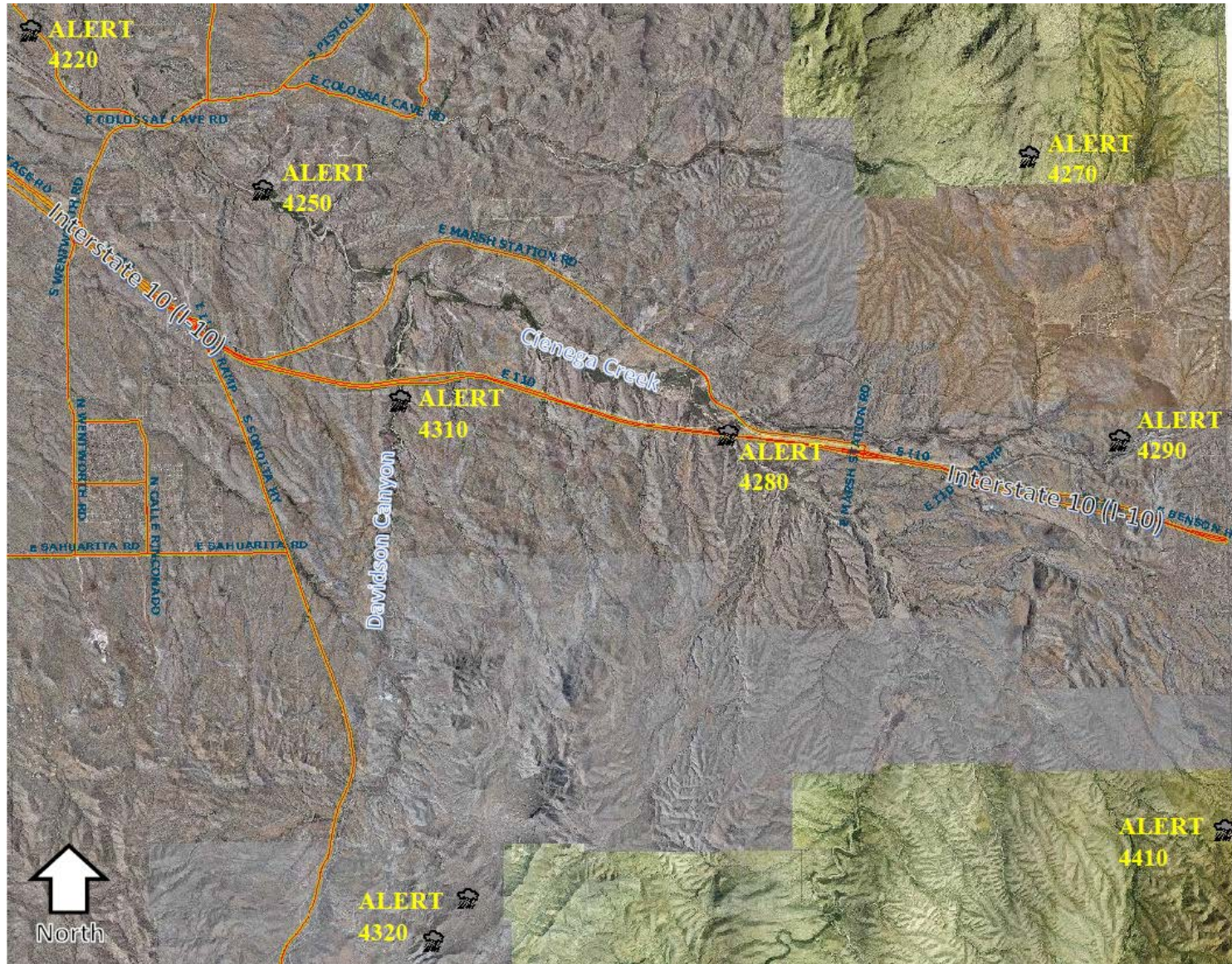


Table 6-1. Precipitation records from gauges surrounding Cienega Creek Natural Preserve.

Calendar Year	Precipitation (inches)						Haystack Mtn. ALERT #4410
	Rancho Del Lago ALERT #4220	Pantano @ Vail ALERT #4250	Davidson Cyn @ I-10 ALERT #4310	Empire Mtn. ALERT #4320	Salcido Place ALERT #4270	Mescal ALERT #4290	
1994	14.37	7.56	12.83	8.78	15.28	13.94	15.59
1995	12.01	6.93	12.24	5.98	12.44	10.16	11.81
1996	12.60	6.10	15.43	9.49	11.30	10.94	10.16
1997	12.68	9.37	14.42	8.54	12.56	11.97	11.06
1998	18.66	16.34	21.10	5.98	14.33	12.72	11.06
1999	6.18	7.40	12.20	8.54	12.24	10.71	11.50
2000	17.72	8.66	22.40	12.36	14.96	16.61	12.64
2001	13.86	12.24	16.69	10.91	10.94	12.13	15.83
2002	6.73	8.70	9.45	5.39	9.80	6.97	7.52
2003	9.33	9.37	10.08	8.07	11.73	9.65	10.98
2004	7.28	8.11	12.44	6.02	12.60	11.10	10.20
2005	10.83	11.38	11.61	6.93	10.00	7.76	8.62
2006	11.10	10.87	18.58	4.88	8.62	8.03	9.13
2007	8.94	11.30	12.64	7.20	12.91	12.99	10.51
2008	10.67	14.72	12.05	9.69	11.06	9.84	12.36
2009	6.57	6.22	7.32	6.38	5.98	5.87	7.76
2010	10.28	9.37	15.20	9.37	12.40	11.65	12.99
2011	9.41	8.74	15.75	8.94	11.38	12.72	12.48
2012	6.30	7.99	10.67	7.72	5.98	6.85	8.62
2013	11.38	9.45	12.09	8.86	8.62	8.86	10.63
2014	9.72	9.57	14.80	9.06	13.94	9.84	8.98
2015	16.77	12.13	18.78	13.50	6.45	17.04	14.53
2016	5.75	11.43	17.27	10.57	14.27	15.35	13.76
AVG 1994-2016	10.80	9.66	14.04	8.30	11.16	10.83	11.13

DISCLAIMER: ALERT System data come from remote automatic sensors. These data are being supplied for general information only. The Pima County Regional Flood Control District makes no warranty, neither expressed nor implied, regarding the accuracy of data provided.

7.0 Findings & Recommendations

Groundwater levels and surface flows have been trending upward over the last couple of years due to greater than average rainfall and less groundwater withdrawals within the Cienega Creek watershed. Higher rainfall did not correlate with larger stream flow volumes recorded by the automated stream gauges along Cienega Creek and Davidson Canyon Wash, suggesting that increased water levels were more influenced by direct infiltration and mountain front recharge (or snow melt) as opposed to stream channel recharge. Analyses of the surface waters along Cienega Creek and Davidson Canyon Wash indicate no degradation from the good water quality that was the basis for the designations of these two watercourses as Outstanding Arizona Waters (OAW's).

A significant downward trend has been observed for surface flows and groundwater levels within the Preserve over the last twenty years or so. Annual median base flows along Cienega Creek near Marsh Station Road have fallen from a high of 3.2 cfs in March 1994 to just under 1.0 cfs in January 2017. The lowest median flow was 0.68 cfs recorded in January 2011. Similarly, stream flow extent along Cienega Creek has decreased significantly over the 9.5-mile reach that was perennial in 1985, with 2017 data reflecting a 64% drop in annual maximum base flow extent and an 85% drop in pre-monsoon base flow extent (PAG, 2017). Groundwater levels within the Preserve have declined at a rate of almost one-half a foot per year since 1995.

Recent trends have provided a better outlook on water availability within the Preserve. Pre-monsoon base flows (January) have reached 1.0 cfs at Marsh Station Bridge for the second consecutive year, after failing to reach that total over the previous five years (2011 through 2015). Surface flow extent during the pre-monsoon period has been better over the last two years, reaching at or above 1.4 miles after three consecutive years of less than one mile, including the historic low of 0.86 miles in 2014. On average, depth to groundwater levels have recovered at a rate of almost one-quarter of a foot per year over the last ten years (since 2006). However, water levels in the Preserve have still been in overall decline of almost 0.5-foot per year the last 22 years.

Since their installation in 2015, water level data loggers continue to provide useful data to evaluate the interaction between streamflow and groundwater. The data collected from the automated precipitation and stream gauges is also a useful tool to evaluate the overall water balance for the Preserve system and, like the water level data loggers, provide more than a “snap shot in time” perspective. Semi-annual monitoring of water quality since 2008 has provided a good baseline reference as land use changes and associated water developments occur in the upstream portions of the Cienega Creek watershed.

Additional stream sensors would be useful to evaluate the overall water budget and determine stream flow and groundwater interactions within the Preserve. Installing gauges to capture stream flows coming into Cienega Creek from Mescal Arroyo and Agua Verde would help evaluate inputs that are not captured by the current gauging system. Flows along Mescal Arroyo may be captured by a gauge just downstream of its confluence with Cienega Creek if preference is to install on District property. A gauge can be installed along Agua Verde Wash just downstream of its confluence with Posta Quemada Creek in order to capture flows from both watercourses. The County owns contiguous lands downstream to the Preserve.

Water quality testing should be modified to include analyses of dissolved metals as well as total metals for water collected along Cienega Creek and Davidson Canyon Wash. Both watercourses are designated OAW's for warm water aquatic and wildlife use, with specific standards listed in **Table 9** above. As noted, some of the standards are for dissolved metals rather than total metals, so inclusion of dissolved metal analyses would better determine potential degradation of the streams based on their intended use.

8.0 References

Pima Association of Governments. 1998. Summary and Evaluation of Cienega Creek Surface Water and Groundwater Monitoring Program. Final Report. Volume I. Prepared for the Pima County Flood Control District. February 1998.

Pima Association of Governments. 2017. Riparian Health Assessment, 2017. Perennial flows persist in Cienega Creek and Davidson Canyon. Draft, July 2017.

Attachment A

Riparian Health Assessment, 2017

Perennial flows persist in Cienega Creek and Davidson Canyon

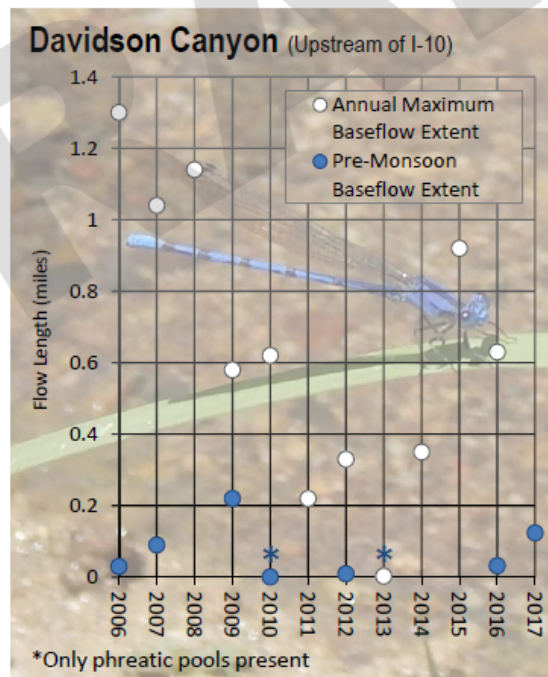
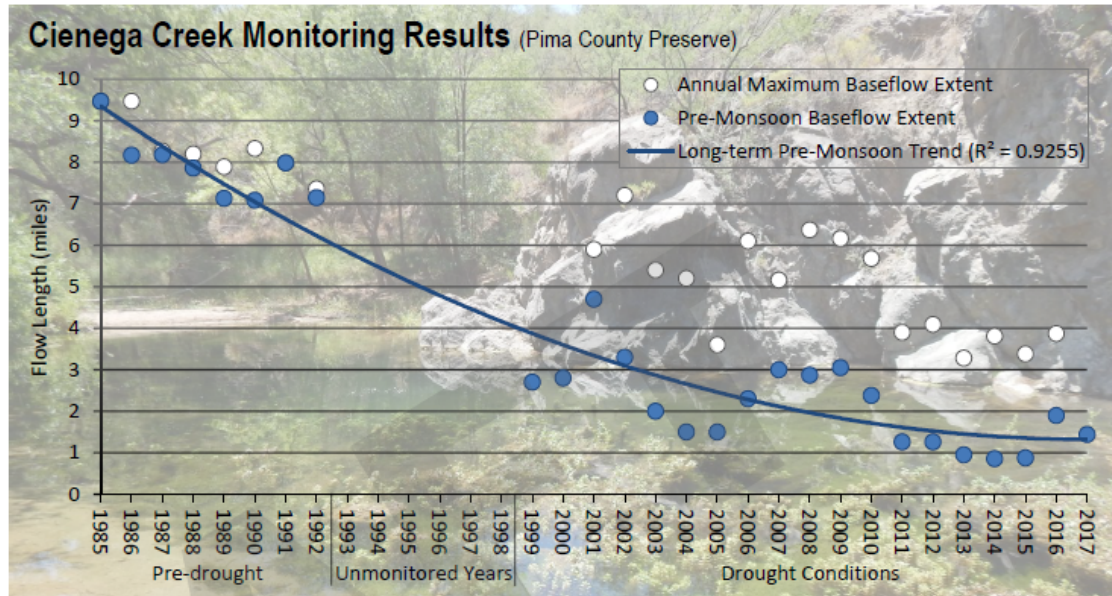
Cienega Creek is one of the few remaining perennial lowland streams in our region, and is used as a proxy for regional riparian conditions. The creek is a stunning example of what many of our riverbeds could look like if similar preservation efforts are employed, but monitoring results are a reminder of the ecosystem's vulnerability to dropping water tables.

Pima Association of Governments (PAG) has monitored riparian conditions in Pima County's Cienega Creek Natural Preserve since 1989. As part of the monitoring program, on a quarterly basis PAG maps baseflow in the reaches of Cienega Creek and Davidson Canyon that fall within the Preserve, both Arizona Outstanding Waters. This handout displays PAG's surface flow extent survey results from the driest time of year (May/June) to reflect the perennial (year-round) surface water. Since 2010, Cienega Creek's seasonal baseflow has ranged from approximately one to four miles within the course of a year, while Davidson has ranged from zero to just under one mile.

In 2017, PAG observed a decrease in Cienega Creek's perennial flow extent following improvement in 2016. This year, June creek flows were present in 15% of the 9.5 mile monitoring area, which had flowed perennially in 1985. This result fits the long-term downward trend, but is improved since record lows were observed between 2011 and 2015. Davidson Canyon saw an increase, with the second highest perennial flow observed since 2006. Davidson results include the length of both flowing segments and phreatic pools.

Based in part on PAG's assessments, in January 2017, PAG's Regional Council passed the Resolution to Support our Heritage of Desert Waters. In keeping with the goals of the Resolution, PAG makes the following recommendations as they apply to Cienega and other riparian areas:

- Continue efforts to provide shallow groundwater outreach in rural areas to sustain our region's heritage of streamflow in the desert.
- Employ green infrastructure techniques that help stormwater to infiltrate into shallow aquifers, to sustain vegetation and to reduce groundwater pumping for irrigation.



- Increase the use of stormwater and reclaimed water to benefit our regionally cherished riparian areas.
- Promote and facilitate efforts to account for the environment in water budgets and river flow in watershed plans.

PAG takes the following actions to support riparian resiliency for management goals:

- Conducts quarterly monitoring to track long-term and seasonal groundwater trends and to assess impacts to the health of the riparian community.
- Develops techniques and shared monitoring protocols with interested organizations.
- Continues to lead public engagement activities that encourage water conservation, pollution prevention and riparian restoration.
- Coordinates with stakeholders in the Cienega Creek watershed, including the Las Cienegas National Conservation Area.



Attachment A

Cienega Creek Preserve Pre-Monsoon Flow Extent 1999 to 2017

This map displays changes in June pre-monsoon baseflows within the Cienega Creek Natural Preserve since 1999. Baseflows are groundwater-based creek flows, without the influence of stormwater runoff. As the creek's flow extent decreases due to sedimentation, drought and/or groundwater pumping, the increasingly segmented flows are limited to reaches where shallow bedrock layers keep the water table close to the surface. Wetter years elevate the water table, allowing segments to connect and flow to a greater extent.

Results from 2017 are shown on the map. The stacked bars show conditions from previous years, translated to-scale into linear bars, allowing easy comparison of flow length and location from year to year. Colors alternate for visual aid. The map displays 8 of the 9.5 miles of Cienega Creek that are monitored on a quarterly basis. Perennial flow has not been observed in the upper 1.5 mile stretch in recent years. The pie charts were generated based on flow extents in the full 9.5 mile monitoring area.

