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Appendix 1

List of 404 permits issued in 2017 for Pima County’s Section 10 permit compliance

404 Permits Issued by U. S. Army Corps of Engineers which utilize Pima County's Section 10 permit for ESA compliance

Corps File Number	Type of Permit Issued	Landowner	Agent	Lat/long	Location by parcel or addresss	MSCP coverage authorized? (y/n)	Grading executed? (y/n)
SPL201700233	RGP-81	Pima County	RFCD	32.36963/-111.13768	T:12S; R:12E; S8	yes	yes

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Appendix 2

Pima County Capital Improvement Projects (CIP) Completed in 2017

CIP Ground Disturbing Projects Closed Since Jan 1, 2017

CipProjectNo	ProjectName	Acres
3CDT15	Corona De Tucson WRF Facility Improvements	4.10
3EOB16	RWRD Emergency Overflow Basin Number Four Creation	10.73
CWW.3SHT16	Tres Rios Sludge Holding Tank	2.22
4MTLYD	DOT Arizona Forest Highway 39, Mount Lemmon Service Yard Facilities	3.52
3NRIC4	Odor and Corrosion Control @ Tanque Verde Siphon	0.14
3AVB16	New Influent Emergency Overflow Basin - Avra Valley WRF	3.18
CPR.PCDSK8	Picture Rocks Skate Park Lighting	0.09
CWW.3GVB17	Green Valley WRF - Bio-Filter	0.15
3PGC18	PANTANO GRADE CONTROL STRUCTURE CAP REHABILITATION	0.06
CFC.5AGCAL	Agua Caliente Park Restoration	2.61
CWW.3AP619	Avra Valley WRF - Pond 6	14.02
CWW.3GRS18	Green Valley WRF- Grit Removal System Replacement /Upgrade	0.04
CWW.3RBP21	Green Valley WRF - Recharge Basins Phase 2	15.48
CWW.3ELF19	Tres Rios WRF - Building 9 - Expand Laboratory Floor Space	0.27
CWW.3GVC18	Green Valley WRF - Two Additional Secondary Clarifiers	0.92
CWW.3BBUMP	Tres Rios WRF Nutrient Recovery Project	1.15
CWW.3TTHM6	TTHM Control Through Centrate Dosing	0.07
CPR.PCCPRK	Catalina Community Park (project closed/ funds reallocated)	0.00
CWW.3DPS15	Silverbell Pump Station Rehabilitation	0.01
CWW.3APS13	System-Wide Conveyance Rehabilitation - Arivaca Pump Station	4.02
CWW.3RIR11	Side Stream Treatment	0.03
CWW.3RWC15	Proposed Addition to RWRD Central Laboratory 3035 W Camino del Cerro	0.03
CFC.5CREST	Canoa Ranch Restoration	30.00
CWW.3CDS16	Corona De Tucson WRF Influent Splitter Box Improvements	0.01
CDE.2AJOCL	Ajo Landfill Closure	16.66
CSU.CRBLDG	Canoa Ranch 2004 Improvements Area	13.53
3RWC12	Roger Rd Shut Down and Clean Closure	2.41
CFM.XSELIB	Southeast Library	6.33
CPR.PCDCPR	Canoa Preserve Restroom - CDBG	1.48
CWW.3CDT22	Corona de Tucson Disinfection $ Service Water Systems	0.13
CWW.3GAS18	TR-WRF Biogas Cleaning and Utilization Project	0.27
CSU.SUNARC	Sunset Campus Archaelogy	10.06
CWW.3RIR08	Ina Rd WPCF Class A Biosolids Improvements	0.35

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Appendix 3

Use of Gila topminnow (*Poeciliopsis occendentalis*) as vector control: AZGFD Authorization Letter and Green Pool list

THE STATE OF ARIZONA
GAME AND FISH DEPARTMENT
5000 W. CAREFREE HIGHWAY
PHOENIX, AZ 85086-5000
(602) 942-3000 • WWW.AZGFD.GOV

March 9, 2017

David M. Ludwig, Program Manager
Pima County
Consumer Health and Food Safety
3950 S. Country Club Rd
Tucson, Arizona 85714

Nick Ramirez, Supervisor
Pima County
Vector Control Program
3950 S. Country Club Rd
Tucson, Arizona 85714

Mr. Ludwig and Mr. Ramirez:

This letter authorizes you and your employees, under the authority of the Arizona Game and Fish Department (Department), to act as Agents of the Department, for the controlled and limited distribution of Gila Topminnow within the boundaries of Pima County, as a means of vector control for mosquito-borne health threats. The Department will provide Pima County Health Department (County) with Gila Topminnow (*Poeciliopsis occidentalis*) to establish a captive population on County property at 3950 S. Country Club Rd. Tucson, Arizona. The County will be allowed to hold and distribute the Gila Topminnow under an Aquatic Wildlife Stocking License(s) issued by the Department, and take of the species will be covered under the Department's Federal Endangered Species Act (ESA) Permit (#TE821577-5). Pima County is required to obtain and maintain Aquatic Wildlife Stocking License(s) from the Department, an application for which can be found on the Department's website at:

https://www.azgfd.com/license/speciallicense/aquaticstocking/.

The County should work in coordination with the Region V Aquatic Wildlife Program Manager, Don Mitchell (DMitchell@azgfd.gov) and the Aquatic Wildlife Branch Chief, Chris Cantrell (CCantrell@azgfd.gov) at Department Headquarters in Phoenix to secure these licenses.

The coverage of the Department's Federal ESA Permit and Aquatic Wildlife Stocking License is extended only to designated County personnel, employed specifically for the Public Health actions, and is not transferrable to any other entity, private or public, including volunteers, contractors, or other County agencies, without first obtaining explicit permission from the Department for any such action.

Coverage under the Department's Federal ESA Permit and Aquatic Wildlife Stocking License will allow the county to use Gila Topminnow to:

1. Hold captive, propagate, handle, transport and stock into appropriate isolated waters, primarily for the purpose of reducing risk from vector –borne disease to the public;

2. Promote the elimination of the use of nonnative Mosquitofish (*Gambusia affinis*) and its associated threat to topminnow and other native aquatic species, throughout much of the topminnow's range in Pima County.

Designated Pima County Health Department personnel are allowed to distribute Gila Topminnow only into specified waters in Pima County. Fish can be stocked into contained, artificial habitats that are not hydrologically connected to water courses. Examples of waters that can be stocked include but are not limited to abandoned swimming pools, backyard ponds, birdbaths, water features, containers, and depressions. Under no circumstances does this letter or the Aquatic Wildlife Stocking License authorize any personnel entrance or access onto private property without the appropriate permissions or authorization to do so.

During the act of transporting and stocking topminnow at locations identified by Pima County Health Department, the employee involved in the action <u>must</u> have:

- A copy of this letter;
- A copy of the Department's Federal Permit (#TE821577-5; eff: 07/10/2015 – 06/30/2020);
- A copy of the current Aquatic Wildlife Stocking License that will be issued to the Pima County Consumer Health and Food Safety Program.

Additionally, annually you must report the following data for all stockings in the Excel spreadsheet provided:

- Date of the stocking;
- Name of the individual performing the stocking;
- Source of fish stocked (your facility);
- Number of fish stocked;
- Street address of location stocked;
- UTMs of location stocked;
- Water source of site;
- Verification that the site stocked is for all practical purposes a closed system;
- Owner of property;
- Appropriate notes or comments about the stocking or the habitat.

A brief annual report summarizing your activities (e.g. number of sites stocked, number of topminnow stocked, general evaluation of the project) during the previous year, and containing the above information in electronic format (MS Excel spreadsheet) will be due to the Department by January 31st of each year. Copies of the report and an e-file of the data should be sent to:

Sabra Tonn (HDMS Program Supervisor: STonn@azgfd.gov);
Ross Timmons (Native Fish Project Coordinator: RTimmons@azgfd.gov);
Don Mitchell (AGFD Region V Aquatic Wildlife Program Manager: DMitchell@azgfd.gov);

In response to this letter and at the earliest practicable opportunity, you are required to provide the Department, a list of all employees who will be caring for or stocking Gila Topminnow. For newly hired employees who will be stocking fish, or for employees who are covered for these actions and whose employment is later terminated, you must inform the Regional Aquatic Wildlife Program Manager (see below) within 10 working days and request their name be added to, or removed from, the list of individuals covered under the Department's Aquatic Wildlife Stocking License and the Department's Federal Permit.

If you have any questions, please contact:

Don Mitchell
Aquatic Wildlife Program Manager
Region 5, Tucson
520-388-4451

Ross Timmons
Native Fish Projects Coordinator
Native Aquatics Wildlife Branch
623-236-7509

Tony Robinson
CAP Supervisor
Native Aquatics Wildlife Branch
623-236-7376

Chris Cantrell
Aquatics Wildlife Branch Chief
623-236-7259

Sincerely,

Jim deVos
Assistant Director, Wildlife Management Division

JDV:rt

Pima County Health Department Topminnow Tracking Report - 2017

(redacted for names and addresses; AZGFD and USFWS have the unredacted data)

DATE	STOCKED BY	NUMBER STOCKED	DATUM	ZONE	EASTING	NORTHING	SOURCE OF WATER	CLOSED SYSTEM	DISEASE CERTIFIED	NOTES ON STOCKING SITE
6/8/2017	Cynthia Bennett	10	NAD83	12N	515,938	3,574,980	Municipal Water Supply	Yes	Yes	Vacant Home. Topminnow Placed In Pool And Spa. Male and Female Placed in Spa As Well As Pool. Fish Observed Swimming the Area and feeding on larvae. Mosquito Larvae Present. Warrant served to enter property. Homeowner disregarded noticies, warrant obtained.
7/12/2017	Cynthia Bennett	22	NAD83	12N	518,344	3,566,985	Rainwater	Yes	Yes	Vacant Home. Topminnow Placed In Pool only.No Spa. Mosquito Larvae Present. Fish Observed Swimming the Area and feeding on larvae. Warrant served to enter property. Homeowner disregarded noticies, warrant obtained.
9/26/2017	Cynthia Bennett	12	NAD83	12N	518,546	3,564,302	Municipal Water Supply	Yes	Yes	Vacant Home. Topminnow placed in pool only.No Spa.Mosquito Larvae Present. Observed Fish swimming area and feeding on larvae. Warrant served to enter property. Homeowner disregarded noticies, warrant obtained.

9/26/2017	Cynthia Bennett	12	NAD83	12N	494,845	3,579,118	Municipal Water Supply	Yes	Yes	Occupied Home. Homeowner in process of foreclosure and cannot maintain pool. Topminnow placed in pool only. Mosquito Larvae Present. Observed Fish swimming area and feeding on larvae. Warrant served to enter property. Homeowner disregarded noticies, warrant obtained.
12/4/2017	Gregg Bustamante	20	NAD83	12N	519,557	3,563,026	Municipal Water Supply	Yes	Yes	Occupied Home.Topminnow placed in pool only.No spa.Mosquito Larvae Present. Observed Fish swimming area and feeding on larvae. Warrant served to enter property. Homeowner disregarded noticies, warrant obtained.

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Appendix 4

Example buffelgrass advisement letter

PIMA COUNTY
ENVIRONMENTAL QUALITY

33 N. Stone Avenue, Suite 700
Tucson, Arizona 85701-1429
www.pima.gov/deq

Ursula Nelson, P.E.
Director

(520) 724-7400
FAX (520) 838-7432

December 15, 2017

Dear Property Owner:

The Pima County Department of Environmental Quality (PDEQ) has received information that you may have buffelgrass on your property located at xxxxxx , Arizona.

Buffelgrass is a non-native invasive grass that threatens our community and the Sonoran Desert. Buffelgrass spreads aggressively by seed and forms dense stands which crowd out native plants. The dense growth supports extremely hot fires in excess of 1,400 degrees Fahrenheit. Such hot fires kill saguaros and other signature plants of the Sonoran Desert and have the potential to destroy personal property, including homes.

In support of regional efforts to eradicate and manage buffelgrass, the Pima County Board of Supervisors adopted changes to the Pima County Code, Title 7, Chapter 33 that identifies buffelgrass as a weed subject to regulation. The Pima County Code gives the County the authority to issue property owners in unincorporated Pima County an Opportunity to Correct, seek a court injunction or abate the property when buffelgrass poses a significant public safety threat such as fire.

At this time, PDEQ is encouraging property owners to voluntarily inspect their property for buffelgrass and take action to remove or control this invasive grass. I have included a brochure with this letter to assist you with the identification of buffelgrass and provide information on effective removal and control of this hazard.

The control of buffelgrass in Pima County will require action from all municipalities and property owners. If your property has buffelgrass, please take the actions necessary to control this potential hazard to your home and our community.

Sincerely,

Jennifer Lynch, Enforcement Manager

Enclosure: Buffelgrass Wanted Dead and Gone Brochure

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Appendix 5

Certificate of Water Rights No. 96545 for Instream Flow in Buehman Canyon (Application No. 33-96545)

DOUGLAS A. DUCEY
Governor

THOMAS BUSCHATZKE
Director

ARIZONA DEPARTMENT of WATER RESOURCES
1110 West Washington Street; Suite 310
Phoenix, Arizona 85007
602.771.8621
azwater.gov

October 17, 2017

Pima County Regional Flood Control District
Attn: David Scalero
97 E Congress St. 2nd Floor
Tucson, AZ 85701

RE: Certificate No. 96545 (Application No. 33-96545 - Buehman Creek) – Instream Flow

Certificate Holder:

The Department of Water Resources (Department) is pleased to forward the enclosed Certificate of Water Right for your records. The certificate is evidence of your right to use a given amount of public waters of the state for the requested beneficial use at the specified location. You may wish to record the document with the county recorder for the county in which the water right is located. A copy of the water right certificate is maintained in the official records of this Department.

The right to the use of water as evidenced by a certificate is not absolute; the basis, measure, and limit of any water right granted under provisions of the Public Water Code is the amount actually put to the stated beneficial use, but never more than the amount stated in the certificate. In addition, your water right is also given a date of priority which is the filing date of the original application. The date is used as a means of ranking the water right in relation to all other water rights within a specific watershed. Your water right could be subject to prior vested water rights. For purposes of management of the water resource in times of scarcity, water rights senior in time to your water right could have "first call" on the available supply of public water. Senior water rights could prohibit your use of the available water resource until their water rights are satisfied.

Because the certificate was issued for less water than the amount that was issued on the permit, this is an appealable agency action. This is an appealable agency action which you are entitled to appeal. Enclosed is a summary of the appeal process and the appeal form (Notice of Appeal) that you should use if you choose to pursue this option.

The watershed in which your water right is located is currently undergoing a superior court proceeding called a water rights adjudication which will determine the nature, extent and priority of all water rights located within the watershed. To participate in the adjudication proceeding, you must file a statement of claimant with the superior court on forms provided by the Department.

Questions concerning the nature of your water right may be addressed to the undersigned at (602) 771-8612. Questions concerning the water rights adjudication proceeding may be addressed to Ana Marquez at (602) 771-8405.

Sincerely,

Kevin Hadder
Surface Water Rights Specialist
Permitting Section

ENCLOSURE

This is to Certify, that Pima County Regional Flood Control District, 97 E. Congress St., 2nd floor, Tucson, AZ 85701, has made proof to the satisfaction of the Department of Water Resources of a right to the use of the waters flowing in Buehman Creek, for recreation and wildlife, including fish, under Application and Permit No. 33-96545.0001. The right to the use of the waters was perfected in accordance with the laws of Arizona; the priority of the water right dates from March 4, 1997; the amount of water to which such right is entitled for the stated purposes is limited to an amount actually beneficially used for such purposes, but shall not exceed an amount, as listed below, expressed as specific monthly flow rates and total annual volume as measured in the Northwest quarter of the Southeast quarter (NW¼SE¼), Section 7, Township 12 South, Range 18 East, Gila and Salt River Base and Meridian.

MONTH	FLOW RATE (CUBIC FEET/SECOND)	MONTHLY VOLUME (ACRE FEET/MONTH)
January	0.28	17.21
February	0.36	19.99
March	0.57	35.04
April	0.41	24.39
May	0.01	0.61
June	0.00	0.00
July	0.06	3.69
August	0.03	1.84
September	0.05	2.97
October	0.04	2.46
November	0.20	11.90
December	0.42	25.82
Total Annual Volume (acre feet/year)		145.9

Location of the places of use: Water will not be diverted from the natural channel of Buehman Creek. The beneficial uses will occur instream along the meandering course of the natural channel of Buehman Creek, within the South half (S½) of Section 14, the Southwest quarter of the Southwest quarter (SW¼SW¼) and the Southeast quarter of the Southwest quarter (SE¼SW¼), Section 13 and the Northeast quarter of the Northwest quarter (NE¼NW¼), the Northwest quarter of the Northeast quarter (NW¼NE¼) and the Northeast quarter of the Northeast quarter (NE¼NE¼), Section 24, Township 12 South, Range 17 East, the Northwest quarter of the Northwest quarter (NW¼NW¼), Section 19, the Southwest quarter of the Southwest quarter (SW¼SW¼), the Northwest quarter of the Southwest quarter (NW¼SW¼), the Southwest quarter of the Northwest quarter (SW¼NW¼), the Southeast quarter of the Northwest quarter (SE¼NW¼) and the Northeast quarter of the Northwest quarter (NE¼NW¼), Section 18 and the Southeast quarter of the Southwest quarter (SE¼SW¼), the Northwest quarter of the Southeast quarter (NW¼SE¼), the Southwest quarter of the Northeast quarter (SW¼NE¼) and the Southeast quarter of the Northeast quarter (SE¼NE¼), Section 7, Township 12 South, Range 18 East, Gila and Salt River Base and Meridian, Pima County, Arizona.

There shall be no impoundments of public waters or interference with the natural surface water flow occurring along the described reach of the stream channel.

There shall be no consumptive use of public waters or degradation of water quality, other than is caused by natural habitat (flora and fauna).

The right to the use of water is restricted to the place of use and for the purposes described previously. There shall be no interference with or detrimental effect upon prior vested water rights.

WITNESS the seal and signature of the Assistant Director,
Arizona Department of Water Resources,
affixed this 17th day of October, 2017.

Elizabeth V. Logan, Manager (Attest)
Surface Water Permit Unit

Clinton Chandler, Assistant Director
Water Planning and Permitting Division

The Department of Water Resources shall be notified of any change of address for the above named person(s), or if ownership of the water right or of the land at the location of the water right is conveyed to another person(s), pursuant to Arizona Revised Statute § 45-164(B).

Certificate of Water Right

State of Arizona

County of Pima

Certificate No. 96545.0000
(Application No. 33-96545.0001)

Arizona Department of Water Resources
1110 W. Washington St., Ste. 310
Phoenix, Arizona 85007

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Appendix 6

Master Restrictive Covenants for Pima County
MSCP Mitigation Land

Master Restrictive Covenant for
Pima County MSCP Mitigation Land

This Master Restrictive Covenant ("**MSCP Master Covenant"**) is entered into by Pima County, a political subdivision of the State of Arizona ("**County**"), the Pima County Regional Flood Control District, a political taxing subdivision of the State of Arizona ("**District**"), and the Arizona Land and Water Trust, Inc., an Arizona nonprofit corporation ("**Beneficiary**") (County, District, and Beneficiary being collectively the "**Parties**").

1. **Background and Purpose**

1.1. The United States Fish and Wildlife Service issued permit #TE84356A to County (the "**Permit**") for the incidental take of threatened and endangered species caused by specific, lawful activities within Pima County. To direct the mitigation of these incidental takes and ensure compliance with the permit, the County has established its Multi-Species Conservation Plan ("**MSCP**"). The objectives of the MSCP (the "**Objectives**") include managing mitigation lands to prioritize conservation of Covered Species and their habitats, prevent landscape fragmentation, and support species establishment or recovery.

1.2. The County owns the real property listed in Exhibit A (the "**Restricted Property**" or "**Restricted Properties**"). A map identifying the Restricted Property is attached hereto as Exhibit B. Individual maps of each of the Restricted Properties are attached hereto as Exhibit C. The Restricted Property contains significant undisturbed natural open space that the County wishes to preserve and protect for the mitigation of incidental take covered by the County's incidental take permit.

1.3. The Parties intend this MSCP Master Covenant to prohibit uses of the Restricted Properties that would impair or interfere with the mitigation efforts of the County, except for any pre-existing uses as shown on imagery by Pictometry or Pima Association of Governments dated 2015 or 2016, whichever is more recent (the "**Pre-existing Uses**").

1.4. The Parties intend that this MSCP Master Covenant assure that the Restricted Properties will be forever preserved as natural open space for the conservation of natural habitat for wildlife, the protection of rare and unique native plants and animals and the scenic enjoyment of the general public.

2. **Recording of Site Specific Restrictive Covenants**

2.1. The Parties intend that a site specific agreement ("**Site Specific Agreement**") be recorded for each individual property listed on Exhibit A and depicted on Exhibits B and C. The Site Specific Agreement shall be in the form of Exhibit D attached hereto. The Parties intend that each Site Specific Agreement incorporate all of the terms and conditions contained in this MSCP Master Covenant. Each Site Specific Agreement will contain the legal description of the referenced property, and recordation of a Site Specific Agreement will subject the real property described therein to the terms of this MSCP Master Covenant and cause such property to be a Restricted Property.

2.2. County hereby delegates to the County Administrator or his designee the authority to sign each of the Site Specific Agreements on behalf of County. District hereby delegates to the General Manager of the District or his designee the Authority to sign each of the Site Specific Agreements on behalf of District.

3. **Nature of MSCP Master Covenant**

3.1. This MSCP Master Covenant runs with each Restricted Property and binds the County and its successors and assigns.

3.2. This MSCP Master Covenant remains in perpetuity with respect to each Restricted Property, unless released by written consent of County, District, and Beneficiary, with the written concurrence of the U. S. Fish & Wildlife Service. Any release will specify if it relates to a specific Restricted Property or to this Master Agreement and, therefore, all the Restricted Properties.

3.3. The uses of the Restricted Properties prohibited by this MSCP Master Covenant remain in effect notwithstanding any future annexation of all, or any portion, of a specific Restricted Property by a municipality.

3.4. This MSCP Master Covenant may not be amended or modified except upon written agreement of County, District, and Beneficiary, and written concurrence from the U.S. Fish and Wildlife Service.

3.5. This MSCP Master Covenant may be enforced by District or Beneficiary as provided in Section 9 below.

4. **The Restrictions**. Except as provided in Section 5 of this MSCP Master Covenant, the following uses of the Restricted Properties are prohibited (collectively the "**Restrictions**"):

4.1. Development of the Restricted Properties, including subdividing or lot splitting of a Restricted Property;

4.2. Construction or placement of new or additional buildings or structures on a Restricted Property, unless the construction supports the purposes for which the Restricted Property was originally intended including any adopted master plan, and does not degrade the Restricted Property's values as expressed in the purpose statement;

4.3. Alteration of the ground surface or natural vegetation, except as may be needed for ranch, range improvement, or trail-based recreational uses, and only if such alterations are consistent with other provisions of the Multi-species Conservation Plan;

4.4. Impoundment, diversion or alteration of any natural watercourse unless for watershed enhancement to improve species habitat or to maintain a Restricted Property's mitigation values;

4.5. Development of, or the granting of, access, rights-of -way or easements for new roads or new utilities, including telecommunications facilities, except where County has no discretion to prohibit the activity;

4.6. Filling, excavation, dredging, mining, drilling, exploration, or extraction of minerals, hydrocarbons, soils, sand, gravel, rock or other materials on or below the surface of the Restricted Property, except where County has no discretion to prohibit the activity;

4.7. Storage, accumulation or disposal of hazardous materials, trash, garbage, solid waste or other unsightly material on the Restricted Property;

4.8. Introduction of non-native fish or amphibians or other non-native animals to or from catchments, tanks, springs or creeks. Other non-native species that might adversely affect the mitigation of permitted activities are also prohibited except for the purposes of supporting existing ranching operations, if any, and limited to those areas identified that have historically been devoted to the growing of such species, as shown on 2015 or 2016 aerial photographs;

4.9. Storage and use of biocides and chemical fertilizers except for residential and agricultural purposes. Aerial application of biocide or other chemicals is prohibited except where County and District concur that it is an appropriate and necessary management technique to promote the recovery and re-establishment of native species, to reduce threats to ecosystem structure and function, or to protect public health, safety and welfare;

4.10. Pumping of water from existing diversions for purposes other than on-site residential, wildlife, recreational, habitat enhancement and agricultural uses associated with livestock grazing on the Restricted Property. Increases in the pumped amounts of surface or subsurface water as allowed by the Arizona Department of Water Resources are not permitted without joint approval from the County and District and concurrence from the U.S. Fish and Wildlife Service;

4.11. Installation of underground storage tanks for petroleum or other polluting substances, except for already existing or permitted septic tanks;

4.12. Confinement of livestock where animals are permanently located in enclosures and the majority of their feed supplied from outside sources. This includes feeder cattle, dairy, pig, poultry and exotic animal farm operations;

4.13. Commercial enterprises inconsistent with the Objectives, excluding farming and ranching. The County and District may jointly approve commercial enterprises, other than farming or ranching, that provide for ecotourism or wildlife-related recreation provided that it is consistent with the Objectives and does not degrade the Restricted Property's mitigation value;

4.14. Residential use for mobile homes, travel trailers, tent trailers, self-propelled recreational vehicles and like structures or vehicles, except temporary use as permitted by County Park Rules or reasonable use as needed to support the protection or enhancement of the Restricted Property's mitigation value;

4.15. Paving of roads using asphalt or concrete except where required by County ordinance;

4.16. Any modification of the topography of the Restricted Property through the placement of soil, dredging spoils, or other material, except for those uses permitted under this document, or to reduce soil erosion or to protect public health, safety and welfare;

4.17. Severance of water rights appurtenant to the Restricted Property including the transfer, encumbrance, lease and sale of water rights;

4.18. Off-road vehicular travel except to facilitate permitted activities on the Restricted Property; and

4.19. Removal of natural, mineral, or cultural resources that is not authorized by County.

5. **Exceptions to Restrictions.** Notwithstanding any other provision of this MSCP Master Covenant, the following uses of the Restricted Properties are not prohibited:

5.1. Any use of the Restricted Property which the County Board of Supervisors in its reasonable discretion determines is necessary to retain, restore, or enhance the mitigation of incidental take covered by the Permit;

5.2. Any Pre-existing Use of the Restricted Property;

5.3. Any use of the Restricted Property expressly permitted by a contract in effect between the County and a third party as of the date this MSCP Master Covenant is recorded; and

5.4. Any use of the Restricted Property which the County Board of Supervisors determines, based on clear and convincing evidence presented to said Board, is necessary to protect the public health, safety or welfare.

6. **Obligations of County**

6.1. County, through its employees, agents and contractors, retains all responsibilities and will bear all costs and liabilities of any kind related to the ownership, operation, upkeep, and maintenance of the Restricted Properties. County remains solely responsible for obtaining any applicable governmental permits and approvals for any activity or use undertaken on the Restricted Properties. All such activity shall comply with all applicable Federal, state, and local laws, regulations, and requirements.

6.2. County, through its employees, agents and contractors, at County's expense, will conduct an inspection of the Restricted Properties at least biennially to determine if there are any violations of the Restrictions. The inspection will be completed by either examination of aerial photographs or by physical inspections with onsite photographs taken at the time of the inspections. The County will prepare and deliver copies of biennial reports ("Reports") of its inspections, which reports will describe the then current condition of the Restricted Properties inspected and note any violations of the Restrictions. Copies of the Reports will be provided to District and Beneficiary upon completion, and in no event later than October 15 of each biennial reporting year. County will maintain the Reports as County records in accordance with Arizona state law.

6.3. County shall report any violations of the terms of this MSCP Master Covenant to District and Beneficiary within 2 working days of County discovery and confirmation of any such violation. For purposes of this Section 6.3, the determination of what shall constitute a reportable violation of this MSCP Master Covenant shall be at County's reasonable discretion. However, County's determination of what is reportable pursuant to this Section 6.3 will not limit District or Beneficiary's right to enforce this MSCP Master Covenant as provided for in Sections 7, 8, and 9 of this MSCP Master Covenant.

6.4. The parties acknowledge that Beneficiary has no legal ownership interest in the Restricted Properties, and it is the parties' intent that the Beneficiary not undertake any responsibility or liability with respect to the Restricted Properties, other than liability related to Beneficiary's negligence ("Beneficiary's Negligence"), as more specifically limited below. Therefore, County agrees:

6.4.1. County (as indemnifying party) shall indemnify, defend and hold harmless, Beneficiary and its officers, directors, employees, agents, affiliates, successors and permitted assigns (collectively, "**Indemnified Party**") against any and all losses, damages, liabilities, deficiencies, claims, actions, judgments, settlements, interest, awards, penalties, fines, costs, or expenses of whatever kind, including attorneys' fees, that are incurred by Indemnified Party (collectively, "**Losses**"), arising out of or related to any third-party claim alleging:

6.4.1.1. breach or non-fulfillment of any provision of this Agreement by County, District, or County or District's personnel;

6.4.1.2. any negligent or more culpable act or omission of County, District, or County or District's personnel (including any reckless or willful misconduct) in connection with the performance of County, District, or County or District's personnel under this Agreement;

6.4.1.3. any bodily injury, death of any person or damage to real or tangible personal property caused by the negligent or more culpable acts or omissions of County, District, or County or District's personnel (including any reckless or willful misconduct);

6.4.1.4. any failure by County, District, or County or District's personnel to comply with any applicable federal, state or local laws, regulations or codes, including any failure related to their performance under this Agreement; or

6.4.1.5. any claim by any third party asserting a failure of Beneficiary to enforce Beneficiary's rights, or perform Beneficiary's duties, under this Agreement. County's obligation to indemnify Beneficiary against third party claims related to any failure of Beneficiary perform Beneficiary's duties, under this Agreement will not preclude County from replacing Beneficiary as provided in Section 8.5. Replacement of Beneficiary will be County's sole remedy for Beneficiary's breach of its obligations under this Agreement.

6.4.2. Beneficiary must give notice to County (a "**Claim Notice**") of any claim filed which may give rise to a Losses. Indemnified Party's failure to provide a Claim Notice does not relieve County of any liability, but in no event shall County be liable for any Losses that result directly from a delay in providing a Claim Notice, which delay materially prejudices the defense of the claim. County's duty to defend applies immediately after receiving a Claim Notice.

6.4.3. County may select legal counsel to represent Beneficiary in any action for which County has an obligation to indemnify, defend and hold harmless Beneficiary, and County shall pay all costs, attorney fees, and Losses.

6.4.4. County shall give prompt written notice to Beneficiary of any proposed settlement of a claim that is indemnifiable under this Agreement. County may settle or compromise any claim without Beneficiary's consent, so long as Beneficiary is not responsible for paying any Losses.

7. **Obligations of District**

7.1. District shall review any and all reports on potential violations of the Restrictions provided by County to District as required by this MSCP Master Covenant, at District's expense.

7.2. If the event of any action that may constitute a violation of the terms of this MSCP Master Covenant, District shall determine, in its reasonable discretion, whether to take any action to enforce the terms of this MSCP Master Covenant.

7.3. In the event that County desires to take action with respect to the Restricted Properties that may constitute a violation of this MSCP Master Covenant, County will obtain District's prior approval of such action, and District shall respond to any such request from County in a timely manner.

7.4. District and County will advise Beneficiary in writing of any non-privileged communications between County and District with regard to the matters referred to in Sections 7.2 and 7.3. District and County will also provide Beneficiary with copies of any written communications, in whatever form, between District and County with regard to the matters referred to in Sections 7.2 and 7.3.

8. **Obligations of Beneficiary**

8.1. Beneficiary shall review any and all reports provided by County to Beneficiary as required by this MSCP Master Covenant, at County's expense. County shall compensate Beneficiary for performing its actions under this Section 8.1 on a time and materials basis, pursuant to the terms of professional services contract entered into between County and Beneficiary (the "Services Agreement"). In the event (i) County and Beneficiary cannot agree upon the Services Agreement; (ii) the Services Agreement is terminated, for any reason; (ii) County fails to timely pay Beneficiary under the Services Agreement; or (iii) County materially breaches any other term of the Services Agreement, then Beneficiary will have the right to terminate its obligations under this MSCP Master Covenant by providing County and District ten days prior written notice.

8.2. If the event of any action that may constitute a violation of the terms of this MSCP Master Covenant, Beneficiary shall determine, in its reasonable discretion, whether to take any action to enforce the terms of this MSCP Master Covenant. Beneficiary shall be reimbursed for any expenses incurred by Beneficiary to enforce this Master Agreement in accordance with the Services Agreement.

8.3. In the event that County desires to take action with respect to a Restricted Property that may constitute a violation of this MSCP Master Covenant, County will obtain Beneficiary's prior approval of such action, and Beneficiary shall respond to any such request from County in a timely manner. Beneficiary shall be compensated for any services performed in response to any such request in accordance with the Services Agreement.

8.4. In the event Beneficiary is no longer able to perform its obligations under this MSCP Master Covenant, or no longer desires to serve as Beneficiary, then Beneficiary shall provide not less than sixty (60) days' notice to County. Beneficiary may designate a replacement Beneficiary subject to County's approval. In the event Beneficiary does not designate a replacement Beneficiary within 45 days' after delivery of the notice, then County will be solely responsible to designate a replacement Beneficiary. Beneficiary's resignation shall be effective sixty (60) days after the delivery of the notice by Beneficiary to County.

8.5. County's sole remedy for Beneficiary's failure to perform Beneficiary's obligations under this Agreement will be to terminate the Services Agreement and replace Beneficiary with a new party who will fill the role of Beneficiary. County will be solely responsible to designate a replacement Beneficiary in such event.

9. **District and Beneficiary's Right To Enforce.**

9.1. District and/or Beneficiary (for purposes of this Section 9, collectively or individually the "**Enforcing Party**") may enforce this MSCP Master Covenant against the County and its successors and assigns.

9.2. If the Enforcing Party has reason to believe that a violation of the Restrictions may have occurred, the Enforcing Party has the right to enter upon the Restricted Properties. The Enforcing Party must provide at least two (2) business days' notice to County prior to entering upon a Restricted Property.

9.3. The Enforcing Party shall hold County harmless from liability for any injuries to its employees or agents occurring on a Restricted Property in the course of its duties pursuant to this MSCP Master Covenant which are not directly or indirectly the result of acts, omissions, or the negligence of County, or County's employees, agents, successors and assigns.

9.4. If the Enforcing Party determines that there is a breach of the terms of the Restrictions, the Enforcing Party may, but is not obligated to, enforce the terms of this MSCP Master Covenant as provided in this Section 9. When evaluating any possible breach or enforcement action, the Enforcing Party will have the right to consult experts (e.g., biologists, engineers, etc.) to assist it in determining both whether or not there is a violation and appropriate remedial action, provided that the cost of any such experts is subject to the maximum dollar limitation in the Services Agreement. Beneficiary will be reimbursed by County for any such expenses in accordance with the Services Agreement.

9.5. Prior to any enforcement action by the Enforcing Party, the Enforcing Party must give written notice to County of such breach (the "**Notice of Breach**") and demand corrective action sufficient to cure the breach and, where the breach involves injury to a Restricted Property resulting from any activity inconsistent with the purpose of this MSCP Master Covenant, to restore the portion of the Restricted Property so injured.

9.6. If (i) under circumstances where an alleged breach can be cured within a 30 day period, County fails to cure an alleged breach within 30 days after receipt of the Notice of Breach, or (ii) under circumstances where an alleged breach cannot reasonably be cured within a 30 day period, County fails to begin curing such breach within the 30 day period, or County fails to continue diligently to cure such breach until finally cured, the Enforcing Party may in any such event bring an action at law or equity to enforce the terms of this MSCP Master Covenant or to enjoin the breach by temporary or permanent injunction, and to recover any damages caused by the breach of the terms of this MSCP Master Covenant or injury to any protected uses or mitigation, including damages for any loss, and to require the restoration of any Restricted Property to the condition that existed prior to the injury.

9.7. In the event any action, suit or proceeding at law or in equity is instituted with respect to this MSCP Master Covenant, the Enforcing Party shall be entitled to reasonable attorneys' fees, expenses and court costs incurred if it is the prevailing party.

9.8. Nothing contained in this MSCP Master Covenant can be construed to entitle the Enforcing Party to bring any action against the County for any injury to or change in the Restricted Property resulting from causes beyond the County's control including unforeseeable acts of trespassers, fire, flood, storm, drought, pests, natural earth movement, vegetative disease, or resulting from any action taken by the County under emergency conditions to prevent, abate or mitigate significant injury to any Restricted Property resulting from such causes.

10. **General Provisions**

10.1. The laws and regulations of the State of Arizona govern this MSCP Master Covenant. Any action relating to this MSCP Master Covenant must be brought in a court of the State of Arizona in Pima County.

10.2. Unless the context requires otherwise, the term "including" means "including but not limited to".

10.3. Each provision of this MSCP Master Covenant stands alone, and any provision of this MSCP Master Covenant found to be prohibited by law is ineffective only to the extent of such prohibition without invalidating the remainder of this MSCP Master Covenant.

10.4. This instrument sets forth the entire Agreement of the County, District and Beneficiary with respect to this MSCP Master Covenant.

10.5. Any notice given under this MSCP Master Covenant must be in writing and served by delivery or by certified mail upon the other Parties as follows:

If to County: Office of Sustainability and Conservation
Attn: Director
Pima County Public Works
201 N Stone Ave., 6th FL
Tucson, Arizona 85701

If to District: Regional Flood Control District
Attn: Director
Pima Works Building
201 N Stone Ave., 9th FL
Tucson, Arizona 85701

If to Beneficiary: The Arizona Land and Water Trust
Attn: Diana Freshwater, President

3127 N. Cherry Ave.
Tucson, Arizona 85719

The Parties have executed this MSCP Master Covenant by their duly authorized representatives.

COUNTY: PIMA COUNTY, a political subdivision of the State of Arizona:

_________________________________ _________________

Chair, Board of Supervisors Date

ATTEST:

_________________________________ _________________

Robin Brigode, Clerk of Board of Supervisors Date

DISTRICT: The Pima County Regional Flood Control District

_________________________________ _________________

Chair, Board of Directors Date

ATTEST:

_________________________________ _________________

Robin Brigode, Clerk of Board of Directors Date

APPROVED AS TO CONTENT:

____

Neil J. Konigsberg, Manager, Real Property Services

____

John Bernal, Deputy County Administrator, Public Works

APPROVED AS TO FORM:

____

Tobin Rosen, Deputy County Attorney

BENEFICIARY: The Arizona Land and Water Trust, Inc.

__________________________________ ____________________

Diana Freshwater, President Date

Pima County
Multi-species Conservation Plan:
2017 Annual Report

Appendix 7

Abstracts to add proposed water rights for stockponds and stock watering on Pima County's Sands and Clyne Ranches.

IN THE SUPERIOR COURT OF THE STATE OF ARIZONA

IN AND FOR THE COUNTY OF MARICOPA

IN RE THE GENERAL ADJUDICATION OF ALL RIGHTS TO USE WATER IN THE GILA RIVER SYSTEM AND SOURCE	CIVIL NOS. W1-11-19A W1-11-19 ORDER ADDING PIMA COUNTY PROPOSED WATER RIGHT ABSTRACTS TO PARTIAL CATALOG

CONTESTED CASE NAME: *In re Pima County*

HSR INVOLVED: San Pedro River Watershed Hydrographic Survey Report.

DESCRIPTIVE SUMMARY: The Special Master adds five abstracts for proposed water rights for stockponds and stock watering analyzed by Watershed File Report No. 111-19-002 to the partial catalog of proposed water rights established in Civil No. W1-11-19.

NUMBER OF PAGES: 8.

DATE OF FILING: March 31, 2017

A Partial Catalog of Water Rights was created pursuant to Order dated March 28, 2017, in W1-11-19. The Partial Catalog will include those abstracts based on Watershed File Reports originally consolidated in W1-11-19. Memorandum Decision, Findings of Fact, and

Conclusions of Law for Group 1 Cases involving Stockwatering, Stockponds, and Domestic Uses, dated November 14, 1994, amended February 23, 1995, approved and modified September 27, 2002, ("Decision") p. 38. Watershed File Report 111-19-002, which was the report that analyzed the water claims considered in this case, is subject to the Decision.

Accordingly,

IT IS ORDERED that the five proposed water right abstracts[1] attached as Appendix A will be included in that Partial Catalog of Water Rights created pursuant to Order dated March 28, 2017, in W1-11-19.

IT IS FURTHER ORDERED correcting the clerical error in Order dated March 27, 2017, that misidentified statement of claim 36-102758 as statement of claimant 39-102758 and confirming that no proposed water right abstract will be issued at this time pursuant to Statement of Claimant 39-17899 based on statement of claim 36-102758.

Susan Ward Harris
Special Master

The original of the foregoing was delivered to the Clerk of the Maricopa County Superior Court on March 31, 2017, for filing and distributing a copy to all persons listed on the Court approved mailing lists for Contested Case Nos. W1-11-19A and W1-11-19

[1] The beneficial use identified in the abstract for 111-19-002-SW001 has been corrected to stock watering.

APPENDIX A

Abstract of Water Right
San Pedro Watershed

1. Proposed Water Right No:	111-19-002-SP001
2. Owner of Water Right:	Pima County
3. Landowner:	Pima County
4. Statement of Claimant No.(s):	39-002020
5. Statement of Claimant Name(s):	Sands Investment Company assigned to Pima County
6. Lessee or Permittee:	None
7. Basis of Right:	38-81495 3R-1651
8. Beneficial Use	Stockpond
9. Priority Date	12/31/1950
10. Quantity:	4 ac-ft with continuous fill
11. Place of Use:	NWNWNW 23 T19S R18E SWSW 14 T19S R18E
12. Point of Diversion:	NWNWNW 23 T19S R18E SWSW 14 T19S R18E
13. Source of Water:	Surface Water (Rain Valley Wash)
14. Name of Facility:	McNally Tank

Abstract of Water Right
San Pedro Watershed

1. Proposed Water Right No:	111-19-002-SP002
2. Owner of Water Right:	Pima County
3. Landowner:	Pima County
4. Statement of Claimant No.(s):	39-002001
5. Statement of Claimant Name(s):	Sands Investment Company assigned to Pima County
6. Lessee or Permittee:	None
7. Basis of Right:	38-81495 3R-1652
8. Beneficial Use	Stockpond
9. Priority Date	12/31/1950
10. Quantity:	4 ac-ft with continuous fill
11. Place of Use:	SWSWSW 23 T19S R18E
12. Point of Diversion:	SWSWSW 23 T19S R18E
13. Source of Water:	Surface Water (Rain Valley Wash)
14. Name of Facility:	Boulder Dam Tank

Abstract of Water Right
San Pedro Watershed

1. Proposed Water Right No:	111-19-002-SP003
2. Owner of Water Right:	Pima County
3. Landowner:	Pima County
4. Statement of Claimant No.(s):	39-002013
5. Statement of Claimant Name(s):	Sands Investment Company assigned to Pima County
6. Lessee or Permittee:	None
7. Basis of Right:	38-13331
8. Beneficial Use	Stockpond
9. Priority Date	12/31/1960
10. Quantity:	4 ac-ft with continuous fill
11. Place of Use:	NENWSW 34 T19S R18E
12. Point of Diversion:	NENWSW 34 T19S R18E
13. Source of Water:	Surface Water (Victoria Draw)
14. Name of Facility:	Victoria Tank

Abstract of Water Right
San Pedro Watershed

1. Proposed Water Right No:	111-19-002-SP004
2. Owner of Water Right:	Pima County
3. Landowner:	Pima County
4. Statement of Claimant No.(s):	39-17677
5. Statement of Claimant Name(s):	Pima County
6. Lessee or Permittee:	None
7. Basis of Right:	38-96686
8. Beneficial Use:	Stockpond
9. Priority Date:	12/31/1958
10. Quantity:	4 ac-ft with continuous fill
11. Place of Use:	NWSW 25 T19S R18E
12. Point of Diversion:	NWSW 25 T19S R18E
13. Source of Water:	Surface Water (unnamed wash, a tributary to Babocomari Creek)
14. Name of Facility:	Goat Spring Tank

Abstract of Water Right
San Pedro Watershed

1. Proposed Water Right No:	111-19-002-SW001
2. Owner of Water Right:	Pima County
3. Landowner:	Pima County
4. Statement of Claimant No.(s):	39-002019
5. Statement of Claimant Name(s):	Sands Investment Company assigned to Pima County
6. Lessee or Permittee:	None
7. Basis of Right:	36-80279 4A-4197
8. Beneficial Use	Stock watering
9. Priority Date	12/31/1919
10. Quantity:	Reasonable Use
11. Place of Use:	SWNENE 33 T19S R18E
12. Point of Diversion:	None
13. Source of Water:	Surface Water (Frigidaire Spring)
14. Name of Facility:	Frigidaire Spring

Pima County
Multi-species Conservation Plan:
2017 Annual Report

Appendix 8

Final Report: Application of Distance Sampling for Pima Pineapple Cactus (*Coryphantha scheeri* var. *robustispina*) Population Estimation and Monitoring

Application of Distance Sampling for Pima Pineapple Cactus (*Coryphantha scheeri* var. *robustispina*) Population Estimation and Monitoring

FINAL REPORT

Arizona Department of Agriculture
Endangered Species Act – Section 6 Grant Program
Project No. - Segment 19, 2015-2017-04

Presented to:
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Arizona Department of Agriculture
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Pima County Office of Sustainability and Conservation
201 N. Stone Ave
Tucson, AZ 85701

September 30, 2017

ABSTRACT

The Pima Pineapple Cactus is a federally-listed endangered species in southern Arizona that is often surveyed for compliance with federal law. The recommended survey protocol for this species (Roller method) attempts a complete census of all individuals, which is time intensive and assumes all individuals are detected during surveys. We tested a new survey method based on distance sampling (DS), which involves measuring distances to cacti observed from transect lines, and compared abundance estimates from DS with values recently obtained with the Roller method. Because DS is based on sampling theory, it requires only a subset of the overall population to be observed to obtain precise estimates of abundance. We observed 105 live Pima Pineapple Cacti while DS along 36.9 km of line transects at 11 study sites in southern Arizona. Density within those study plots averaged 1.47 individuals/ha with an estimated total of 294 individuals overall based on DS, and precision of estimates was high (CV = 0.139). Based on what we presumed to be known values of abundance from the Roller method, both density and abundance were well estimated by DS, which underestimated abundance by just 11.4% overall. Abundance estimates from DS were also highly correlated with values from the Roller method on both the untransformed ($r = 0.82$, $p = 0.002$), and especially logarithmic scales ($r = 0.92$, $p < 0.001$). Estimates of detection probability from DS indicate that between 4-8% of cacti are likely to be undetected by observers during surveys with the Roller method, especially in areas dominated by larger rocky substrates (versus sand or silt). Combined with recommendations we present to improve accuracy, DS is an effective method for surveying this species for various research and monitoring applications.

INTRODUCTION

The Pima Pineapple Cactus (*Coryphantha scheeri* var. *robustispina*; hereafter "PPC") has a relatively narrow distribution near the ecotone between desert-scrub and semi -desert grasslands in south-central Arizona and adjacent Sonora, Mexico. In response to various threats such as urban development, invasion of non-native grasses, overgrazing, and climate change, the PPC was listed as endangered in 1993 and a draft recovery plan was recently issued by the U.S. Fish and Wildlife Service (USFWS 2007, 2017). Although a number of studies provide information on the ecology and distribution of the PPC (e.g., Roller 1996a; McDonald 2005; Kidder 2015), major gaps of knowledge remain. Among these information gaps, is the need for an efficient survey method that can provide inferences on the distribution and abundance of this endangered species across both space and time, and information on environmental factors that influence these parameters.

With regard to survey methods, the current recommended survey protocol for the PPC (Roller 1996b) attempts a complete census of populations and thus complete enumeration of population size in a given focal area. Such an approach is appropriate where ground disturbance is proposed or in other situations where complete population enumeration and mapping are required for compliance with the Endangered Species Act. Nonetheless, efforts to census populations are often too time intensive to be efficient for research and monitoring applications, and are often based on unrealistic assumptions of perfect detection probability. For PPC, these issues are especially relevant because individual cacti are often small, may occur in areas of dense grass and shrubs, and are widely spaced over large areas, increasing the probability some individuals will be present but undetected during censuses. Where researchers endeavor to assess patterns of distribution and abundance across space and time, and habitat relationships, robust field methods based on sound sampling theory (e.g., observing a random sample and extrapolating to a larger population) should be capable of providing accurate inferences on populations with much greater efficiency.

Distance sampling (DS) is an effective method for estimating the distribution, abundance, and habitat relationships of both terrestrial and aquatic wildlife populations, and is applicable over broad geographic areas and for rare species given sufficient sampling effort (Thomas et al. 2002, 2010). Although DS has mainly been applied to vertebrate populations (e.g., Rosenstock et al. 2002, Flesch et al. 2016), it can be useful for plants despite few examples of its application (Buckland et al. 2007, Kissa and Sheil 2012, Schorr 2013). Distance sampling involves measuring the distances to focal objects from lines or points, and modeling a detection function that adjusts estimates of abundance for variation in detection probability. A recent pilot effort focused on applying DS to measuring abundance of the PPC produced encouraging results (Powell 2015). Before DS can be adopted to address research and monitoring questions for the PPC, however, more information and testing are needed. Although DS is highly efficient for estimating and monitoring spatiotemporal variation in abundance, it is largely untested in arid environments and for plants (but see Anderson et al. 2001).

Here, we test a novel field-based approach for surveying the PPC based on DS. To do so, we compare estimates of population size and densities obtained during DS procedures with estimated known values of these parameters based on censuses that were often coupled with intensive repeated monitoring and thus involved additional effort. This work was conducted at 11 sites in southern Arizona, which we selected non- randomly based on criteria discussed below. Thus, inferences reported here pertain only to the study sites themselves, not the entire population of cacti across the range of the taxon. Additionally, we discuss issues related to the design and implementation of DS for the PPC based on our findings, and assess factors that influence detection probability during line -transect sampling. Finally, we assess associations between local estimates of density of PPC (e.g., within-site estimates) and environmental factors such as vegetation cover and soil substrate size to provide an example of how DS can be applied to understand habitat relationships.

OBJ ECTIVES

Our project focused on the following three objectives:

1. A statistical comparison of estimates of PPC density and abundance based on DS and the Roller (1996b) or other similar census methods in the same areas.
2. Estimates of the influence of environmental variables on abundance and detection probability of PPC.
3. Guidance on the application of DS for PPC monitoring and research programs.

METHODS

Study Area and Design: We surveyed the PPC at sites in the Brawley (Altar Valley) and Santa Cruz watersheds in eastern Pima County located south of Tucson, Arizona (Fig. 1). We focused in areas known to support PPC and selected study sites based largely on two criteria: 1) areas with long histories of intensive PPC monitoring such that abundances and densities of PCC were largely known and had been documented within approximately 4 years of our efforts, and 2) lands owned or managed by Pima County where the presence of PPC was known but where densities were unknown and thus needed to be documented to support our efforts. Because this design did not involve random selection of study plots, inferences provided here pertain only to the sampled plots rather than to the broader population of potential plots or the entire range of the taxon. In addition to these criteria, we stratified effort between the two dominant vegetation communities (Sonoran desert -scrub and semi -desert grassland) in which PPC occur, sampled across gradients in elevation, and considered as broad a range of natural variation in PPC densities found in Arizona as possible.

With regard to the first criteria, we selected 5 of 6 sites (Anvil, Guy Street, Mendoza, Palo Alto, Stagecoach) in the Brawley watershed where long-term PPC monitoring efforts were established in 1997 by B. Schmalzel (2000) and 2002 by R. Routson (2003) and continued by M. Baker through September 2012 (Baker 2013). We also considered 2 sites on Sycamore Canyon Properties east of Sahuarita where PPC monitoring began in 2004 and continued until just before our surveys (Westland Resources 2004, 2017, S. Hart, pers. comm.). At each of these 7 sites, the distribution and abundance of PPC were initially documented using the Roller (1996b) method. The Roller method involves multiple observers spaced 4-6 m apart walking parallel transects and exhaustively searching for cacti until a focal area is completely covered, with additional effort recommended in some situations. Thus, under the Roller method each observer is responsible for covering a distance 2-3 m away during surveys. After initial site surveys, PPC that were found were monitored across time, which involved observers searching for previously unknown cacti while walking new routes to known plants so as to maximize coverage, and adding new individuals to the sample. Thus, data we considered are the best enumeration of population sizes available for these areas but may not provide a full enumeration of all individuals. This is because of the time since plots were last surveyed and plant mortality, and because an untested assumption of the Roller method is that it allows for complete enumeration of population sizes by assuming detection probability is perfect within 2-3 m of observers. Access to all sites was provided by landowners and land management agencies.

With regard to the second criteria, we selected 4 additional study sites, including one on Canoa Ranch and 3 on Sopori Ranch (Fig. 1). These sites were selected to augment sample sizes for comparing known and distance-based estimates of densities, to help ensure effort spanned as close to the natural known range of variation of PPC densities in the wild as possible, and to bolster inferences on associations between densities and environmental factors. At these sites, 2 observers (different from those that completed DS) employed the Roller method in an attempt to completely enumerate population size. Additionally, any new individuals discovered incidentally after surveys during DS were incorporated into estimates of population size at sites. Thus, assuming the accuracy of past surveys and population stability, PPC populations at sites we sampled were completely enumerated during that last 0-4 years so that estimates from DS could be compared to estimated known values.

Before DS, we uploaded plot boundaries into handheld global positioning systems (GPS) to ensure surveys overlapped past coverage. Because >80% of individuals occupied only a portion of the Anvil and Mendoza plots (4 of 5 for Anvil; 69 of 71 for Mendoza), we implemented DS on portions of these plots and adjusted Baker's estimates (2013) to improve efficiency. We used recent pilot data from DS the PPC along line transects (Powell 2015) to guide survey design. That effort found an effective strip width of transects between 8 and 13 m, and that the furthest PPC detected from lines was at ≈25 m. Thus, we placed sets of parallel line transects 50-m apart across plot boundaries in a direction approximately equaled to the longest dimension of each plot (except at Sycamore Canyon A where transects were parallel to shortest plot dimension), and began surveys from a random point on plot boundaries approximately 25 m from the edge of the boundary. We then sampled environmental conditions (see below) at 100-m intervals along each line, beginning approximately 100 m from plot boundaries (Fig. 1).

Distance-sampling surveys: Distance sampling stationary objects such as plants involves two main assumptions to ensure accurate estimation: 1) perfect detection of focal objects on the transect line, and 2) accurate measurement of distances between lines and focal objects. Additionally, a key design consideration when implementing DS is to place lines according to a randomized design. This ensures lines are positioned independently of focal objects and that objects are not uniformly distributed with respect to their distances from lines, which can bias estimates (Buckland et al. 2015). Bias is defined as differences between estimates obtained during sampling and the known or parametric value for the population.

To implement DS, two surveyors slowly walked each line with one surveyor focused on and immediately around lines, while the other surveyor walked short serpentine paths around lines but remained within approximately 0-6 m of lines and scanned the line and the surrounding area for cacti (see Fig. 3 in Anderson et al. 2001). This arrangement ensured focused effort on and around the center line as well as effort along both sides of lines. Surveyors carefully scanned clumps of vegetation focusing near center lines to help ensure all PPC on or immediately around lines were detected. Observers also frequently scanned behind them to ensure cacti that may have been obstructed in one direction were detected from the opposite direction. Because PPC sometimes occurred in small clusters of several individuals spaced ≈10-20 m apart, after detecting a PPC observers scanned the surrounding area from lines, and noted individuals detected only while measuring cacti away from lines as incidentals that were not included in analyses. All surveys were conducted during low winds (<10 km/hr), during daylight hours when the sun was well above the horizon, and in winter or spring when cover of green grasses and forbs was minimal. All observers were trained in the identification of PPC and practiced DS and line placement at 2 non-focal sites to perfect techniques before implementation.

For each PPC detected, we gathered the following information: 1) perpendicular distance from the transect line to the center of the PPC to the nearest dm for cacti within 0-8 m of lines and typically to the nearest m otherwise (measured with a tape and rangefinder, respectively), 2) height of PPC in cm from the ground to top of the tallest spine (measured with a ruler), 3) width in cm of the PPC or clump (measured with a ruler), 4) the number of pups or small heads, 5) status of plant (e.g., live or dead), 6) whether plants were marked and if so the code, and 7) used a GPS to record UTMs of all individuals.

To assess the influence of various potential covariates of detection probability and quantify environmental conditions along lines, we established points every 100 m along lines. Around each point we placed a 10-m radius plot centered on point. Within each 10-m radius plot, we gathered the following information: 1) volume of vegetation between 0-1 m above ground (measured to nearest 10% between 20-80% and 5% otherwise), 2) grass cover (nearest 10% between 20-80% and 5% otherwise), 3) mean understory height of rooted vegetation (e.g., grasses, forbs, sub-shrubs; nearest dm), and 4) size class of dominant soil substrate (1-fine sand with few larger particles, 2-coarser gravel with particles up to about 1 cm diameter, 3–rocky substrate with particles >2 cm diameter). For vegetation volume, we considered vegetation rooted within plots and visually estimated volume assuming 100% volume around plant canopies. For understory height, we visually estimated the mean height of all understory plants excluding cacti and yucca (e.g., those in the lowest vegetation layer) rooted within plots weighted by cover (e.g., larger plants had higher influence than small ones). For grass cover, we considered annual (excluding small basal species such as *Schismus* sp.) and perennial grasses rooted within plots and focused on basal cover. Additionally, for each plot we noted the dominant vegetation community (desert-scrub and semi-desert grassland) and recorded UTM coordinates of all survey points with a GPS. Subsequently, we used the slope and interpolate shape tools in ArcGIS 10.3.1 to estimate the elevation (m) and slope (%) at each point using a 10-m resolution digital elevation model (DEM) from the National Elevation Dataset available from the U.S. Geological Survey. We used a DEM to estimate elevation because GPS error was sometimes high.

Analyses: To estimate transect effort, we computed the length of transect lines by summing distances between successive points and adding the length of any remainders <100 m in length that were required to completely survey plots. To calculate distances between successive points, we used UTM coordinates that we recorded with a GPS and used Pythagorean Theorem. To estimate the abundance and density of PPC, we treated each transect line as a replicate and stratified by site so that estimates were computed for each site, but could also be post-stratified to estimates densities for each transect line within a site. To compute the density of PPC across the entire population of sites, we weighted estimates at each site by the total area of each site. Before analyses, we inspected histograms of raw distance data and established bin sizes (e.g., cut-points) of 2.5 m to smooth data, and right truncated 5% of detections (Fig. 2). Both of these techniques improve model fit by addressing issues such as "heaping" and because there is little information in the "tails" of distance data, which may require complex adjustments when fitting models, which are often not biologically justified (see details in Buckland et al. 2001, Thomas et al. 2010).

We used two strategies to estimate density, abundance, detection probability, and other parameters, and used the Microsoft Windows-based program Distance version 6.2 for all calculations (Thomas et al. 2010). First, we fit a simple detection function to data with use of conventional distance sampling procedures. Second, we fit detection functions with covariates with use of multiple-covariates distance sampling to assess the influence of various factors (other than distance) on the scale of detection functions. In both cases, we fit a single detection function to data for all sites combined because sample sizes were insufficient to fit separate functions for each site. As covariates, we considered estimates of vegetation volume, grass cover, understory height, soil substrate size, and slope, which we averaged among points along each line. Estimates of slope were log transformed to minimize the influence of extreme values. To fit detection functions, we first considered each covariate individually, assessed parameter estimates and their standard errors (SE) to identify influential covariates, and then fit additive combinations of some covariates. To select the best approximating model, we ranked models based on Akaike information criterion adjusted for small sample sizes (AIC_c), evaluated the shapes of detection functions, precision of estimates, and goodness-of-fit for highly ranked models, and selected the best overall model from which we made inferences (Thomas et al. 2010). We considered uniform, half-normal (HN), and hazard-rate (HR) detection functions for models without covariates, and HN and HR functions for models with covariates. When fitting HN and HR functions, we considered models with 0-2 cosine, simple polynomial, and hermite adjustment terms. We excluded dead PPC from estimates.

To further understand factors that influenced the observation process during DS, we used multiple linear regression to assess factors that explained variation in detection distances to PPC. Thus, we fit detection distance as a response variable and considered the following potential covariates: mean vegetation volume, grass cover, understory height, soil substrate size, and slope along lines where each PPC was detected, and the height of each PPC. We log transformed some factors including the detection distance to better meet model assumptions.

To quantify the efficacy of DS, we computed percent differences between values from past censuses and estimates of density and abundance from DS (e.g., bias) at the scale of each site and for the overall population. Additionally, we computed Pearson correlation coefficients to quantify the strength of linear relationships between both raw and log-transformed estimates of density from censuses and those from DS. To assess factors that explained bias at the scale of sites, we used linear regression with bias as the response variable, and the following factors as potential explanatory factors: mean vegetation volume, grass cover, understory height, soil substrate size, log slope, elevation, PPC height, and plot area. For the categorical factor census method (e.g., Roller only vs. Roller and repeated monitoring), we used a *t*-test.

To assess environmental factors that explained variation in PPC densities across space, we used our best overall detection function model and post-stratified estimates by transect line so as to compute densities at the scale of each line. We censored data from short lines <200-m in length, some of which were required to fully cover sites, because they contained little information that could influence inferences. This procedure resulted in a sample of 76 lines that averaged 476 m (SE = 16) in length along which densities ranged from 0 to 10.5 plants/ha (mean ± SE = 1.5 ± 0.2). We then developed a linear-mixed effect model to assess the influence of various environmental factors on variation in local densities. To develop models, we fit log density as the response variable and considered the following potential explanatory factors, which we generated after eliminating one factor for each correlated ($r \geq 0.66$) pair of factors that we assumed was less descriptive (e.g., understory height because it was correlated with vegetation volume, and elevation which was correlated with substrate size): mean vegetation volume, grass cover (log transformed), soil substrate size, slope (log transformed), and vegetation community. We also considered quadratic terms for all continuous variables. Because the number of potential explanatory factors was high and data to develop candidate models *a priori* was limited, we used stepwise procedures with mixed variable selection and the stepAIC function in the MASS library in R (Venables and Ripley 2002, R Development Core Team 2016) to select explanatory factors. We used Bayesian information criterion (BIC) to guide variable selection because it penalizes model complexity more than AIC_c and reduces chances of overfitting. To adjust for correlations among observations from lines within the same sites, we fit a random intercept for site. All models were fit with the nlme library in R (Pinheiro et al. 2012, R Development Core Team 2016).

RESULTS

Effort and Detections: We recorded 105 live and 15 dead PPC during DS along 36.9 km of line transects across the 11 sites. Linear effort ranged from as low as 866 m at the smallest site (Sopori 3; 4 ha) to 5,745 m at a larger site (Guy Street; 23.8 ha). Across all sites, we measured environmental covariates within 10-m radius plots at 476 points, which ranged from as few as 14 points at the smallest site to 70 at a larger site. Effort was similar in the Santa Cruz (*n* = 6 sites) and Brawley (5) watersheds. Although there were more sites in desert-scrub (7) than semi-desert grassland (4), on average sites in grassland were larger than those in desert-scrub. Elevation ranged from as low as 799 m at Guy Street in the Brawley watershed to 1,092 m at Sycamore Canyon Properties in the Santa Cruz watershed. We completed DS in February, March, November, and December of 2016, and in February 2017.

Model Selection and Detection Probability: We fit 14 candidate models of detection functions that included between 1 and 4 parameters (Table 1). There was strong evidence factors other than distance influenced detection probability (*P*; ranges from 0-1), with little support for a model that included no covariates (ΔAIC_c = 4.55). The top-ranked model included the covariate substrate size, with *P* declining as soils became increasing dominated by large particles ($\beta \pm$ SE = -0.44 ± 0.19). At 10 m from lines, for example, *P* declined from 0.58 in areas with small- to moderate-sized substrates (e.g., 1.6) to 0.35 in areas with moderate- to large-sized substrates (e.g., 2.3; Fig. 3). Although understory vegetation volume (-0.012 ± 0.0066), grass cover (-0.008 ± 0.004), and cactus height (0.045 ± 0.026) influenced *P* in the expected directions when fit independently (Fig. 3), once the effect of substrate size was considered there was little evidence these covariates improved model fit given associated increases in model complexity (Table 1). In contrast, understory vegetation height (-0.0056 ± 0.0071) and slope (-0.091 ± 0.19) had no influence on *P* (Table 1). Regardless of which covariates were included, estimates of density, average *P*, and other parameters were similar at the scale of the overall population (Table 1). In all cases, half-normal key functions with cosine adjustment terms provided the best fit.

Estimates of *P* from the top-ranked model averaged 0.49 (95% CI = 0.42-0.56), with an effective strip width of line transects (e.g., the distance at which *P* = 0.5) of 9.71 m (95% CI = 8.35-11.28; CV = 0.076). At 2 m from lines, *P* averaged 0.96 and declined to 0.92, 0.80, 0.43, and 0.06 at 3, 5, 10, and 20 m from lines, respectively (Fig. 4).

Raw detection distances to PPC we observed from transect lines (e.g., actual distances between lines and cacti) was explained by the height of plants and by mean grass cover (R^2 = 0.103), but other factors had little ($p \leq 0.15$ for log slope) or no ($p \geq 0.41$) association with distances after controlling for these factors. On average, detection distances increased by 5.3 ± 1.8% with each 1-cm increase in the height of plants ($p = 0.005$), but decreased 0.82 ± 0.37% ($p = 0.031$) with each 1% increase in mean grass cover. Mean height of PPC detected along lines was 12.2 cm (SE = 0.40) with only 2.5% of individuals ≤2.8 cm and only 10% ≤6.6 cm, indicating few cacti were small.

Density and Abundance: Across the entire population of sites, we estimated a density of 1.465 live individuals/ha, and an abundance of 294 individuals overall. Importantly, precision of estimates was relatively high (CV= 0.139; 95% CI in Table 1). These estimates were based on a total sample of 100 individuals after truncating 5% of observations (e.g., those at distances >20 m from transect lines), indicating that we detected approximately one third of all individuals estimated to occur within the boundaries of focal sites. At the scale of individual sites, density estimates ranged from 0.146 to 5.95 individuals/ha and abundance from 3 to 125 individuals, with much lower precision (Table 2).

Efficacy of Distance Sampling: Across the entire population of sites, both density and abundance were fairly well estimated by DS with an overall bias across the population of -11.4% (e.g., DS underestimated densities). At the scale of individual sites, however, bias in density estimates ranged from as low as 59.6% underestimation to as high as 64.1% overestimation, with the absolute value of bias as low as 7.3% (Table 2). Density estimates from DS were also highly correlated with estimates based on census efforts on both the untransformed ($r = 0.82$, $p = 0.002$), and especially, logarithmic scales ($r = 0.92$, $p < 0.001$; Fig. 5). Based on an estimated known population size of 332 PPC across all sites, we detected approximately 30% of individuals during DS. With regard to factors that explained bias, there was some evidence bias increased ($\beta \pm SE = -1.03 \pm 0.65$, $p = 0.14$) as mean grass cover increased. Although there was no evidence means differed due to high variability and small sample size ($p = 0.41$), mean bias averaged 14.9 ± 28.5% higher at sites where densities were documented with the Roller method (mean = 18.0% underestimation) than those where the Roller method followed by intensive repeated monitoring was used (mean = 3.0% underestimation).

Factors that Explained Densities: Local densities at the scale of individual transect lines within sites (see Table 2 for sample sizes and effort) increased with increasing slope and soil substrate size, and decreased with increasing understory vegetation volume ($p \leq 0.022$) after adjusting for repeated measurements of the same sites (Table 4). Densities decreased by 1.5 ± 0.6% with each 1% increase in grass cover. After accounting for the effects of all three factors, there was no evidence variation in local densities was associated with grass cover ($p = 0.59$) or vegetation communities ($p = 0.21$). Based on the top-ranked model (Table 1), density averaged 1.00 individuals/ha in desert -scrub (CV = 0.224, 95% CI = 0.64-1.56) and 1.84 in semi-desert grassland (CV = 0.235, 95% CI = 1.15-2.93); because confidence intervals overlapped these estimates suggest similar densities in both communities at least based on the sample sizes obtained here.

DISCUSSION

We tested a new method for estimating abundance of the endangered Pima Pineapple Cactus (PPC) in southern Arizona based on distance-sampling procedures (Buckland et al. 2001). Although distance sampling (DS) is a proven and efficient method for estimating abundance and detection probability in a broad range of terrestrial and aquatic animal systems (Thomas et al. 2002, 2010), to our knowledge, our efforts represent just its fifth application in a plant system (Buckland et al. 2007, Jensen and Meilby 2012, Kissa and Sheil 2012, Schorr 2013). Overall, results of our efforts were auspicious and suggest DS can provide precise and fairly unbiased estimates of density and other parameters for research and monitoring applications in this and likely other similar systems in the Sonoran Desert. Additionally, we also provided insights into environmental factors that influence detection probability and abundance, which will be useful to managers, policy makers, and researchers in understanding PPC ecology and guiding surveys. Application of DS, however, was far from perfect and thus we suggest some modifications to the procedures used here to improve inferences.

Estimates of bias based on what we presumed to be parametric values of densities from census efforts and estimates from DS was fairly low across the entire population of sites we sampled, equaling just 11.4% underestimation overall. At the scale of individual sites, however, bias at some localities was much higher and included both underestimation and overestimation. Importantly, the magnitude of bias seemed relatively consistent across the entire range of densities we considered as indicated by a fairly tight linear relationships and high correlation between values from DS and census procedures. Additionally, the precision of estimates from DS was also relatively high (CV =0.139), with 95% confidence intervals that were narrow even despite relatively small sample sizes of 100 individuals. For DS along line transects, a recommended minimum sample size of between 60 and 80 focal objects is recommended to obtain unbiased estimates (Buckland et al. 2001). These results suggest DS can provide relatively accurate estimates of density across a wide range of natural variation in densities we considered (e.g., 0.1-5.5 individuals/ha), and likely, across the full natural range of densities that occur in the wild. On average, PPC densities are estimated to be approximately 1 individual/ha across the range of the species (Baker 2013, McDonald 2005).

Two additional factors also provide support for the applicability of DS for PPC population estimation. Important assumptions of DS include perfect detection of focal objects on the transect line and use of a randomized design to ensure lines are positioned independently of focal objects, so that objects are not uniformly distributed with respect to their distances from lines. In cases where individual plants are closely clustered, focal objects may not be distributed uniformly with respect to lines, especially when plots are small (Buckland et al 2007). Frequency histograms of detection distances of PPC had an obvious “shoulder” and declined relatively monotonically with distance from lines, especially when data were appropriately binned and thus smoothed. Such results suggest PPC distribution was sufficiently uniform to eliminate issues imposed by clustering (see Buckland et al. 2015 for details). Although PPC were sometimes founds in small groups of several nearby plants, clustering did not seem to impose significant bias, eliminating the need for crossed designs and other approaches for addressing these issues (see Buckland et al. 2007 for details on these designs). With regard to perfect detection of focal objects on the transect line, there was some evidence negative bias of estimates was due to plants, especially small ones, being hidden by vegetation along lines (see below). Nonetheless, the relative openness of arid environments that provide habitat for this species, the unique silhouette of PPC, and recommendations we summarize below, should adequately mitigate this issue. In general, DS is a suitable and efficient method for estimating PPC abundance, and should also be useful for monitoring spatiotemporal changes in distribution and abundance such as has been included in Pima County's Multi-species Conservation Plan (Pima County 2016).

Several factors likely influenced observed bias of estimates, and knowledge of these factors has important implications for understanding our results and guiding future efforts. First, while we assumed values from past censuses represented parametric values, actual population sizes and thus densities were not known exactly. This is because surveys of the five plots we considered in the Brawley watershed were last conducted ≈4 years ago, because new individuals were continuously documented during repeated monitoring, and because PPC populations at these sites declined at an average rate of ≈4.9%/year over 9 years (2003-2012) based on data provided by Baker (2013). Similarly, estimates at sites censused with the Roller method followed by repeated monitoring across time were likely more accurate than those at the four sites where we conducted Roller surveys ourselves given greater search effort even despite the temporal issues noted above. Moreover, even by spacing observers at 4-6 m intervals as dictated by the Roller (1996b) method, estimates of detection probability we report here suggest between 4-8% of individuals are likely to be undetected during Roller-type surveys. Such factors likely contributed to bias we observed here and suggests the Roller method does not ensure perfect detection probability unless sites are surveyed multiple times perhaps. Second, while we attempted to search clumps of dense vegetation near lines for PPC during surveys, there was some evidence bias increased with increasing grass cover. While such patterns are based on small sample sizes, they suggest we failed to detect some PPC on or close to lines, especially when grass cover was high. Finally, distances to observed PPC varied markedly with the height of PPC plants and with grass cover, suggesting we likely missed more small individuals than larger ones, especially in areas with moderate to high grass cover. Together, these factors suggest high likelihoods of negative bias during DS, such as we observed here, and the need for designing surveys to minimize bias associated with these factors.

Some inferences we summarized on habitat relationships are consistent with the known biology of PPC, whereas others varied somewhat. Similar to our results for densities, McPherson (2002) found that occurrence of PPC plants was positively associated with larger-sized soil substrates (e.g., gravel vs. sand). However, Kidder (2015) suggested that at one site higher sand content was associated with larger PPC and more pups. Although McPherson (2002) found the occurrence of PPC plants was associated with moderate levels of herb and woody plant cover, we found that densities declined with increasing grass cover, although few sites had cover that exceeded 15%. Similarly, Kidder (2015) noted that PPC grew in sites that had uniformly high incoming solar radiation (i.e., growing in the open) and equated the open areas where PPC occurred to low levels of competition for soil moisture with other plants. Although McPherson (2002) found occurrence of PPC plants was not associated with any specific landform or slope position, we found local densities within sites increased in areas with high slopes, potentially due to the relationship between steeper slopes and prevalence of larger soil substrates. Differences in the scale of measurements and focal parameter between studies (small -scale, plant -centered plots and occurrence - McPherson 2002; larger area-based scale along lines and density - this study) may explain some differences in observed habitat associations. Regardless, such results suggest the applicability of DS for assessing large-scale habitat relationships. Because our study was not designed specifically to assess habitat relationships, however, results reported here are preliminary.

Although often considered a nuisance parameter, understanding factors that influence detection probability (*P*) is important for designing survey methods because the best techniques have a high and consistent probability of detecting the target species and low sampling error (Thompson et al. 1998). We found that the size of soil substrates had the greatest influence on *P* during DS, with lower *P* associated with larger substrates. A likely explanation for this result is that rockier substrates make cacti more difficult to see by oncoming observers because they break up the unique silhouette of plants. We also found that when considered individually in detection functions, *P* declined with increasing understory vegetation volume and grass cover, and decreasing PPC height. Once the influence of substrate size was considered, however, there was little evidence these covariates significantly influenced the scale of detection functions due likely to small sample sizes. With the addition of more samples in the future, we suspect these factors will improve model fit and accuracy, and thus should be measured as part of DS protocols. This possibility is emphasized by the fact that detection distances increased as the height of plants increased and decreased with grass cover. Although such results suggest we were more likely to miss small PPC during DS, average height of PPC we detected (12.2 cm) was similar to that found by Baker (2013; 10.9 cm) across time, and overall bias was fairly low. These patterns and the fact that DS can provide accurate results despite missing a large portion of focal objects (Buckland et al. 2001) suggest DS is an appropriate technique for estimating PPC abundance at least in populations with typical size distributions. Regardless, the influence of covariates of *P* had relatively small effects on the overall magnitude of density estimates, at least at the population scale, and on average, *P* was high (≈0.50) suggesting DS surveys for PPC are likely to be generally efficient. To our knowledge, this study is the first to explicitly estimate *P* of PPC populations and assess environmental factors associated with variation in *P*.

<u>Recommendations</u>: Despite promising results, several modifications to the protocol we used here should improve accuracy. First, our estimates of effective strip width and *P* suggest ≈20% of areas between neighboring parallel line transects were not adaqualetly covered. Because considering these areas will improve accuracy, we recommend reducing spacing between lines from 50 to 40 m, and perhaps somewhat closer in areas with dense grass cover. This modification will augment the number of individual cacti detected but may result in a few larger individuals being detected from neighboring lines, which can be addressed by truncation and censoring observations before analyses. Second, more effort should be placed on detecting all individuals, especially smaller ones, on or immediately around the transect line. Such effort could involve somewhat longer search times (e.g., slower walking speeds) and more intensive searches under and around clumps of low vegetation during DS. Third, surveys at sites with steep slopes and dense vegetation along drainage channels were often problematic when lines were not perpendicular to contours. This is because surveying steep slopes and walking through dense vegetation along washes while surveying for cacti was difficult, distracting, and sometimes required repositioning lines to flatter or more open areas (such as Palo Alto where we markedly overestimated densities). To address this issue, we suggest placing lines perpendicular to the slope gradient so that observers walk up and down steep slopes and across washes rather than along contours and drainage channels. Finally, we also recommend that the timing of DS surveys for PPC be focused during periods when herbaceous vegetation cover is likely to be minimal and when grasses are not green. In our region, this time period is often between November and June unless fall and winter rains have been substantial. While additional field study and simulations

across a gradient of contexts are needed to better understand the efficacy of DS for PPC, results obtained here together with the above recommendations offer promising opportunities. Finally, because DS can easily be completed within the context of Roller-type surveys without significant increases in effort, we recommend DS be integrated into existing protocols to facilitate additional study. Combining techniques would allow estimation of the number of individuals present but undetected during surveys and thereby help improve results. In general, our results combined with these recommendations validate the applicably of DS for estimating abundance of PPC and suggest, that when coupled with an appropriate sampling design, DS is capable of accurately estimating abundance of PPC across the range of taxon and for more focused applications in space.

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Table 1: Candidate models of detection functions we considered when estimating the density of the Pima Pineapple Cactus based in distance sampling at 11 sites in south-central Arizona, 2016-17. *K* denotes the number of model parameters, *D* is estimated density (no. of live individuals/ha), CV is the coefficient of variation, *N* is total abundance or population size, LCL and UCL are lower and upper 95% confidence intervals, ESW is effective strip width, and *P* is average detection probability. Estimates are from program Distance (version 6.2; Thomas et al. 2010), based on a sample of 105 cacti detected (5% of observations truncated), and all models are based on half normal key functions with cosine adjustments.

	Model Selection		Density				Abundance			Detection	
Covariates	*K*	ΔAICc	*D*	*D* CV	*D* LCL	*D* UCL	*N*	*N* LCL	*N* UCL	ESW	*P*
Substrate Size	2	0.00	1.465	0.139	1.109	1.937	294	222	388	9.71	0.485
Substrate Size + Grass Cover	3	0.12	1.484	0.140	1.120	1.965	297	224	394	9.59	0.479
Cactus Height + Substrate Size + Grass Cover	4	1.44	1.493	0.140	1.126	1.979	299	226	397	9.53	0.476
Cactus Height + Substrate Size	3	1.52	1.472	0.139	1.113	1.948	295	223	390	9.66	0.483
Substrate Size + Vegetation Volume 0-1 m	3	1.86	1.467	0.139	1.109	1.941	294	222	389	9.69	0.485
Cactus Height + Grass Cover	3	2.06	1.466	0.139	1.108	1.941	294	222	389	9.70	0.485
Vegetation Volume 0-1 m	2	2.98	1.440	0.138	1.091	1.901	289	219	381	9.88	0.494
Grass Cover	2	3.17	1.439	0.138	1.090	1.899	288	218	381	9.89	0.494
Cactus Height	2	3.21	1.434	0.138	1.087	1.893	287	218	379	9.92	0.496
Cactus Height + Grass Cover + Veg. Volume 0-1 m	4	3.85	1.470	0.140	1.109	1.947	294	222	390	9.68	0.484
None {CDS model}	1	4.55	1.406	0.141	1.059	1.866	282	212	374	10.12	0.506
Grass Cover + Vegetation Volume 0-1 m	3	4.87	1.443	0.138	1.092	1.907	289	219	382	9.85	0.493
Understory Height	2	5.88	1.412	0.137	1.072	1.860	283	215	373	10.07	0.504
Slope (log)	2	6.41	1.408	0.136	1.069	1.853	282	214	371	10.11	0.505

Table 2: Comparison of estimates of density (*D*) and abundance (*N*) of the Pima Pineapple Cactus based in distance sampling at 11 sites and all sites combined in south-central Arizona, 2016-17. Census results are based on the Roller (1996) method and the Roller method followed by intensive repeated monitoring over time, and completed within 0 to 4 years of distance sampling effort. Bias denotes the % difference between census results and estimates from distance sampling. Population estimates are area-weighted averages. Distance-based estimates are from program Distance (version 6.2; Thomas et al. 2010), based on a sample of 105 cacti detected (5% of observations truncated), and based on a half normal key function with cosine adjustment.

		Census Results				Distance Sampling Results						Bias (%)	
Site	Plot Area (ha)	*D*	*N*	Source	Method	*D*	*N*	CV	No. Observed	Effort (m)	No. of Lines	*D*	*N*
Anvil*	18.3	0.219	4	Baker	Monitoring	0.146	3	1.004	1	3,525	7	-33.1	25.0
Canoa	23.4	2.35	55	This study	Roller	1.07	25	0.301	10	4,825	8	-54.6	-54.5
Guy Street	23.8	0.252	6	Baker	Monitoring	0.179	4	0.733	2	5,745	11	-28.8	-33.3
Mendoza*	24.2	2.85	69	Baker	Monitoring	1.30	32	0.287	13	5,133	10	-54.2	-53.6
Palo Alto	24.6	3.26	80	Baker	Monitoring	5.02	125	0.231	38	3,902	10	56.0	56.3
Sopori 1	7.4	1.62	12	This study	Roller	2.18	16	0.292	4	947	3	34.7	33.3
Sopori 2	8.0	3.86	31	This study	Roller	1.56	12	0.452	6	1,985	6	-59.6	-61.3
Sopori 3	4.0	5.53	22	This study	Roller	5.95	24	0.302	10	866	4	7.6	9.1
Stagecoach	31.6	0.222	7	Baker	Monitoring	0.363	11	0.469	3	4,252	8	64.1	57.1
Sycamore 1	16.7	1.86	31	Westland	Monitoring	1.72	29	0.342	9	2,696	9	-7.3	-6.5
Sycamore 2	18.4	0.817	15	Westland	Monitoring	0.686	13	0.505	4	3,003	7	-16.0	-13.3
All Sites	**200.4**	**1.66**	**332**	**---**	**---**	**1.47**	**294**	**0.139**	**100**	**36,878**	**83**	**-11.4**	**-11.4**

*Distance sampling transects covered only portions of original plots containing the majority of the cactus population, with plot area and densities adjusted from those reported in Baker (2013). The Anvil plot contained 4 of 5 known plants and the Mendoza plot contained 69 of 71 known plants.

Table 3: Comparison of geographic, topographic, and vegetation factors at 11 sites where we implemented distance sampling for the Pima Pineapple Cactus in south-central Arizona, 2016-17. Means and standard errors (SE; or range) are based on sample sizes (*n*) noted for each site, which are based on measurements at points (elevation, slope), within 10 m of points (vegetation factors), or at the site scale (region, dominant vegetation community). Units for substrate size are: 1-fine sand with few larger particles, 2-coarser gravel with particles up to about 1 cm diameter, 3–rocky substrate with particles >2 cm diameter.

				Elevation (m)		Slope (%)		Substrate Size		Grass Cover (%)		Vegetation Volume 0-1 m (%)		Understory Height (cm)	
Site	Region	Vegetation Community	*n*	Mean	Range	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Anvil	Brawley	Grassland	42	829	8	1.5	0.1	1.0	0.00	13.7	2.5	13.5	2.2	14.1	1.6
Canoa	Santa Cruz	Grassland	56	934	15	3.7	0.2	2.1	0.11	64.3	4.0	53.2	2.2	63.5	2.5
Guy Street	Brawley	Desert-scrub	70	802	7	1.8	0.1	1.1	0.03	1.1	0.3	14.2	1.2	10.3	0.8
Mendoza	Brawley	Grassland	66	978	18	5.4	0.3	1.9	0.08	38.1	2.3	25.5	1.9	28.6	1.2
Palo Alto	Brawley	Grassland	48	890	20	8.0	1.1	1.7	0.11	10.4	1.6	22.4	2.4	27.9	2.1
Sopori 1	Santa Cruz	Desert-scrub	14	991	9	6.1	0.7	2.2	0.15	3.8	1.0	25.0	5.1	14.4	1.5
Sopori 2	Santa Cruz	Desert-scrub	30	992	11	7.9	1.3	2.2	0.16	3.2	0.9	24.2	2.8	16.6	1.7
Sopori 3	Santa Cruz	Desert-scrub	14	985	11	6.6	0.9	2.0	0.00	2.0	1.0	15.5	2.7	11.5	1.5
Stagecoach	Brawley	Desert-scrub	58	1,027	21	3.2	0.1	1.1	0.05	3.9	0.5	14.3	1.1	13.9	1.1
Sycamore 1	Santa Cruz	Desert-scrub	36	1,083	14	3.2	0.1	2.7	0.09	3.0	1.0	31.9	3.0	29.3	3.9
Sycamore 2	Santa Cruz	Desert-scrub	42	1,003	15	2.8	0.1	2.7	0.11	3.1	1.0	34.7	3.1	16.1	2.3

Table 4: Factors that explained variation in local densities (log no./ha) of the Pima Pineapple Cactus along 76 line transects at 11 sites in southern Arizona, 2016-17. Parameter estimates and standard errors (SE) are from a linear mixed-effects model in which site was fit as a random intercept (σ^2 = 0.03 intercept; 0.27 residual) and estimates of local density derived from distance sampling was fit as the response variable. Non-significant factors are not included in this table but noted in the text.

Factor	Estimate	SE	|*t*|	*p*
Intercept	-0.62	0.31	1.98	0.052
Vegetation Volume 0-1 m (%)	-0.015	0.006	2.36	0.022
Slope (log %)	0.65	0.19	3.45	0.001
Substrate Size (rank)	0.36	0.16	2.28	0.026

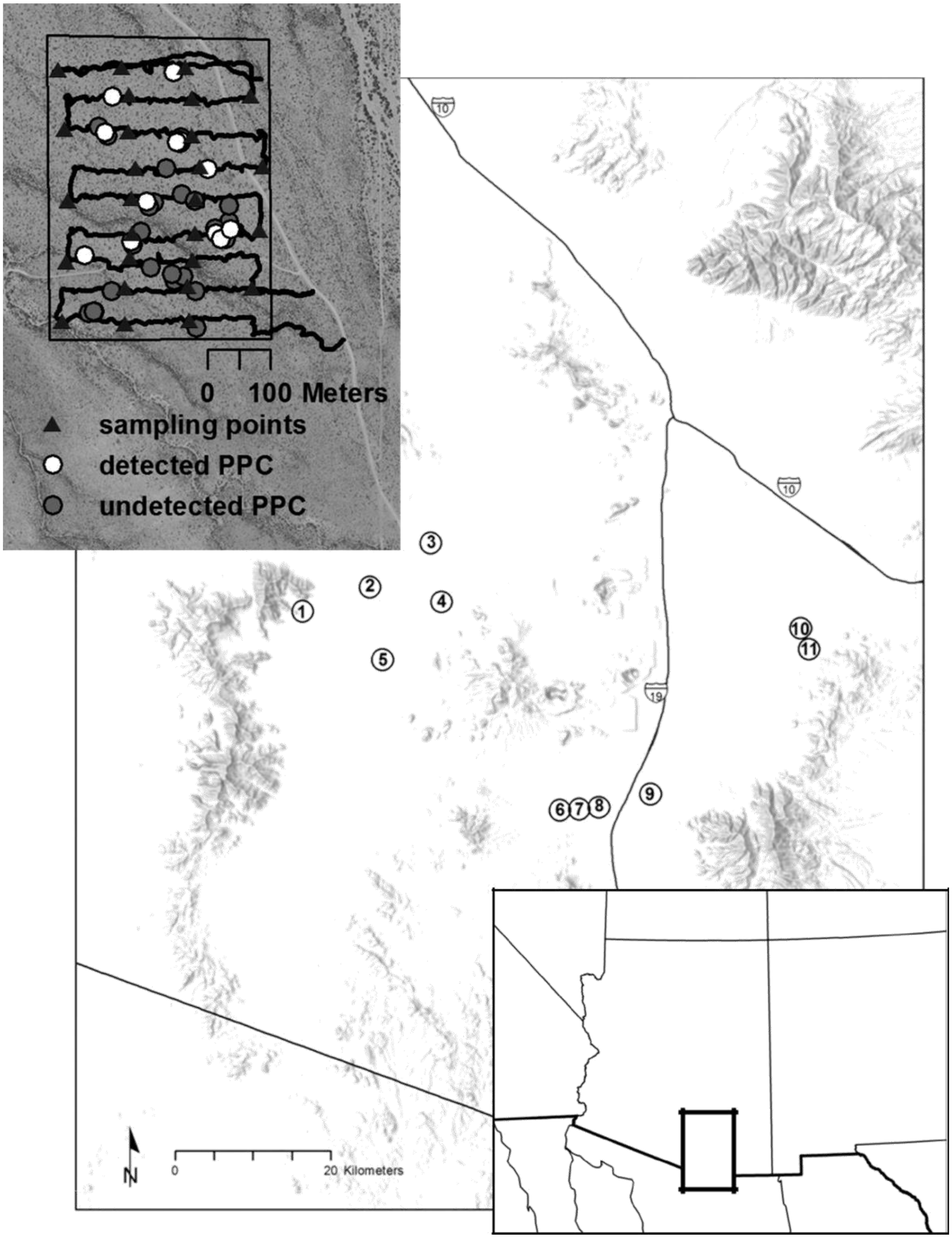

Figure 1: Location of 11 sites where we estimated densities and detection probability of the Pima Pineapple Cactus with use of distance-sampling methods in south-central Arizona, 2016-17. Top inset figure shows the arrangement of line transects and cacti detected and not detected at site number 11 and the sampling points located at 100-m intervals at which we sampled environmental attributes, and lower inset shows the location of the study area with reference to state and national boundaries. Sites are as follows: 1) Mendoza, 2) Anvil, 3) Guy Street, 4) Stagecoach, 5) Palo Alto, 6-8) Sopori 1-3, 9) Canoa, 10-11) Sycamore 1-2.

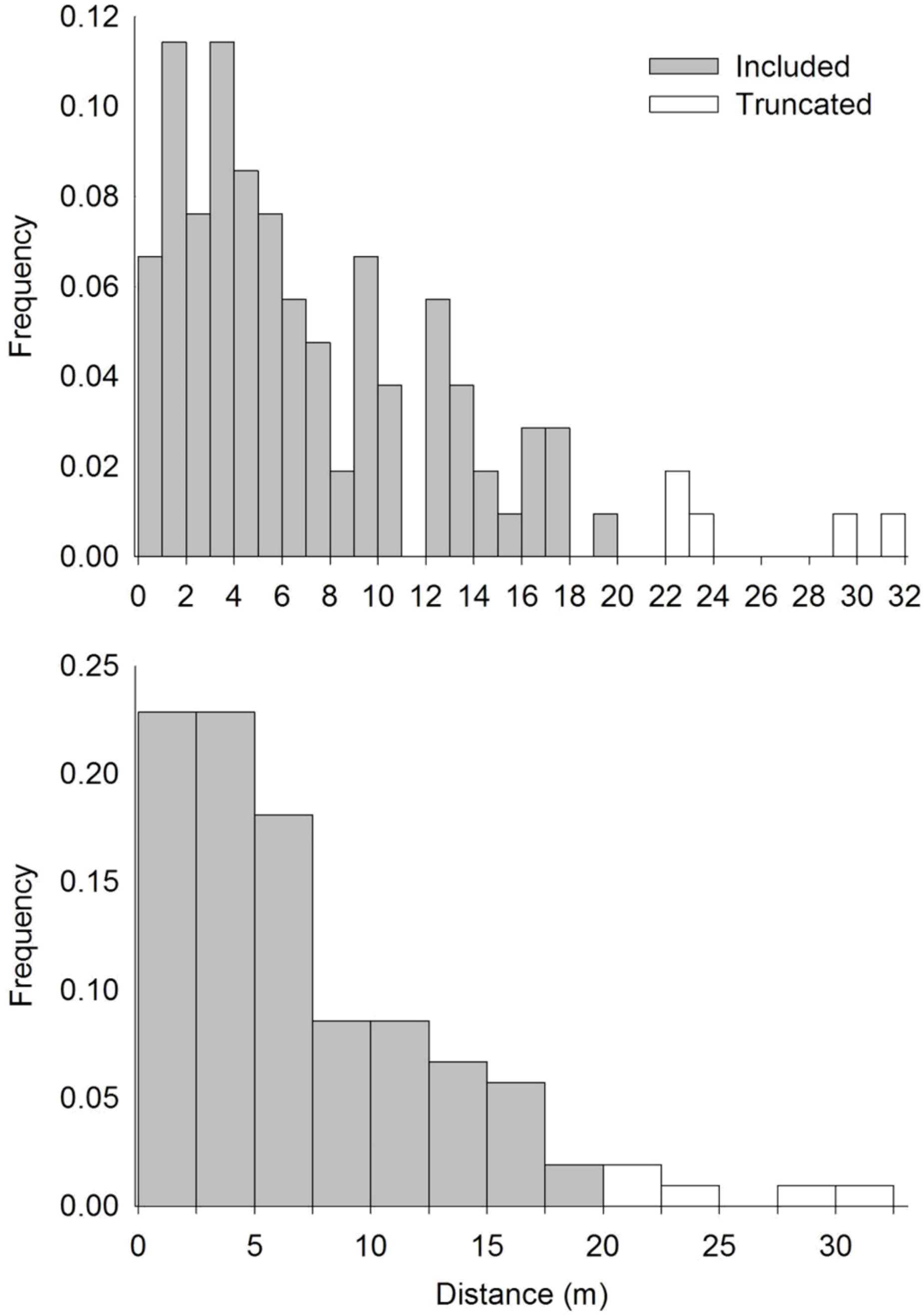

Figure 2: Frequency histograms of detection distances of 105 Pima Pineapple Cacti observed during line-transect surveys in southern Arizona, 2016-17. Top figure shows raw frequencies within 1-m bins and lower figure shows frequencies within the 2.5 m bins used when modeling detection functions. Open bars at distances >20 m represent 5% of observations we truncated when fitting detection functions.

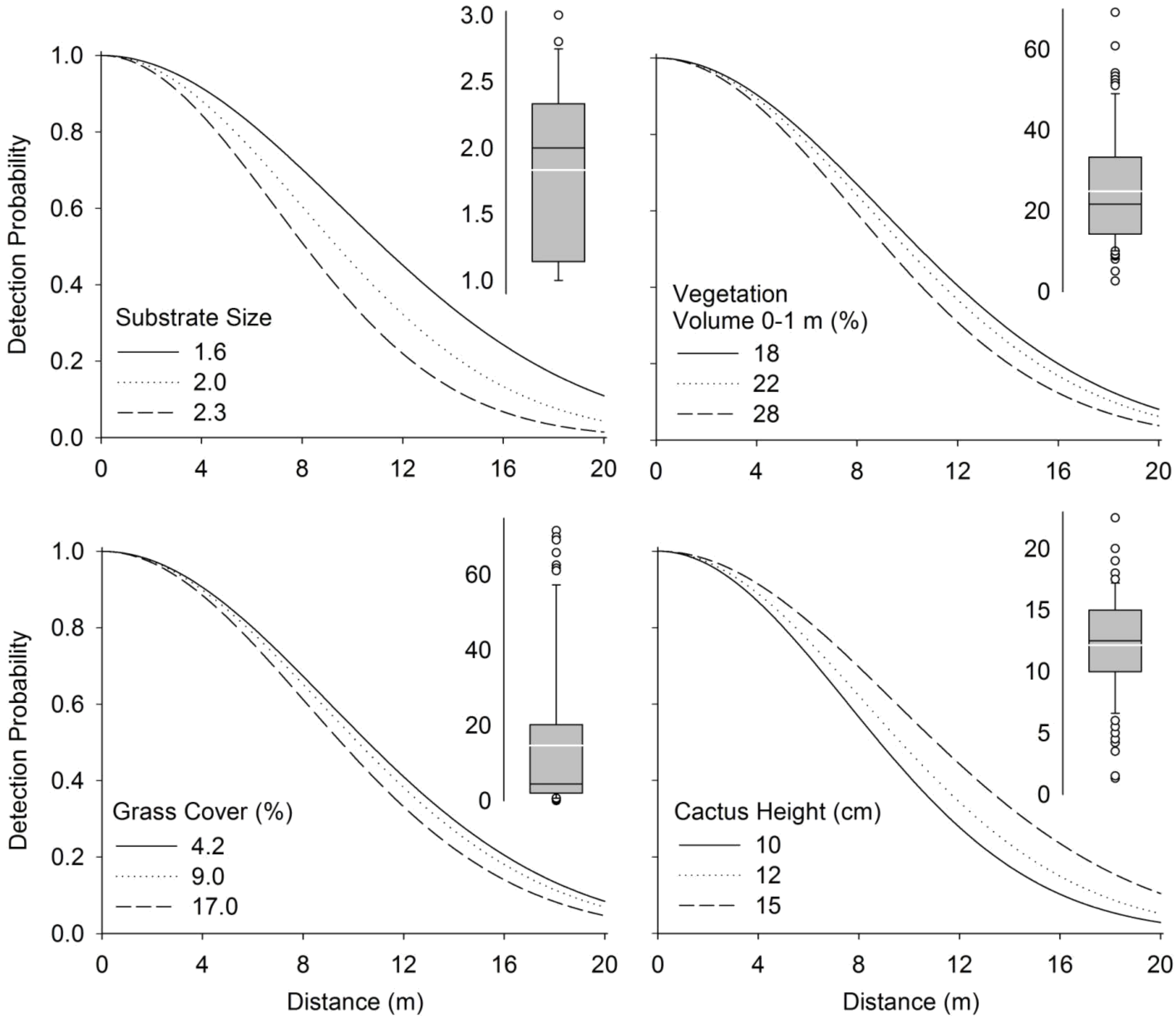

Figure 3: Influence of four covariates on detection probability of the Pima Pineapple Cactus from distance sampling along line transect at 11 sites in south-central Arizona, 2016-17. Estimates are based on multiple covariates distance sampling and half normal key functions with cosine adjustments in which each covariate was fit individually. Estimates are shown at covariate levels equaled to the lower, middle (e.g., median), and upper quartiles, which are indicated by the bottom, black line, and top of inset box plots that show the distribution of each covariate (white lines are means). Model selection criteria for each model are provided in Table 1.

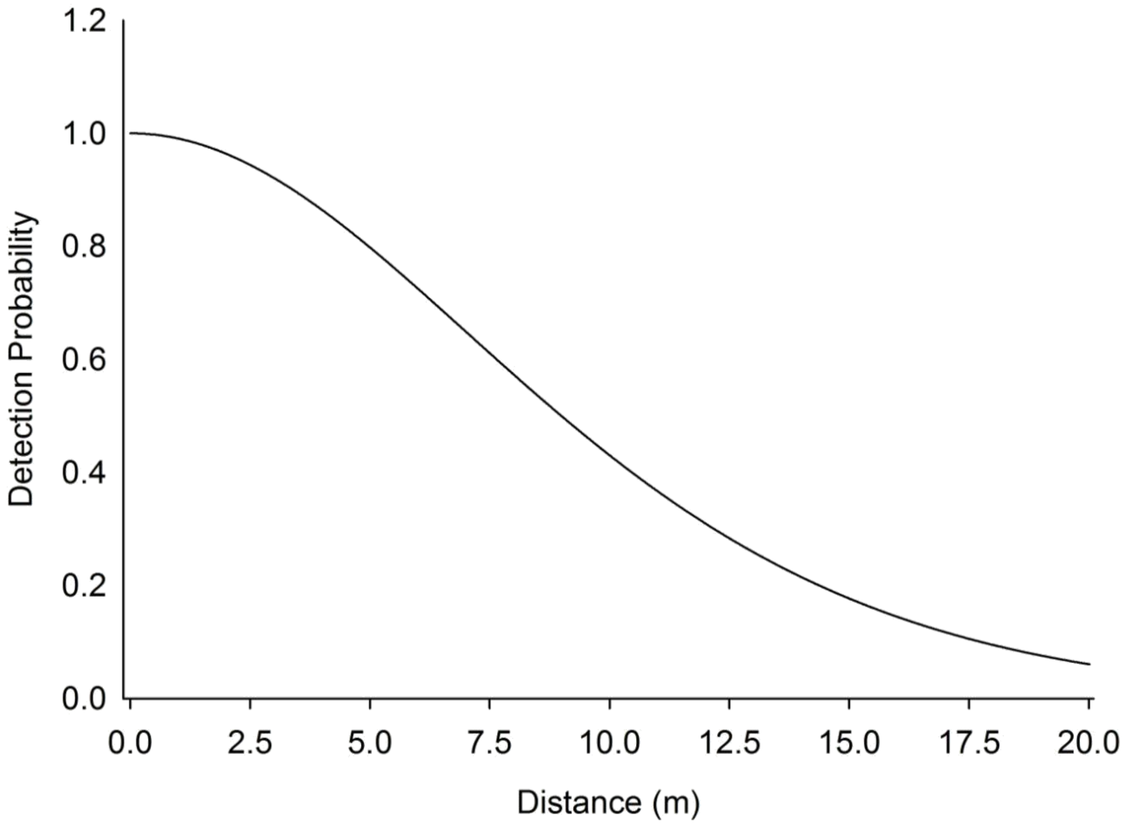

Figure 4: Top-ranked detection function model for the Pima Pineapple Cactus based on distance sampling along line transect at 11 sites in south-central Arizona, 2016-17. Estimates are based on 100 observations, multiple covariates distance sampling, and a half normal key function with cosine adjustments in which substrate size was fit as a covariate. The plotted function is the average detection function conditional on the observed covariates.

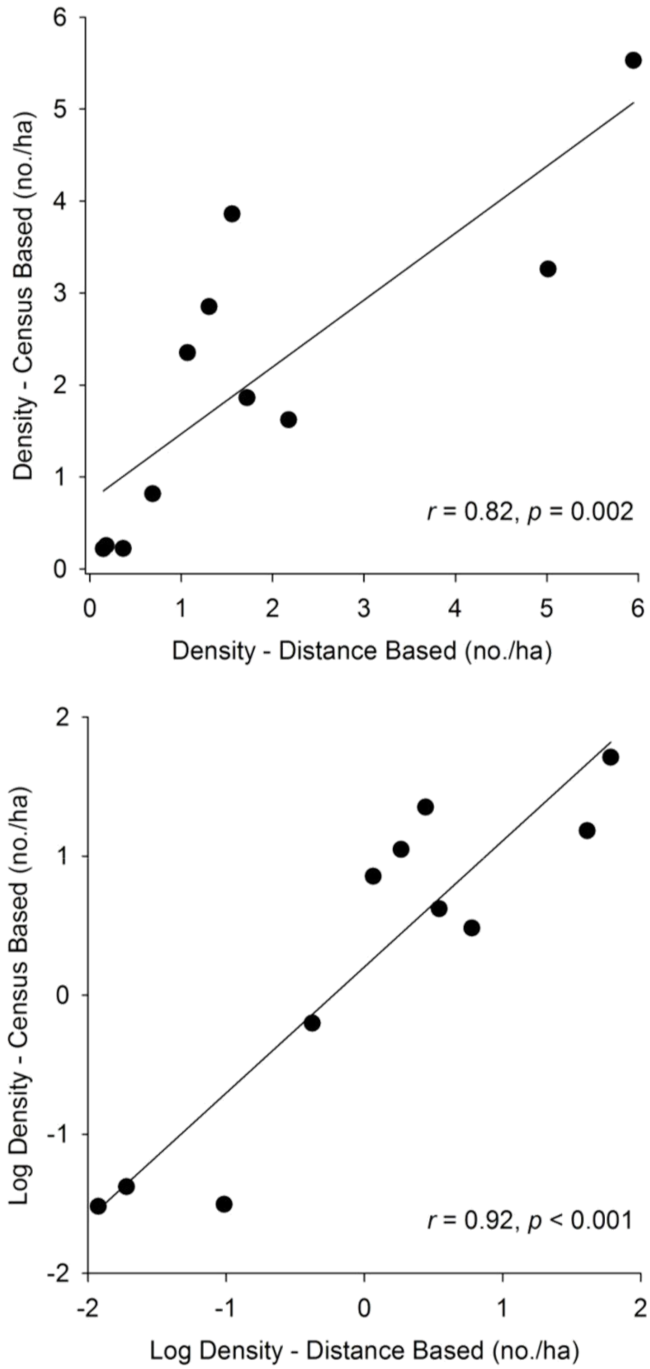

Figure 5: Linear associations between estimates of density (no./ha; top) and log density (bottom) of the Pima Pineapple Cactus at 11 sites in south-central Arizona, 2016-17. Estimates from distance sampling are based on 100 observations, multiple covariates distance sampling, and a half normal key function with cosine adjustments in which substrate size was fit as a covariate. Estimates from censuses were based on the Roller (1996b) method often combined with repeated monitoring and searches across time. Pearson correlation coefficients (*r*) are shown on figures.

Pima County
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Appendix 9

Pima County Cactus Ferruginous Pygmy-Owl (*Glaucidium brasilianum cactorum*) Survey Protocol

Pima County Cactus Ferruginous Pygmy-Owl Survey Protocol

Developed by: Aaron D. Flesch, University of Arizona, School of Natural Resources and the Environment

Brian Powell Pima County Office of Sustainability and Conservation

Ian Murray Pima County Office of Sustainability and Conservation

Introduction

We will follow a similar protocol to that outlined under the large survey area – research protocol described by USFWS (2000). We made various small modifications to this protocol to augment efficiency without reducing its reliability based on research recently completed in neighboring northern Sonora, Mexico (Flesch and Steidl 2007, Flesch 2013, 2014). Detailed survey information based on >600 individual pygmy-owls in Sonora indicates that detectability of pygmy-owls during much of the breeding season is high (0.89-1.0 from 100-300 m from nests), that owls respond rapidly to call broadcasts (mean response time = 2.6 min, 99.6% of owls detected in ≤8 min), and that response rates and detectability remain high at times 2-hours after local sunrise and 1-hour before local sunset (Flesch and Steidl 2007). Therefore, we will propose some small modifications to the existing protocol to increase its efficiency without altering its effectiveness. The material below includes original and modified text from USFWS (2000).

1. A valid Arizona Game and Fish Department Scientific Collecting License outlining relevant permissions to carry out pygmy owl surveys must be held by the primary surveyor for all surveys. Permission to access a property for surveyingmust be obtained from each private property owner or those having management authority (public lands) prior to conducting surveys. Where permission cannot be obtained from adjacent landowners, call stations should be placed on the property boundary and publicroads without trespassing so that coverage may be extended to adjacent areas.

2. Call stations should be surveyed twice during the spring with one survey during the territory-establishment period between approximately February 1 and March 31 and one survey during the nesting season between April 1 and June 15. There should be at least 15 days between each spring survey at a given site. Additionally, stations should be surveyed once in the fall shortly after the period when juveniles are dispersing. These surveys will focus between September 15 and October 31 and allow detection of juveniles that may have recently settled in the area as well as any previously documented resident individuals.

3. Surveys should be conducted in potential habitat from 1 hour before sunrise to 3 hours after sunrise, or from 2 hours before sunset to 1 hour after sunset (use an official sunrise table for correct times). Surveys may also be conducted at night during a full moon or nearly full moon three days on either side of a full moon while the moon is visible. If the moon sets or is obscured by clouds, surveys should not be conducted.

4. Surveys should not be conducted under adverse weather conditions (e.g., moderate or strong winds [greater than 12 mph] or during rain). Under these conditions, owls may not be able to hear broadcasted calls and the surveyor's ability to hear an owl response may be reduced. In addition, surveys should not be conducted at call stations that have loud noises (e.g., traffic, aircraft, barking dogs, etc.) that reduce the effectiveness of broadcasted calls or impair the

surveyor's ability to hear responding owls. Call stations should be placed away from noisy areas or rescheduled for another time (e.g., weekends when there is less traffic in urban areas), and where possible placed on elevated wash terraces or other areas that aid listening vs. in deep wash channels or depressions that may obstruct sounds. The survey period spent at stations with periodic noise (e.g., aircraft, traffic, etc.) should be extended to compensate for periodic noisy survey conditions if they cannot be avoided.

5. Call stations along survey transects should be spaced at no more than 500 m (0.3 mi) apart with most stations placed 300-400 apart depending on terrain, location of nesting substrates, and coverage needs. Call stations in mesic riparian areas that support tall gallery forest should be no more than 300 m apart due to tree density and noise. In areas where habitat is widely spaced, where a single transect is placed along multiple wash channels so as to cover distant habitat patches, or where land in-holdings are present, stations can be placed further away.

6. At each call station prior to broadcasting a taped call we will listen for a 1-minute period.This will allow the surveyor todetect any spontaneous calling and also to become familiar with features at the station (i.e., large trees or saguaros, residences, water sources, etc.) that may affect pygmy-owl presence or detectability.

7. Following the initial listening period, the surveyor will broadcast CFPO calls for 30 seconds, followed by a 30-45 second listening and observation period. The surveyor should broadcast calls in all directions of habitat. The volume should be set to an adequate level to get complete coverage along a survey route without causing distortion of the call. Equipment used should be able to produce a loud, clear call without distortion and a sound level between 95-105 decibels at a distance of 1 m from the speaker (Proudfoot et al. 2002).

8. Repeat this calling/listening sequence for at least 6 minutes. Extend this sequence for up to an additional 5 minutes or more if noise disturbances such as barking dogs, air traffic or vehicles cannot be avoided and they affect your broadcast or ability to hear (see number 6 above).

9. During the survey/listening sequence, the surveyor should periodically scan trees and cactus (particularly cavities and trees) for pygmy-owls that may be present but not vocalizing. Binoculars should be used to assist the surveyor locate owls. A rangefinder and compass may be used to estimate the direction and distance of any responding owls. Note any mobbing behavior by other birds in response to the tape broadcast and investigate appropriately.

10. After completing the 6-minute broadcast/listening sequence, we will observe and listen for an additional 1 minute before placing gear away and proceeding to the next call station. Any detections following this 1-minute period that occur at the station will be noted as having occurred at the station. Combined with the initial 1-minute listening period, the total time spent at each call station should be a minimum of 8 minutes.

11. For each route surveyed, we will complete a datasheet <u>that includes the following</u> data fields: survey date, survey time, surveyor, weather conditions, moon phase, official sunrise or sunset time, location and elevation of each calling station (UMT), and the distance between successive stations. For each pygmy-owl detection, we will note the time elapsed from the start of broadcasts to detection, the sex of owls based on vocalization, the call type (territorial call, chitter call, alarm call), the initial distance and direction to owls from the station, the final detection distance, the number of pygmy-owls detected, and whether the owl was detected at the prior station or represents a new individual. We will use the

distance, direction, and timing of responses to discriminate multiple individual pygmy-owls. For owls detected while walking to neighboring stations, we will record this same information and note the distance to the closest station. Other species of owls detected at stations will also be noted.

12. In order to maximize the efficiency of inter-agency species management efforts, any positive detections of pygmy-owls will be sufficiently documented and communicated to the local USFWS office. Copies of all datasheets and survey maps will be shared with the USFWS and AGFD during annual scientific collecting license renewal.

If a pygmy-owl is heard or seen:

1. End call broadcast at the station to avoid harassing the owl, unless additional responses are needed to pinpoint location of the pygmy-owl. Estimate the direction and distance of the initial location of pygmy-owl detection (e.g., using a rangefinder and compass), as well as the time required for the initial response. Sex of the responding owl should also be noted where possible.

2. Place the next broadcast station a minimum of 500 m away so that additional owls can be detected in the area and those individuals can be discriminated from owls already observed at prior stations based on distance, direction, and timing of responses.

3. After the survey route is complete and where possible, observe the pygmy-owl without disturbing it (i.e., do not chase the owl or harass it with calls). Record all observations, use of cavities and prey observations are especially important. Listen for female or fledgling vocalizations or other evidence that there may be other pygmy-owls in the area.

4. Record owl locations using UTM (NAD 83) coordinates and ensure all relevant data such as survey date, time, weather conditions, moon phase, official sunrise/sunset times, and responses of any other bird species are accurately and legibly filled out.

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Pima County
Multi-species Conservation Plan:
2017 Annual Report

Appendix 10

Western yellow-billed cuckoo (*Coccyzus americanus*)
2017 Monitoring Report

Western Yellow-Billed Cuckoo 2017 Survey Results
Pima County Multi-species Conservation Plan

The western yellow-billed cuckoo is an MSCP-covered species under Pima County's recently issued Section 10 permit, and the County has agreed to monitor for this species every three years following established protocols. Pima County (County) followed the USFWS-approved survey protocol (Halterman et al. 2015) to survey for western yellow-billed cuckoos on two County properties: Bingham Cienega Natural Preserve and Cienega Creek Natural Preserve. Additionally, the County conducted exploratory, one-visit surveys for cuckoos in four additional drainages on County preserves. The County contracted with Tucson Audubon Society to complete the survey visits during survey periods two and three (three visits total).

Pima County YBCU monitoring sites – full protocol

Pima County followed the basic monitoring protocol with four survey visits completed across the three survey periods (June 15-30, July 1-31, and August 1-15). As indicated by the protocol, two of the survey visits were conducted in survey period two.

Cienega Creek Natural Preserve. There are patches of appropriate cuckoo habitat (native broad-leafed riparian woodland or mesquite bosque) intermittently spread along much of the County's Cienega Creek Natural Preserve. We broadly divided the Preserve into two transects with the west transect located between the Del Lago Golf Course diversion dam in the west to the 'Horseshoe Bend' region of Cienega Creek just east of where Marsh Station Road crosses Cienega Creek. The east transect took in the area of the Preserve between the 'Horseshoe Bend' region in the west to the abandoned Pantano Townsite in the east. Survey transects at Cienega Creek were linear and followed the course of the stream channel. Portions of both transects included both wet and dry stretches of Cienega Creek.

Bingham Cienega Natural Preserve. Bingham Cienega Natural Preserve is located along a typically dry stretch of the lower San Pedro River. Riparian habitat quality at Bingham Cienega has declined precipitously over the recent past such that the cienega and downstream marshy habitat no longer have surface water, or even moist soil, during early summer. However there are dense mesquite bosques in the north and south end of the Preserve, broad-leaf riparian woodland at the historic cienega (mostly velvet ash with some cottonwood and a buttonbush understory), as well as scattered patches of mesquite with some netleaf hackberry and walnut trees growing along old fencerows and fields. We distributed survey points throughout these habitat patches in a similar manner to where Tucson Audubon Society conducted cuckoo surveys on Bingham Cienega in 2016.

Pima County YBCU monitoring sites – exploratory surveys

Pima County reduced its Section 10 permit monitoring obligations for southwestern willow flycatchers due to a current lack of suitable habitat on one of the proposed monitoring locations for this species (i.e., A7 Ranch). As a result, County and USFWS mutually agreed to shift survey effort to the cuckoo; County staff worked with Susan Sferra to identify additional areas where knowledge of cuckoos on County preserves was lacking or insufficient. Consequently, County staff conducted a single survey pass in potentially suitable cuckoo habitat in Edgar Canyon and lower Buehman Canyon (Santa Catalina Mountains) and in Posta Quemada Canyon (Rincon Mountains). Staff completed an additional exploratory cuckoo survey in the County-owned portion of Davidson Canyon, south of Cienega Creek. These surveys were all done during survey period 2.

Surveys on County-owned lands in Edgar and lower Buehman Canyons (both draining into the lower San Pedro River) were located on the east side of the Santa Catalina Mountains. Areas surveyed were intermittent streams, containing some permanent water, under a canopy of native broad-leafed riparian woodland (sycamore, velvet ash, walnut, Goodding's willow and cottonwood) intermixed with mesquite bosque. Portions of lower Buehman Canyon surveyed also included a parcel of privately owned land which the County had a Right of Entry for to conduct biological assessments in preparation for potential future acquisition. In 2016, Tucson Audubon staff surveyed for cuckoos on County land in upper Buehman Canyon with no detections, but potential habitat in this part of Buehman Canyon is likely of lesser quality than that found in lower Buehman Canyon. This area was the focus of the 2017 survey effort.

Posta Quemada Canyon is located in Pima County's Colossal Cave Mountain Park, in the Agua Verde Creek drainage at the south end of the Rincon Mountains. Surveys were in an ephemeral stretch of the canyon with a small section of native broad-leaf riparian woodland (mostly cottonwood with some velvet ash and Goodding's willow) and mesquite bosque. County staff also completed an exploratory survey of the County-owned part of Davidson Canyon south of Cienega Creek. Habitat here was mostly velvet mesquite, interspersed with occasional Goodding's willow and velvet ash, and ephemeral stretches with small amounts of water.

Results

Bingham Cienega Natural Preserve

We detected cuckoos throughout the Bingham Cienega Natural Preserve property. The most cuckoos detected on a particular survey (survey 2a; 14 July 2017) was 9, while the fewest detected birds on a given survey was 5 in periods 1 and 2 (survey 2b; 07/26/2017; Table 1). Cuckoos were detected throughout the preserve with detections occurring during all of the surveys in mesquite bosque habitat in the northern part of the property as well as the mix of riparian broad-leaf woodland near the dry cienega in the central part of the preserve. We detected cuckoos during some (but not all) of the survey periods in the mesquite bosque habitat in the southern part of the preserve. Using the instructions regarding interpretation of breeding status given in Halterman et al. (2015) we estimate that there were 3 probable breeding territories and 2 possible breeding territories at this site.

Cienega Creek Natural Preserve

Cuckoos are densely distributed along the surveyed portions of the Cienega Creek property. We detected cuckoos in both mesquite bosque and native riparian woodland habitats. The greatest number of cuckoos detected was 18 during survey period 3, and the fewest detected was 8 during survey period 2 (survey 2a; 14 and 17 July 2017; Table 1). In the western part of the Cienega Creek Preserve, we estimate that there were 2 possible breeding territories and 1 probable breeding territory. In the eastern part of the Preserve, we estimate that there were 5 probable breeding territories, 4 possible breeding territories, and 1 confirmed breeding territory.

Exploratory Surveys

We did not detect any cuckoos during single-visit surveys of Posta Quemada Canyon and the lower, County-owned portions of Davidson Canyon during survey period 2. (However, note an incidental cuckoo observation in Barrel Canyon on 16 August 2017 near its intersection of upper Davidson Canyon; Table 1). While we did not detect any cuckoos in Edgar Canyon during survey period 2, we made an incidental observation of a cuckoo in this same transect on 19 September 2017 that was giving an alarm call, suggesting possible nesting activity at this site. We detected 4 cuckoos during surveys of lower Buehman Canyon during survey period 2.

This submission contains the western yellow-billed cuckoo survey forms and vegetation data in an attached tabular form (MS excel) and attached USGS topographic maps indicating the survey locations and cuckoo detections by survey period. Also included are JPEGs of the survey areas overlaid on aerial imagery (NAIP2013).

Table 1. Summary survey results for Pima County western yellow-billed cuckoo monitoring (2017).

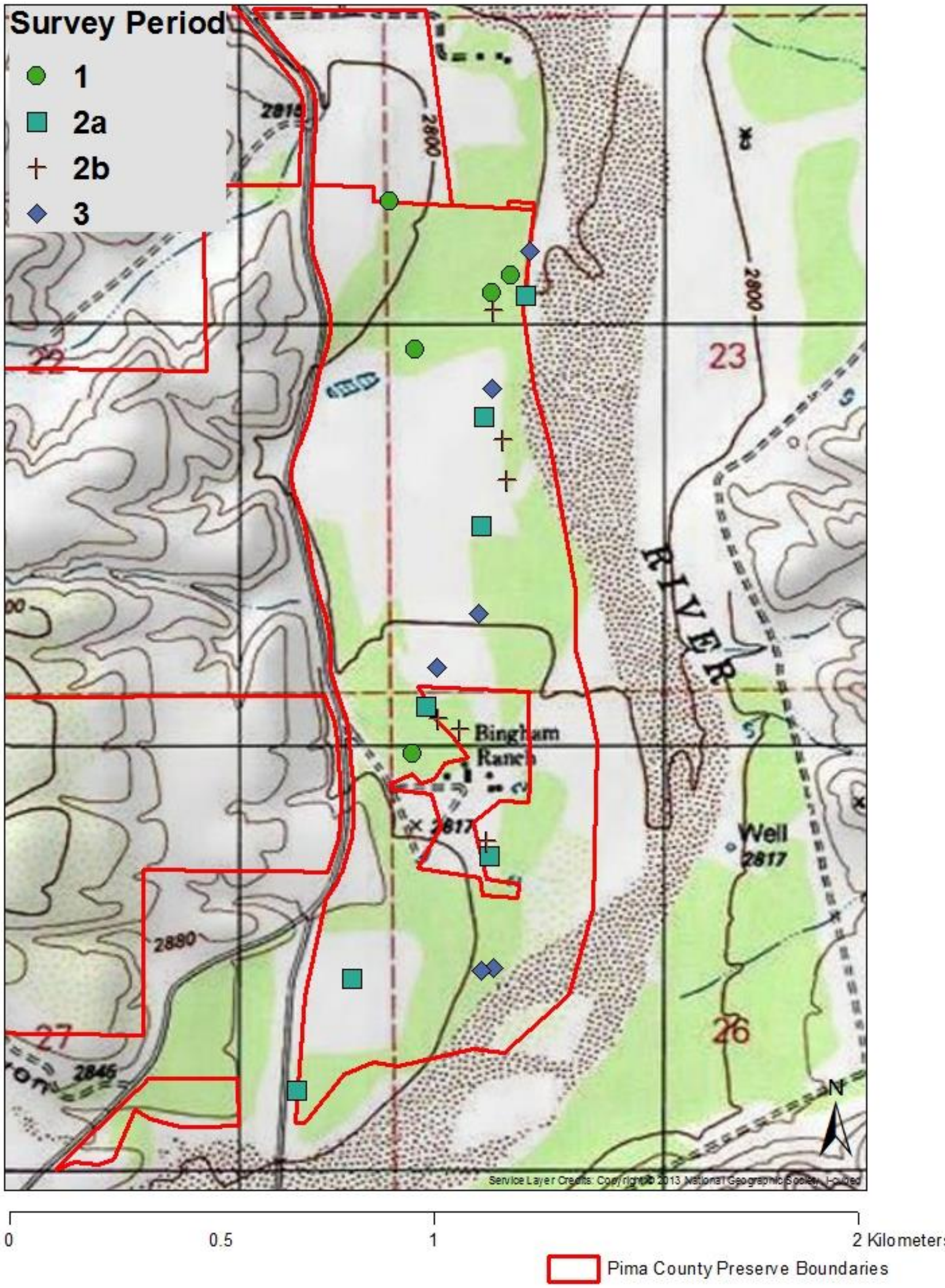
Site	Transect distance (km)	Survey Period 1 June 15 - 30	Survey Period 2 July 1 – 31 (2 surveys)	Survey Period 3 August 1 - 15
		YBCU detections	YBCU detections	YBCU detections
Full protocol sites				
Cienega Creek Natural Preserve*	13.0	18	8 (survey 2a) 16 (survey 2b)	10
Bingham Cienega Natural Preserve	2.1	5	9 (survey 2a) 5 (survey 2b)	6
Exploratory survey sites				
Lower Buehman Canyon	3.3	1 (incidental)	2	N/A
Willock Property (Lower Buehman Canyon)	0.6	N/A	2	N/A
Edgar Canyon**	1.2	N/A	0	1 (incidental – 09/19/2017)
Posta Quemada Canyon	0.6	N/A	0	N/A
Davidson Canyon	4.4	N/A	0	N/A
Additional incidental observations				
USFS land (near junction of Barrel Canyon/SR83	1 (incidental - 8/16/2017)			
Alamo Wash, City of Tucson land/ E 5th St and N Wilmot Rd	1 (incidental – 7/11/2017)			

*Results presented for the east and west portions combined.
**Two discontinuous stretches surveyed combined.

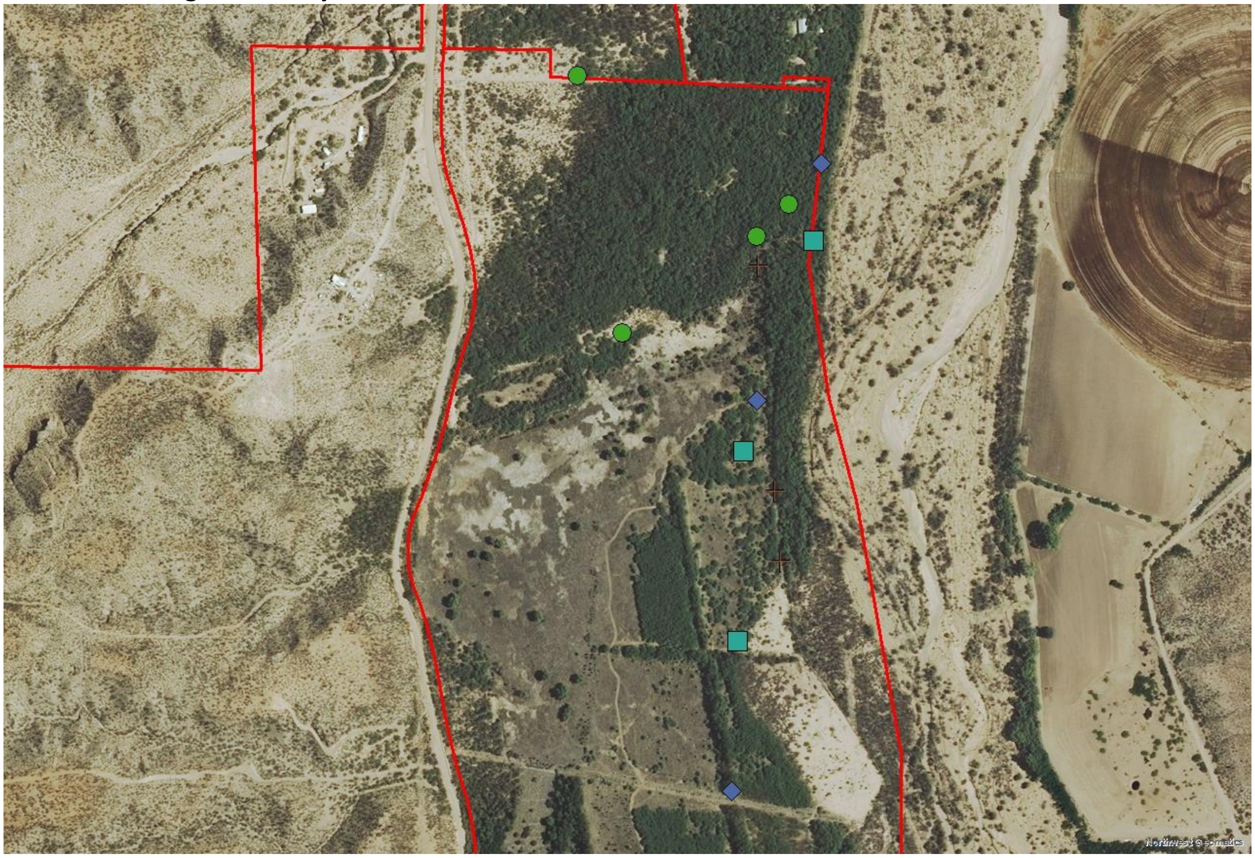
Literature Cited

Halterman, M.D., M.J. Johnson, J.A. Holmes and S.A. Laymon. 2015. A Natural History Summary and Survey Protocol for the Western Distinct Population Segment of the Yellow-billed Cuckoo: U.S. Fish and Wildlife Techniques and Methods, 45 p.

Pima County YBCU Detections 2017 Bingham Cienega Natural Preserve

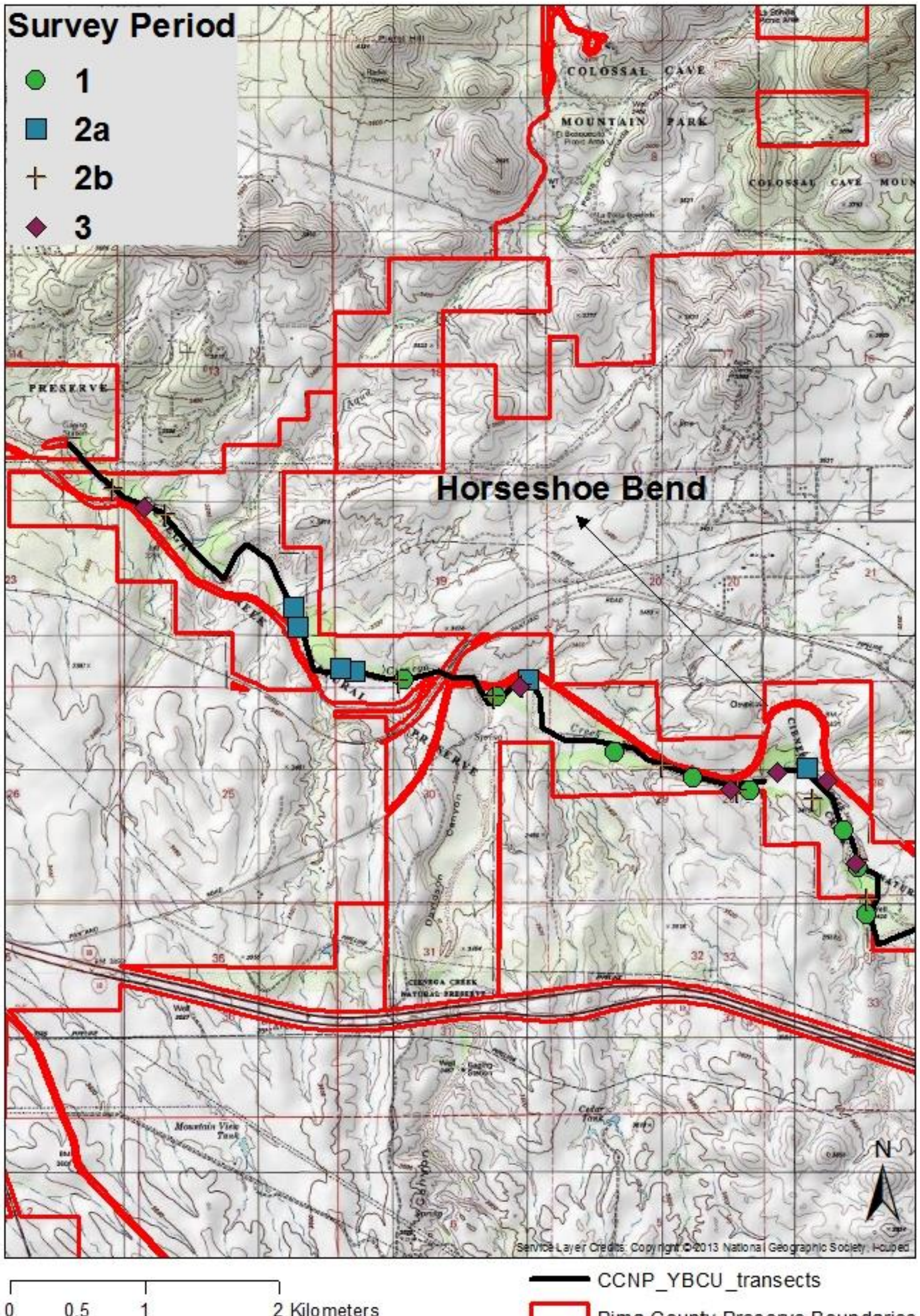


Bingham Cienega Natural Preserve – northern part. Symbols represent corrected YBCU detections (see Bingham Cienega YBCU detection map above for a key to the survey periods). Visible on the right side of the image is the dry San Pedro River channel.

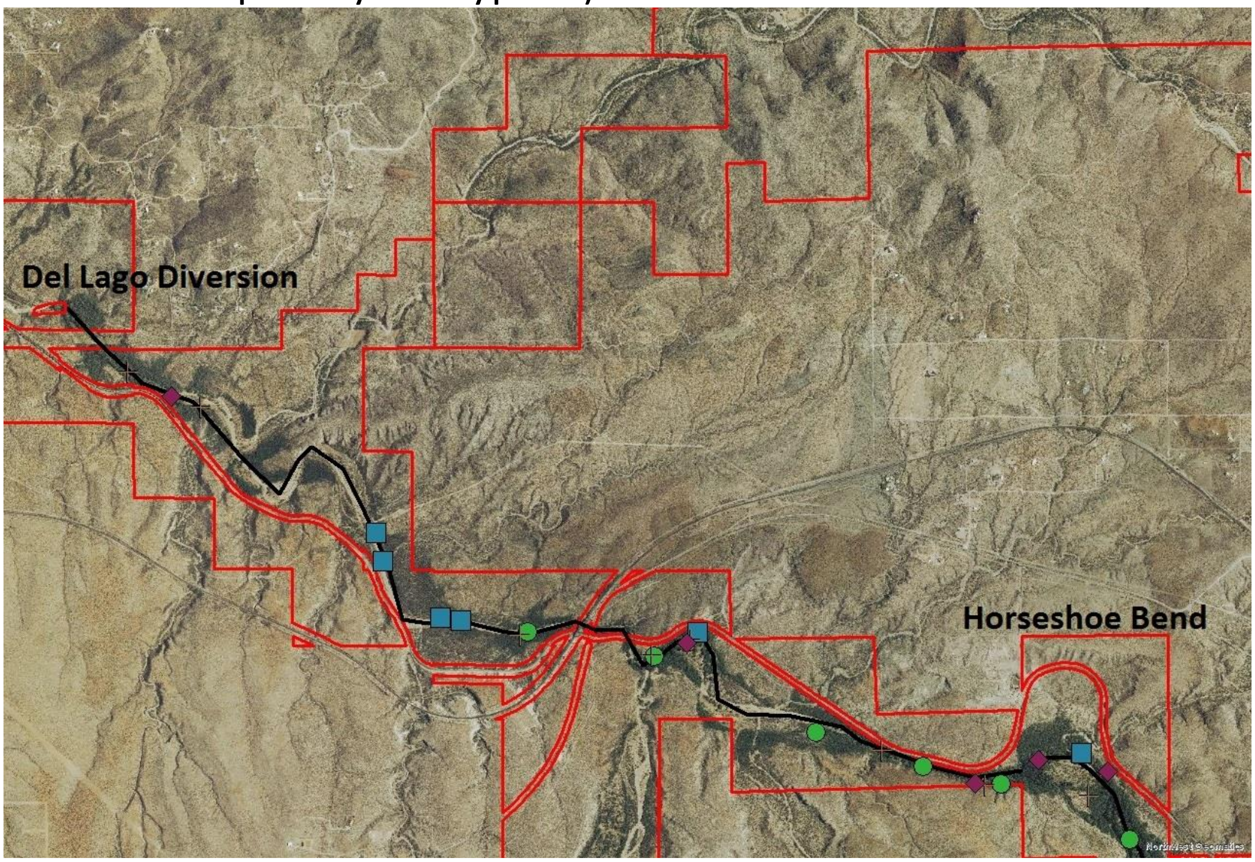


Bingham Cienega Natural Preserve – southern part. Symbols represent corrected YBCU detections (see Bingham Cienega YBCU detection map above for a key to the survey periods). The historic cienega covered by broad-leaf riparian woodland is located northwest of the Bingham ranch house and outbuildings visible in the center of the image. Visible on the right side of the image is the dry San Pedro River channel.

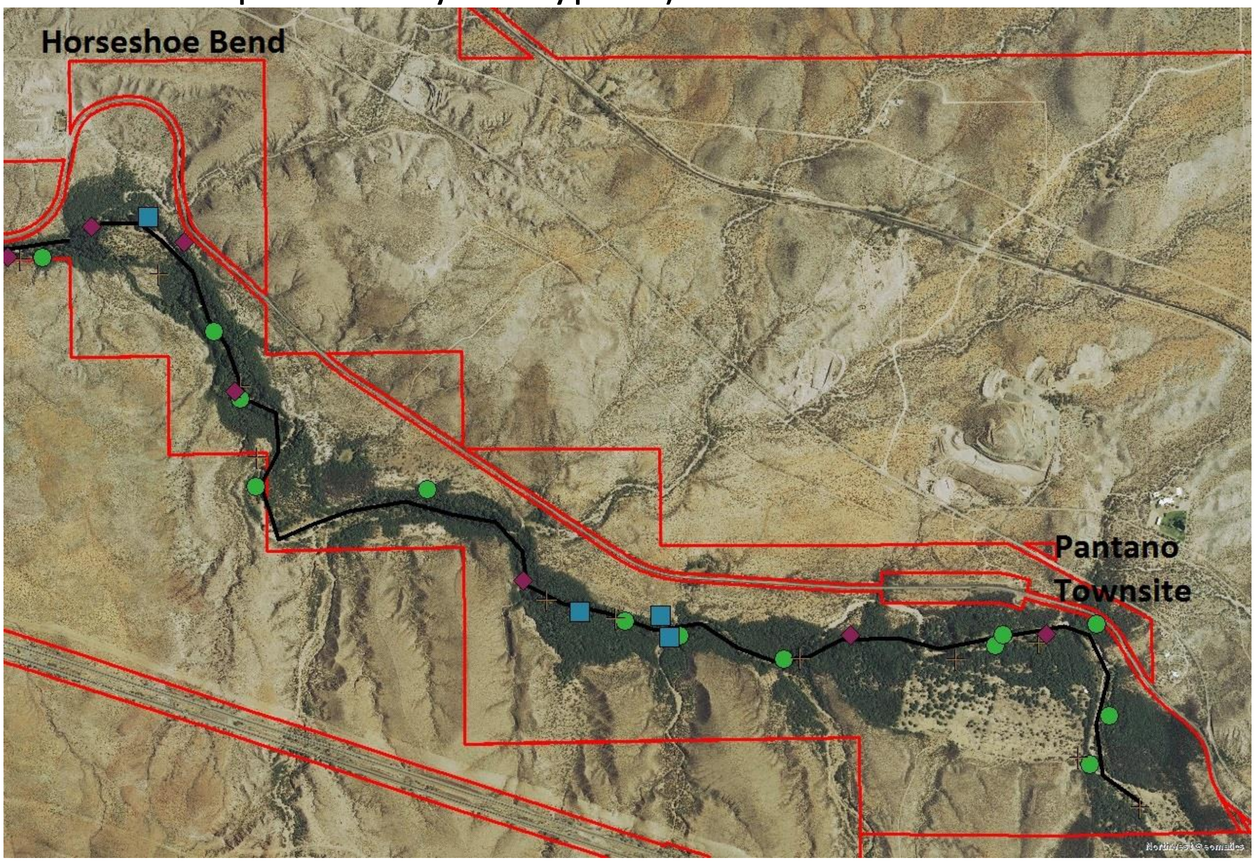
Pima County YBCU Detections 2017 - Cienega Creek Preserve West Section



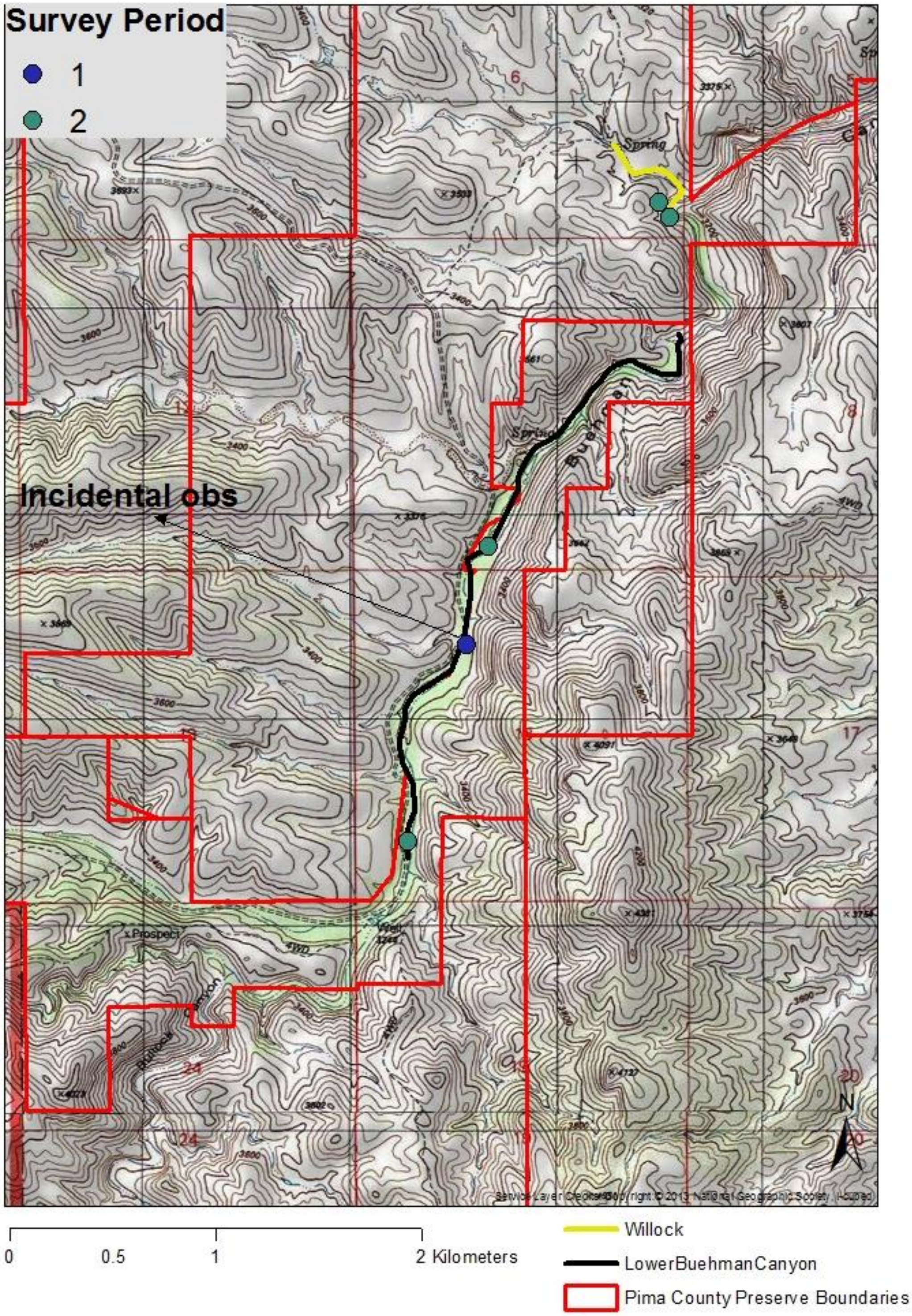
Cienega Creek Natural Preserve – west section extending from the Del Lago diversion dam in the left to the Horseshoe Bend to the right. Symbols represent corrected YBCU detections (See Cienega Creek YBCU detection map for a key to survey periods).



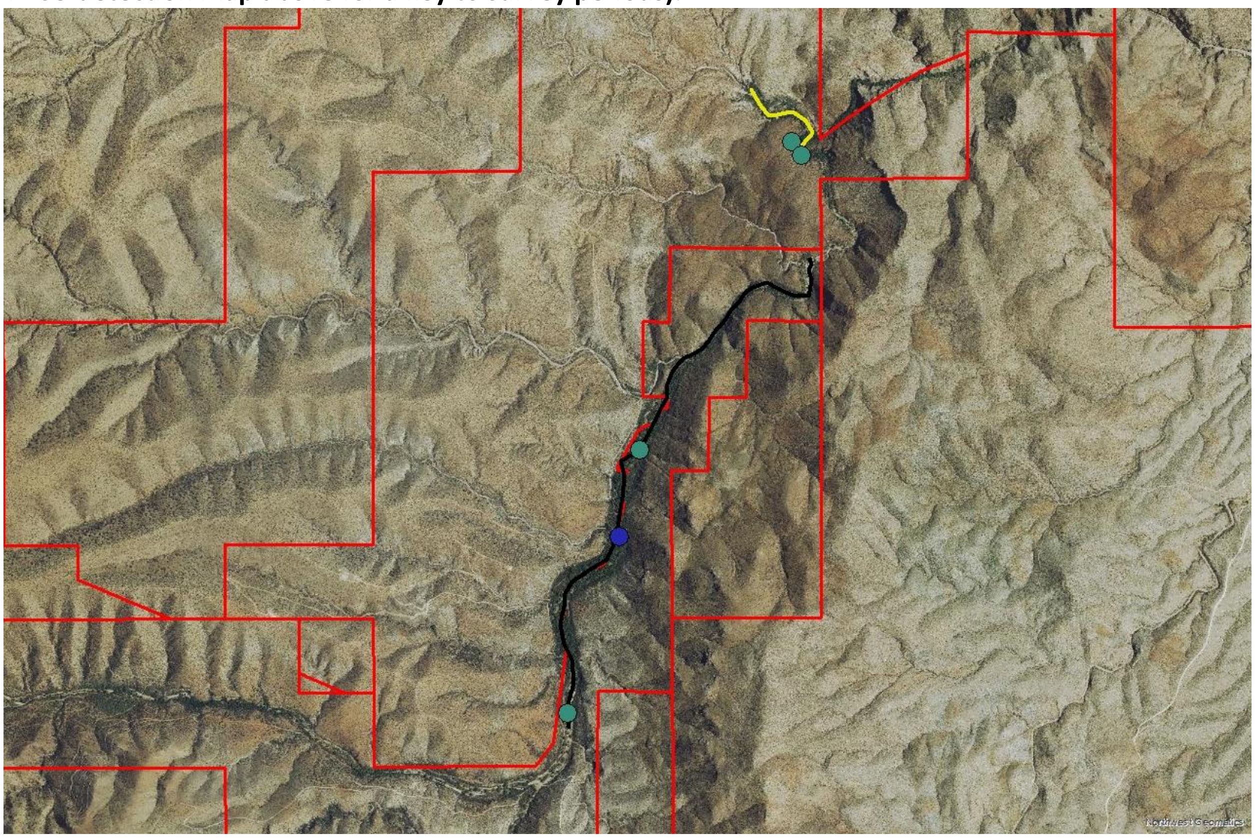
Cienega Creek Natural Preserve – east section extending from the Horseshoe Bend in the left to the Pantano Townsite to the right. Symbols represent corrected YBCU detections (See Cienega Creek YBCU detection map above for a key to survey periods).



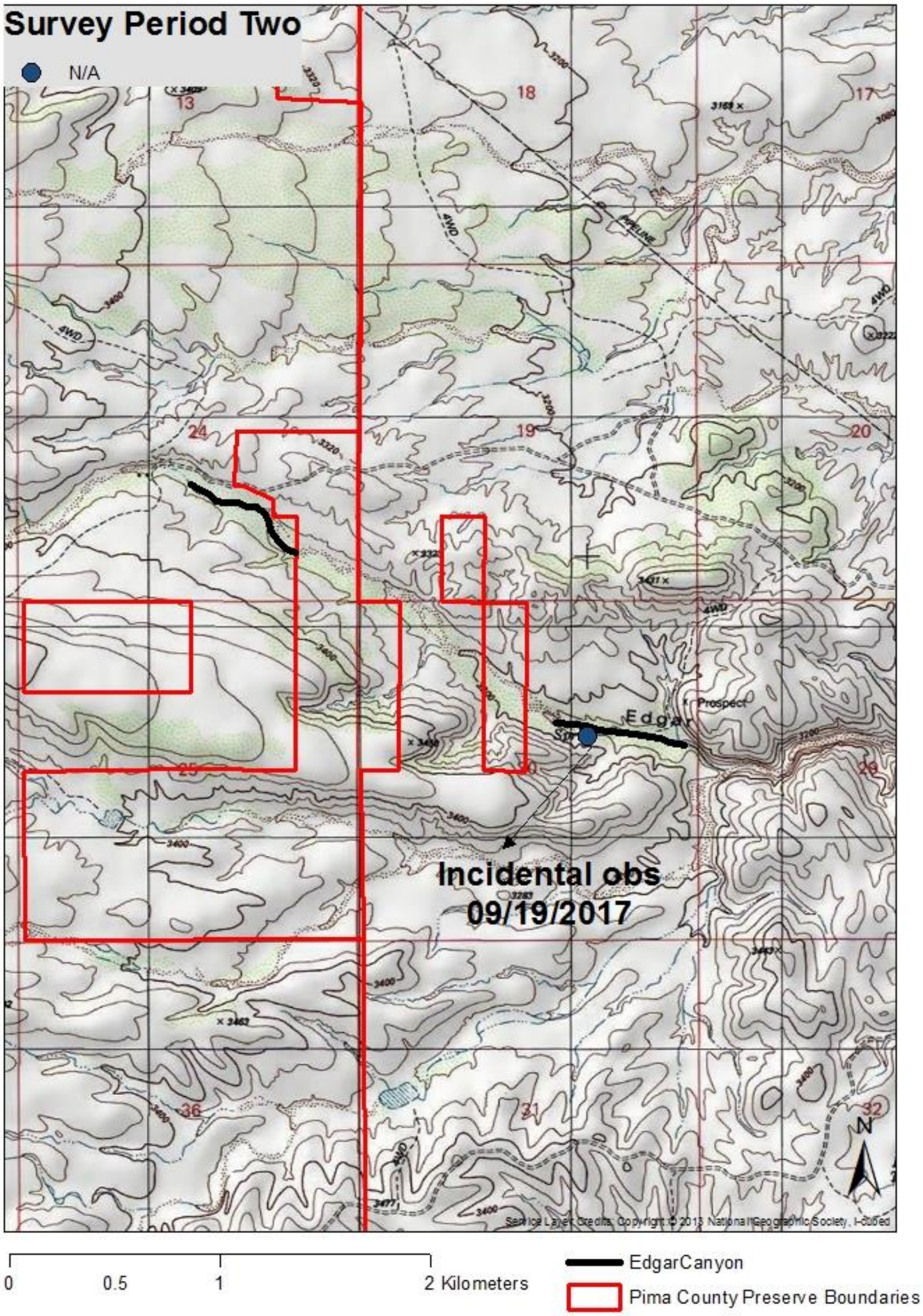
Pima County YBCU Detections 2017 Lower Buehman Canyon/ Willock Property Exploratory Survey



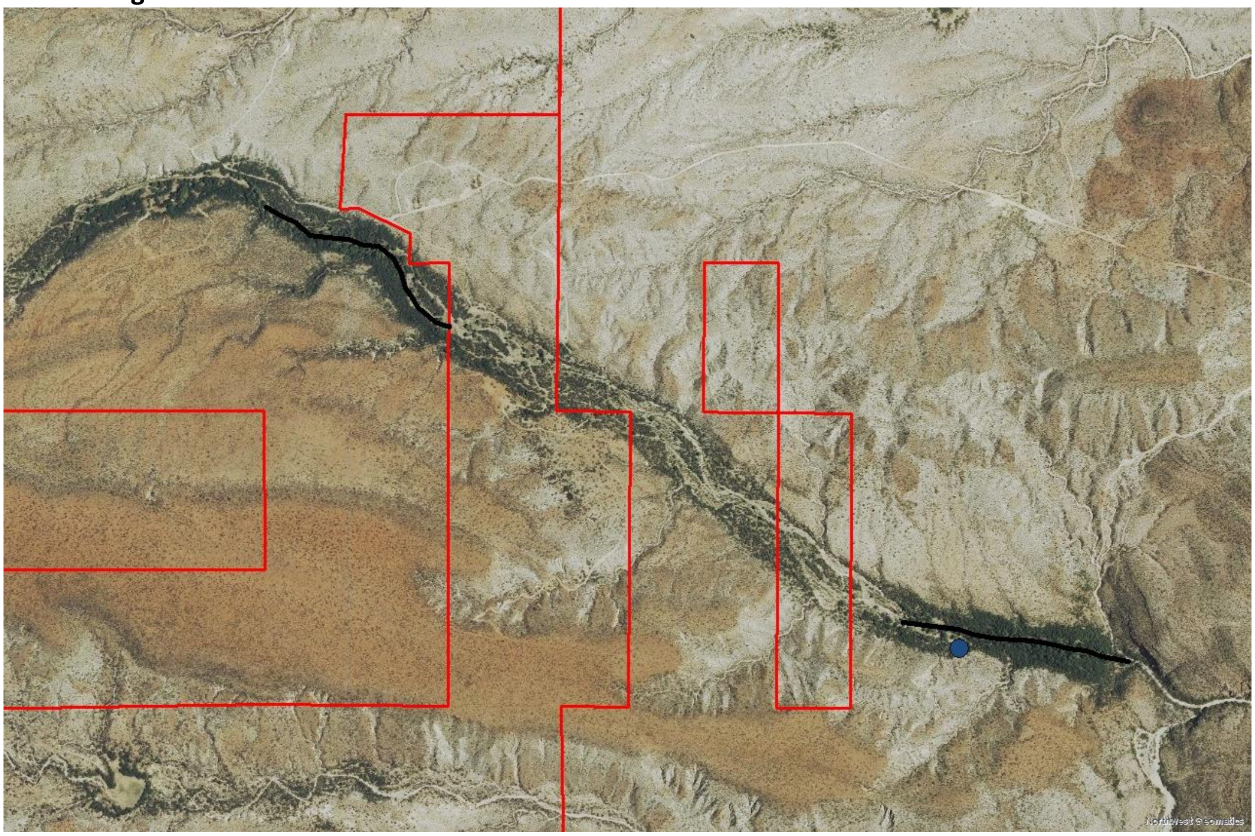
Lower Buehman Canyon (black transect) and Willock Property (yellow transect) Exploratory YBCU surveys on 13 July 2017. Symbols represent corrected YBCU detections (See Lower Buehman Canyon YBCU detection map above for a key to survey periods).



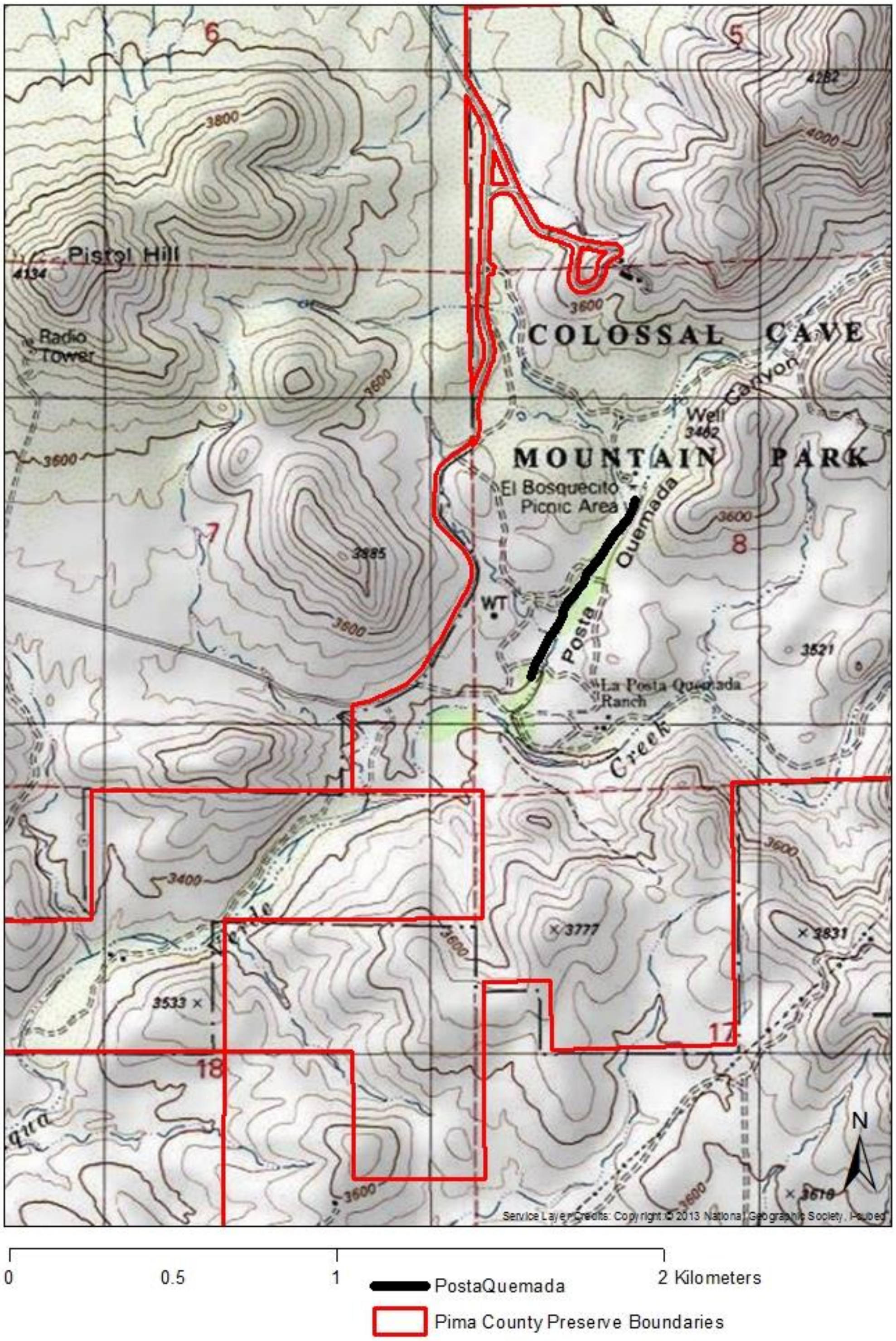
Pima County YBCU Detections 2017 Edgar Canyon Exploratory Survey (0 detected) and Incidental Obs



Edgar Canyon exploratory YBCU surveys (black transects). No cuckoos were detected during the exploratory surveys on 20 July 2017, but on 19 September 2017 a cuckoo giving an alarm call was seen here during other work.

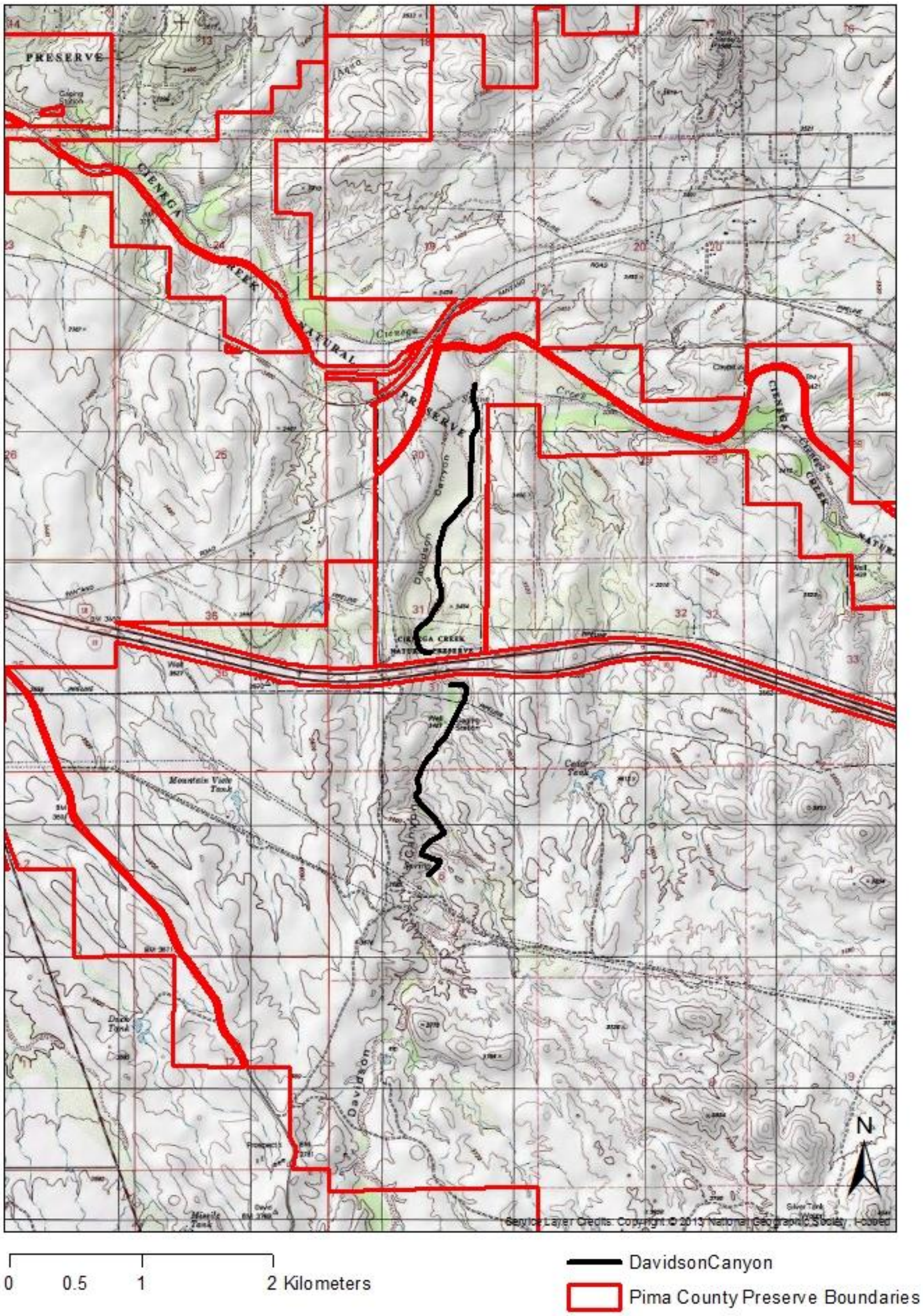


Pima County YBCU Exploratory Survey Posta Quemada Canyon
Survey Period Two - 0 Detections

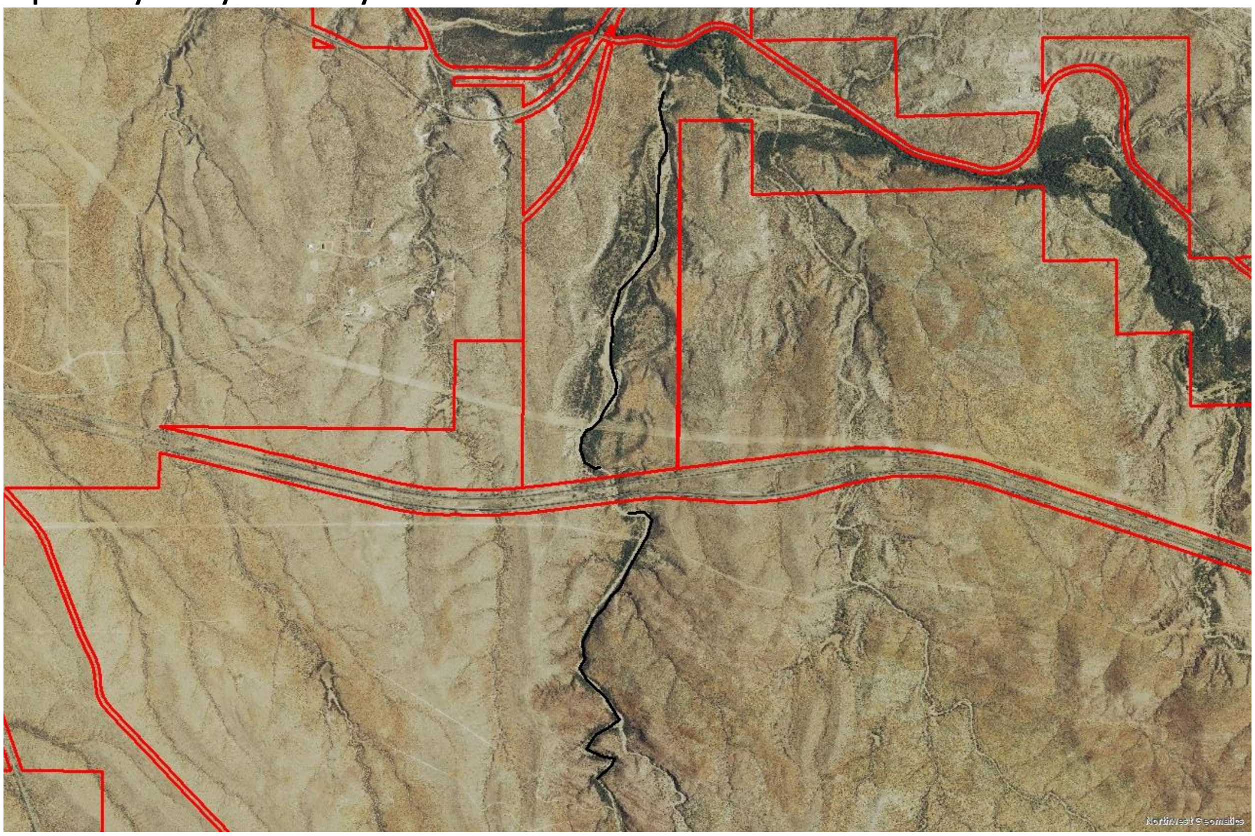


Posta Quemada Canyon (Colossal Cave Mountain Park) exploratory YBCU survey (black transect). No cuckoos were detected during the exploratory surveys on 12 July 2017.

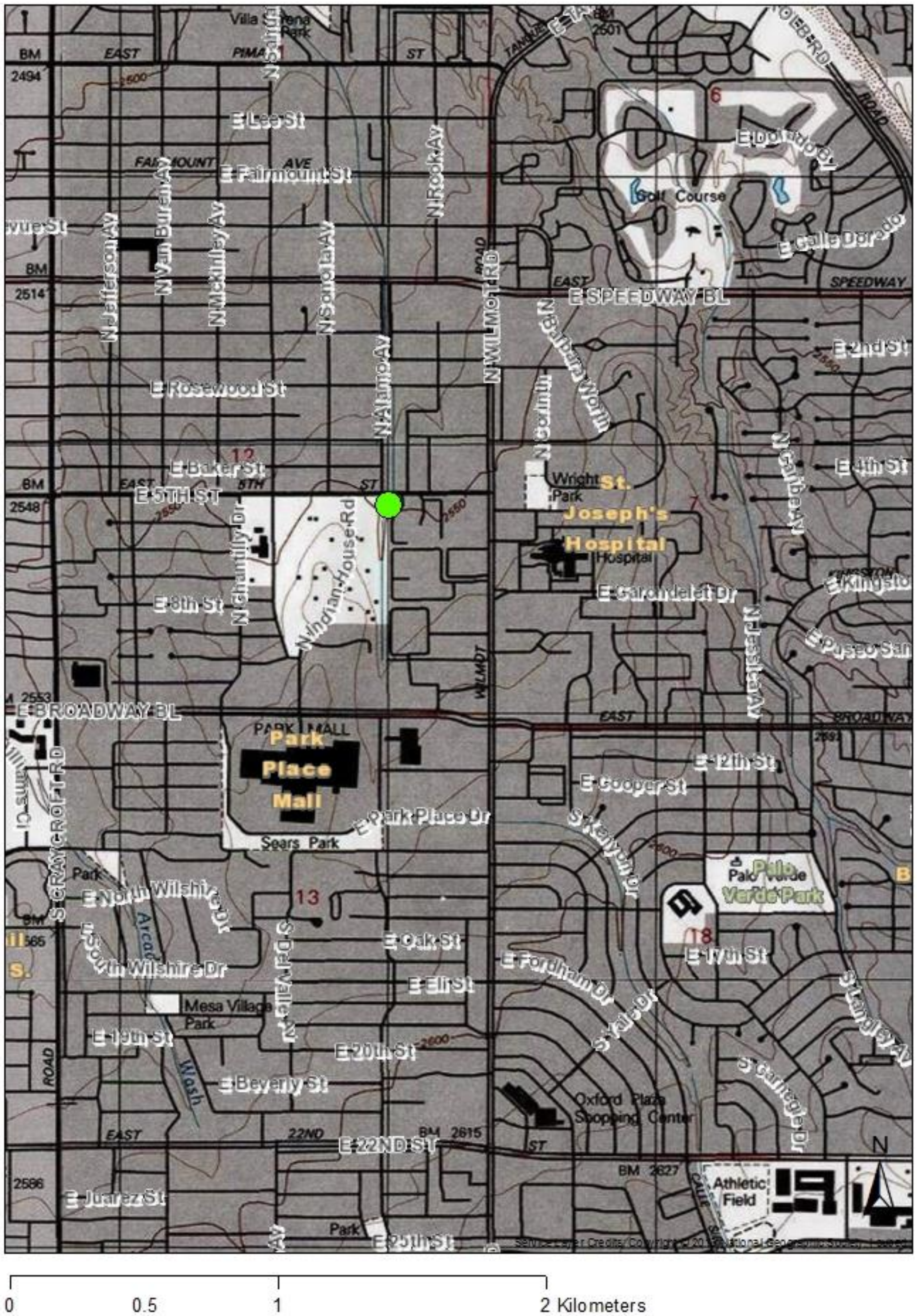
Pima County YBCU Exploratory Survey 2017 Davidson Canyon
Survey Period Two - 0 Detections



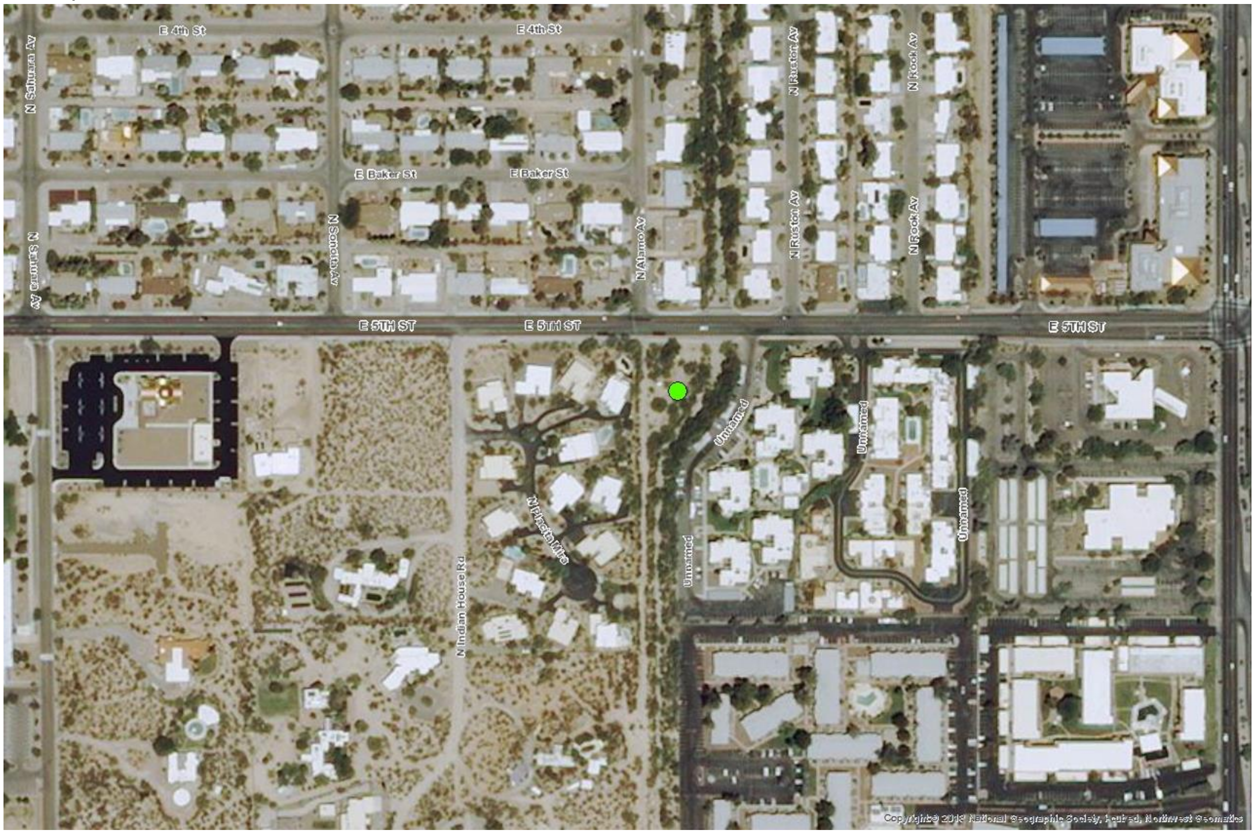
Davidson Canyon exploratory YBCU surveys (black transects). No cuckoos were detected during the exploratory surveys on 27 July 2017.



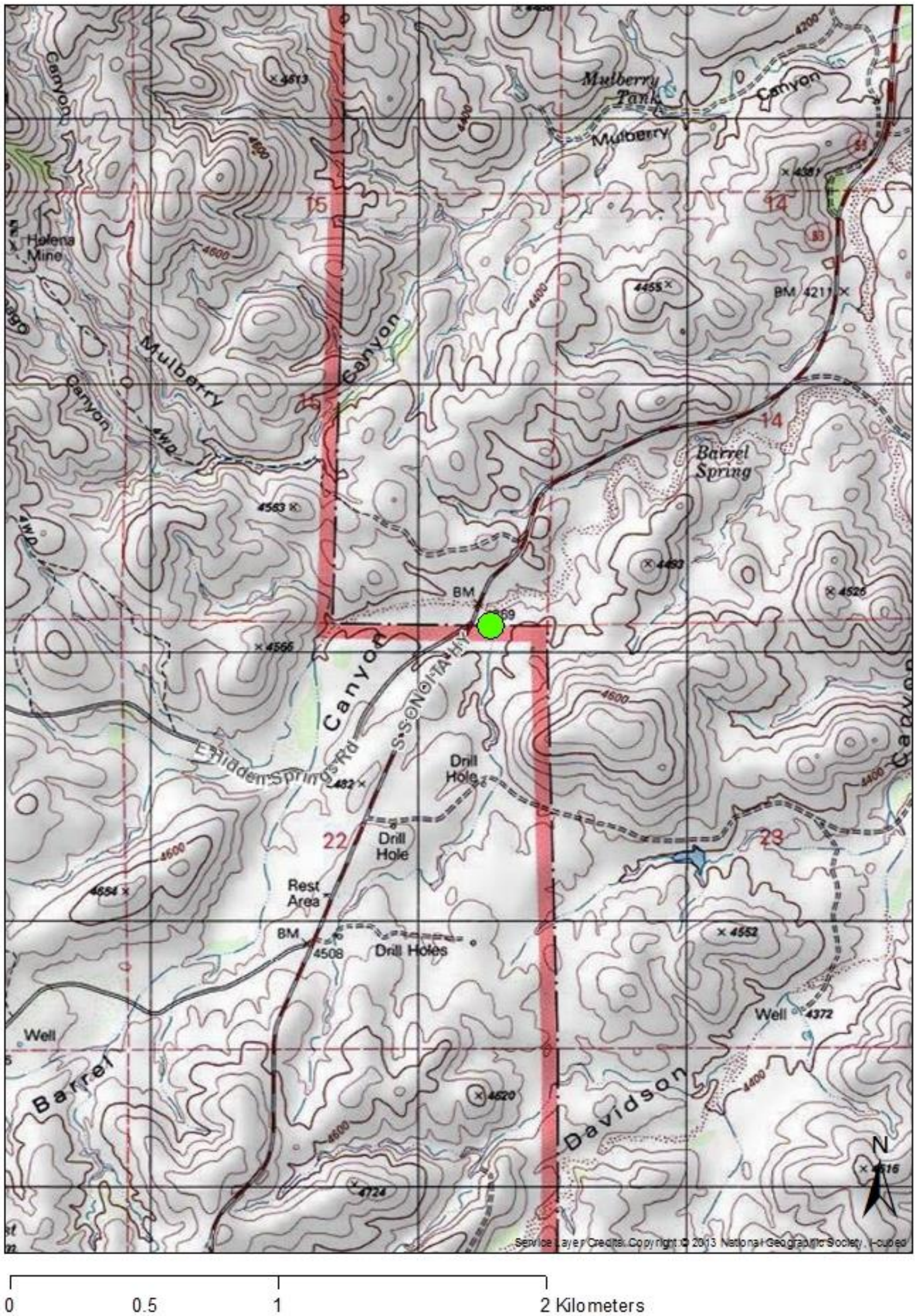
Pima County YBCU Incidental Detection
City of Tucson land (Alamo Wash)



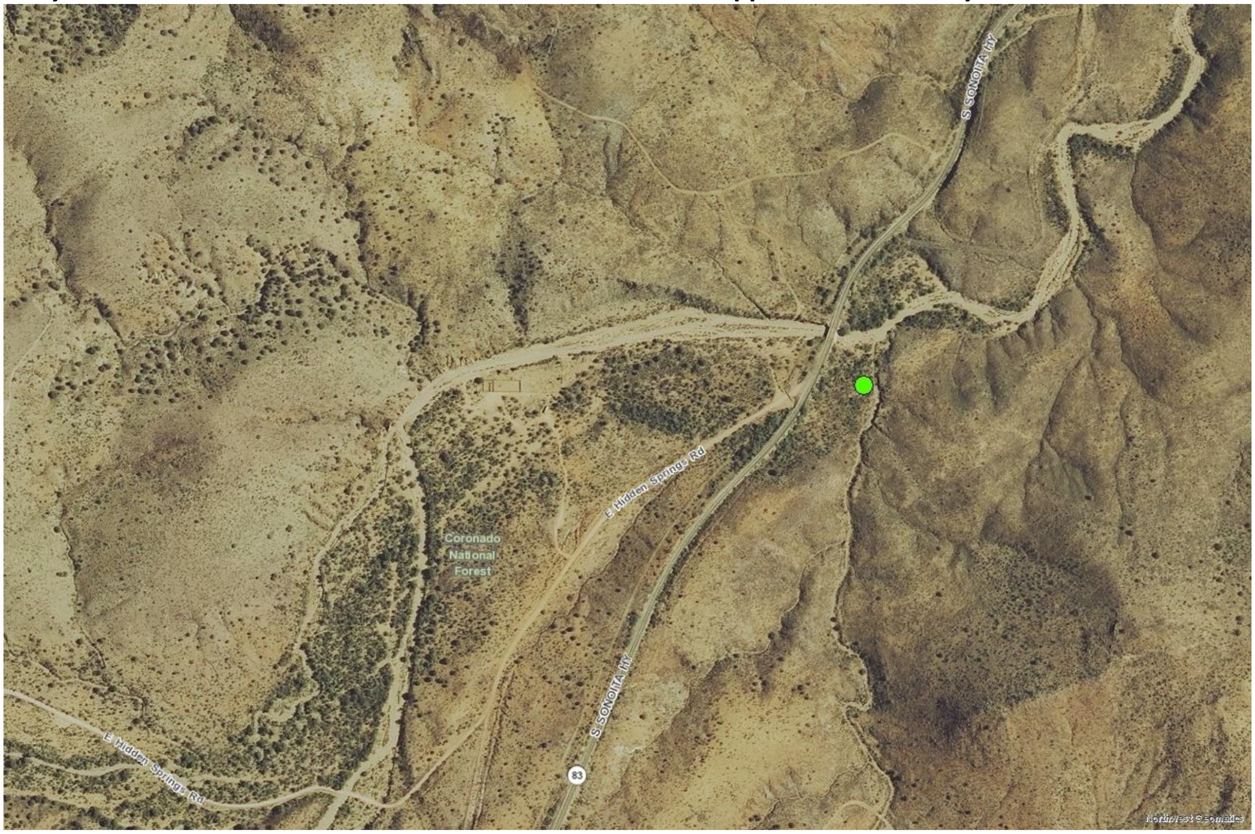
Incidental observation of a silent YBCU on 11 July 2017 on City of Tucson land adjacent to Alamo Wash, south of E 5th Street and west of N Wilmot Road.



Pima County YBCU Incidental Detection
USFS land, Barrel Canyon



Incidental observation of a calling YBCU on 16 August 2017 on U.S. Forest Service land in Barrel Canyon at AZ SR 83 about 2 km SW of its intersection with upper Davidson Canyon.



Pima County
Multi-species Conservation Plan:
2017 Annual Report

Appendix 11

Southwestern willow flycatcher (*Empidonax traillii extimus*)
2017 Survey Results

Southwestern willow flycatcher 2017 Survey Results
Pima County Multi-species Conservation Plan

Pima County followed the USFWS-approved survey protocol (Sogge et al. 2010) to survey for southwestern willow flycatchers on two Pima County preserve properties, Bingham Cienega Preserve and Cienega Creek Preserve. The southwestern willow flycatcher is an MSCP-covered species under the County's recently issued Section 10 permit, and the County has agreed to monitor for this species every three years following established protocols. During 2017 Pima County followed the 'general survey' iteration of the monitoring protocol with one survey visit completed during each of the three survey periods (May 15-31, June 1-24, and June 25- July 17).

Surveys on Cienega Creek Natural Preserve were done on four different stretches of creek, all of which had some permanent water during the surveys, with mostly native broad-leafed riparian woodland (e.g., cottonwood, velvet ash, Goodding's willow, and mesquite) and a diverse shrub understory ranging from sparse to dense along the survey lengths. Surveys transects at Cienega Creek were linear and followed the course of the stream channel. Riparian habitat quality at Bingham Cienega has declined precipitously over the recent past such that the cienega and downstream marshy habitat no longer have surface water, or even moist soil, during early summer. We surveyed sinuous transects in each of four discrete habitat patches which had the best potential habitat left on the property. Bingham Cienega is a historical flycatcher survey site but we do not have available the exact survey locations of previous surveys. Presumably, surveys were focused on the main cienega north of the Bingham ranch house (Cienega patch; ash/cottonwood/buttonbush woodland) as well as the brushy and wet outflow of this cienega. To our knowledge, 2002 was the last confirmed nesting of southwestern willow flycatcher at this site (a time when there was surface water and lush riparian habitat on the site). Indeed, Durst et al. (2007) considered Bingham Cienega to be a site where flycatchers were considered extirpated, with the express acknowledgement that extirpated sites could become re-occupied in the future.

We did not detect any flycatchers on any survey visit on Bingham Cienega and Cienega Creek Natural Preserve (Table 1). Bingham Cienega Natural Preserve does not currently contain any suitable flycatcher breeding habitat. Soil surfaces were dry at Bingham Cienega, and the shallow ground water levels continue to drop here. The main cienega is in decline with the large ash and cottonwood trees showing stress, and in many cases dying. Buttonbush continues to survive here, but the dry conditions make habitat conditions poor for flycatchers. The only surface water on site is a small fish pond fed by a well adjacent to the ranch house and which is on a life estate inholding and not part of the available survey areas. The nearby habitat that is on County land (SE pond patch) is dry and primarily mesquite bosque with not much understory development. Historically, there was a shallow pond of water at the north end of the property (NW tamarisk). Currently this pond is dry, and the dense, but narrow rim of tamarisk surrounding it is starting to die from lack of water. Areas nearby were noted to have some creosote and barrel cacti. The NE fence patch is currently mesquite bosque habitat with an understory of graythorn and some hackberry. Neither of these dry areas currently have flycatcher habitat potential.

Sections of Cienega Creek Natural Preserve with permanent water have areas of habitat (albeit not continuous) with appropriate understory vegetation development (and in many cases a canopy of native broadleaf trees) which could support breeding flycatchers.

This submission contains the southwestern willow flycatcher survey and detection forms as well as the habitat descriptions and attached USGS topographic maps indicating the survey locations. Also included are JPEGs of the survey areas overlaid on aerial imagery (NAIP2013).

Table 1. Summary survey results for Pima County southwestern willow flycatcher monitoring (2017).

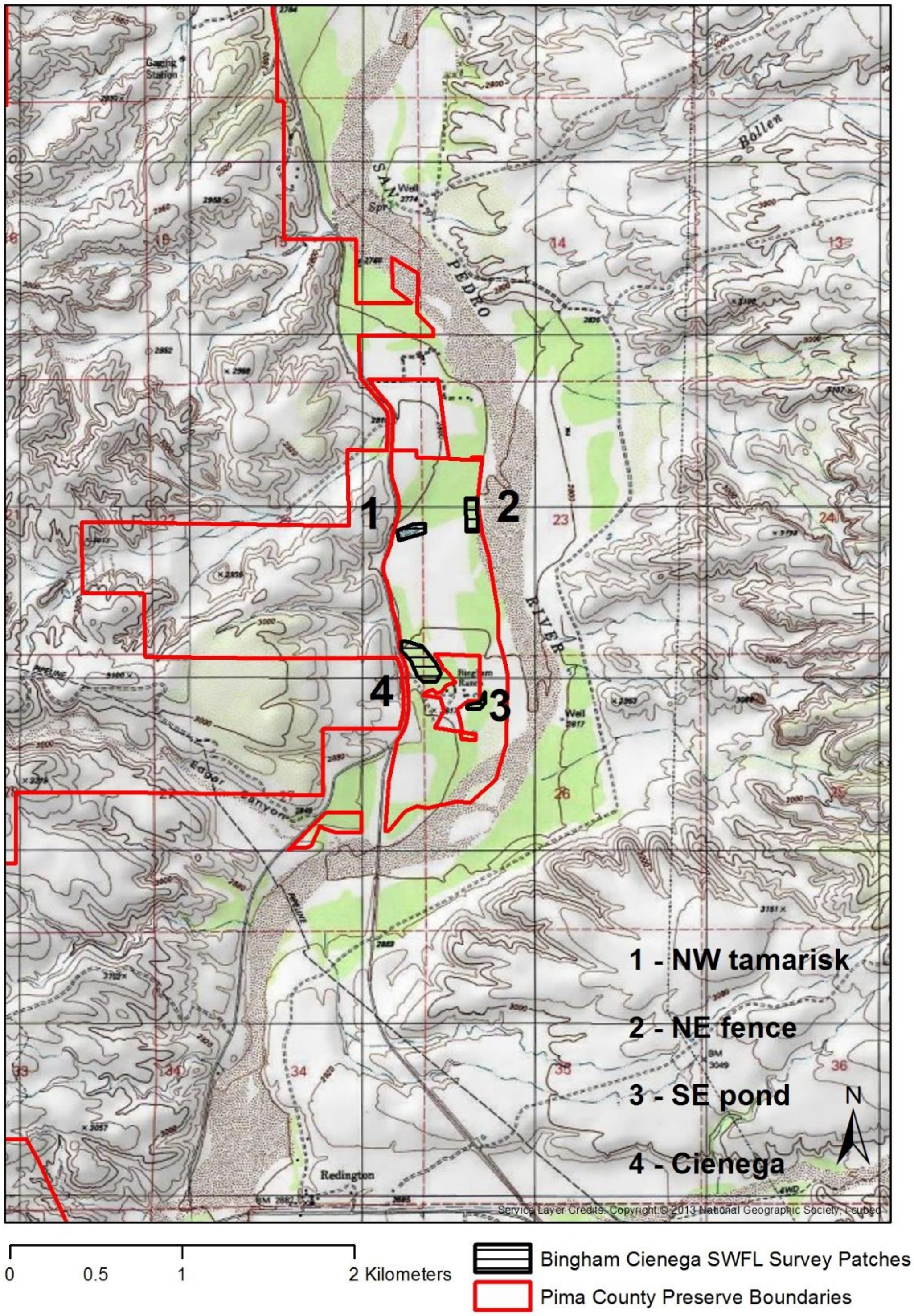
Site	Survey Period 1 May 15 - 31		Survey Period 2 June 1 - 24		Survey Period 3 June 25 – July 17	
	Area length (km) Survey time (h)	SWFL	Area length (km) Survey time (h)	SWFL	Area length (km) Survey time (h)	SWFL
Bingham Cienega Natural Preserve						
NW tamarisk	0.2 km; 0.5 h	0	0.2 km; 0.5 h	0	0.2 km; 0.8 h	0
NE fence	0.2 km; 0.4 h	0	0.2 km; 0.5 h	0	0.2 km; 0.3 h	0
Cienega	0.3 km; 0.9 h	0	0.3 km; 1.5 h	0	0.3 km; 0.5 h	0
SE Pond	0.1 km; 0.2 h	0	0.1 km; 0.3 h	0	0.1 km; 0.5 h	0
Cienega Creek Natural Preserve						
Del Lago	1.0 km; 1.2 h	0	1.0 km; 1.0 h	0	1.0 km; 1.4 h	0
3 Bridges	1.3 km; 1.0 h	0	1.3 km; 0.6 h	0	1.3 km; 1.5 h	0
Horseshoe	1.6 km; 2.0 h	0	1.6 km; 2.0 h	0	1.6 km; 1.3 h	0
Pantano	1.7 km; 1.3 h	0	1.7 km; 1.3 h	0	1.7 km; 2.0 h	0

Literature Cited

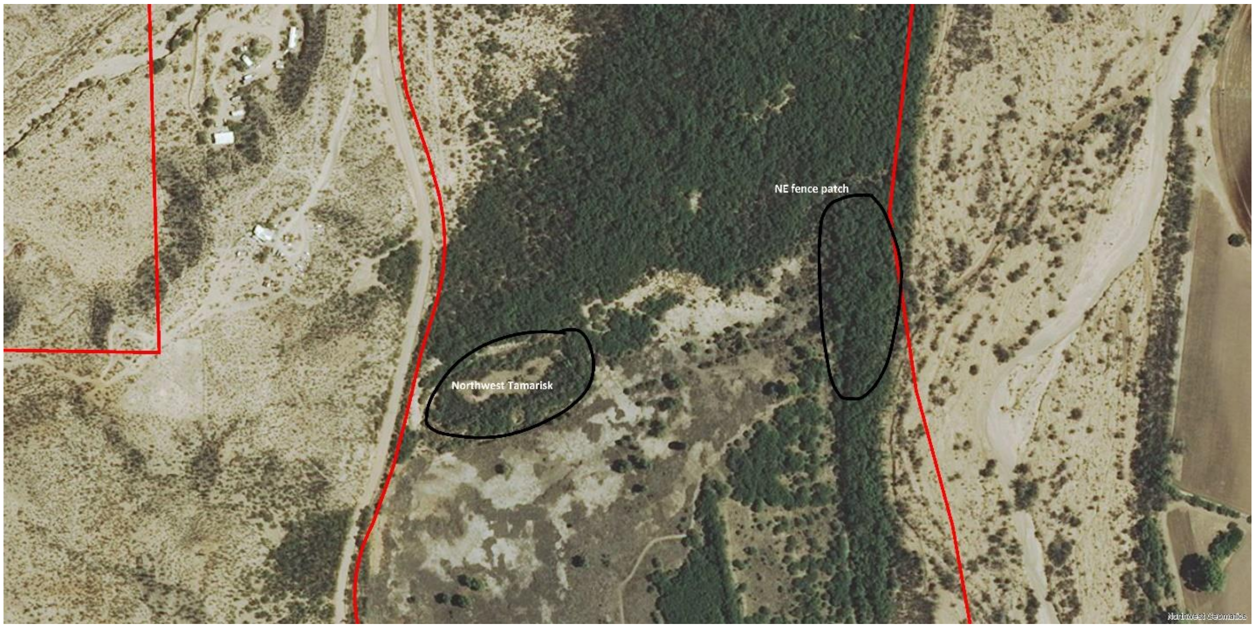
Durst, S.L., Sogge, M.K., Stump, Shay D., Williams, Sartor O., Kus, Barbara E., and Sferra, Susan J. 2007. Southwestern Willow Flycatcher Breeding Site and Territory Summary – 2006. USGS Open File Report 2007-1391. [http://pubs.usgs.gov/of/2007/1391/].

Sogge, M.K., Ahlers, D., and Sferra, S.J. 2010. A natural history summary and survey protocol for the Southwestern Willow Flycatcher. U.S. Geological Survey Techniques and Methods 2A-10. 38 pp.

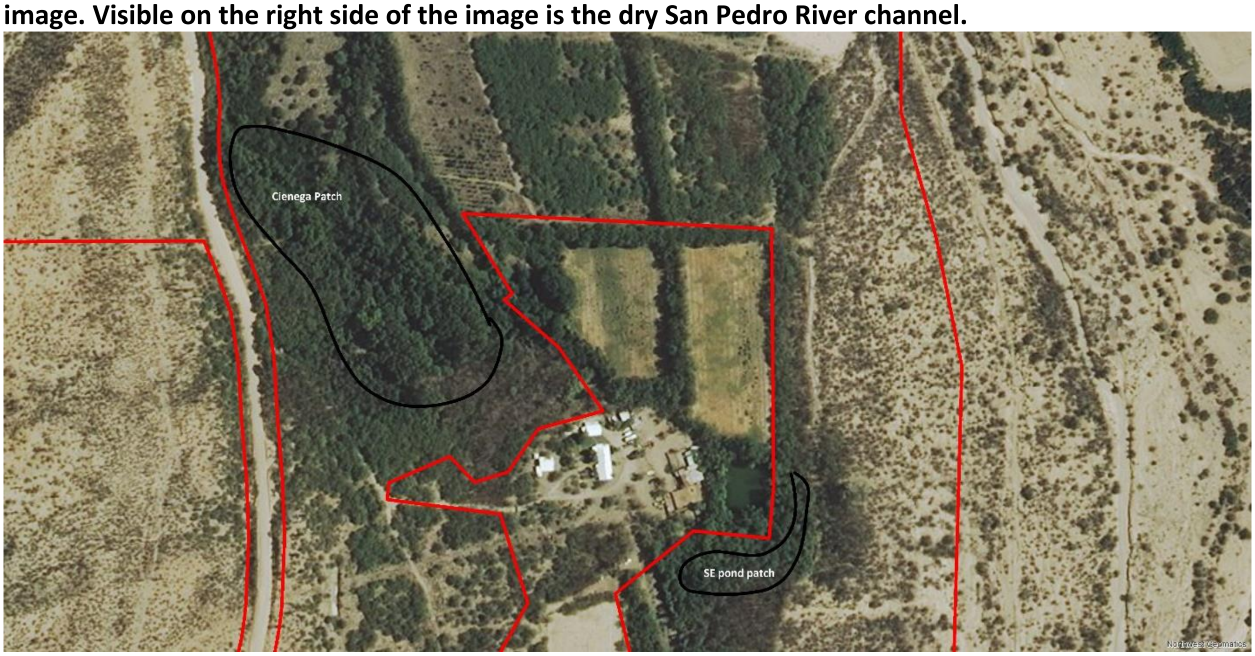
Pima County SWFL Survey 2017 - Bingham Cienega



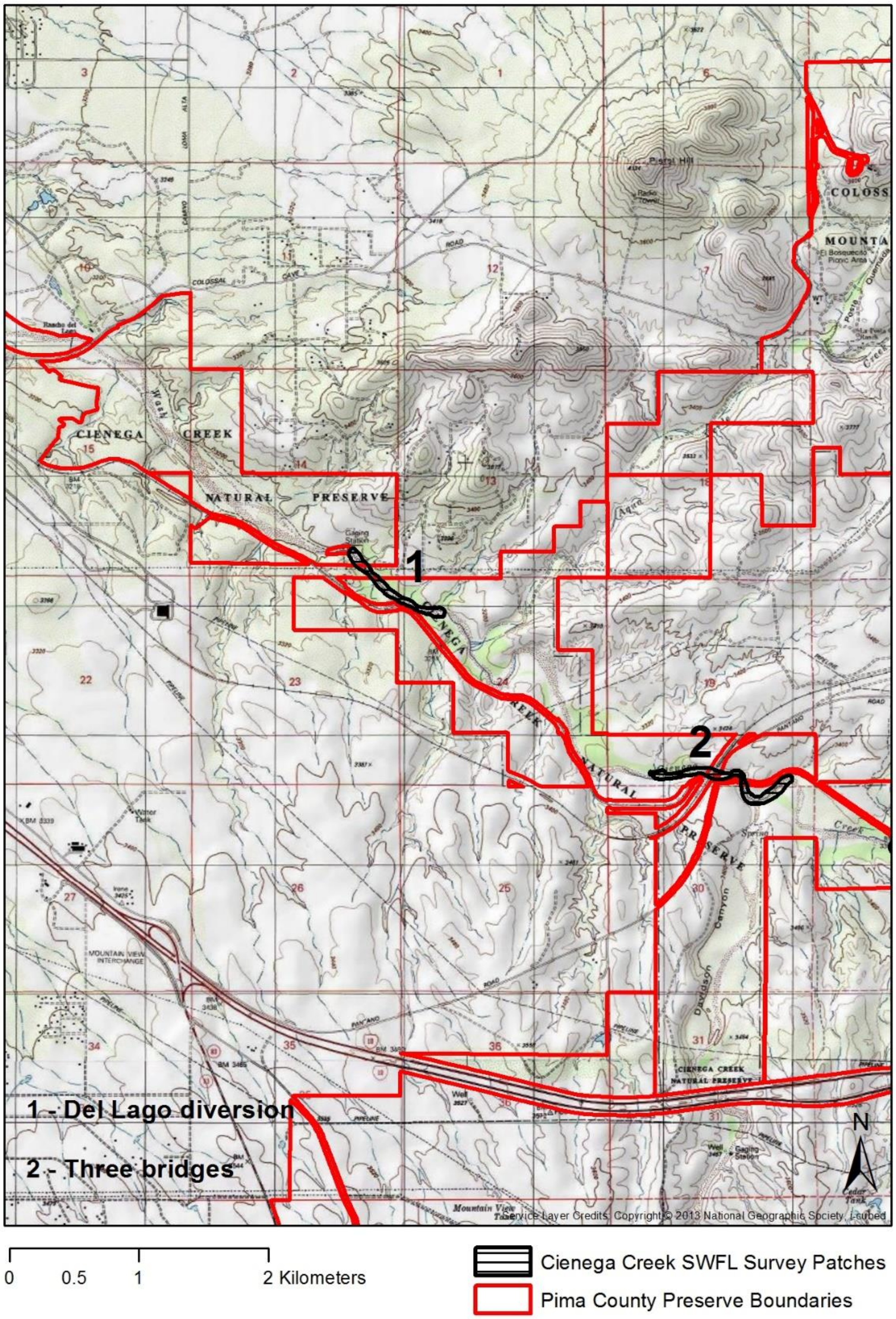
Bingham Cienega Natural Preserve. Left most polygon is the northwest tamarisk survey patch and to the right is the NE fence survey patch. Visible on the right side of the image is the dry San Pedro River channel.



Bingham Cienega Natural Preserve. Top polygon is the cienega survey patch and the bottom is the SE pond survey patch. The life estate inholding with nearby fish pond is visible in the center of the image. Visible on the right side of the image is the dry San Pedro River channel.

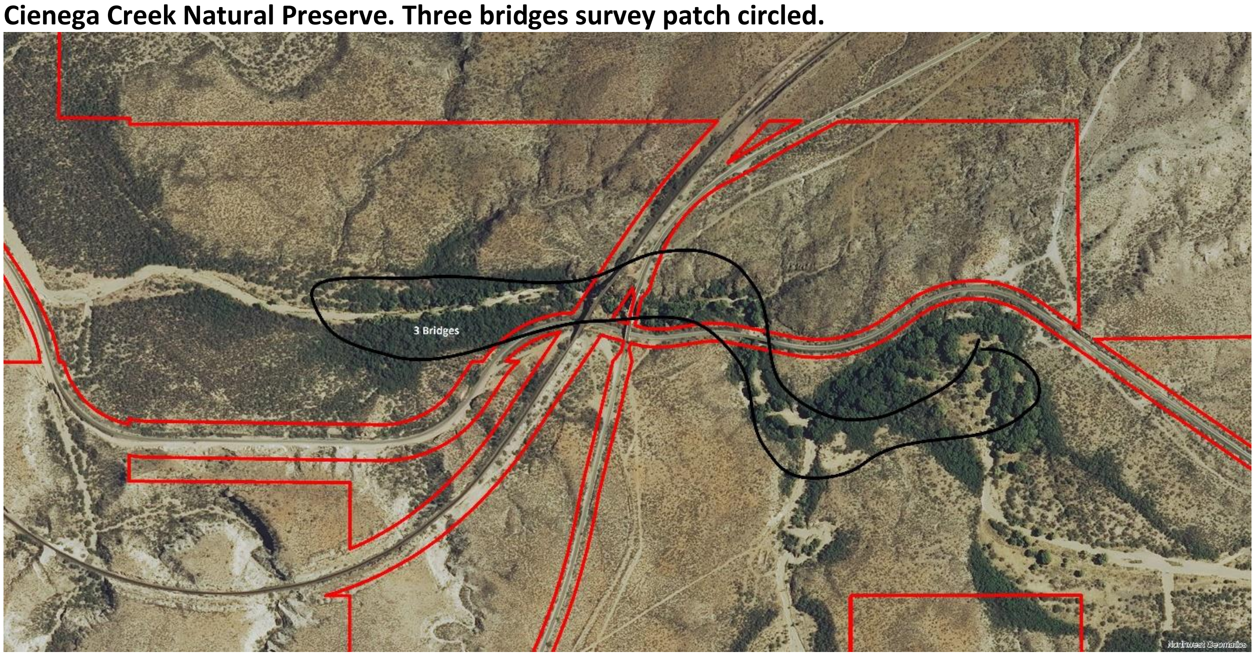


Pima County SWFL Survey 2017 - Cienega Creek Preserve
West Section

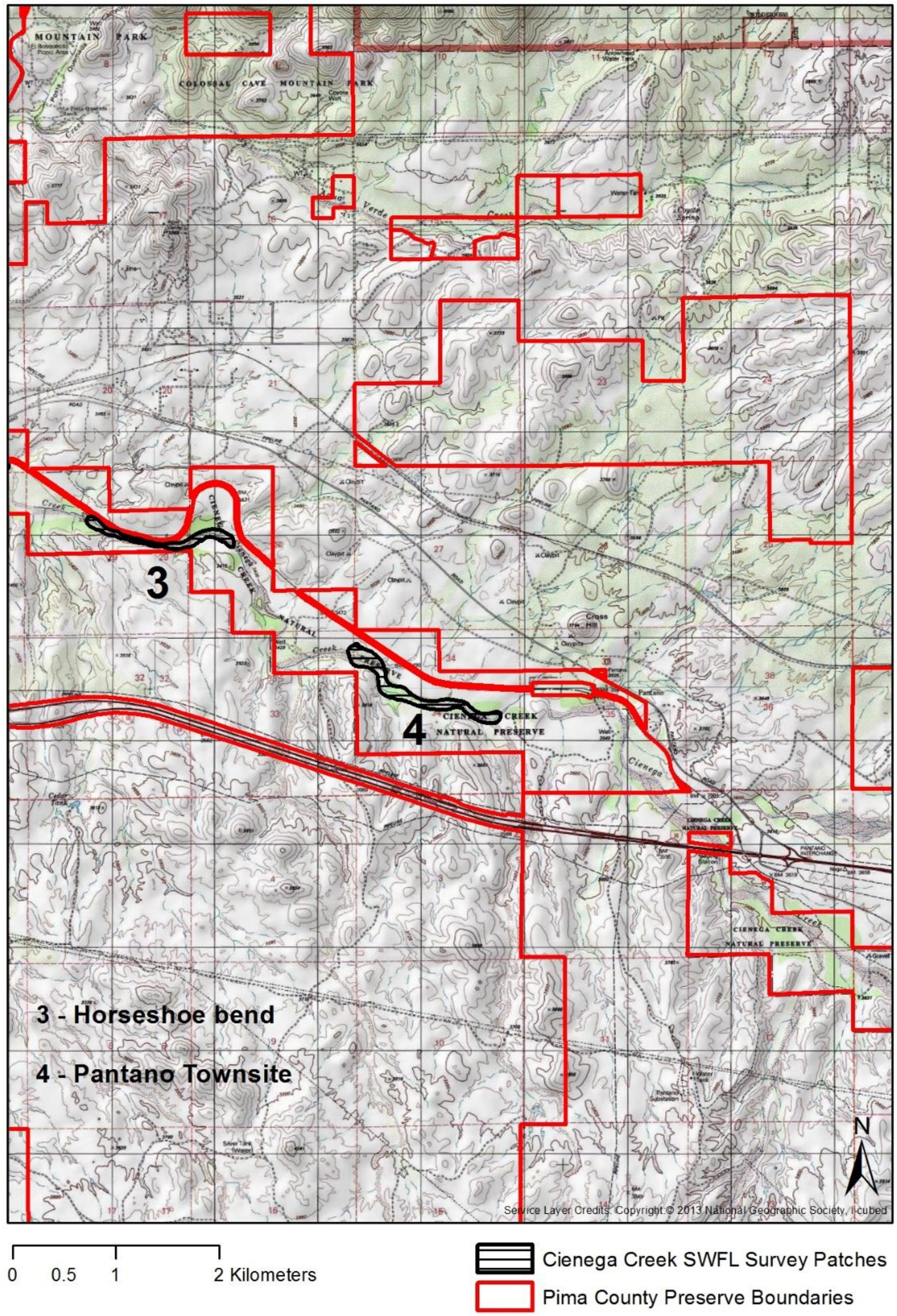


Cienega Creek Natural Preserve. Del Lago diversion survey patch circled.

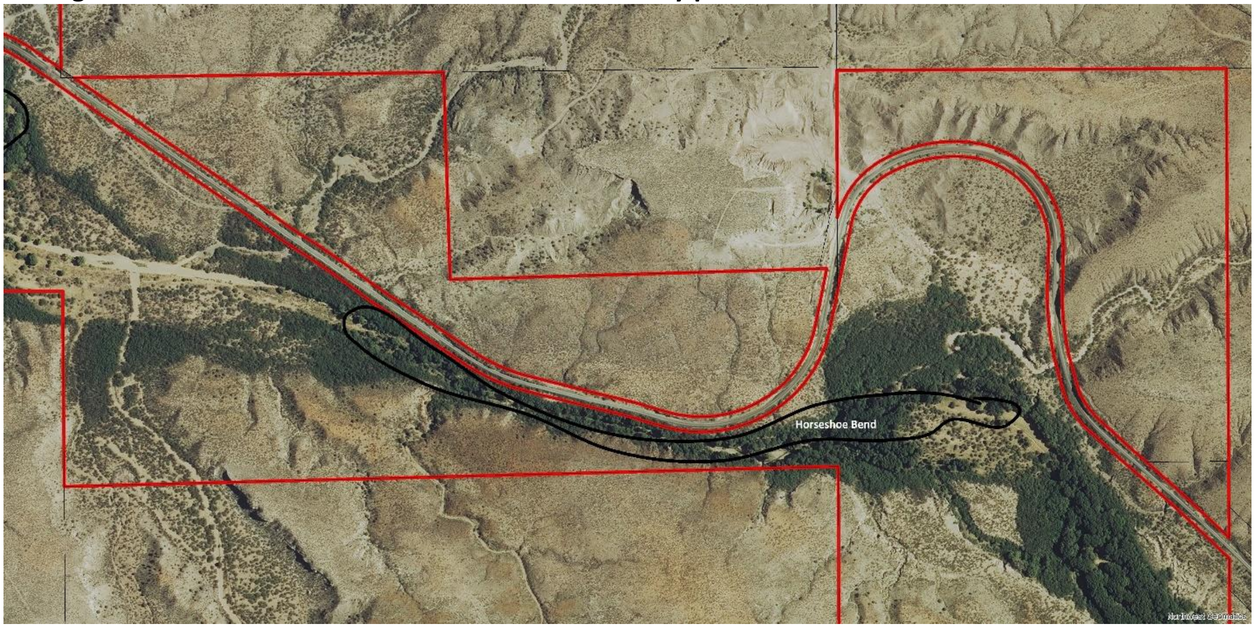
Cienega Creek Natural Preserve. Three bridges survey patch circled.



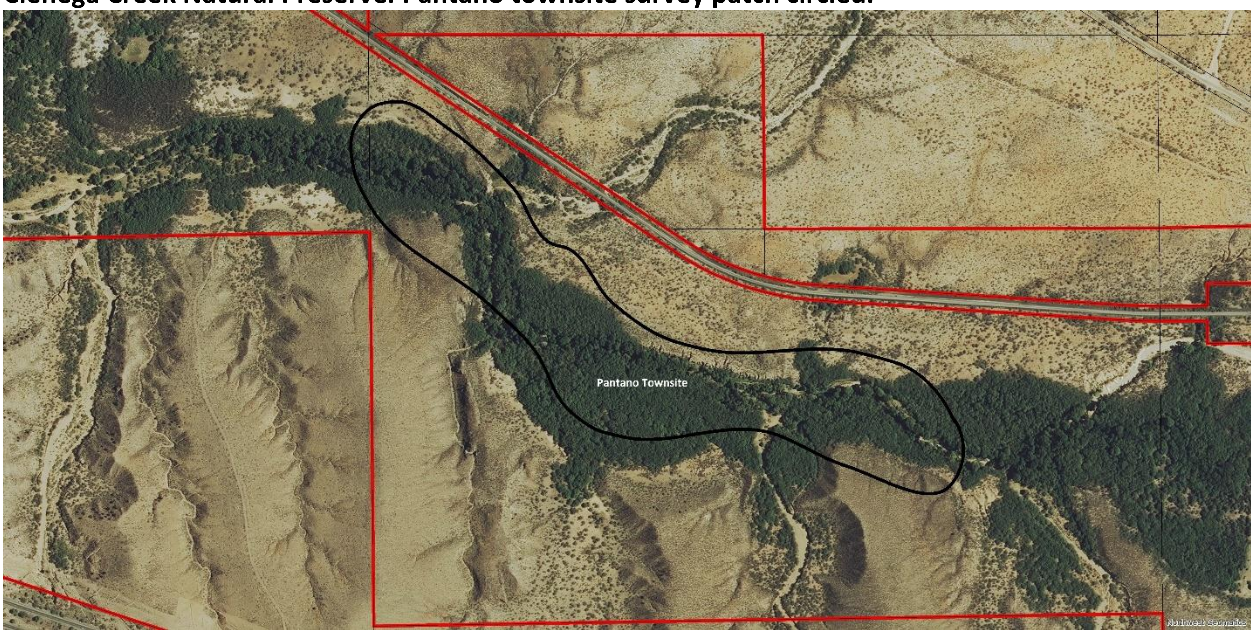
Pima County SWFL Survey 2017 - Cienega Creek Preserve East Section



Cienega Creek Natural Preserve. Horseshoe bend survey patch circled.



Cienega Creek Natural Preserve. Pantano townsite survey patch circled.



Pima County
Multi-species Conservation Plan:
2017 Annual Report

Appendix 12

Groundwater Level Monitoring Report –

June 2016 to June 2017

GROUNDWATER LEVEL MONITORING REPORT
JUNE 2016 to JUNE 2017

Prepared by
PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT
Water Resources Division
David Scalero, Principal Hydrologist
Frank Postillion, Chief Hydrologist
December 2017

Cover photos: Stressed cottonwood trees June 8, 2016 vs June 1, 2017. Vegetation in the more recent photograph shows improvement but the trees remain under stress.

Executive Summary

Overview

The Water Resources Division of the Pima County Flood Control District (District) monitors groundwater levels within various watersheds to help assess the effects of climate and land use changes on the overall health of floodplains in Eastern Pima County. The Santa Cruz River at Canada Del Oro Wash and Rillito Creek confluences (CTRDN), Canada Del Oro Wash in Catalina (CDO), Santa Cruz River at Canoa Ranch, Cienega Creek at Cienega Creek Natural Preserve (CCNP), and Tanque Verde Creek at Sabino Canyon and Agua Caliente Wash confluences were evaluated based on the presence of significant natural and recreational values. Precipitation and stream flow data are included in this assessment to evaluate the interconnection between surface water and groundwater. Data collection is by various means, including manual water level measurements, downloading water levels from installed dataloggers and accessing centralized databases that gather water level, precipitation and stream flow data from automated systems.

As of June 2017, there continues to be a few areas of shallow groundwater (water levels above 50 feet below land surface) in the region. A shallow groundwater area exists along Cienega Creek from Pantano Jungle to Pantano Dam (~9 miles) and along Davidson Canyon from Davidson #2 well down to the confluence with Cienega Creek (~1.5 miles) and may extend further upstream along Davidson Canyon based on the intermittent presence of surface water at Davidson Spring (~1 mile upstream of Davidson #2 well). Monitor wells indicate two shallow groundwater areas along Tanque Verde Creek between Soldier Trail and Houghton Road (~2.2 miles) and from Tanque Verde Road to just downstream of Sabino Canyon Road (~1.6 miles). These two areas may be larger based on factors other than well water levels (i.e. riparian vegetation, intermittent stream flow, etc.).

Groundwater levels have recovered in many of the areas since 2014, with averages ranging from 7.6 feet (2.5 feet/year) at CCNP to just over 18 feet (6 feet/year) along the Tanque Verde at Agua Caliente Wash confluence. Much of the recovery is due to precipitation and associated streamflow runoff/recharge and mountain front recharge. Reduced pumping at the downstream end of Cienega Creek (50% since 2014), along Canoa Ranch (~80% since 2013) and in the Sabino/Tanque Verde and Agua Caliente/Tanque Verde confluences (40-50% since 2000) has most likely helped water level recovery in these areas.

The CDO near Catalina is the one area that continues to see groundwater declines, with an average of -8 feet (-2.67 feet/year) for seven wells since 2014. This may be predominantly due to continued groundwater pumping for the community of Saddlebrooke and surrounding developments, which has averaged almost 3,200 acre-feet per year since monitoring began in 2009.

There continues to be a long-term downward trend in groundwater levels for most of the areas since 1995, with average annual declines ranging from about 0.5 feet at the Cienega Creek Natural Preserve and the Tanque Verde Creek-Sabino Creek confluence to a little over three feet along the SCR at Canoa Ranch. Although there have been a few high flow volume years along these watercourses since 1998, these have been bracketed by many low flow volume years. Coupled with high volumes of pumping, which only recently have declined in most areas, several years of below average precipitation and low annual flow volumes have negatively affected groundwater levels in the region. Continued monitoring will tell whether the more recent recoveries are a good sign for things to come or just a temporary delay in a downward trend.

The District continues to maintain permanent water level dataloggers in six wells at the Cienega Creek Natural Preserve and in five wells along the CDO in the Catalina Regional Park. Over the next fiscal year, District staff plans to install water-level dataloggers in two wells at CTRDN and in two wells at Canoa Ranch. Water levels will be measured on a semi-annual basis for those wells not equipped with dataloggers. District staff continues to gather automated data from ADWR and City of Tucson (Tucson Water) for wells maintained by these agencies at the downstream end of Cienega Creek, at Canoa Ranch and along Tanque Verde Creek near the Sabino Creek and Agua Caliente Wash confluences. Staff also continues to collect U.S. Geologic Survey and District (ALERT) gauges for precipitation and stream flow data to evaluate surface water and groundwater connectivity. The District is cooperating with groups such as Watershed Management Group and others to educate well owners in these shallow groundwater areas on the benefits of water conservation in order to conserve on pumping and capture local on-site water with passive water harvesting to help increase local recharge and recovery of water levels.

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Introduction

Groundwater level monitoring in eastern Pima County is being performed to evaluate the possible effects climate and land use changes are having on local groundwater levels within various watersheds of the Santa Cruz River Basin. This activity is one component of a comprehensive watershed management program, currently under development by the Pima County Regional Flood Control District (District). The comprehensive watershed management program will help assess the overall health of watersheds in Eastern Pima County.

Groundwater levels are currently measured in areas having significant natural resource values, including shallow groundwater and important riparian habitat, improved floodplain function as well as passive recreational interest. Shallow groundwater areas are defined as having groundwater levels 50 feet or shallower below land surface; and often sustain important riparian vegetation including cottonwoods, willows and old-stand mesquites. The wells measured are primarily on Pima County properties, but some are privately owned. Some information on well levels is provided by other agencies, including the Arizona Department of Water Resources and the City of Tucson (Tucson Water).

The groundwater level information in this report describes the results of field measurements taken from June 2016 through June 2017 at the following locations:

- Santa Cruz River at Corazon de Tres Rios Del Norte
- Canada del Oro Wash near Catalina, Arizona
- Santa Cruz River at Canoa Ranch
- Cienega Creek at Cienega Creek Natural Preserve,
- Tanque Verde Creek near it's confluence with Sabino Creek, and
- Tanque Verde Creek near it's confluence with Agua Caliente Wash.

Precipitation and stream flow measurements were used to evaluate the interconnection between surface water and groundwater in the areas of interest. The precipitation and stream flow data were obtained from the District's Automated Local Evaluation in Real Time (ALERT) system and the U.S. Geologic Survey (USGS) Water Resources Department. Stream gauges operated by the District are primarily used for flood threat recognition and do not necessarily measure low flows. Within the last few years the District has begun modifying its stream gauges in the above referenced study areas to measure low flows. Gauges operated by the USGS are designed to measure both low and high flows.

Santa Cruz River at Corazon de Tres Rios Del Norte

The Corazon de Tres Rios Del Norte (CTRDN) is made up of the area encompassing the confluences of the Rillito and Canada del Oro Wash (CDO) with the Santa Cruz River (SCR), and is an important regional location for water resources management, recharge, flood control and public recreation. Pima County has planned the CTRDN for future flood control; environmental enhancement, public recreation and groundwater recharge activities.

Water levels were measured quarterly at the following monitor wells and one piezometer well (**Figure 1**):

- MW-1 - South bank of Rillito, approximately 900 feet west of SCR confluence
- MW-2 - West bank of SCR, approximately 0.5 mile upstream of CDO confluence
- PZ-1 - Approximately 160 feet West of MW-2
- Sunset Pit 1 – North of Curtis Street, just West of I-10 Frontage Road
- Sunset Pit 2 – Along Silverbell Road, between Curtis Street and Sunset Road
- Orange Grove Pit 1 – Along Silverbell Road, just South of Orange Grove Road

This is the third consecutive year that water levels have recovered in the above wells. In June 2017, MW-1 had a total depth to water of 127.9 feet below land surface (bls), a recovery of 3.1 feet since June 2016. Similarly, MW-2 had a depth to water of 108.8 feet bls, 1.2 feet higher than June 2016. Despite these recent recoveries, water levels in these wells have declined at an average of 0.32 to 1.04 feet per year (1.6 to 5.2 feet total) since they were drilled in May 2012. Two of the other monitoring wells, Sunset Pit 1 and Orange Grove Pit 1, showed water level recoveries of 6.3 feet and 1.2 feet respectively since June 2016. Sunset Pit 2 well was abandoned in April 2017 due to new bridge construction, but did show signs of recovery from June 2016 to April 2017 (1.6 feet).

Shallow Piezometer PZ-1, considered to be in a perched water table area, was dry throughout the 2016/2017 Fiscal Year (FY16/17). The area near PZ-1 may be affected by clay lenses that will temporarily store water from localized tributary flows from the Tucson Mountains and by large SCR flood flows. Adjacent vegetation includes cottonwood trees, good indicators of shallow or perched groundwater conditions at this site. Typically, cottonwood trees need relatively shallow groundwater (above 15 feet bls) to flourish, unless supplemented with outside irrigation. The highly stressed tree (presence of yellow leaves and fewer leaves overall) from June 2016 is looking healthy in June 2017, suggesting that perched water levels in the area may have risen to a point where the tree can survive (see comparison images on cover), even though there was no indication from PZ-1.

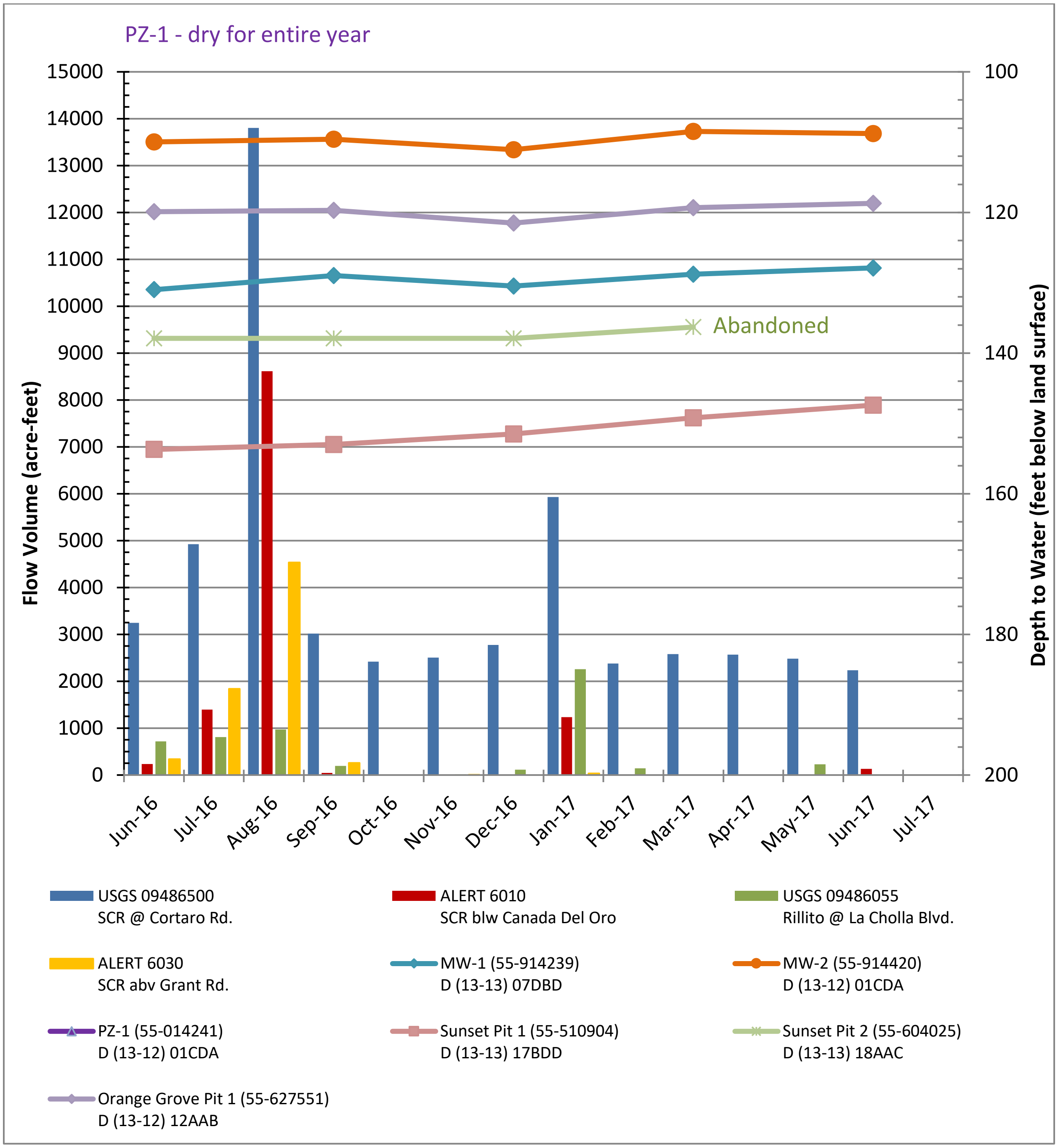
Figure 1. Map of Wells in the Corazon Tres Rios Del Norte

Illustration A-1 shows a comparison between quarterly groundwater levels at CTRDN and flows along the SCR and Rillito over the last year. This includes two new stream gauges installed along the SCR in July 2015: ALERT 6030, SCR above Grant Road, and ALERT 6010, SCR below CDO confluence. A small rise in water levels (0.0-2.0 feet) in September 2016 was likely due to significant volumes of flow along the SCR in June through August 2016, with over 8,600 acre-feet measured at the ALERT 6010 gauge in August 2016. All three wells with shallower water levels declined a little from September to December 2016 as drier conditions prevailed. Modest flow volumes (1,000-2,000 acre-feet) along the SCR and Rillito in January, however, produced a water level recovery of 2.3-4.1 feet from December 2016 to June 2017. The higher levels of recovery in the Winter 2017 compared to the Summer 2016, despite significantly lower flow volumes, provides further evidence that more recharge in the area occurs during the winter, when flows occur over a longer duration and when pumping is reduced by Tucson Water and others.

Since well monitoring is on a quarterly basis, it is possible groundwater levels may rise and fall between the months they are measured due to recharge from storm water events occurring in the normally dry tributary washes and inconsistent effluent base flow on the SCR. Staff installed water level data loggers in MW-1 and MW-2 in October 2017 to obtain daily water-level measurements and to better assess the effects of effluent and storm-water recharge.

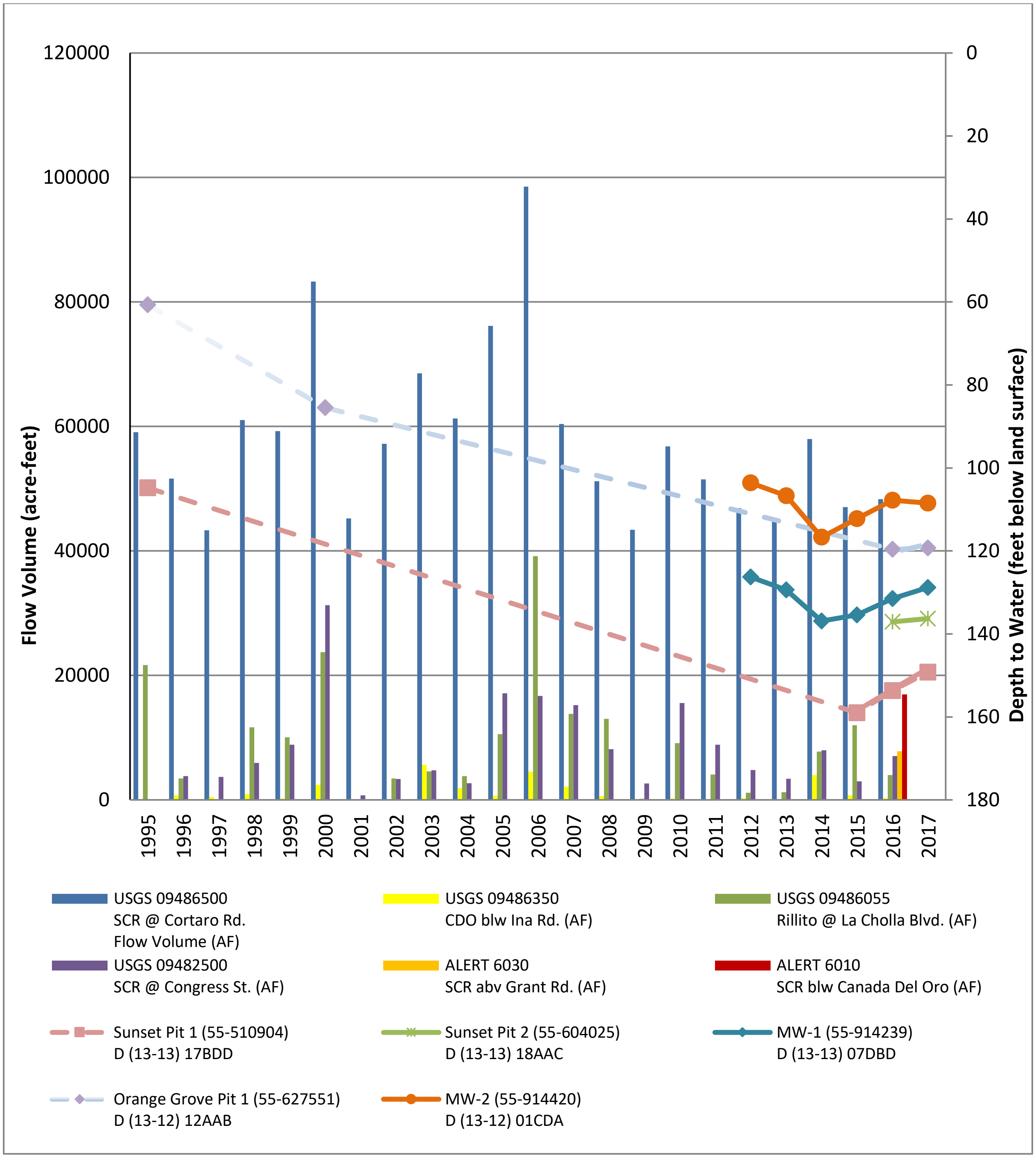
Illustration A-2 shows annual groundwater levels for all of the monitoring wells in the CTRDN compared to measured stream flow volumes since 1995. Annual water levels were generally measured during the Winter Season, sometime between late-December and early-March. Data during this time period is very sparse, with only two wells having been measured before 2012 and only the newly constructed wells (MW-1, MW-2 and PZ-1) monitored on a regular basis from 2012 to present time. Overall, groundwater levels in this area appear to be trending significantly downward since the mid-1990s based on the data from Sunset Pit 1 and Orange Grove Pit 1 wells. Although both MW-1 and MW-2 show an overall decline in the water table since 2012, recent data shows levels continuing to trend upward since 2014 at 2.7 feet/year. The base effluent flow is generally around 40,000 AF/year past Cortaro Bridge gage, and amounts above that are flood flows that tend to enhance recharge in the SCR. In addition, effluent flows on the SCR have had significant water quality improvement since mid-2014, increasing the ability of the effluent to recharge the riverbed. The 2014 summer flood flows were also very large, with one flood peaking at over 20,000 cfs, helping to scour the river bottom and remove previously channel particle clogging bio-solids or smutzdecke.

Illustration A-1: Monthly Flow Volumes vs. Groundwater Levels at Corazon de Tres Rios del Norte, June 2016 – June 2017



Note: Bottom of PZ-1 is 21.7 feet below land surface (bls); there were no water level measurements recorded above that depth during the Fiscal Year.

Illustration A-2: Annual Flow Volumes vs. Groundwater Levels at Corazon de Tres Rios del Norte, 1995 – 2017



Note: Dashed lines represent unknown movement in groundwater levels due to lack of data.

Canada Del Oro Wash near Catalina, Arizona

Following the 2003 Aspen Fire in the Santa Catalina Mountains, the District acquired a large portion of floodway and floodplain of the Canada Del Oro Wash (CDO) between Edwin Road and the Catalina State Park through its Floodplain Land Acquisition Program. Several of the acquired properties had wells that approached historical shallow groundwater conditions and still measure between 50 to 100 feet bls. The floodway in this area is now a resource conservation natural park, and groundwater levels in the area have the potential for recovery to above 50 feet bls, provided wetter conditions prevail and nearby municipal pumping is moderated.

Groundwater levels were measured on a quarterly basis beginning in 2009 in the following wells along the Canada Del Oro Wash (**Figures 2A and 2B**):

- Rancho Solano – West bank of CDO, ~ 0.3 mile North of Saddlebrooke
- Danforth – Near west bank of CDO, ~ 400 feet South of Pinal County Line (Edwin Road)
- Coleman – West bank of CDO, ~ 400 feet South of Cloud Nine Drive
- Milne North – West bank of CDO, ~ 650 feet South of Hawser Street and Lago Del Oro Parkway intersection
- Milne South – West Bank of CDO, ~ 775 feet South of Hawser St. and Lago Del Oro Parkway intersection
- Turney – West bank of CDO, ~ 425 feet Southwest of Milne South Well
- Yankovich – West bank of CDO, ~ 450 feet South of Wilds Road
- Trotter – West Bank of CDO, near intersection of Trotter Place and Lago del Oro Parkway
- Branch – West Bank of CDO, ~ 400 feet North of Pima Pistol Club Inc.

Over the last year, water levels recovered in most of the upstream wells (wells near and north of the Pinal County line), but declined in all of the downstream wells. In June 2017, depths to groundwater in this area ranged from 86.3 feet bls (Milne South Well) to almost 126 feet bls (Branch Well). Differences in water levels from June 2016 to June 2017 ranged from -2.1 feet (Yankovich Well) to +7.0 feet (Danforth Well).

Illustration B-1 shows a comparison of groundwater levels and flows along the CDO Wash from June 2016 to June 2017. A moderate flow volume (greater than 300 acre-feet) occurred along the CDO at Rancho Solano during the month of September 2016, with smaller amounts (less than 150 acre-feet) occurring in November and December 2016. The stream gauge at Golder Ranch Drive recorded small volumes of flow in June 2016 and September 2016. It is most likely that the Winter flows in the upstream portion of the area helped reduce the steady decline of groundwater levels measured in the lower watershed since regular monitoring began in 2009.

Figure 2A. Map of Wells along the Canada Del Oro Wash in Catalina, Arizona

Figure 2B. Map of Wells along the Canada Del Oro Wash in Catalina, Arizona

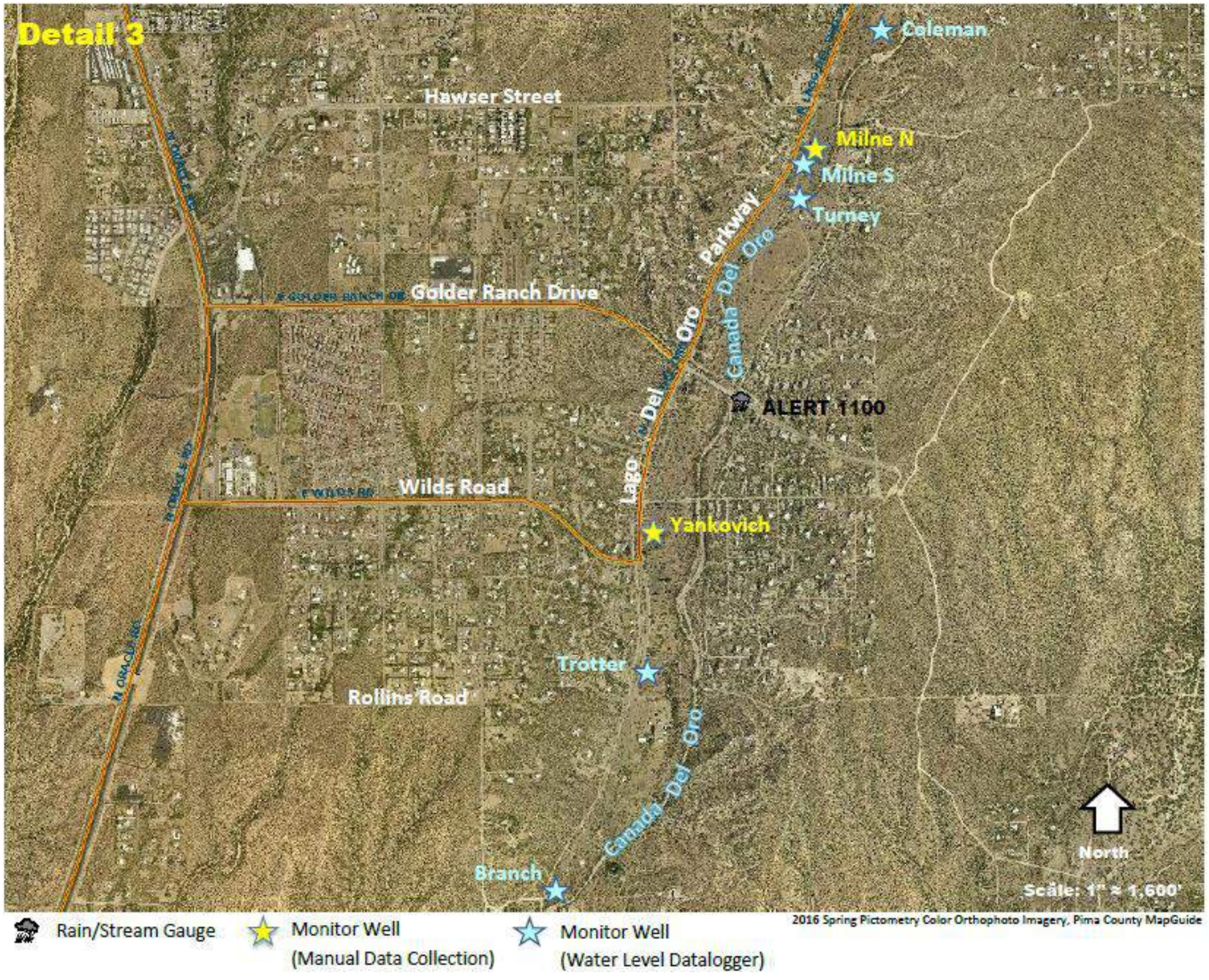
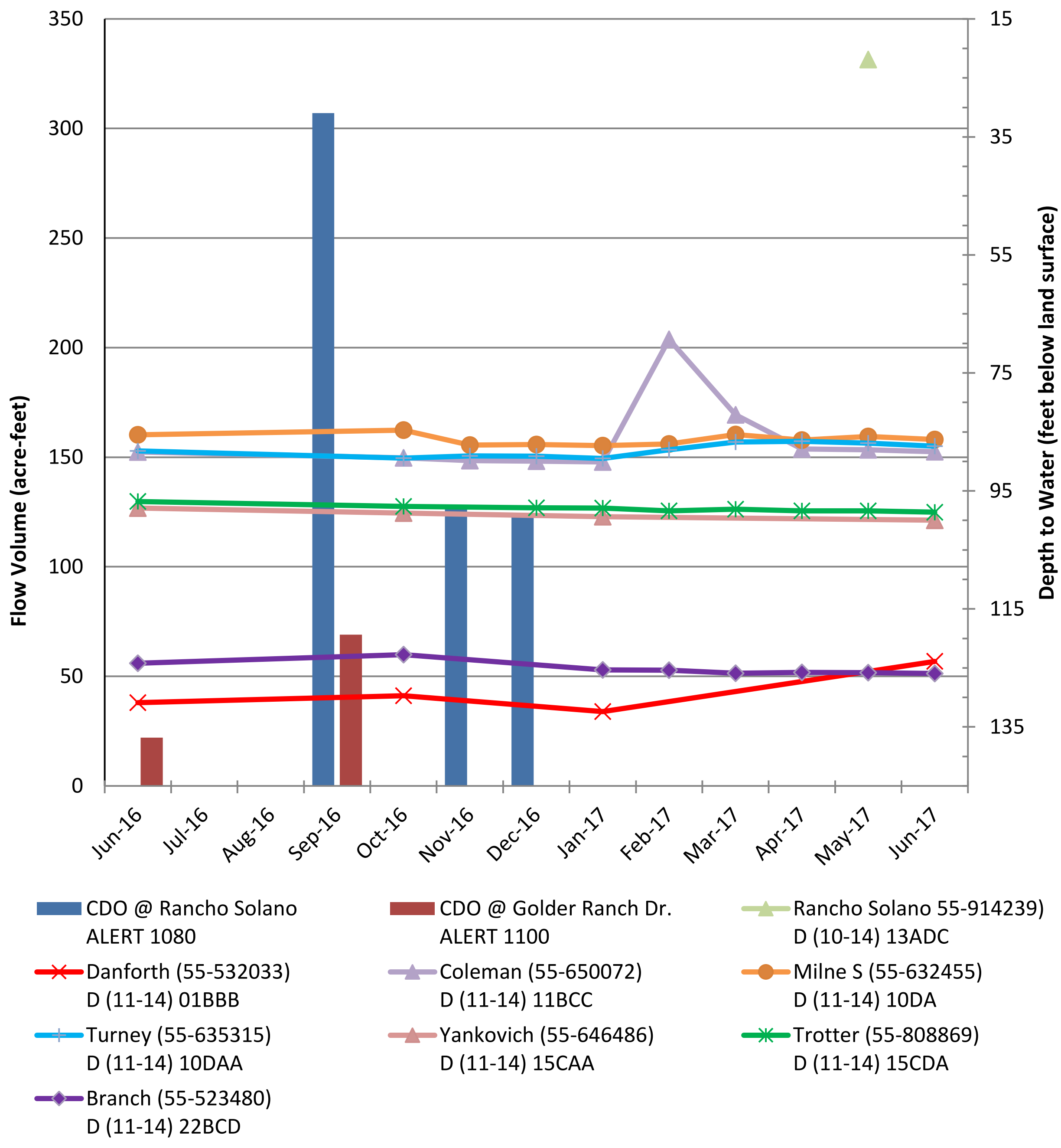


Illustration B-1: Monthly Flow Volumes vs. Groundwater Levels along the Canada Del Oro Wash in Catalina, June 2016 - June 2017



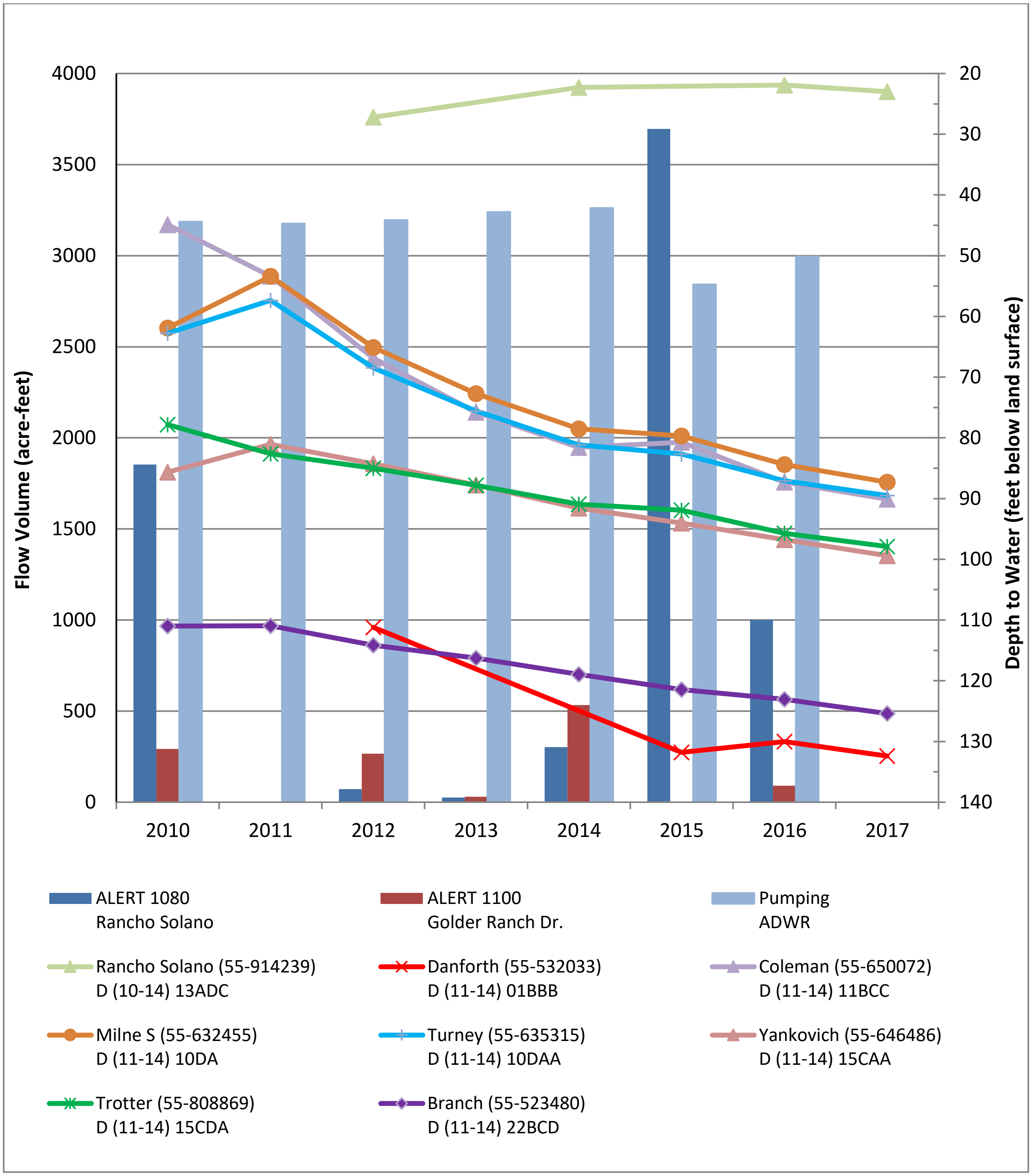
Note: The measurement for Rancho Solano Well is estimated due to flow level in the adjacent creek. This well could not be measured due to an obstruction at about 22 feet bls.

Annual water-level measurements from March of each year since 2009 were used for **Illustration B-2**. After a brief water-level recovery from November 2009 to June 2010, due to in-channel recharge from significant winter flows along the CDO, water levels have been predominantly declining in the area downstream of Rancho Solano. Rancho Solano is currently the only site where the water levels have been consistently above 50 feet bls, suggesting the shallow groundwater area does not extend beyond the community of Saddlebrooke. The Rancho Solano Well had an obstruction in May 2017 and could not be measured. The level was estimated based on the vertical difference from the well head and flowing water in the CDO. The combination of well pumping in the Saddlebrooke area (~ 3,000 AF annually) and near Golder Bridge plus the lack of significant surface flows at Golder Ranch Drive since 2009 have resulted in average groundwater level declines of about 3-6 feet per year North of Golder Ranch Drive and about 1.5-2.5 feet per year South of Golder Ranch Drive. The largest decline for the area occurred at Coleman Well, which is the closest monitor well to the pumps that serve Saddlebrooke and the surrounding developments, approximately 1.2 to 2.0 miles.

Annual precipitation in Calendar Year 2016 (CY2016) for the area ranged from 9.4 inches just north of Saddlebrooke (Golder Ranch) to 15.94 inches near Charouleau Gap in the Santa Catalina Mountains (Cherry Spring), based on records provided by the District's ALERT rain gauges (**Table 1**). The gauges at Rancho Solano, Golder Ranch and Golder Ranch Drive reported 1.78-2.34 inches below the average reported over the last 20 years, when drought conditions have prevailed over Eastern Pima County, while the gauges at Cherry Spring and Dodge Tank reported about 0.5 to just under 2 inches higher than average totals over the same period. It appears that the increase in rainfall over the mountains has had some effect on rising water levels in the upstream portion of the CDO (above Golder Ranch Drive), but not enough rainfall has fallen to produce stream flows needed to recharge the CDO and increase water levels below Golder Ranch Drive.

Staff installed water level data loggers in the Coleman, Milne S, Turney, Trotter and Branch Wells in October 2016. These dataloggers provide daily data (every 6 hours) to determine any fluctuations due to surface water flows. Unfortunately, there were no flows recorded along the CDO at Golder Ranch Drive since the time of their installation.

Illustration B-2: Annual Flow Volumes vs. Groundwater Levels along the Canada Del Oro Wash in Catalina, 2009 - 2017



Note: Flows in CY2016 were through June.

Table 1. Precipitation records from gauges surrounding the well monitoring area along Canada Del Oro Wash.

Year	Precipitation (inches)				
	Golder Ranch Rd. ALERT #1100	Dodge Tank ALERT #1040	Cherry Spring ALERT #1050	Golder Ranch ALERT #1010	Rancho Solano ALERT #1080
1986	14.06	16.24	19.96	15.72	18.35
1987	10.49	9.5	16.07	11.89	15.37
1988	12.3	11.47	13.56	9.75	14.53
1989	6.82	6.29	10.06	6.63	6.05
1990	17.2	17.63	23.5	15.39	20.16
1991	10.2	11.54	14.65	11.5	13.82
1992	14.09	17.24	27.17	18.74	24.33
1993	13.82	21.93	28.11	17.32	22.32
1994	11.73	13.7	17.56	8.27	17.24
1995	9.09	10.11	12.64	6.34	7.24
1996	8.56	9.41	13.26	No Data	10.94
1997	11.69	11.97	14.02	10.08	13.7
1998	18.5	18.74	21.92	22.8	23.58
1999	12.6	13.27	17.52	12.24	13.74
2000	12.95	15.51	16.14	14.8	14.53
2001	12.36	11.38	15.35	13.94	13.82
2002	7.05	8.62	6.81	7.2	6.85
2003	8.9	10.24	13.58	11.77	14.13
2004	12.64	15.28	16.77	13.7	10.87
2005	12.83	13.94	14.25	11.02	10.75
2006	11.38	11.81	15.39	8.98	13.54
2007	12.32	16.54	20.51	14.65	19.09
2008	13.46	14.45	17.13	13.11	16.77
2009	7.76	10.43	9.92	10	10.04
2010	15.43	20.28	19.68	16.02	17.17
2011	11.18	12.48	15.08	9.84	13.39
2012	12.62	13.49	16.14	12.83	15.65
2013	8.31	11.1	10.87	12.4	14.25
2014	12.64	13.7	15.51	13.19	13.98
2015	13.90	17.33	18.82	10.81	16.51
2016	9.40	15.52	15.94	10.73	11.96
Overall AVG	**11.82**	**13.59**	**16.38**	**12.39**	**14.67**
1986-1994 AVG	**12.30**	**13.95**	**18.96**	**13.37**	**16.91**
1996-2016 AVG	**11.74**	**13.59**	**15.46**	**12.51**	**13.06**

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Santa Cruz River at Canoa Ranch

Canoa Ranch, in southern Pima County near the Santa Cruz County line, includes the floodplain and terraces of the SCR. Pima County purchased the 4,800 acre Canoa Ranch in 2001, and it has become an area of interest for flood control, environmental enhancement, recreational development and groundwater recharge activities. District staff performed a water resources study of Canoa Ranch and vicinity evaluating the impacts of pumping and climate on this shallow groundwater area (Postillion, et al, 2013). The report recommended regular monitoring of groundwater levels in strategic on-site wells and after moderate to large flow events in an effort to further understand the relationship between recharge and recovery on groundwater levels on the Ranch.

In October 2014, the District began to manually measure water levels quarterly in two on-site wells. At the same time, District staff started collecting data from ADWR's Groundwater Site Inventory (GWSI) database for two other wells in the area that are equipped with automated groundwater level sensors. Another monitor well was added after a field investigation in March 2016. All five wells are adjacent to the SCR at the following locations (**Figure 3):**

- Ranch HQ - West bank of SCR at Canoa Ranch Headquarters
- Canoa 16 - East bank of SCR ~ 1.9 miles downstream of Elephant Head Road Bridge (ADWR automated sensor)
- Canoa 15 – East bank of SCR ~ 1.4 miles downstream of Elephant Head Road Bridge
- Canoa 13 – Along Elephant Head Road ~ 0.4 mile West-Northwest of SCR (ADWR automated sensor)
- Canoa 14 – Near Elephant Head Road ~ 0.33 mile East-Southeast of SCR

Water levels in the wells varied as a response to pumping and some recharge. In June 2017, depths to water in these wells ranged from 78.2 feet bls (Canoa 15) to 134.5 feet bls (Standpipe). The Standpipe Well did show a decline of 0.7 feet in water level over the last year, while the remaining five wells had recoveries ranging from 0.33 feet to 3.8 feet. Canoa 15 and 16 continue to show recovery in the central portion of the Canoa Ranch properties, which is most likely the result of reduced pumping since 2014 of the nearby Freeport McMoran Mine supply wells.

Illustration C-1 shows a comparison of groundwater levels and flows along the SCR near Elephant Head Road from June 2016 to June 2017. All of the wells show recovery after a couple of moderate flow volumes (~ 1,500 acre-feet) in August and September 2016, with the Ranch HQ Well showing the largest recovery of almost 9 feet and Canoa 16 showing a small recovery of only 0.27 feet. The Ranch HQ Well is pumped at times to supply water to the ranch, so the dramatic increase may be due to reduced pumping of this well in addition to increased water recharge in the area. After a dip in water levels in December 2016 (0.02-2.8 feet), water levels rose some by March 2017 (0-0.4 feet). Water levels remained fairly steady from March to June

Figure 3. Map of Wells along the Santa Cruz River at Canoa Ranch

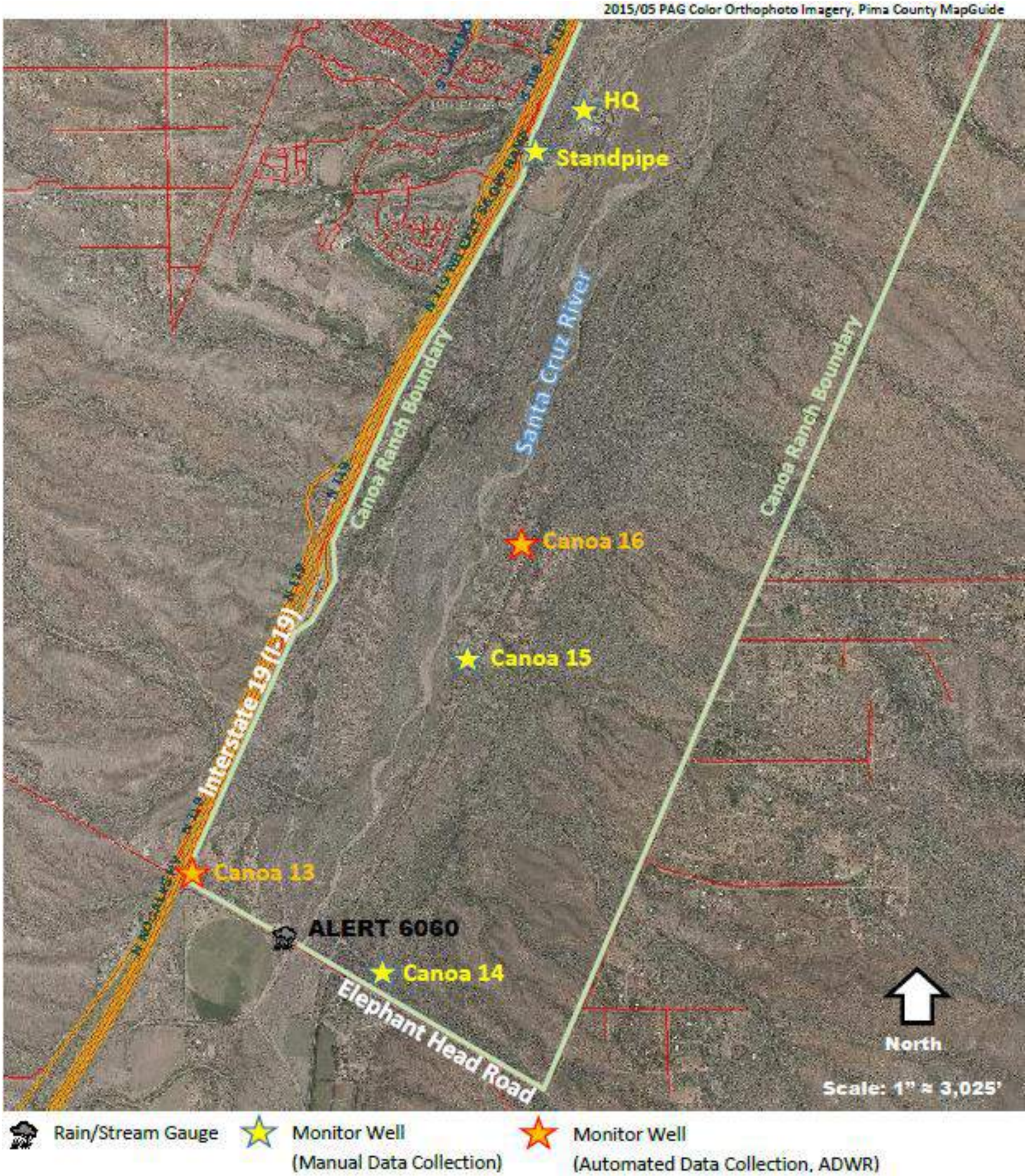
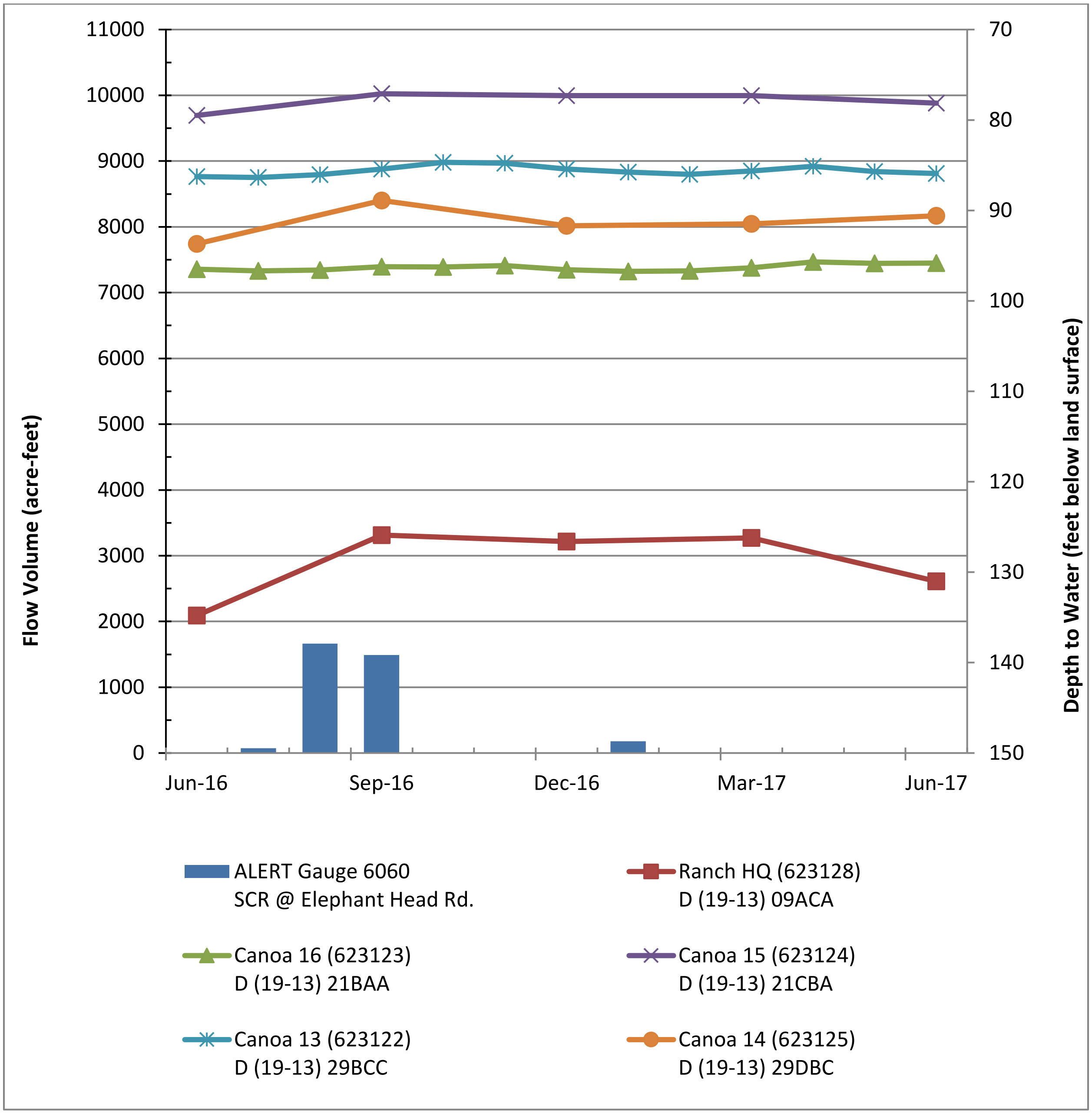


Illustration C-1: Monthly Flow Volumes vs. Groundwater Levels at Canoa Ranch, June 2016 - June 2017



2017, except near the Canoa Ranch Headquarters, where levels fell 2.2 feet at the Standpipe Well and 4.8 feet at the Ranch HQ Well. This is mostly likely due to pumping at the Ranch HQ Well during the dry Spring months (April through June).

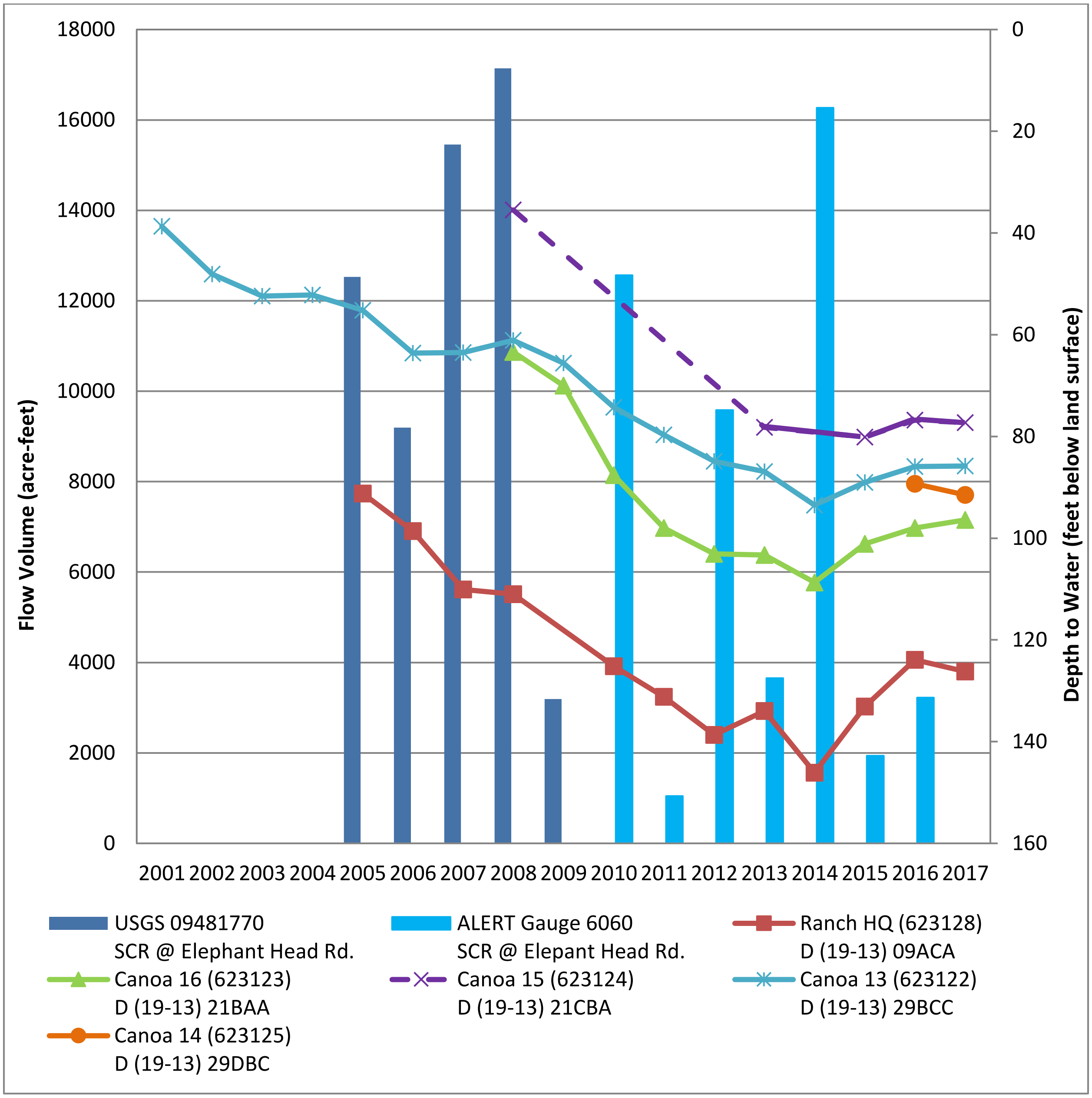
Illustration C-2 shows a comparison between groundwater levels at Canoa Ranch and stream flows recorded at Elephant Head Road since CY2000, when automated measurements at Canoa Well 13 were first recorded by ADWR. Overall, groundwater levels appear to be trending downward in the Canoa Ranch area since 2001, as shown by long-term data recorded at the Canoa 13 and Canoa 16 wells. Based on a well water level decline of about 47 feet (about 3 ft/yr) from 2001-2017, shallow groundwater has been depleted in the vicinity of Canoa 13 well. Groundwater levels recovered for a year or two after significant runoff volumes in 2007, 2008 and 2014. Limited groundwater data in this area to date makes it difficult to accurately determine surface water and groundwater interactions.

In the last eleven years, moderate flood events and higher-than-normal cumulative annual flows from 2005-2008 and in 2014 helped produce a temporary cessation of water-level declines in wells near the SCR at Canoa Ranch. Significantly reduced flow volumes in 2009, 2011, 2013 and 2015-2016 made the earlier water-level stabilization events temporary. Average declining rates of about 3 ft/yr have been the norm at the Ranch HQ and Canoa 13 Wells since 2005.

Water levels in all of the monitoring wells have made significant gains from 2014-2016 due to a large reduction in pumping from the Freeport-McMoran production wells in the vicinity (**Illustration C-3**) and large flood flows in 2014. Continued monitoring will help to evaluate how important this reduction in groundwater withdrawals is to the recovery of the groundwater table at Canoa Ranch.

Annual precipitation in CY2016 for the area surrounding Canoa Ranch ranged from 7.7 inches at Continental Road to over 22 inches in the Santa Rita foothills (**Table 2**). These totals were significantly lower than the previous year, which could account for annual declines in some of the wells and only slight recoveries in the others despite the dramatic reduction in pumping in the area. Comparisons of 2016 rainfall amounts to averages over the period of record (since 1986) varied widely in the gauges, ranging from -2.17 inches at Tinaja Ranch (Sierrita Mountain Foothills) to +4.31 inches at Florida Canyon (Santa Rita Mountain Foothills).

Illustration C-2: Annual Flow Volumes vs. Groundwater Levels at Canoa Ranch, Calendar Years 2001-2017



Note: USGS Gauge 09481770 was decommissioned at the end of September 2009, so flow records from ALERT Gauge 6063(at same location) were used since this time.

Illustration C-3: Groundwater Withdrawals (Freeport-McMoran) vs. Groundwater Levels at Canoa Ranch, Calendar Years 1984-2017

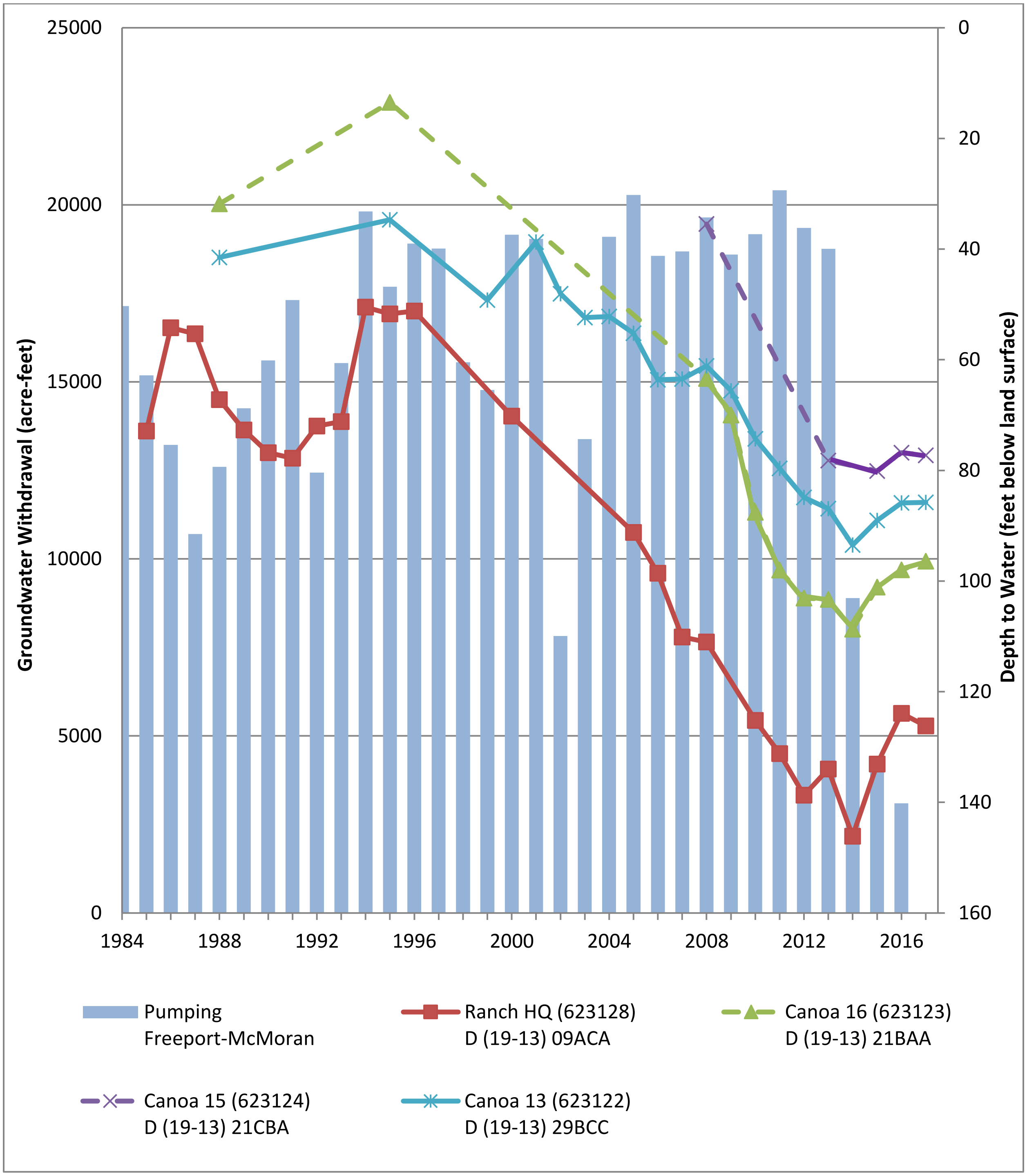


Table 2. Precipitation records from gauges surrounding Canoa Ranch.

Year	Precipitation (inches)						
	SCR @ Tubac ALERT #6080	SCR @ Canoa ALERT #6060	Elephant Head Butte ALERT #6350	Florida Canyon ALERT #6390	Tinaja Ranch ALERT #6320	Keystone Peak ALERT #6310	Continental Road ALERT #6050
1986							IR
1987		8.21				IR	9.85
1988		12.51	IR			12.74	10.4
1989		IR	10.06		IR	7.03	6.16
1990		15.91	19.69		19.13	14.37	15.55
1991		11.18	13.46		7.72	10.27	10.2
1992		14.84	19.17		17.05	16.06	13.11
1993		16.88	16.85		10.35	17.72	17.48
1994		13.86	14.21		16.65	12.83	12.87
1995		8.26	7.83		14.25	10.75	6.93
1996		7.56	10.12		11.69	7.99	6.34
1997	IR	9.96	12.64		11.5	9.84	11.93
1998	13.22	8.58	14.53		17.87	9.61	12.17
1999	9.49	8.94	10.71		13.35	12.32	9.53
2000	16.69	13.74	16.69		19.25	15.94	14.84
2001	14.61	9.33	15.91		13.62	11.14	11.81
2002	8.23	7.99	7.87		9.49	8.03	8.07
2003	12.05	11.18	12.68	15.43	13.35	15.51	10.04
2004	7.48	5.39	8.07	13.46	9.21	8.23	7.87
2005	14.49	9.33	8.98	12.13	9.53	12.48	8.07
2006	15	9.25	11.02	19.29	9.21	14.29	8.7
2007	10.83	9.17	15.39	20.08	9.61	14.72	6.1
2008	16.69	10.75	13.9	16.5	11.69	12.72	13.35
2009	10.55	6.69	8.58	10.55	5.55	9.25	6.18
2010	15.04	11.27	15.31	25	13.46	12.49	12.34
2011	10.79	9.53	11.14	17.91	14.84	15.37	11.3
2012	11.85	10.08	9.92	16.89	10.87	11.81	6.57
2013	11.18	9.57	6.14	17.28	11.02	14.25	7.83
2014	11.97	12.6	10.91	20.28	13.19	20.2	8.43
2015	19.96	13.62	15.57	24.29	18.14	16.40	10.28
2016	10.80	10.14	11.80	22.26	10.11	11.87	7.70
Overall AVG	**12.68**	**9.85**	**11.85**	**17.95**	**12.28**	**12.98**	**9.54**
1986-1994 AVG	**--**	**11.94**	**15.57**	**--**	**14.18**	**13.00**	**11.95**
1996-2016 AVG	**12.68**	**9.75**	**12.09**	**17.95**	**12.55**	**12.59**	**9.50**

IR = Incomplete Record

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Cienega Creek at Cienega Creek Natural Preserve

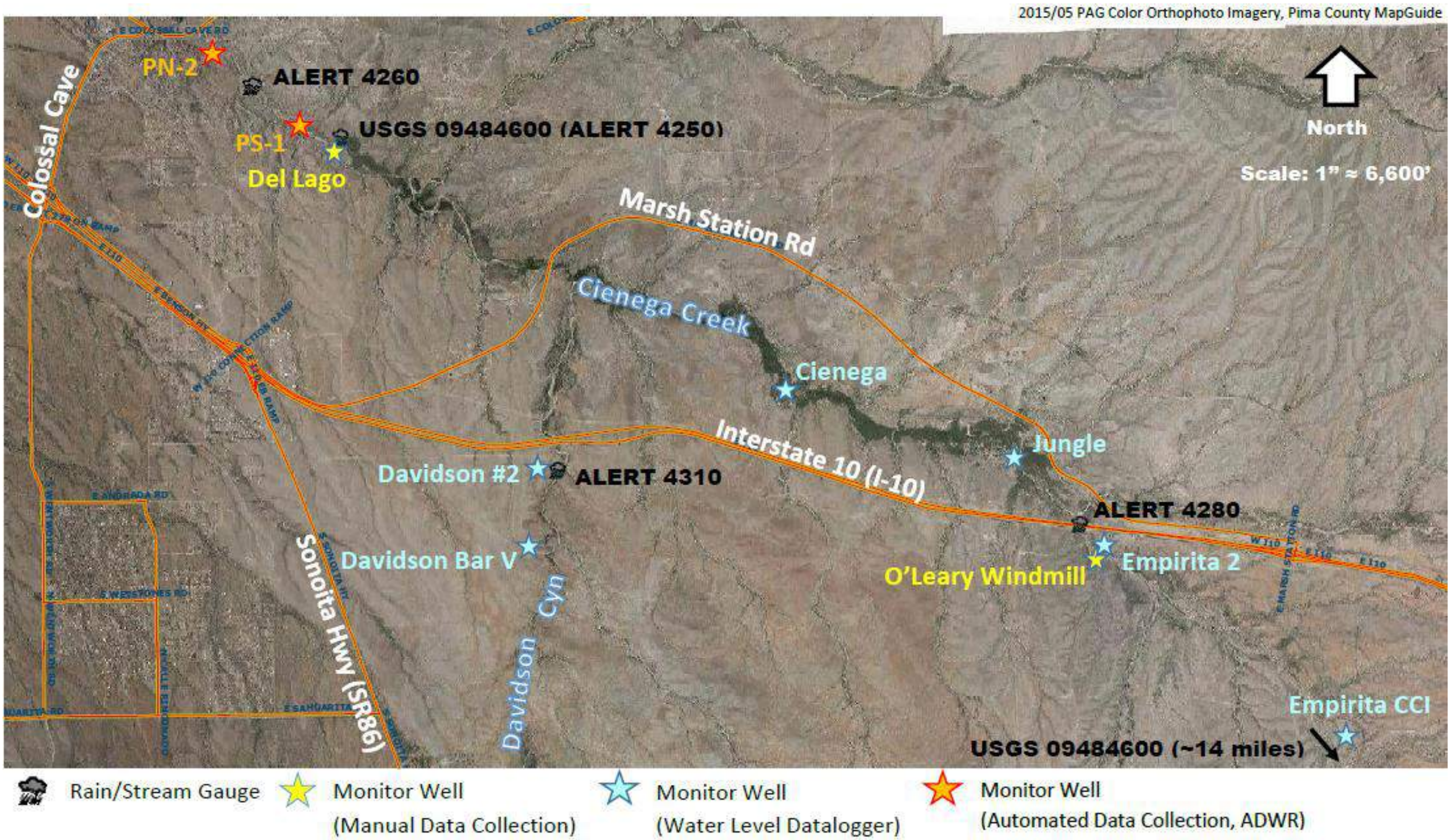
The Cienega Creek Natural Preserve (Preserve), encompassing approximately 4,000 acres in eastern Pima County, was purchased by the District in 1986 to protect this reach of Cienega Creek, one of the few low-elevation perennial streams in Pima County. Stream flows along the creek help support rare and endangered fish and frogs as well as dense areas of riparian vegetation that provides shelter and forage to a wide variety of native wildlife. This area is also important to human populations due to its scenic, cultural and recreational values and is included in the Pima County Parks system. In an effort to help protect this resource, the District has conducted an extensive monitoring program that includes measurement of stream flows and groundwater levels, precipitation records and water quality analyses. A draft groundwater report prepared as part of a Cienega Creek Risk Assessment effort provides additional analyses of the interactions of surface flows, drought, and water demands on groundwater levels in the Preserve (Postillion, et al, 2015).

Groundwater level measurements were collected from June 2016 to June of 2017 from the following wells within the Cienega Creek Natural Preserve (**Figure 4**):

- PN-2 – South bank of Cienega Creek, 0.3 miles upstream of Colossal Cave Road Bridge
- PS-1 – Along Cienega Creek, 0.5 miles downstream of Pantano Dam
- Del Lago – South bank of Cienega Creek, near Pantano Dam
- Davidson 2 – West bank of Davidson Canyon Wash, 0.3 miles upstream of I-10 Bridge
- Davidson Bar V – Along ridge line west of Davidson Spring, ~ 1.4 miles upstream of I-10 Bridge over Davidson Canyon Wash
- Cienega – Northeast bank of Cienega Creek, ~ 3 miles upstream of Three Bridges area
- Jungle – West bank of Cienega Creek, ~ 1 mile downstream of I-10 Bridge
- Empirita 2 – East bank of Cienega Creek, ~ 1 mile upstream of I-10 Bridge
- O'Leary Windmill – West bank of Cienega Creek, ~ 1.3 miles upstream of I-10 Bridge

Daily data from wells PS-1 and PN-2 were collected by automated sensors and recorded on ADWR's GWSI database. Daily data from Davidson 2, Davidson Bar V, Cienega, Jungle, Empirita 2 and Empirita CCI Wells were downloaded from sensors installed by District staff in July 2017. Del Lago and O'Leary Windmill were measured manually on a semi-annual basis.

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



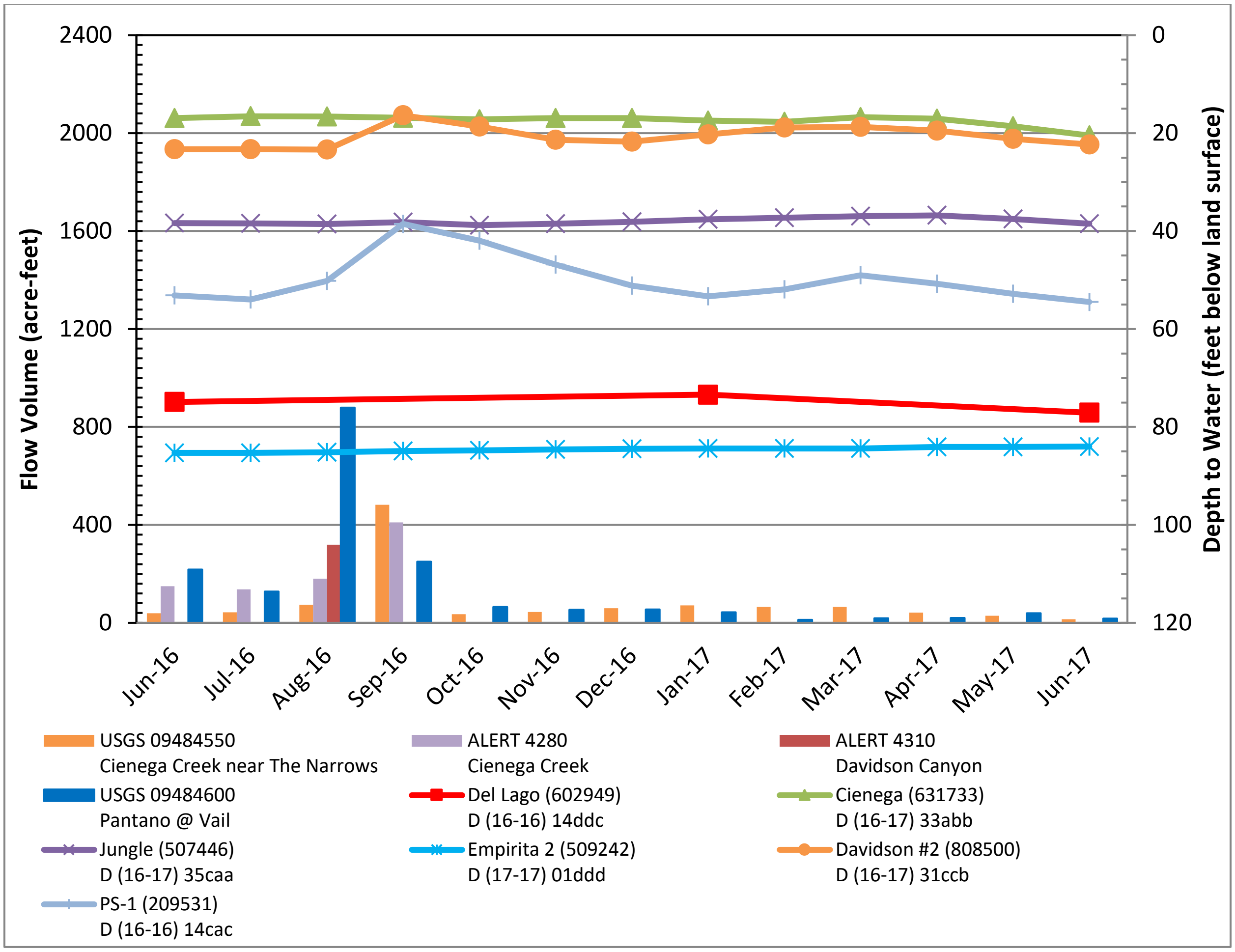
Water levels measured in June 2017 ranged from 20.5 feet bls (Cienega) to 220.1 feet bls (PN-2). Over the last year (June2016-June2017), water levels recorded in the two automated wells downstream of the Pantano Dam indicated declines in water levels ranging from 0.9 foot (PN-2, deep well) to 1.3 feet (PS-1, shallow well). Near the middle of the Preserve, Cienega Well declined 3.5 feet and the Jungle Well slightly declined by 0.1 foot. In the upstream portion, Empirita 2 showed a recovery of 1.3 feet, while Empirita CCI declined by 0.8 foot. Along Davidson Canyon Wash, the shallow well, Davidson #2, had a one-foot water level recovery and the deep well, Davidson Bar V, recorded a 0.6-foot recovery over the last year.

Groundwater levels in relation to stream volumes at The Narrows (USGS Gauge #09484550), Pantano Dam (USGS Gauge #09484600), Cienega Creek (ALERT #4280) and Davidson Canyon (ALERT #4310) from June 2016 through June 2017 are shown in **Illustration D-1**. Water levels in only three of the wells (PN-2, PS-1 and Davidson #2) significantly increased with the onset of summer monsoon runoff in August through September 2016. Although there were flows recorded along Cienega Creek near I-10 during the same period, it appears they were not substantial enough to affect the groundwater levels in the upper and central portions of the Preserve. After a brief decline from October through December 2016, groundwater levels within the shallow wells along Cienega Creek appear to recover slightly through March 2017 without any record of significant flow in the area. The water level in the deep well at the downstream end of the Preserve (PN-2) has steadily declined since its peak in December 2016, while the deep well in Davidson Canyon (Davidson Bar V) remained relatively stable during the entire FY16/17.

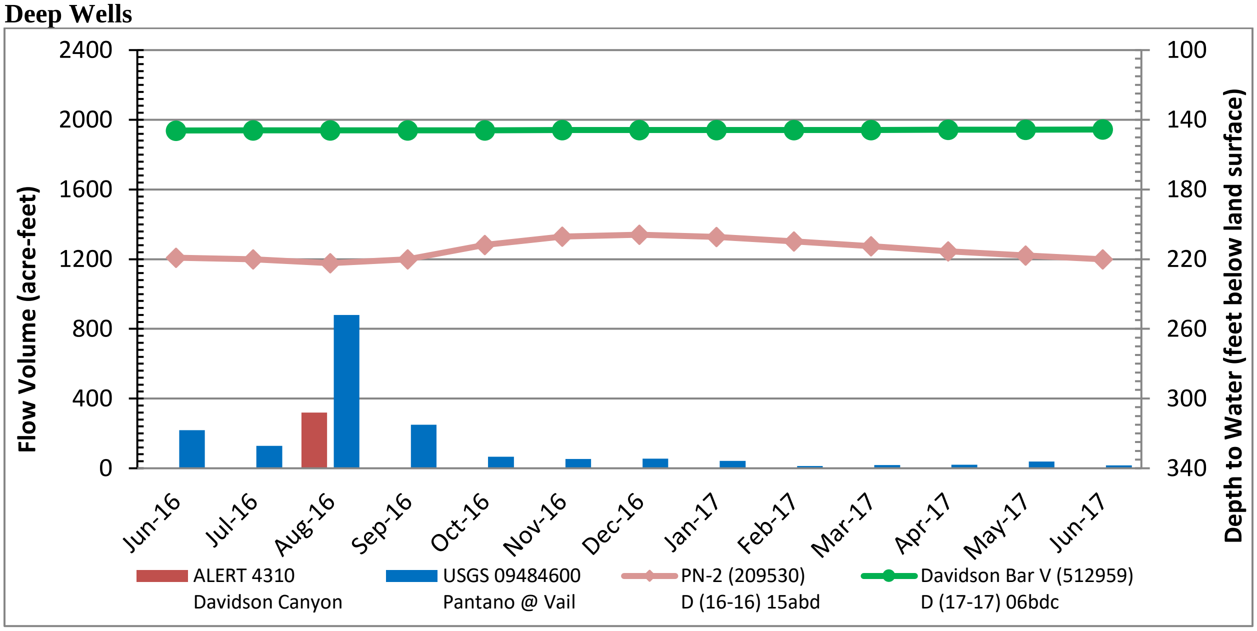
Stream flow and well monitoring at the Preserve have been conducted for over 20 years**.** A number of wells show distinct seasonal trends in water levels since 1994 (**Illustration D-2**), with highs typically falling during or just after the summer monsoon period (August and September) and lows near the end of spring (May and June). Annually, groundwater levels have risen or fallen due to the amount of stream flows occurring along Cienega Creek or Davidson Canyon Wash (**Illustration D-3**). Groundwater levels have typically recovered after high volume years and declined after very dry years. As noted above, groundwater levels in the downstream wells appear to be more impacted by stream flows than those further upstream. Reasons for this could be a lack of perennial flow due to diversion of surface flows by Del Lago Golf LLC, a wider streambed in areas downstream of the dam, less vegetation along the stream banks to intercept groundwater, more available vadose zone and the addition of flows from major tributaries such as Davidson Canyon Wash and Agua Verde Creek.

Illustration D-1: Monthly Flow Volumes vs. Groundwater Levels at Cienega Creek Natural Preserve, June 2016 - June 2017

Shallow Wells



Deep Wells



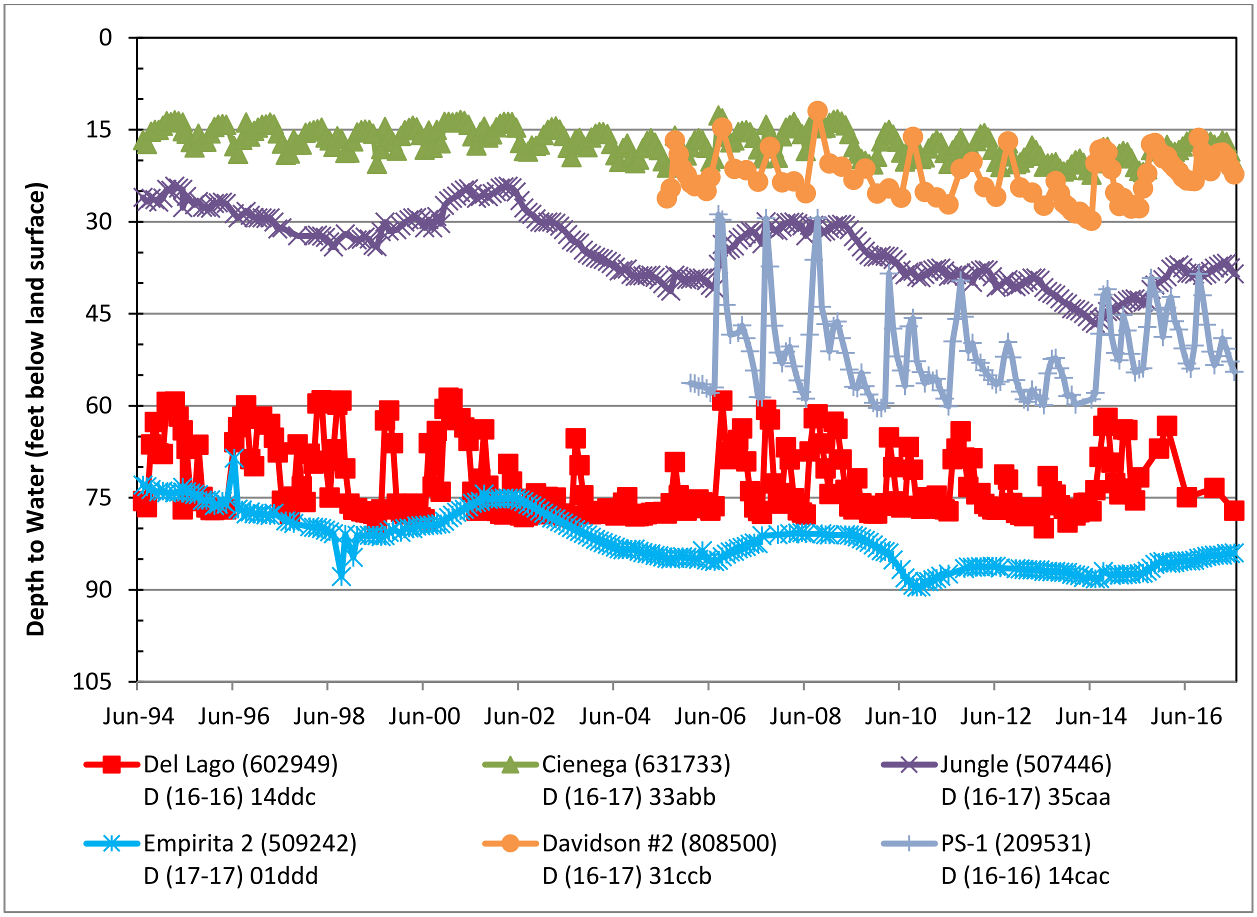
The overall water level trend at Cienega Creek Natural Preserve has been downward over the last 22 years (**Illustration D-3)** with an average annual rate of decline of 0.46 feet in four monitoring wells (**Table 3**). However, water levels have recovered since 2006, with seven of the nine monitoring wells indicating an average rising rate of 0.24 feet per year (**Table 3**). Note that the eleven-year average is highly influenced by wells in the downstream area. Both the long-term (since 1995) and short term (since 2006) changes in water levels have declined since last year's evaluation, despite the two most upstream wells showing recovery. This indicates that the most recent rising trend in the water table from January 2014 through January 2016 may only be temporary if drier conditions continue to prevail.

Although the recent recovery in water levels downstream of Pantano Dam may likely be due to flow volumes in 2014-2016, a reduction in pumping from nearby municipal wells for the Vail community since 2015 may also be a contributing factor. **Illustration D-4** displays pumping records and estimates of exempt well pumping in the Vail area south to the Narrows since 1995. The correlation between pumping and groundwater levels in the downstream well (PN-2) appears to be as pronounced as the correlations between groundwater levels and surface flows. However, this is the only well that appears to be affected by the reduction in pumping. The overall downward trend in groundwater levels at the downstream end of the Preserve may be attributed to significant pumping in the Vail area from 2000 to 2014. Continued data collection and evaluation may provide more insight to the effects of reduced groundwater pumping in this area.

In CY2016, precipitation in the vicinity of CCNP ranged from 5.75 inches at Rancho Del Lago (~ 2.35 miles Northwest of Colossal Cave Road Bridge) to 17.27 inches at Davidson Canyon Wash near I-10 (**Table 4**). 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 the Preserve) to +4.44 inches along Mescal Arroyo (East of the 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). 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.

Illustration D-2: Monthly Groundwater Levels at Cienega Creek Natural Preserve, June 1994 - June 2017

Shallow Wells



Deep Wells

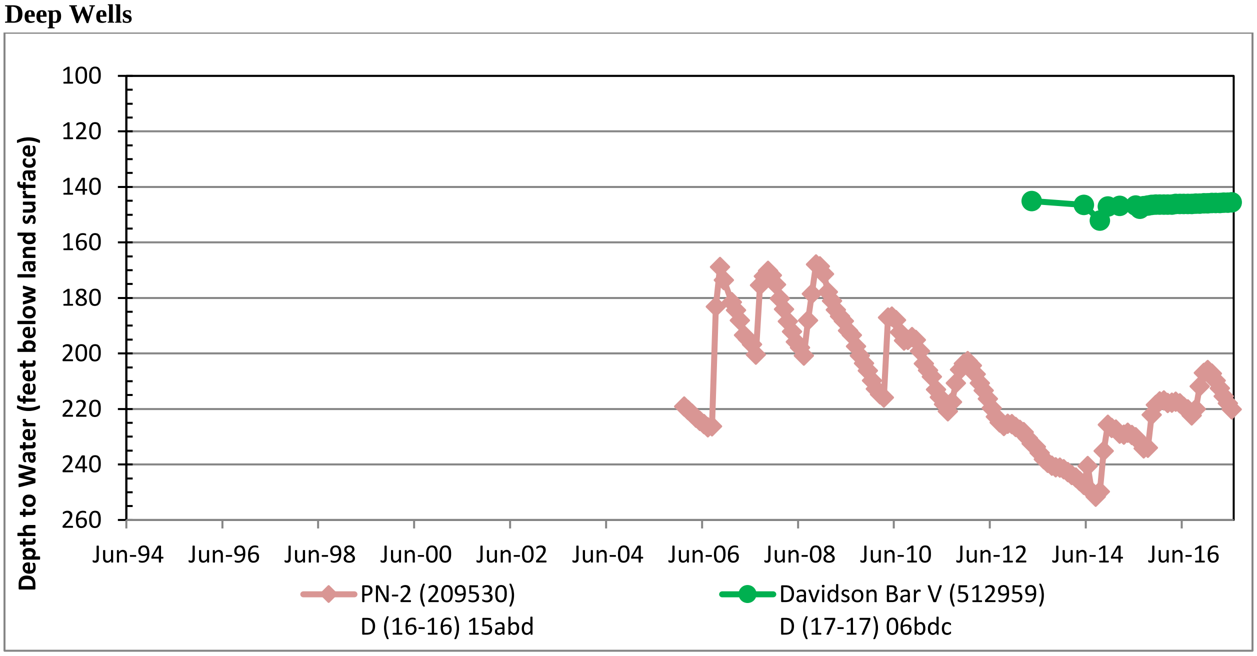
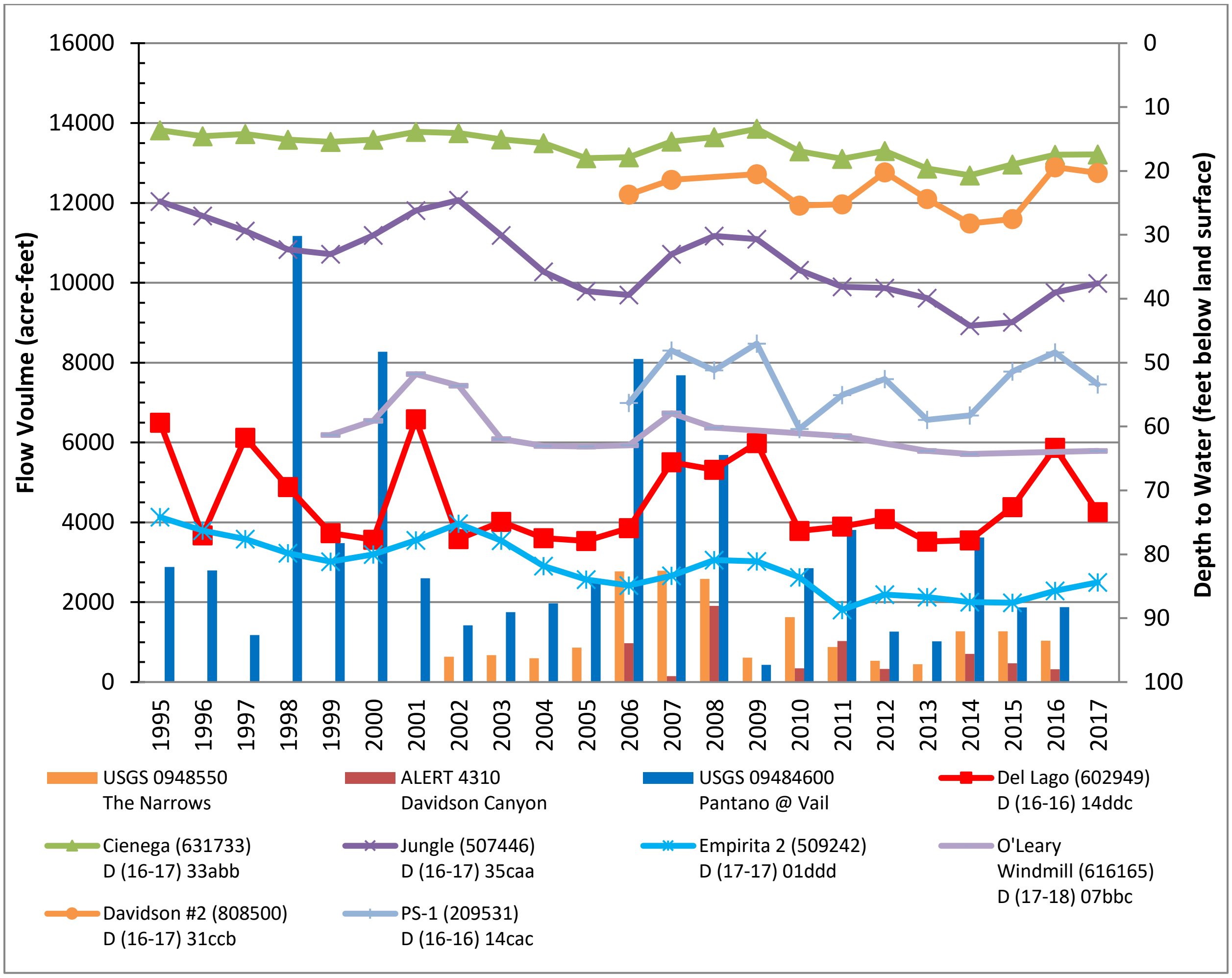


Illustration D-3: Annual Flow Volumes vs. Shallow Groundwater Levels at Cienega Creek Natural Preserve: 1995-2017

Shallow Wells



Deep Wells

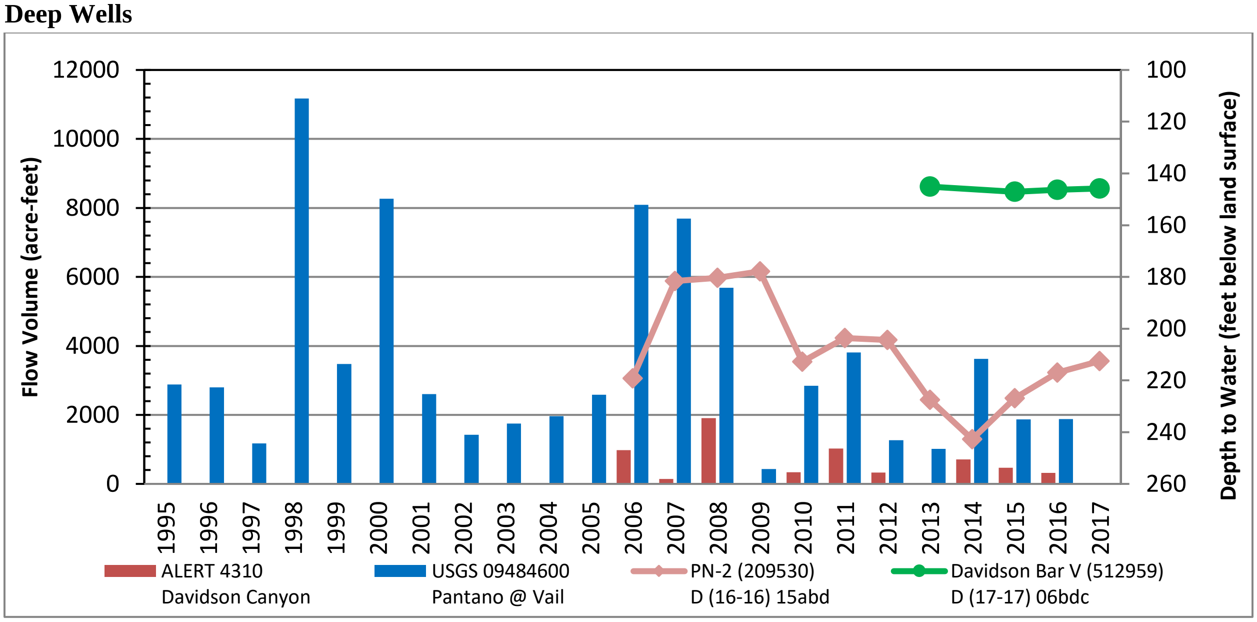
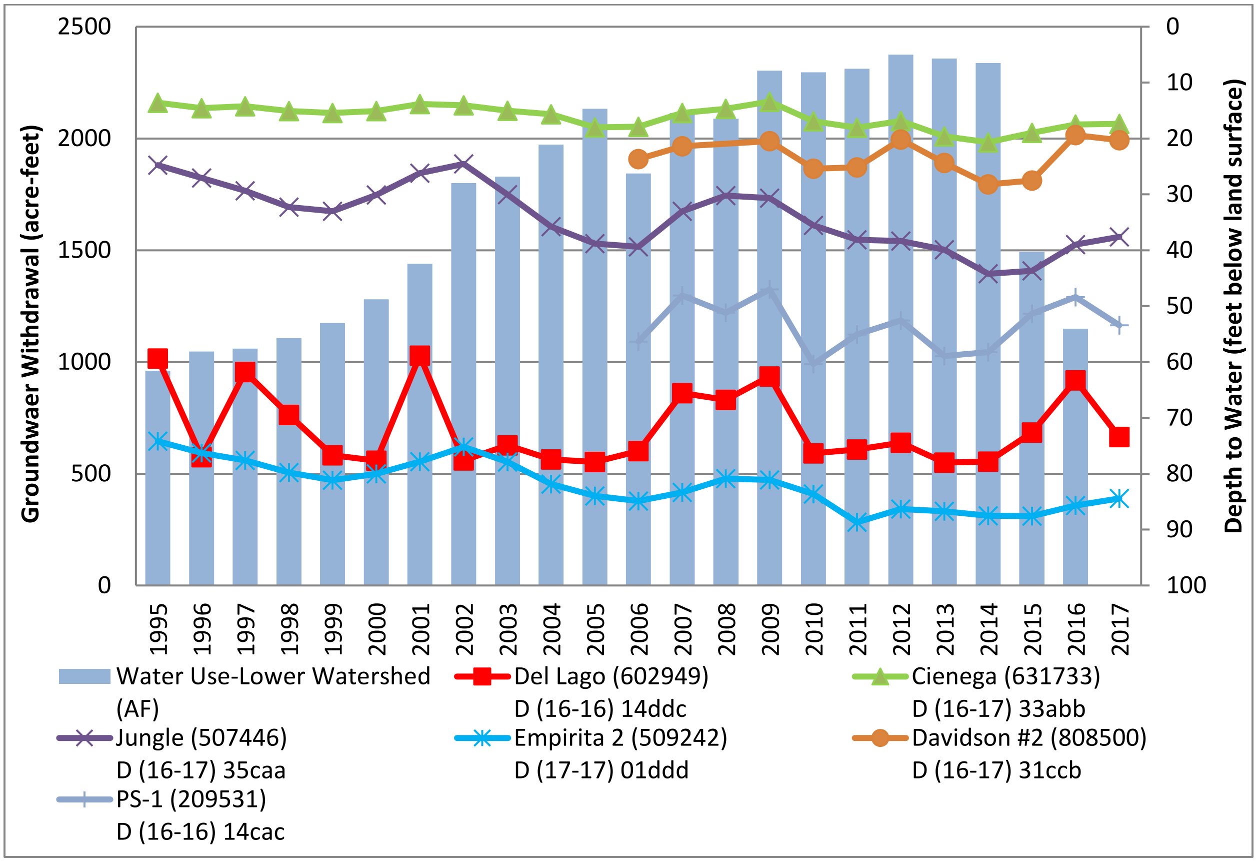


Table 3. Water Level Changes Along Cienega Creek and Davidson Canyon Wash within the Cienega Creek Natural Preserve

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.**

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

Shallow Wells



Deep Wells

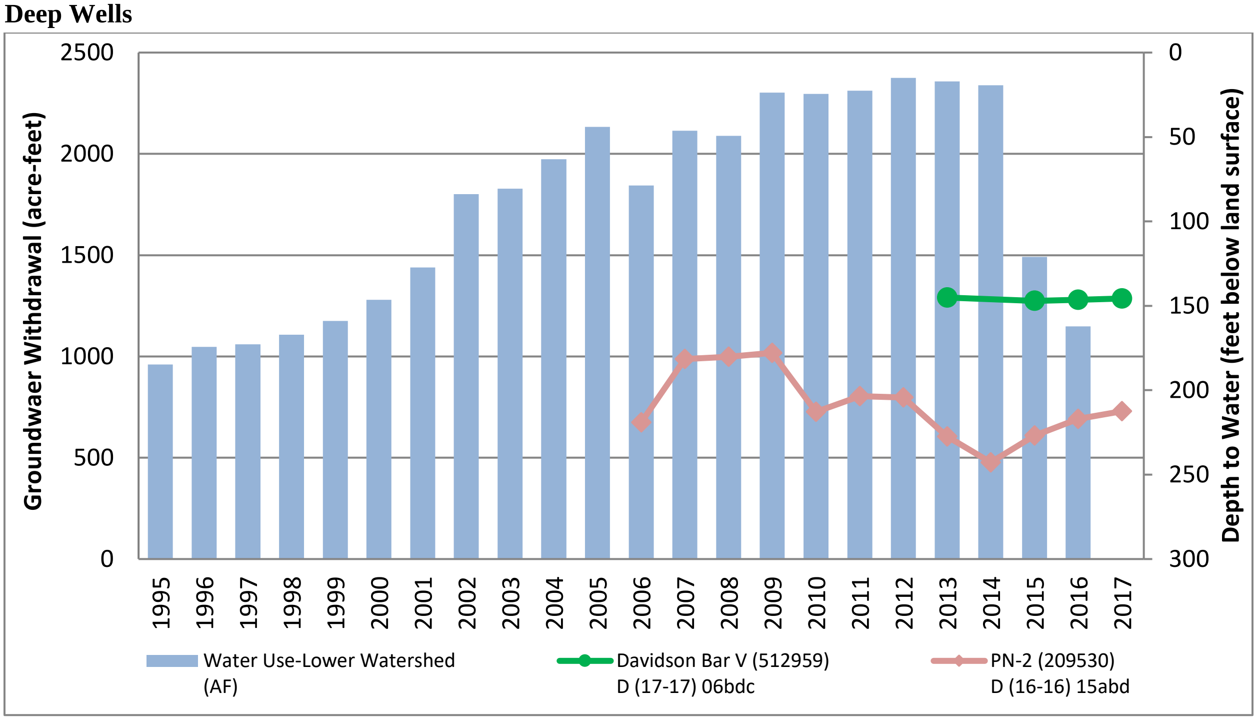


Table 4. Precipitation records from gauges surrounding Cienega Creek Natural Preserve.

Year	Precipitation (inches)						
	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	Haystack Mtn. ALERT #4410
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**

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Tanque Verde Creek at Confluence with Sabino Creek

Located within an urbanized area in north-central Tucson, an extensive shallow groundwater area at the confluence of Tanque Verde Creek and Sabino Creek helps support a mix of riparian vegetation including Freemont cottonwood, Arizona ash and old-stand velvet mesquite. This area is primarily supplied by intermittent surface flows coming out of Sabino Canyon and recharge along the front range of the Santa Catalina and Rincon Mountains. The presence of surface water during parts of the year and stands of riparian vegetation help to provide forage and shelter to native wildlife and is a popular site for human visitors.

Monthly groundwater level measurements in 2017 were only available for the following City of Tucson (COT) wells near the confluence of Tanque Verde Creek and Sabino Creek (**Figure 5**):

- COT C-073A – South bank of Tanque Verde Creek, near Tanque Verde Road Bridge
- COT C-084A – North bank of Tanque Verde Creek, 1.1 miles upstream of Tanque Verde Road Bridge
- COT B-104A – South bank of Tanque Verde Creek, near Sabino Canyon Road Bridge

All three wells are equipped with automated water-level recorders that provide daily data that is manually downloaded by COT staff at irregular intervals during the year. To study long-term trends in this area, records from the following COT wells were also included (**Figure 5**):

- COT C-086A – North bank of Tanque Verde Creek, 0.3 miles downstream of Sabino Canyon Road Bridge
- COT C-123B – South bank of Tanque Verde Creek, 0.3 miles downstream of confluence with Sabino Creek
- COT C-074A – East bank of Sabino Creek, 1.7 miles upstream of confluence with Tanque Verde Creek
- COT C-055A – East bank of Sabino Creek, 1,000 feet Northeast of COT C-074A

In May/June 2017, groundwater levels in the Tanque Verde Creek-Sabino Creek confluence ranged from 30.8 feet bls near Sabino Canyon Road (B-104A) to 92.6 feet bls upstream of Tanque Verde Road bridge (C-084A). Both C-073A and C-084A showed declines in groundwater levels over the last year, 1.1 feet and 1.5 feet respectively, while B-104A showed a 3.2-foot recovery. The declines in the former two wells occurred despite significant flow volumes recorded in the Tanque Verde and Sabino Canyon watersheds in January and February 2017 (**Illustration E-1)**. All three wells, however, did indicate significant water level recovery from January to March 2017, ranging from 3.9 feet upstream of Tanque Verde Road Bridge to 18.7 feet at the bridge itself.

Figure 5: Map of Wells within the Tanque Verde Creek-Sabino Creek Confluence

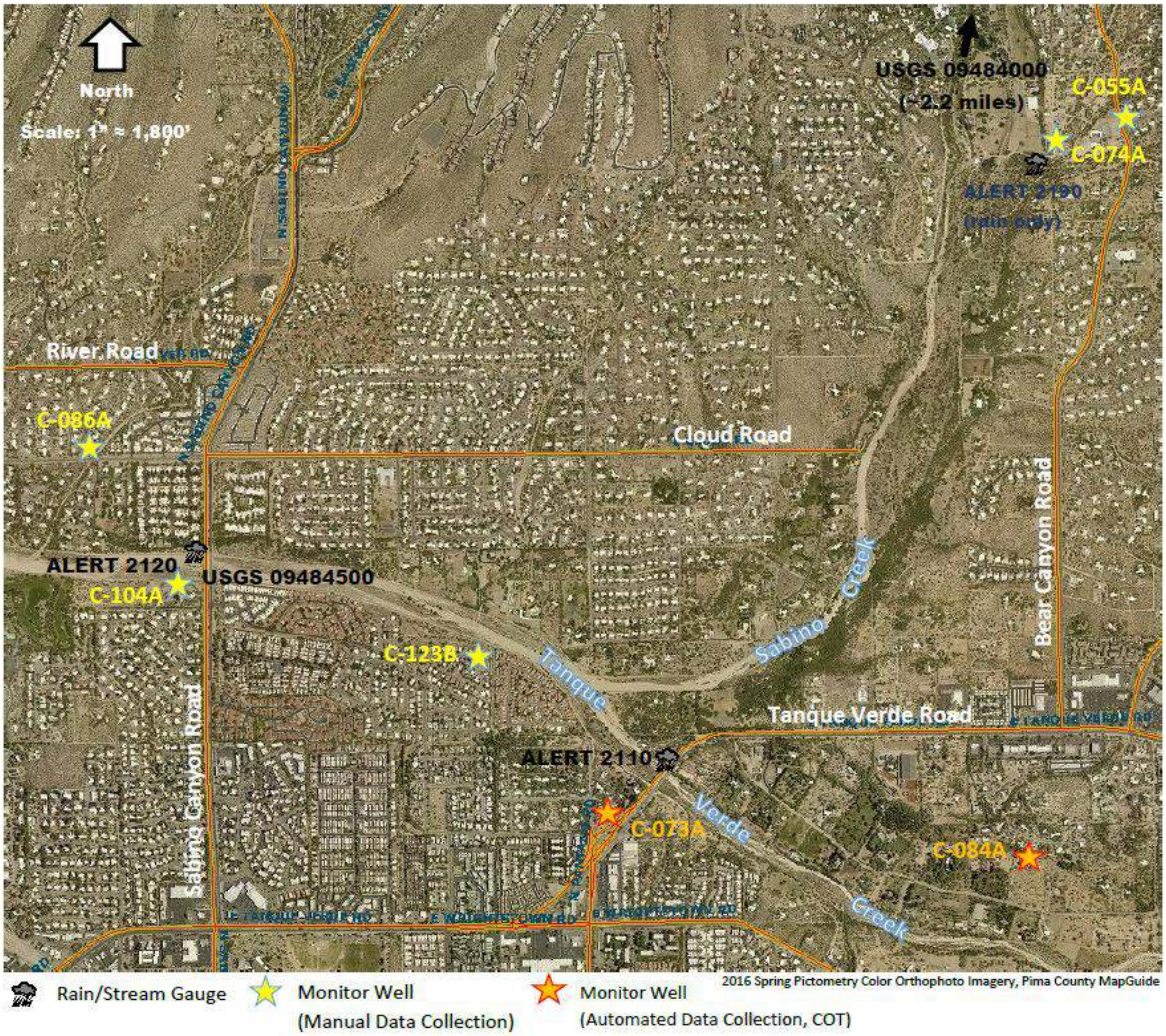


Illustration E-1: Monthly Flow Volumes vs. Groundwater Levels at Tanque Verde Creek -Sabino Creek Confluence: May 2016 - June 2017

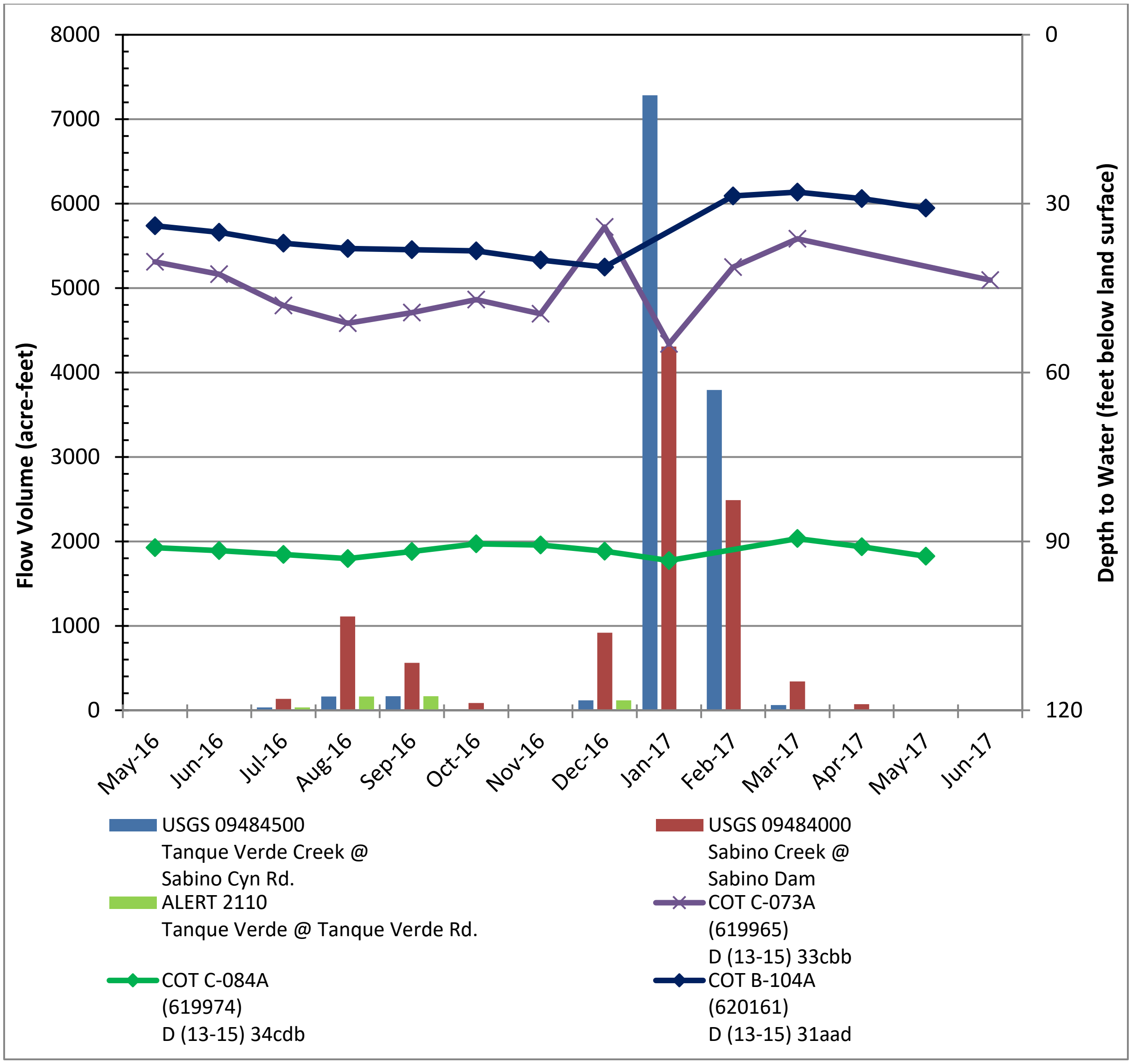
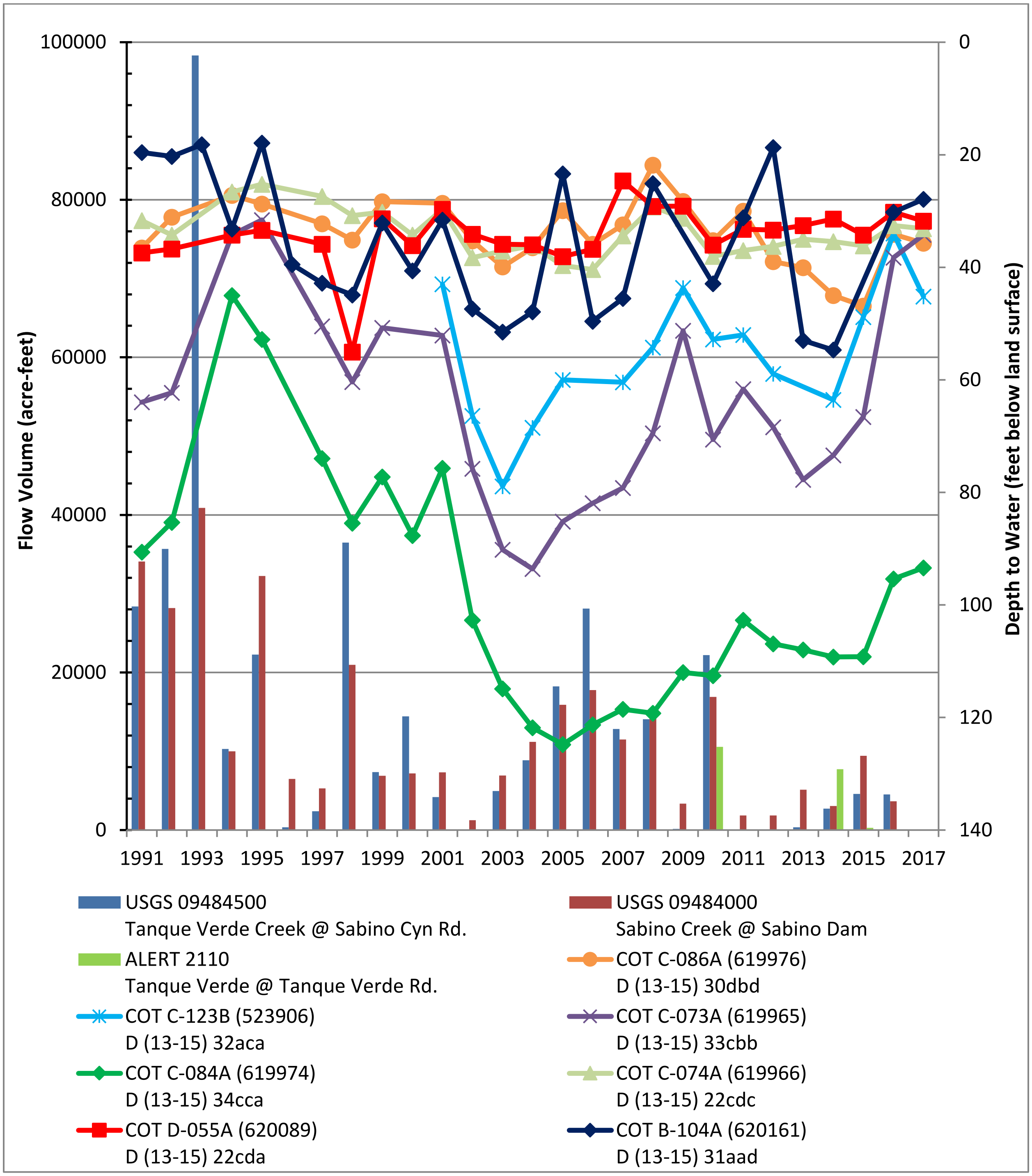


Illustration E-2 displays various well hydrographs (using winter data) with stream flows in the area since 1991. All of the wells have been influenced to some degree by stream flow recharge along both Sabino and Tanque Verde Creeks. The wells along Tanque Verde Creek upstream and downstream of the Sabino Creek confluence appear to be impacted significantly by the amount of stream flow. This is most likely the result of flows being related to storm water runoff/recharge along the ephemeral Tanque Verde Creek, compared to more intermittent flows occurring along and just downstream of Sabino Creek . The shallower wells along Sabino Creek appear to maintain a more constant water level as does C-086A, which is close to an ephemeral tributary wash.

Illustration E-2: Annual Flow Volumes vs. Groundwater Levels at Tanque Verde Creek-Sabino Creek Confluence: 1991-2017



The overall trend for water levels in this area has been downward since 1995 (**Illustration E-2).** The average water level decline for all the wells was 0.44 feet per year (**Table 5**), which is an improvement over last year's 0.74 feet per year decline. Note that Well C-055A along Sabino Canyon showed a slight recovery over the 22-year period. Since 2005, the average water level trend for the area has been predominantly upward at a rate of 1.19 feet per year (**Table 5**), an improvement over last year's average of 0.98 foot. However, two wells downstream of the confluence (C-086A and B-104A) still show declining water levels since 2005.

Although large flow volumes are normally the reason for water level recovery in the area, as depicted in **Illustration E-2**, the most recent recoveries over the last five to 6 years is more likely the result of annual reductions in pumping. **Illustration E-3** compares annual groundwater withdrawals and groundwater levels at the Tanque Verde Creek-Sabino Creek confluence since 1991. Groundwater withdrawals for the area are a combination of reported values provided by ADWR and non-reported values estimated by Watershed Management Group (WMG, 2017) using the number of exempt wells in the area and the aerial extent of irrigated pasture and surface water bodies (i.e. lakes and ponds). Note that groundwater withdrawals for the Tanque Verde Creek-Sabino Canyon area includes records from all of the watersheds displayed in **Figure 6**. Average annual water withdrawal over the last 10 years (since 2007) is just over 7,500 acre-feet compared to over 11,400 acre-feet for the previous 10 years and over 12,000 acre-feet over the previous 20-year record. Groundwater withdrawal in 2016 was 7,745 acre-feet, which was greater than 2015 (6,442 acre-feet), but was the sixth consecutive year that withdrawals were under 8,000 acre-feet, indicating a continuing downward trend for pumping in the area since 2001.

Annual precipitation in CY2016 for the area vicinity ranged from 9.76 inches at Tanque Verde Creek near Sabino Canyon Road to 11.83 inches at Sabino Canyon Dam (**Table 6**). These amounts are much lower than 2010 and 2015 and ranged from -0.12 inches to +2.20 inches from the calculated average since 1994. Increased precipitation in 1998, 2006 and 2010 are reflected in both increased annual flow volumes and recovering groundwater levels over the course of the respective calendar years. These wet years were followed by much drier years, resulting in significant declines in flow volumes and groundwater levels. This is especially evident in the wells tapping into groundwater levels greater than 50 feet bls. Although precipitation was above average in 2015 and mostly higher than average in 2016, there were no subsequent increases in annual flow volumes along both creeks. Thus, groundwater levels were more likely influenced by recharge of localized flows off surrounding urban areas and the continued reduction in pumping of local municipal wells.

Illustration E-3: Annual Groundwater Withdrawals (Pumping) vs. Groundwater Levels at Tanque Verde Creek-Sabino Creek Confluence: 1991-2017

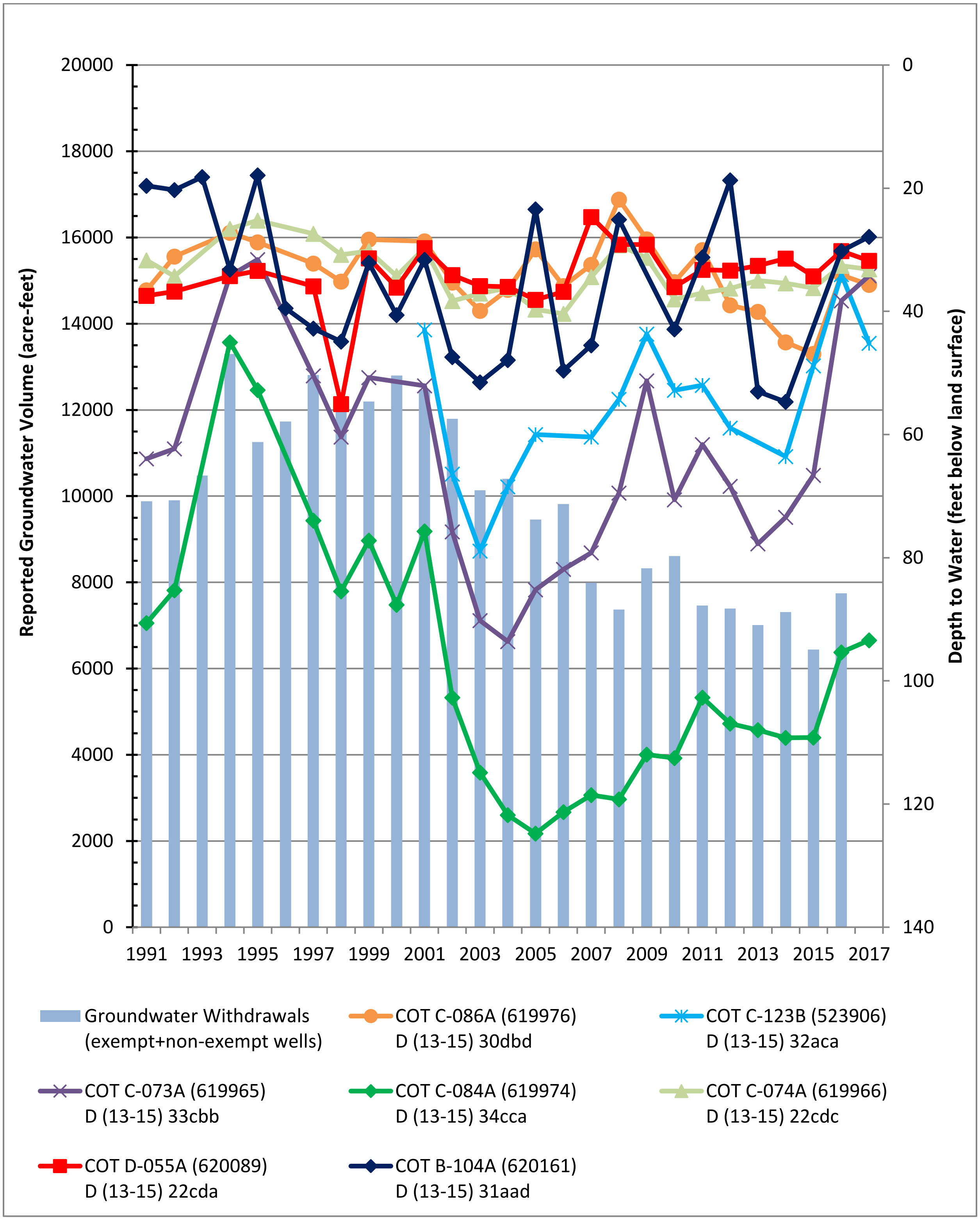


Table 5. Approximate 20-Year and 10-Year Water Level Changes Within and Adjacent to the Tanque Verde Creek- Sabino Creek Shallow Groundwater Area.

Wells55- Registry Well Name	Well Location	Dates Total Change, Change/Year (22-Year Record)	Dates Total Change, Change/Year (12-Year Record)
620089 (COT, C-055A)	D-13-15-22CDA	1995-2017 (22 yr.) +1.60 ft., +0.07 ft./yr.	2005-2017 (12 yr.) +6.30 ft., 0.53 ft./yr.
619966 (COT, C-074A)	D-13-15-22 CDC	1995-2017 (22 yr.) -7.93 ft., -0.36 ft./yr.	2005-2017 (12 yr.) +6.50 ft., +0.54 ft./yr.
619974 (COT, C-084A)	D-13-15-34CDB	1995-2017 (22 yr.) -40.61 ft., -1.48 ft./yr.	2005-2017 (12 yr.) +31.40 ft., +2.62 ft./yr.
619965 (COT, C-073A)	D-13-15-33 CBB	1995-2017 (22 yr.) -2.62 ft., -0.12 ft./yr.	2005-2017 (12 yr.) +51.00 ft., +4.25 ft./yr.
523906 (COT, C-123B)	D-13-15-32 ACA		2005-2017 (12 yr.) 14.80 ft., +1.23 ft./yr.
619976 (COT, C-086A)	D-13-15-30 DBD	1995-2017 (22 yr.) -6.94 ft., -0.32 ft./yr.	2005-2017 (12 yr.) -5.80 ft., -0.48 ft./yr.
620161 (COT, B-104A)	D-13-15-31aad	1995-2017 (22 yr.) -10.00 ft., -0.45 ft./yr.	2005-2017 (12 yr.) -4.50 ft., -0.38 ft./yr.
AVERAGE		**Number of Years = 22 Change/Year = -0.44 ft.**	**Number of Years = 12 Change/Year = +1.19 ft.**

Figure 6: Streamshed Boundary Map for Sabino Canyon and Tanque Verde Creek (WMG, 2017)

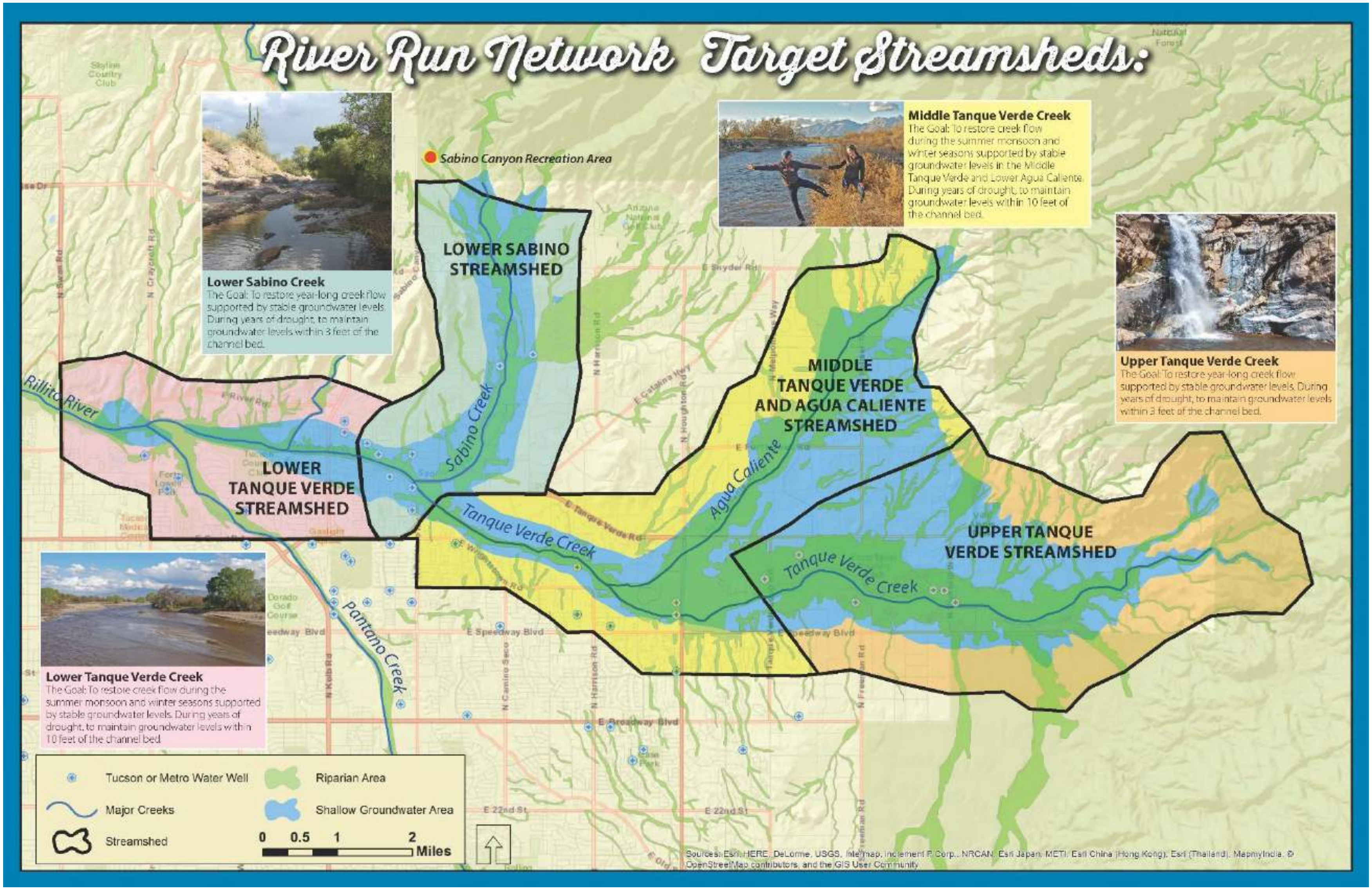


Table 6. Precipitation records from gauges surrounding the Tanque Verde Creek-Sabino Creek confluence.

Year	Precipitation (inches)					
	Sabino Cyn Rd. @ Tanque Verde Wash ALERT #2120	Tanque Verde Rd. @ Tanque Verde Wash ALERT #2110	El Marah-Bear Cyn Rd. ALERT #2190	Sabino Cyn Dam ALERT #2160	Tanque Verde Rd. @ Agua Caliente ALERT #2200	Houghton Rd. near Catalina Hwy ALERT #2210
1994	13.15	17.52	9.57	8.23	11.77	9.53
1995	10.08	9.84	10.16	10.16	6.61	10.47
1996	11.89	9.96	10.31	11.81	10.75	9.61
1997	6.26	9.80	11.65	12.01	9.02	10.63
1998	13.98	14.84	18.15	19.25	14.69	15.04
1999	9.80	8.70	8.90	10.00	8.23	0.00
2000	13.31	12.83	13.98	16.69	13.98	15.79
2001	7.76	8.66	9.57	10.12	9.21	10.16
2002	7.32	6.22	7.28	8.11	6.97	6.97
2003	9.41	8.11	8.86	13.50	9.33	9.13
2004	9.49	8.35	8.50	12.44	9.33	10.04
2005	8.50	9.09	9.76	10.91	7.95	8.43
2006	12.20	13.86	15.43	16.18	15.00	15.16
2007	11.77	10.98	10.39	13.07	11.46	9.37
2008	8.94	9.41	13.54	16.89	11.02	11.18
2009	5.28	5.20	6.22	7.40	6.85	8.86
2010	11.54	11.26	12.68	14.37	11.38	13.15
2011	7.20	9.02	9.65	10.28	11.26	13.23
2012	7.44	8.07	9.33	9.21	8.90	7.95
2013	5.35	5.63	7.01	7.56	8.70	9.06
2014	9.41	9.69	10.16	9.17	9.29	10.67
2015	13.13	15.11	15.25	12.97	16.03	17.10
2016	11.26	12.40	13.04	11.71	11.23	11.73
Overall AVG	9.76	10.20	10.84	11.83	10.39	10.58

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Tanque Verde Creek at Confluence with Agua Caliente Wash

Within a suburbanized area in northeast Tucson, an extensive shallow groundwater area at the confluence of Tanque Verde Creek and Agua Caliente Wash helps support a mix of riparian vegetation including Freemont cottonwood, Arizona ash and old-stand velvet mesquite. This area is primarily supplied by intermittent surface flows coming out of Tanque Verde Creek and recharge along the front range of the Santa Catalina and Rincon Mountains. The presence of surface water during parts of the year and stands of riparian vegetation help to provide forage and shelter to native wildlife; and the area is a popular site for human visitors.

Groundwater level measurements through May 2016 were available for the following City of Tucson (COT) wells near the confluence of Tanque Verde Creek and Agua Caliente Wash (**Figure 7**):

- COT C-084A – North bank of Tanque Verde Creek, 1.1 miles upstream of Tanque Verde Road Bridge
- COT C-118A – Along Speedway Boulevard, 0.25 miles East of Harrison Road
- COT D-046A – Along Tanque Verde Road, about 0.1 miles West of the intersection with Houghton Road
- COT C-075A – Along Tanque Verde Creek, just downstream of Houghton Road
- COT C -075B – Along Tanque Verde Creek, just downstream of Houghton Road
- COT D-062A – North bank of Tanque Verde Creek, just West of Tanque Verde Loop Road
- COT TV-001A – North bank of Tanque Verde Creek, 1.7 miles downstream of Wentworth Road crossing
- COT E-020A – South bank of Tanque Verde Creek, 1.1 miles downstream of Wentworth Road crossing.

All of these wells are equipped with automated water-level recorders that provide daily data, which is manually downloaded by COT staff at irregular intervals during the year.

In May 2017, groundwater levels in this area ranged from 9.3 feet bls along Tanque Verde Creek near Soldier Trail (E-020A) to 150.9 feet bls along Speedway Boulevard near Harrison Road (C-118A). Five of the wells with records from May 2016 through May 2017 indicated recovering water levels over the last year, ranging from 0.74 feet to 10.82 feet (**Illustration F-1)**. The rise in water levels over the last year is most likely attributed to significant stream flow volumes along Tanque Verde Creek in January 2017. The most upstream well, E-20A, declined over the last year (0.21 feet) as did the most downstream well, C-084A (1.53 feet). Well E-20A is in a very shallow groundwater area (less than 10 feet bls), while C-084A is much deeper (greater than 90 feet bls).

Figure 7: Map of Wells within the Tanque Verde Creek-Agua Caliente Wash Confluence

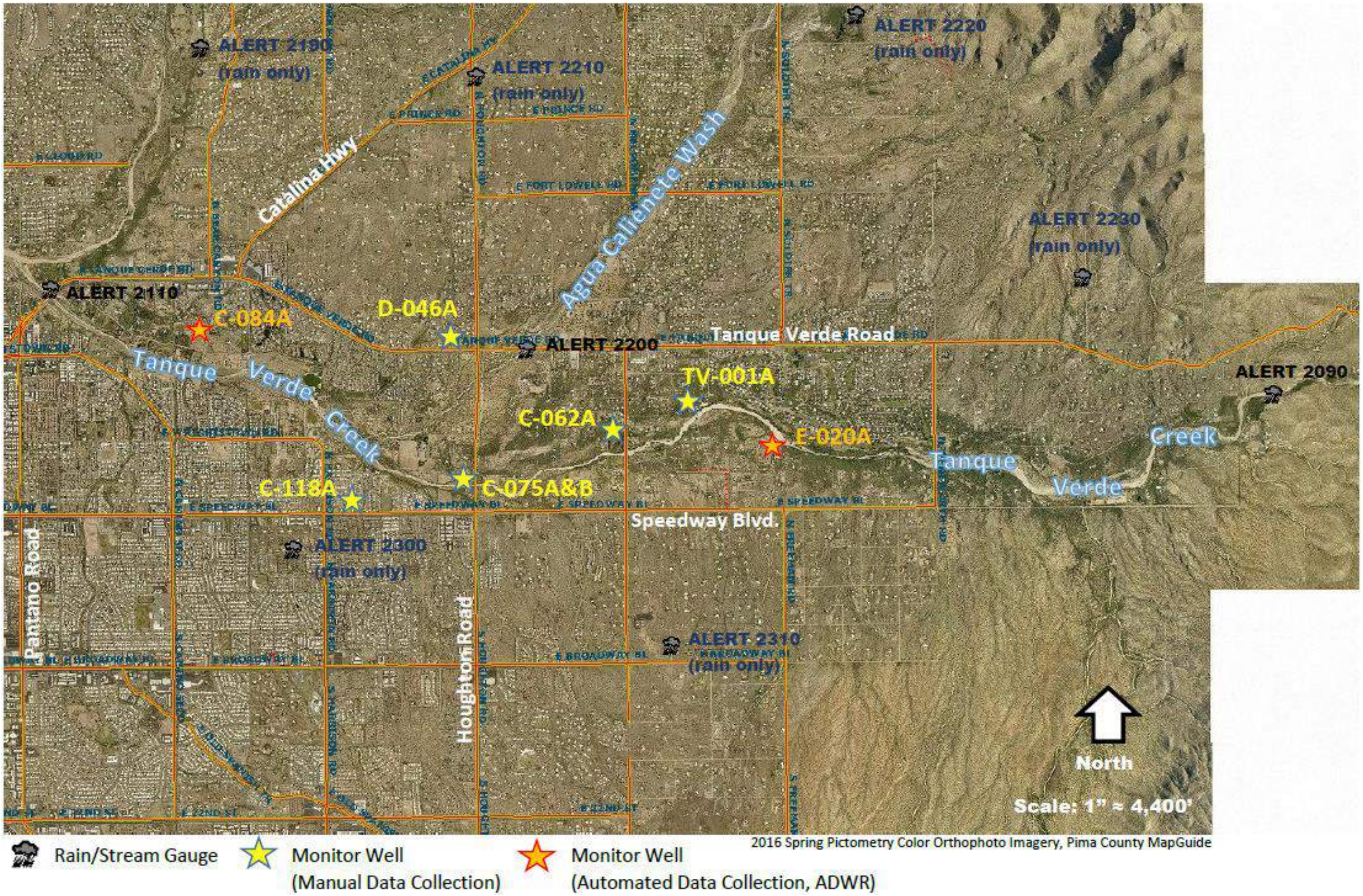


Illustration F-1: Monthly Flow Volumes vs. Groundwater Levels at Tanque Verde Creek –Agua Caliente Wash Confluence: May 2016 - May 2017

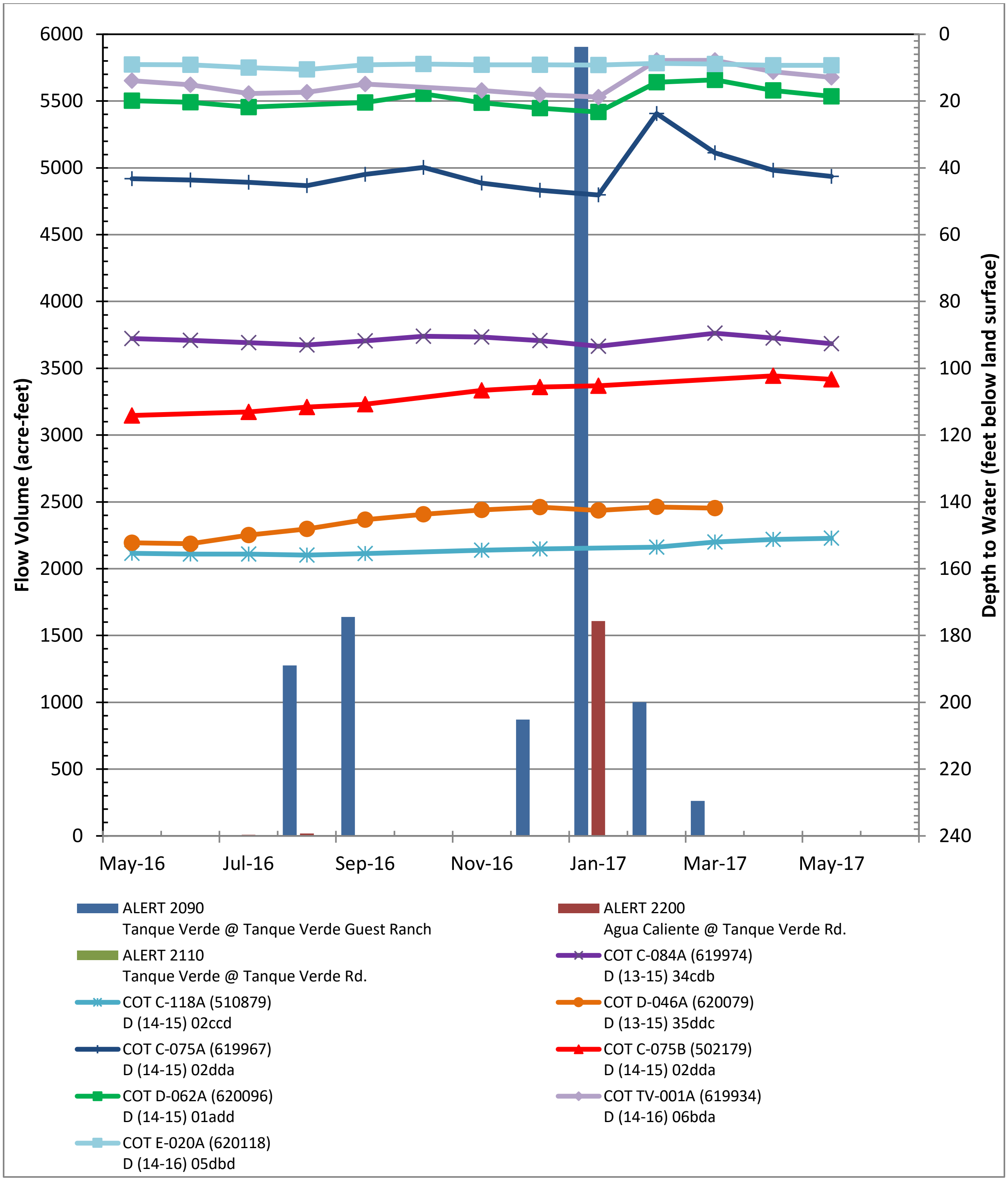


Illustration F-2 displays various well hydrographs (using winter data) with stream flows in the area since 1991. Note that ALERT steam flow data is limited to the last ten years or so. All of the wells have been influenced to some degree by stream flow recharge along Tanque Verde Creek, which mostly occurs in the area just downstream of the gauge at Tanque Verde Guest Ranch (ALERT 2090). High volumes of flow in this area are mostly the result of intermittent flows coming out of Redington Pass during the Winter Season and residual flows after summer storms. The other two stream gauges record mostly storm water runoff along the ephemeral reaches of Agua Caliente Wash and Tanque Verde Creek.

The overall trend for water levels in this area has been downward since 1995, as depicted in **Illustration F-2** and **Table 7.** The average water level decline for all the wells was 1.47 feet per year, similar to last year's average of 1.40 feet per year over 21 years. Wells tapping deep groundwater have been declining at a much greater rate (~2.14 ft/yr) than those tapping shallow groundwater (-0.12 ft/yr). Since 2005, the average water level trend for the area shifted upward at a rate of 1.21 feet per year.

Similar to the Tanque Verde Creek-Sabino Creek confluence, large flow volumes are normally the reason for water level recovery in the area, but annual reductions in pumping may also play a big role in more recent groundwater level recovery. **Illustration F-3** compares annual groundwater withdrawals and groundwater levels at the Tanque Verde Creek-Agua Caliente Wash confluence since 1991. As in the Tanque Verde Creek-Sabino Creek area, groundwater withdrawals are a combination of reported values from ADWR and non-reported values estimated by Watershed Management Group (WMG, 2017). Groundwater withdrawals for the Tanque Verde Creek-Agua Caliente Wash area includes records from the Middle and Upper Tanque Verde Creek watersheds displayed in **Figure 6**. Average annual water withdrawal over the last ten years (since 2007) is just under 4,000 acre-feet, compared to over 7,100 acre-feet the previous 10 years, and near 7,500 acre-feet over the previous 20-year record. Groundwater withdrawals in 2016 totaled 4,620 acre-feet, which was 1,250 acre-feet more than in 2015 and the first time withdrawals topped 4,000 acre-feet since 2010. There has generally been a steady decline in pumping for this area since a peak of about 8,600 acre-feet in 2000.

Annual precipitation in CY2016 for the area encompassing the monitored well sites ranged from 9.69 inches southeast of the intersection between Speedway Boulevard and Harrison Road (ALERT 2300) to 12.45 inches at Agua Caliente Park (**Table 8**). These amounts were about 1.6 inches to almost 5.2 inches lower than last year's totals, but ranged from 0.3 inches to 2.34 inches above their respective averages since 2006, except for ALERT 2300, which was about 3.2 inches lower. Although there appears to be some correlation with precipitation and stream flows in this area, much of the stream flow volume is derived from sources upstream in Redington Pass, which were not evaluated for this report.

Illustration F-2: Annual Flow Volumes vs. Shallow Groundwater Levels at Tanque Verde Creek-Agua Caliente Wash Confluence: 1991-2016

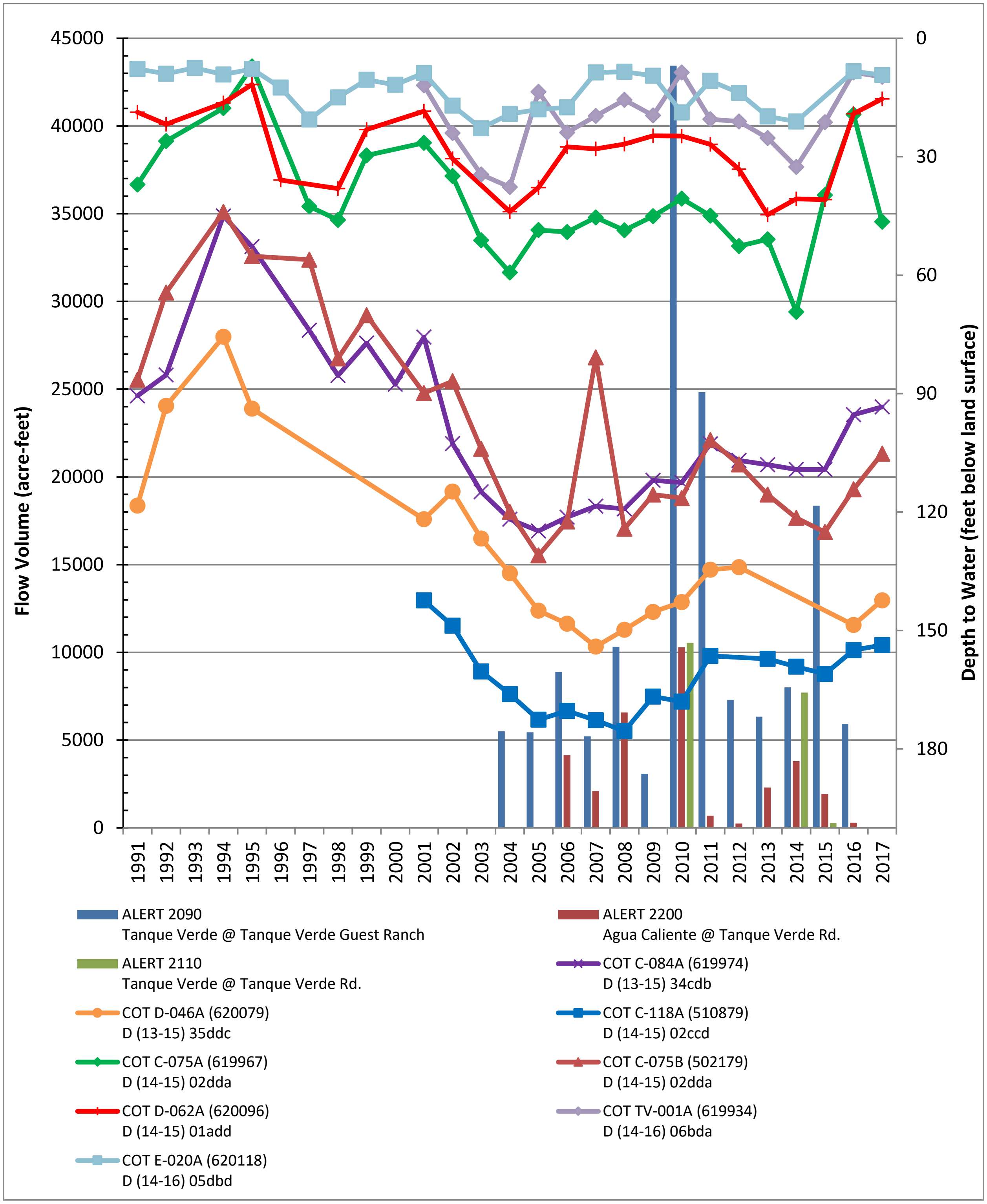


Illustration F-3: Annual Groundwater Withdrawals (Pumping) vs. Groundwater Levels at Tanque Verde Creek-Agua Caliente Wash Confluence: 1991-2017

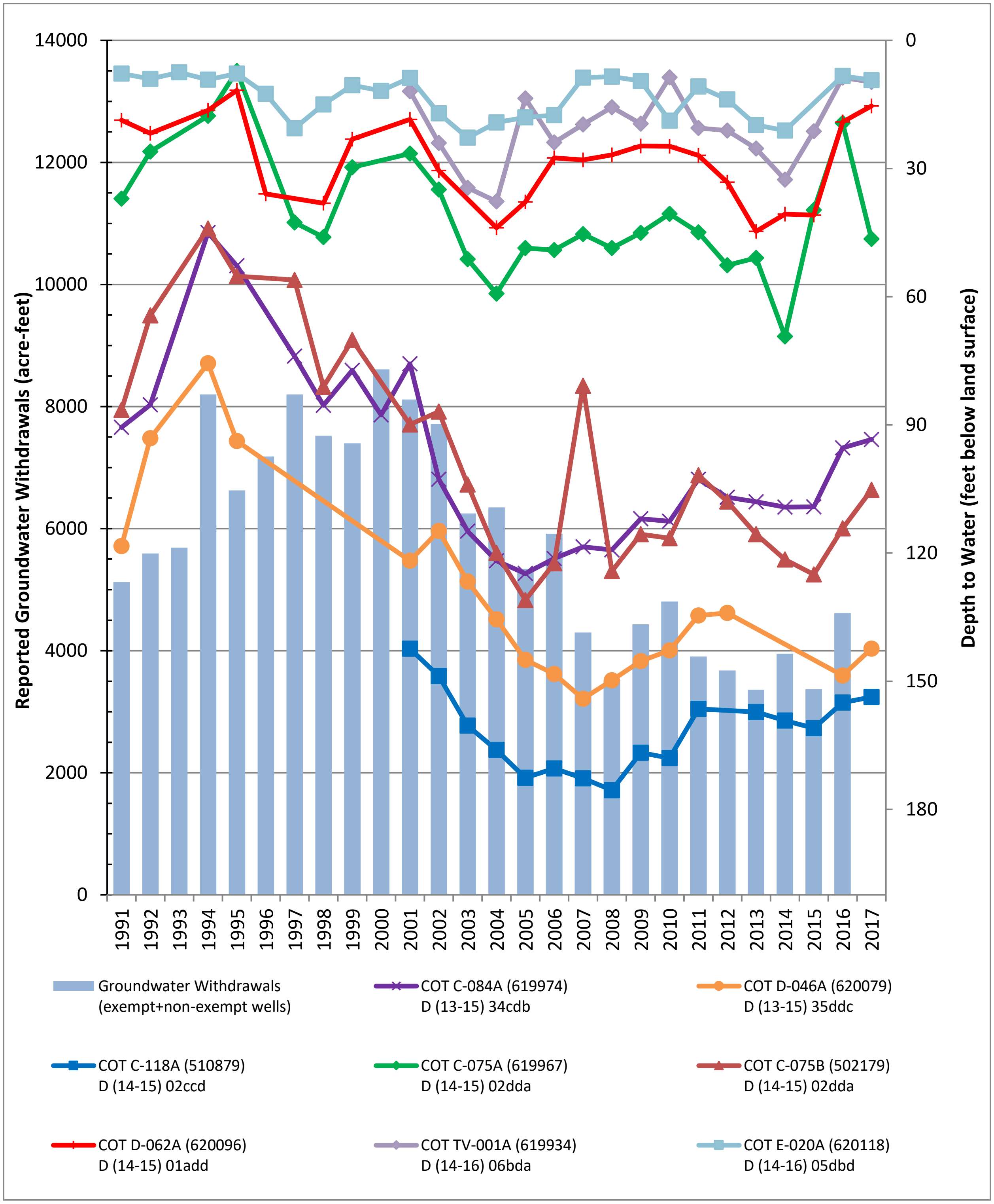


Table 7. Approximate 20-Year and 10-Year Water Level Changes Within and Adjacent to the Tanque Verde Creek - Agua Caliente Wash Shallow Groundwater Area.

Wells55- Registry Well Name	Well Location	Dates Total Change, Change/Year (22-Year Record)	Dates Total Change, Change/Year (10-Year Record)
619974 (COT, C-084A)	D-13-15-34CDB	1995-2017 (22 yr.) -40.60 ft., -1.85 ft./yr.	2005-2017 (12 yr.) +31.40 ft., +2.61 ft./yr.
620079 (COT, C-046A)	D-13-15-35 DDC	1995-2017 (22 yr.) -48.60 ft., -2.21 ft./yr.	2005-2017 (12 yr.) +2.60 ft., +0.22 ft./yr.
510879 (COT, C-118A)	D-14-15-02 CCD		2005-2017 (12 yr.) +18.90 ft., +1.58 ft./yr.
619967 (COT, C-075A)	D-14-15-02 DDA	1995-2017 (22 yr.) -39.30 ft., -1.79 ft./yr.	2005-2017 (12 yr.) +2.10 ft., +0.18 ft./yr.
502179 (COT, C-075B)	D-14-15-02 DDA	1995-2017 (22 yr.) -50.00 ft., -2.72 ft./yr.	2005-2017 (12 yr.) +25.80 ft., +2.15 ft./yr.
620096 (COT, D-062A)	D-14-15-01 ADD	1995-2017 (22 yr.) -3.60 ft., -0.16 ft./yr.	2005-2017 (12 yr.) +22.50 ft., +1.88 ft./yr.
619934 (COT, TV-001A)	D-14-16-06 BDA		2005-2017 (12 yr.) +3.90 ft., +0.33 ft./yr.
620118 (COT, E-020A)	D-14-16-05 DBD	1995-2017 (22 yr.) -1.50 ft., -0.07 ft./yr.	2005-2017 (12 yr.) +8.70 ft., +0.73 ft./yr.
AVERAGE		**Number of Years = 22.0 Change/Year = -1.47 ft.**	**Number of Years = 12.0 Change/Year = +1.21 ft.**

Table 8. Precipitation records from gauges surrounding the Tanque Verde Creek-Agua Caliente Wash confluence.

	Precipitation (inches)					
Year	COT Well D37 ALERT #2300	Tanque Verde Rd. @ Agua Caliente Wash ALERT #2200	Agua Caliente Park ALERT #2220	COT Well E23 ALERT #2310	Camino Rinconada ALERT #2230	Tanque Verde Guest Ranch ALERT #2090
2006	13.94	14.21		14.49	11.69	13.66
2007	12.36	12.24	13.78	13.27	11.57	13.90
2008	11.46	10.24	12.56	10.39	9.49	12.52
2009	5.75	7.48	8.27	6.38	5.83	7.24
2010	11.54	10.59	14.25	10.98	10.87	13.66
2011	11.22	12.24	17.32	15.00	11.34	13.94
2012	6.14	8.5	9.69	8.39	7.80	9.53
2013	6.54	9.02	8.74	9.61	7.05	9.84
2014	9.49	8.78	10.83	9.53	11.26	9.21
2015	11.66	15.75	15.63	14.45	10.35	16.06
2016	6.47	11.23	13.41	11.97	9.93	13.16
Overall AVG	9.69	10.93	12.45	11.31	9.93	12.07

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.*

Findings and Recommendations

Groundwater levels continue to show signs of recovery since June 2014 in most of the monitored shallow groundwater areas. Much of this recovery can be attributed to increased precipitation and associated runoff/infiltration. However, evidence in a few areas shows the positive effects of reduced pumping on groundwater levels, including the Lower Cienega Creek/Vail, Canoa Ranch, Tanque Verde Creek/Sabino Creek and Tanque Verde Creek/Agua Caliente Wash areas. The CDO near Catalina is the one area that has continuing groundwater declines, which may be predominantly due to continued groundwater pumping for the community of Saddlebrooke and surrounding developments.

Overall, water levels have been trending downward in most of the shallow groundwater areas since 1995, with average annual declines ranging from about 0.5 feet at the Cienega Creek Natural Preserve and the Tanque Verde Creek-Sabino Creek confluence to a little over three feet along the SCR at Canoa Ranch. Conversely, groundwater levels over the last ten years are trending upward at the Tanque Creek-Sabino Creek confluence, the Tanque Verde Creek-Agua Caliente Wash confluence, and at the Cienega Creek Natural Preserve. Reduced pumping by municipal water companies in these areas coupled with several large flood flow years in 2005 through 2008, 2010 and 2015 may be the reasons for the recovery.

Canoa Ranch continues to show water level declines over the last ten years despite increased rainfall and stream flows from 2005-2008 and in 2010 and 2014. This shows that pumping from municipal and industrial wells in the area has had a substantial effect on the water table and it may take more than a couple of years of significantly reduced pumping for water levels to fully rebound. Since 2014, water levels have recovered from 2 to 8 feet annually; but levels are not close to the shallow groundwater levels of the mid- to late-1990s. The CDO at Catalina also shows a significant decline in water levels over the last 7 years, with an average annual decline of 3 feet. Pumping from nearby municipal wells for the Saddlebrook community and surrounding neighborhoods are most likely the cause, and very little flows have been recorded at Golder Ranch Drive over the last 7 years. CTRDN also appears to be mostly affected by municipal well pumping in the surrounding areas, along with reductions in treated wastewater within the stream channel from the Agua Nueva treatment facility.

At the Cienega Creek Natural Preserve, the District continues to maintain permanent water-level dataloggers in six of the wells upgradient of Pantano Dam, in addition to the two downgradient ADWR installed dataloggers. District staff also maintains five water-level dataloggers in wells along the CDO in the Catalina Regional Park. During FY2017-18, District staff plans to install water-level dataloggers in wells at CTRDN and Canoa Ranch in addition to continuing to collect automated data from ADWR. Staff will continue to collect groundwater level data from Tucson Water for the wells along Tanque Verde Creek near the Sabino Creek and Agua Caliente Wash confluences. Staff will also continue to collect data from U.S. Geologic Survey and District ALERT gauges, including any newly installed gauges, for the collection of precipitation and stream flow data to evaluate surface water and groundwater connectivity.

Staff continues to encourage groups such as The Watershed Management Group and others to educate well owners in these shallow groundwater areas on the benefits of water conservation. The overall goal is to conserve on pumping and capture local on-site water with passive water harvesting to help increase local recharge so water levels in these areas will continue to recover.

References

Postillion, F. G., Scalero, D and M. Krieski, 2013. Canoa Ranch Groundwater Evaluation. Hydrologic Evaluation of the Occurrence and Nature of Groundwater, and Water Level Trends and Water Balance Related to Future Water Resource Use in the Canoa Ranch Area, Upper Santa Cruz Basin, Pima County, Arizona. April.

Postillion, F.G, Scalero, D, Prietto, J., J. Becker, 2015. Cienega Creek Basin Groundwater Evaluation. Draft. Pima County Regional Flood Control District. July.

Watershed Management Group (WMG), 2017. Water use data collected by the River Run Network for Target Streamsheds: Lower Sabino Creek, Lower Tanque Verde Creek, Middle Tanque Verde Creek and Agua Caliente and Upper Tanque Verde Creek. Personal communication (email) with Catlow Shipek, Watershed Management Group, November 21.

Pima County
Multi-species Conservation Plan:
2017 Annual Report

Appendix 13

Monitoring Report on Invasive Species Presence in the Central Arizona Project Aqueduct

Invasive Species in the Central Arizona Project (CAP)s

Invasive is defined as non-native species whose introduction causes or is likely to cause harm. The following invasive species have been identified throughout the CAP (unless otherwise noted):

- Quagga mussel (*Dreissena bugensis*)
- Asian Clam (*Corbicula fluminea*)
- Colonial hydroid (*Cordylophora caspia*)
- Rock Snot (*Cymbella* spp.) – not documented below Tucson Aqueduct Reach 1

Fish Species in the CAP - Sampled annually by Reclamation from 1995-2010; 2015

- Black Bullhead (AMME - *Ameiurus* melas)
- Yellow Bullhead (AMNA - *Ameiurus natalis*)
- Goldfish (CAAU - *Carassius auratus*)
- Grass Carp (CTID - *Ctenopharyngodon idella*)
- Common Carp (CYCA - *Cyprinus carpio*)
- Red Shiner (CYLU - *Cyprinella lutrensis*)
- Threadfin Shad (DOPE - *Dorosoma petenense*)
- Channel Catfish (ICPU - *Ictalurus punctatus*)
- Green Sunfish (LECY - *Lepomis cyanellus*)
- Bluegill (LEMA - *Lepomis macrochirus*)
- Redear Sunfish (LEMI - *Lepomis microlophus*)
- Hybrid Sunfish (LESP - *Lepomis* spp.)
- Smallmouth Bass (MIDO – Micropterus dolomieu)
- Largemouth Bass (MISA - *Micropterus salmoides*)
- White Bass (MOCH – Morone chrysops)
- Striped Bass (MOSA - *Morone saxatilis*)
- Flathead Catfish (PYOL – Pylodictis olivaris)

Below are tables documenting the number of fish caught by Reclamation sampling at Red Rock Pumping Plant, which is just above Tucson Aqueduct Reach 3, and at San Xavier Pumping Plant (Tucson Aqueduct Reach 5). Fish have also been sampled (hook and line) in Lower Raw Water Impoundment (Tucson Aqueduct Reach 6) and Black Mountain Operating Reservoir (Black Mountain Pipeline).

Red Rock Pumping Plant (Tucson Aqueduct Reach 2; Pinal County)

Year	AMNA	CAAU	CTID	CYCA	CYLU	DOPE	ICPU	LECY	LEMA	LEMI	MISA	MOSA
1995	5	0	0	5	2	0	0	59	21	1	26	0
1997	2	0	0	0	11	56	0	0	9	11	4	1
1998	0	0	0	3	0	0	1	0	3	19	9	1
1999	0	0	0	0	3	4	0	0	15	32	11	0
2000	0	2	0	3	0	0	0	0	2	7	3	3
2001	0	0	0	0	0	0	3	1	0	7	1	0
2002	0	0	10	1	0	0	0	0	3	21	4	6
2003	0	0	1	0	0	0	1	0	7	0	6	11
2004	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	3	2	0	1	0	0	14	11	7	4
2006	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	1	0	0	2	0	0	1	3	1
2008	0	0	1	1	0	0	0	0	0	3	2	0
2009	0	0	1	0	0	0	1	0	4	2	8	2
2010	0	0	3	0	0	0	0	0	1	0	10	3
2015	0	0	0	0	15	0	3	0	0	0	0	2

San Xavier Pumping Plant (Tucson Aqueduct Reach 5)

Year	AMME	AMNA	CAAU	CTID	CYCA	CYLU	DOPE	ICPU	LECY	LEMA	LEMI	LESP	MISA	MOSA
1995	16	0	6	14	0	10	0	0	327	318	11	0	1	0
1997	1	0	0	0	0	0	0	0	41	367	28	0	0	0
1998	0	0	1	6	0	0	1	0	0	238	1	0	0	0
1999	4	0	2	3	0	0	7	0	0	3	0	574	0	0
2000	1	0	2	0	0	0	0	0	7	85	5	204	0	0
2001	0	0	1	2	0	0	0	0	5	25	23	13	0	0
2002	16	0	4	0	0	0	0	1	8	20	58	67	4	0
2003	8	0	0	2	0	1	0	4	12	95	136	17	26	0
2004	7	2	2	2	0	28	0	38	0	19	28	2	10	0
2005	7	0	0	9	0	0	0	4	0	13	16	0	17	0
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	1	0	0	7	3	0	0	26	0	48	204	1	44	0
2008	0	0	0	1	13	0	0	2	0	1	46	0	5	0
2009	0	0	0	8	0	0	0	5	0	5	87	0	48	0
2010	0	0	0	0	0	0	0	1	0	4	17	0	3	0
2015	0	0	0	2	15	5	0	4	0	0	3	0	26	1

Lower Raw Water Impoundment (Tucson Aqueduct Reach 6)

- Common Carp (CYCA - *Cyprinus carpio*)
- Bluegill (LEMA - *Lepomis macrochirus*)
- Largemouth Bass (MISA - *Micropterus salmoides*)

Black Mountain Operating Reservoir (Black Mountain Pipeline)

- Common Carp (CYCA - *Cyprinus carpio*)
- Channel Catfish (ICPU - *Ictalurus punctatus*)
- Bluegill (LEMA - *Lepomis macrochirus*)
- Redear Sunfish (LEMI - *Lepomis microlophus*)
- Hybrid Sunfish (LESP - *Lepomis* spp.)
- Largemouth Bass (MISA - *Micropterus salmoides*)

Invertebrate Species in the CAP – Substrates sampled by CAP personnel from 2007 – 2011 at three location in Hayden Rhodes Aqueduct Reach 11 (North Phoenix and Scottsdale). Samples were identified by Reclamation personnel.

- EPHEMEROPTERA
  - Baetidae
    - *Acentrella insignificans*
    - *Camelobaetidius warreni*
    - *Fallceon quilleri*
  - Caenidae
    - *Caenis sp.*
  - Leptohyphidae
    - *Tricorythodes sp.*
- ODONATA
  - Coenagrionidae
    - *Argia sp.*
  - Gomphidae
- NEUROPTERA
  - Sisyridae
    - *Climacia chapini*
- TRICHOPTERA
  - Helicopsychidae
    - *Helicopsyche sp.*
  - Hydropsychidae
    - *Smicridea sp.*
  - Hydroptilidae
    - *Hydroptila sp.*
  - Leptoceridae
    - *Nectopsyche sp.*
    - *Oecetis sp.*
- LEPIDOPTERA
  - Pyralidae
    - *Petrophila sp.*
- COLEOPTERA
  - Dytiscidae
    - *Hydroporinae*
- DIPTERA
  - Ceratopogonidae
    - *Dasyhelea sp.*
  - Chironomidae
  - Orthocladiinae
    - *Cricotopus sp.*
    - *Nanocladius sp.*
    - *Orthocladius sp.*
    - *Parakiefferiella sp.*
    - *Pseudosmittia sp.*
    - *Thienemanniella sp.*
  - Chironominae
    - *Apedilum sp.*
    - *Chironomus*
    - *Dicrotendipes sp.*
    - *Nilothauma sp.*
    - *Paratanytarsus sp.*
    - *Polypedilum sp.*
    - *Pseudochironomus sp.*
    - *Rheotanytarsus sp.*
    - *Xenochironomus sp.*
  - Tanypodinae
    - *Ablabesmyia sp.*
    - *Pentaneura sp.*
    - *Thienemannimyia group*
  - Empididae
    - *Hemerodromia sp.*
  - Simuliidae
    - *Simulium sp.*
- PORIFERA
- CNIDARIA
    - *Hydra sp.*
- TURBELLARIA
- NEMERTEA
    - *Prostoma sp.*
- OLIGOCHAETA
  - Naididae
- CLADOCERA
  - Daphniidae
    - *Daphnia sp.*
- OSTRACODA
- AMPHIPODA
  - Crangonyctidae
    - *Crangonyx sp.*
  - Hyalellidae
    - *Hyalella azteca*
- ACARI
  - Lebertiidae
    - *Lebertia sp.*
  - Sperchonidae
    - *Sperchon sp.*
- GASTROPODA
  - Physidae
- BIVALVIA
  - Corbiculidae
    - *Corbicula sp.*
  - Dreissenidae
    - *Dreissena bugensis*

Aquatic Vegetation Species in the CAP – Vegetation sampled by CAP personnel (as a result of heavy growth events).

Cymbella spp. (Rock Snot) found from Colorado River to Tucson Aqueduct Reach 1

Hayden Rhodes Aqueduct Reach 1 (near Bouse, AZ)

- Spiny Naiad (*Najas marina*)
- Southern Naiad (*Najas guadalupensis*)
- Horned Pondweed (*Zannichellia palustris*)
- Sago Pondweed (*Stuckenia pectinata*)
- Curly-leaf Pondweed (*Potamogeton crispus*)
- Muskgrass (*Chara*)
- Eurasian watermilfoil (*Myriophyllum spicatum*)
- Filamentous Algae

Hayden Rhodes Aqueduct Reach 2 (downstream of Bouse, AZ)

- Filamentous Algae

Waddell Canal Reach 1 (near Lake Pleasant)

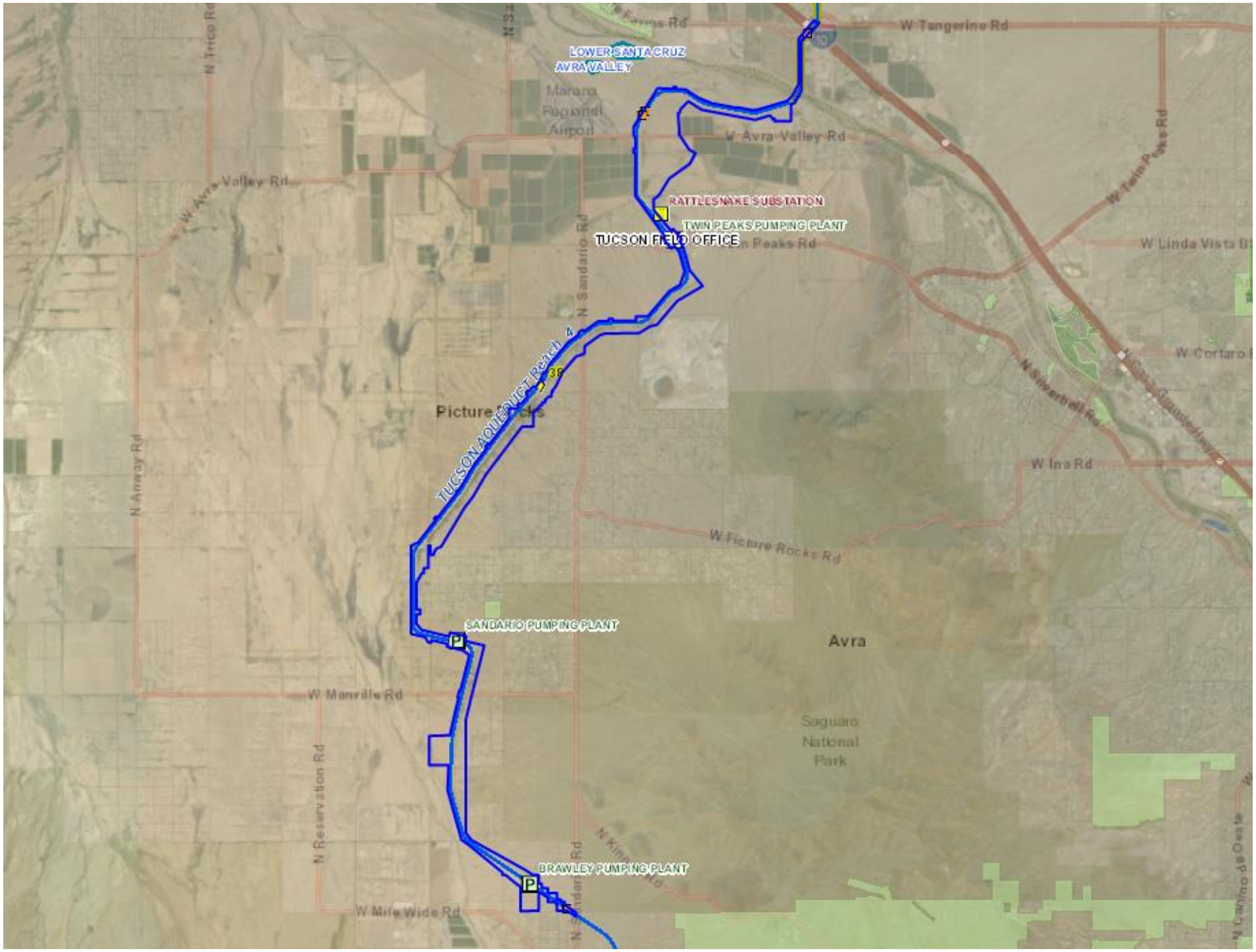
- Filamentous Algae

Tucson Aqueduct Reach 5 (near San Xavier Pumping Plant)

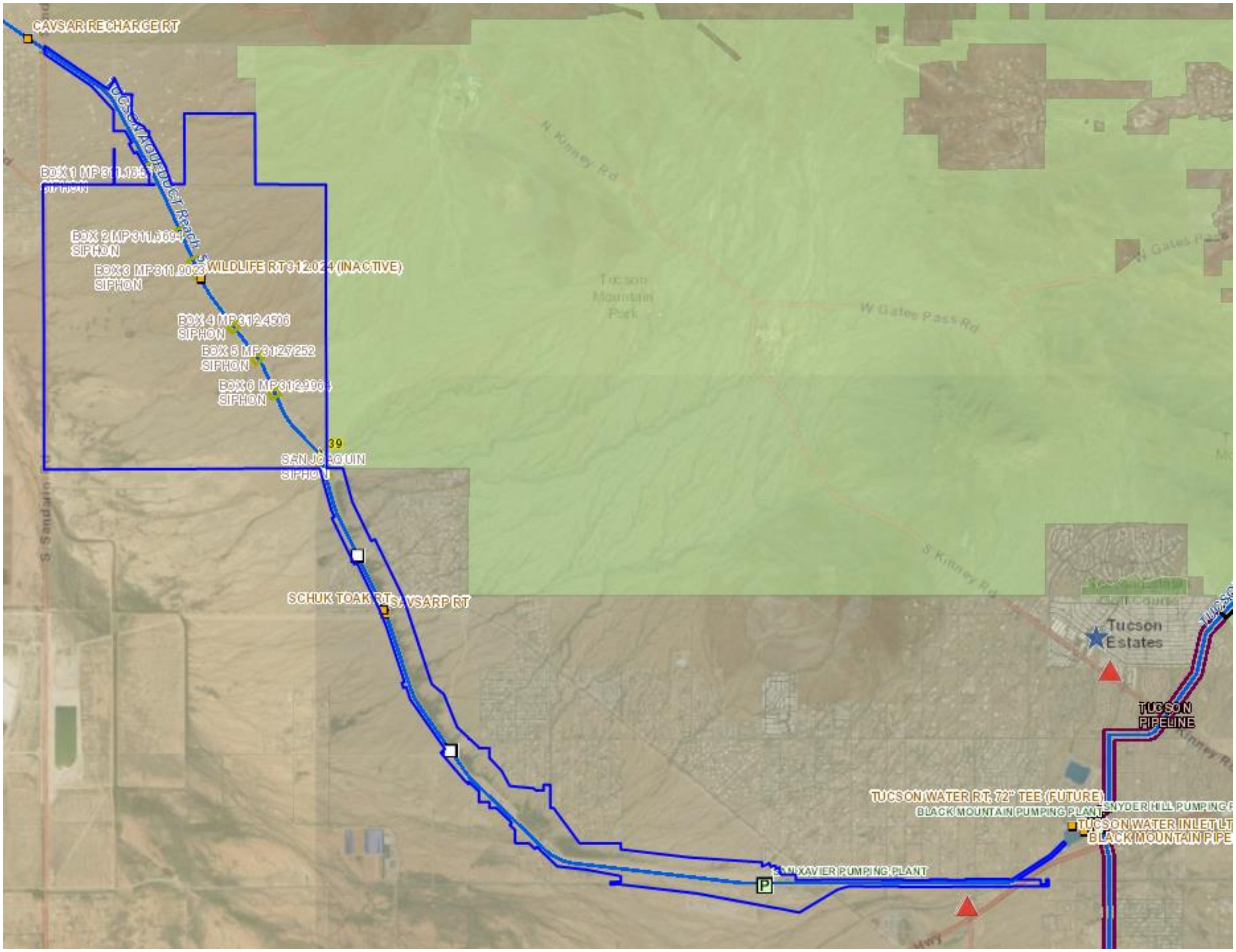
- Horned Pondweed (*Zannichellia palustris*)
- Sago Pondweed (*Stuckenia pectinata*)
- Muskgrass (*Chara*)
- Cattail/Bulrush (*Typha* spp.)
- Filamentous Algae

Tucson Aqueduct Reach 3

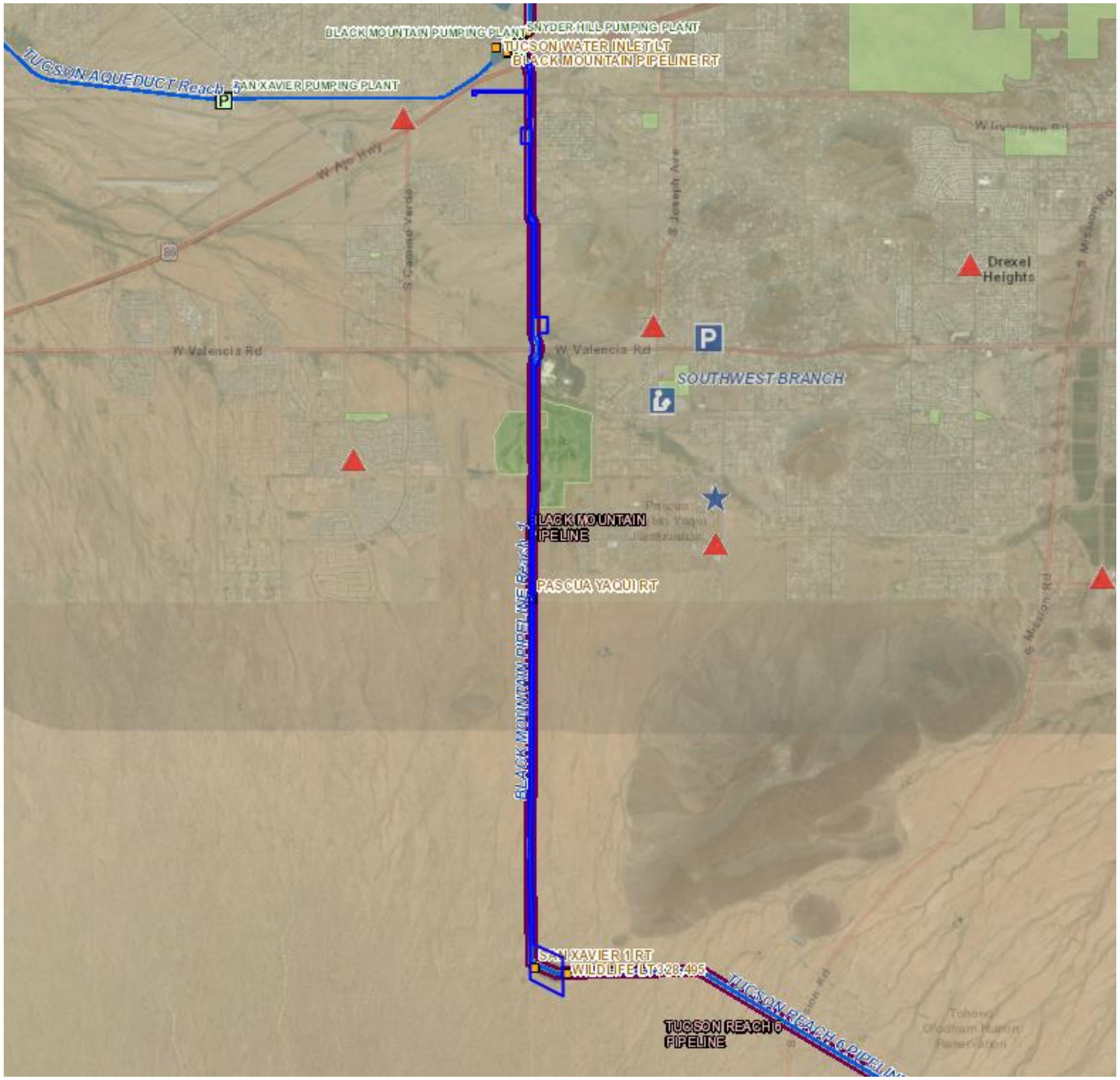
Tucson Aqueduct Reach 4



Tucson Aqueduct Reach 5



Black Mountain Pipeline



Tucson Reach 6 Pipeline