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Appendix 1

List of 2019 Pima County Regional Flood Control District County Improvement Projects CIP utilizing Army Corps Streamlined Programmatic Consultation

1 page

Appendix 1. Projects Using MSCP Programmatic Consultation

Corps SPL#	Project Name	CIP Project Number	Type(s) of Permits Sought	Date Permit(s) Issued	Landowner	404 Applicant	Agent	Lat/long	Year Completed	Location	Certifcate of Coverage Authorized?	Certificate of Coverage #	Certificate of Coverage Expiration Date	MSCP Yr Reported
Corps provides; one SPL can have multiple permits	*Corps/Applicant Provides*		*Corps provides; note as many as apply*	*Corp provides*	*Corps/Applicant Provides (see dropdown list)*	*Corps provides*	*Corps provides based on applicant's info*	*Corps provides based on applicant's info*	*Corps provides; different from MSCP year*	*Provided by county project manager (county projects) or applicant (private projects); type of info is whatever provides most accurate description*	*County provides - Y or N for private projects; NA for public projects (see dropdown list)*	*County provides CofCov # when authorized; if this is blank, no Certificate has been authorized*	*County Provides*	*County OSC provides calendar year for which County records indicate the project was reported as impact for MSCP purposes (Re: Certificates of Coverage - this will report year grading occurs and Certificate is Executed*
SPL-2017-00233	Lower SCR Sediment Removal @ Avra Valley Rd	5SCRMP	RGP 81	5/10/2017	Mixed	Pima RFCD	Mike Cabrera	32.39781/-111.13768	2017	T12S; R12E; S8	N/A			2017
SPL-2016-00565	SCR Sediment Removal Phase 1: Grant to Speedway	5SCRMP	NWP-3(a) = Ph1	Non-Notifying	County/District	Pima RFCD	Mike Cabrera	32.24453/-110.98987	2018	T14S; R14E; S7	N/A			
SPL-2019-00498	Fagan Ranch II-Phase 1	N/A	NWP-29/39	TBD	Private	Jim Campbell	Jim Tress, Westland	31.92362/-110.7713		T17S; R15E; S25	Y	P18CC00079	2/15/2025	
SPL-2016-00565	SCR Sediment Removal Phase 2-Speedway to Congess	5SCRMP	NWP-3(a) = Ph2	Non-Notifying	County/District	Pima RFCD	Mike Cabrera	32.22938/-110.98475	2019	T14S; R14E; S7	N/A			
SPL-2019-00110	Rillito River Sediment Removal - Oracle - La Canada	5RRWMP	NWP-3(a)	Non-Notifying	County/District	Pima RFCD	Mike Cabrera	32.29357/-110.98663	2019	T13S; R13E; S23	N/A			
SPL-2014-00670	El Corazon Bank Protection		NWP-13	2/26/2019	County/District	Pima RFCD	Mike Cabrera	32.321106/-111.059917		T13S; R13E; S7	N/A			
SPL-2019-00099	SCR Sediment Removal @ Sanders Rd. Bridge	5SCRMP	RGP-81	4/17/2019	County/District	Pima RFCD	Mike Cabrera	32.434760/-111.233608	2019	T12S; R12E; S27	N/A			
SPL-2016-00565	SCR Sediment Removal Phase 3: Congress to Silverlake	5SCRMP	NWP-3(a)	Non-Notifying	Mixed	Pima RFCD	Mike Cabrera	32.20417/-110.98926		T14S; R14E; S7	N/A			

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Appendix 2

2019 County Improvement Projects Covered by Pima County's Section 10(a)1(b) Permit

2 pages

Appendix 2. 2019 CIP projects Covered by Pima County's Section 10(a)1(b) Permit

Dept	Program ID	Program Name	Program Description	Substantial Completion AMS	Location
CD	CCD.H04MCS	The Marist on Cathedral Square	Pres / re-use Marist College & demo Tucson Cath Diocese Off for 83 low income rentals for 62+ senior	01/30/2019	111 S. Church & corner of Ochoa / Church Ave.
CD	CCD.N04STL	City of South Tucson Land Acquisition	Purchase 3 parcels; install signalized ped crossing @ 10th & Julian + 10th & 27th St; striping	09/30/2019	118-24-3290; 118-24-3430, Intersection of 10th Ave & 27th St, Intersection of 10th Ave & 40th St
CD	CCD.NR4052	5 Points Business Coalition	Support improvement projects in high stress neighborhoods.	08/30/2019	West: I-10, South: 22nd St, East: Southern Pacific Railroad, North: Broadway/Cushing Street
FC	CFC.5CATRG	Catalina Ridge Drainage Channel Improvements	Reconstruct drainage channel near Canada Del Oro Estates & Rivers Edge Subdivisions	12/30/2019	Avenida Vallejo and Lauren Ashley Place, Oro Valley
FM	CFM.XMJSDI	Main Jail - Storage and Dishwasher Area Improvements	Upgrading dishwasher and storage areas.	07/30/2019	1270 W. Silverlake
FM	CFM.XSCCFL	FM - Superior Courts Common Area Flooring Replacement	Repairing damaged common area flooring on floors 2-6 in Superior Courts bldg.	03/30/2019	110 W. Congress
TR	CTR.4CFCOT	Cortaro Farms Rd Cmno de Oeste to Thornydale	Widen Cortaro Farms Road, to 4 lanes with multi-use, outside curbs, storm drains and landscaping.	04/30/2019	Cortaro Farms Rd: Camino de Oeste to Thornydale
WW	CWW.3AVB16	New Influent Emergency Overflow Basin - Avra Valley WRF	Emergency Overflow Basin for Avra Valley WRF.	12/30/2019	10000 W. Snyder Rd, 85735 S36 T14 R11
WW	CWW.3AVS18	Avra Valley WRF SCADA & Automation Impr FY 17/18	Design, construction, and integration SCADA sys, process control automation improvements Avra Valley	03/04/2019	10000 W. Snyder Rd.
WW	CWW.3EOC14	SCADA Emergency Operations Center	Project will provide the design, construction, and integration of SCADA Process Control.	01/07/2019	3434 E 22nd St.
WW	CWW.3MR919	Sewer Manhole Rehabilitation #9 aka Atterbury Wash	Planned rehab of conveyance system for manhole 09.	11/30/2019	E121213E
WW	CWW.3MRP19	Minor Rehabilitation Projects FY 18/19	Minor rehabilitation projects -- fixing cracked pipes, relining manholes, and general maitenance.	11/30/2019	E121213E
WW	CWW.3PPS13	Principal Pump Station	Modifications will repair, rehabilitate or replace mechanical and electrical equipment	10/28/2019	2900 N Camino Principal
WW	CWW.3SQD18	Tres Rios WRF 600HP Blower Starter Replacement	Remove existing stating equip for blowers and replace w/new "soft start" technology starters.	01/07/2019	7101 N Casa Grande Hwy
WW	CWW.3TRP19	System-wide Treatment Rehabilitation Program	Rehab/Replace defective equip, pipes, and infrastructure throughout division.	07/30/2019	T13S R12E SEC1

Appendix 2. 2019 CIP projects Covered by Pima County's Section 10(a)1(b) Permit

FC	CFC.5RRWMP	Rillito River Maintenance	Phase 2 sediment removal Oracle to La Canada	NA	Rillito river bed, City of Tucson
FC	CFC.5SCRMP	Santa Cruz River Maintenance: Congress to Speedway	Phase 2 sediment removal Congress to Speedway	NA	Santa Cruz river bed, City of Tucson
FC	CFC.5SCRMP	Santa Cruz River Maintenance: Sanders Bridge	Sediment removal on north and south banks	NA	Sanders Road bridge, Marana

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Appendix 3

Potential Future County Improvement Projects
(Chartered but Incomplete)

9 pages

Appendix 3. Potential Future Capital Improvement Projects (Chartered but Incomplete)

Program ID	Program Name	Program Description
CCD.N04STL	CD - City of South Tucson Land Acquisition	Purchase 3 parcels; install signalized ped crossing @ 10th & Julian + 10th & 27th St; striping
CCD.NR4052	CD - 5 Points Business Coalition	Support improvement projects in high stress neighborhoods.
CDE.2INARD	DE - Ina Road Landfill Closure Phase 1	Complete closure of IRCDL per APP 100913.01 and in accordance with approved ADEQ Plans.
CFC.4BFACQ	FC - Floodprone Land Acq Program	Acquisition of floodprone properties.
CFC.4F2205	FC - Arroyo Chico Detention Basin USACOE	This is a multi-phased $27.5 million project for flood control in Tucson Arroyo Chico.
CFC.5AGCL1	FC - Agua Caliente Park Pond 1 Restoration	Line Pond 1 and reduce quantity pumped and associated costs to maintain historic character.
CFC.5CATRG	FC - Catalina Ridge Drainage Channel Improvements	Reconstruct drainage channel near Canada Del Oro Estates & Rivers Edge Subdivisions
CFC.5CDONB	FC - CDO Wash North Bank: Thornydale to I-10	The project has two phases. Bank protection and pedestrian underpasses at 1-10
CFC.5CORZN	FC - El Corazon de los Tres Rios Del Norte	Planning and acquisition of properties along the Santa Cruz River and Sunset Road.
CFC.5CREST	FC - Historic Canoa Ranch Restoration	Restore, enhance and protect 30-acres of floodplain terrace and associated functions.
CFC.5ELVDO	FC - Airport Wash / El Vado Wash Drainage Improvements	Drainage improvement w/channel capacity & infrastructure improvements and re-mapping.
CFC.5ERGLF	FC - Historic Canoa Ranch Restoration	Restore, enhance and protect 30-acres of floodplain terrace and associated functions.
CFC.5FTRDN	FC - Tres Rios del Norte USACOE Study	Provide environmental restoration, flood control, and groundwater recharge on the Santa Cruz River.
CFC.5GVDW6	FC - Green Valley Drainageway Program	Stabilize Drainage Way through repair and addition of five grade control structures .
CFC.5HASOL	FC - Rillito River Upper Bank at Hacienda Del Sol	Planned improvements include: Tiered retaining wall structure with existing culverts being replaced
CFC.5LKMNA	FC - El Rio Preserve Bank Protection	Design & construction of scour and bank protection and channel stabilization for the El Rio Preserve
CFC.5PRRIL	FC - Property Rights Assessments for Rillito River	Assess RFCD property rights along the Rillito River focused on infrastructure maintained by RFCD.
CFC.5PRSCR	FC - Property Rights Assess Santa Cruz River	Assess RFCD property rights along the Santa Cruz River.
CFC.5RMPAF	FC - Riparian Mitigation Project Acquisition Fund	Remove properties from floodplain & revert it back to natural state
CFC.5RRWMP	FC - Rillito River Maintenance Projects	Major sediment removal projects on the Rillito River.
CFC.5RUPRR	FC - Ruthrauff, Gardner lane UPRR Culvert	Culvert & channel @ Gardner Ln/UPRR & 2nd channel @ UPRR between Wetmore & Ruthrauff.
CFC.5SCLIV	FC - Santa Cruz River Living River Management Plan	Develop strategy for water recharge, riparian habitat enhancement and flood risk reduction.
CFC.5SCRBS	FC - Continental Ranch Bank Protection	Major sediment removal, bank protection, repair and stabilization projects on SCR.
CFC.5SCRIR	FC - Santa Cruz River Irvington to Drexel Improvements	Repairs to sinkholes, erosion and irrigation, refurb pathways, handrail, new improvements
CFC.5SCRMP	FC - Santa Cruz River Maintenance Projects	Major sediment removal projects on Santa Cruz River.
CFC.5UDTON	FC - Tohono O'Odham Nation Urban Drainage	Improve flood control and recreational services for the Sells Community Center and Oasis School.
CFC.5URBAD	FC - Urban Drainage	Mitigate flooding problems within the city.
CFC.5XMSWS	FC - Christmas Wash Drainage Improvements	ROW acquisitions, structure demolition and floodplain cleanup, LID water harvesting opportunities,
CFM.BNPACC	FM - New Pima Animal Care Center	New animal care facilities will be constructed on/around existing site on Silverbell Rd in Tucson.
CFM.BPACMB	FM - Pima Animal Care Center Misc Bond Projects	Add'l improvements to PACC facilities

CFM.X3233S	FM - 32-33 N. Stone Electric Capacity Study	Analysis of capacity for elec use, label equip, identify protection needed to open elec panels, code
CFM.X32FIP	FM - 32 N. Stone Facade Improvements	Rebuild masonry corners with appropriate expansion and flashing components for brick façade structur
CFM.X32IMP	FM - 32 N. Stone - Interior Improvements 14th and 15th Floor	Renovate 14th & 15th floors to incl new restrooms, offices, breakrm, copy/file rm, and IDF rm.
CFM.XADSEC	FM - Adult Detention Security Replacement	Design team defining needs for integrated security electronics system whole PC adult denten complex
CFM.XAE2RV	FM - Admin East 2nd Floor Renovation	Design/construct offices for PC Risk Mgmnt Dept & small div of finance on 2nd fl Admin East.
CFM.XAW5TI	FM - Administration West 5th Fl Improvements	To perform demolition & Asbestos Abatement followed by 5th fl improvements.
CFM.XBNCSC	FM - Banner UMSC Building Improvements	Partial replacement and upgrade of fire alarm system & replace 2 air handlers
CFM.XCHILL	FM - Downtown Central Plant Chiller & Pump Replacement	Chiller and pump capacity to be increased to support additional bldgs. with chilled water
CFM.XD16TI	FM - Public Defender 16th Fl Tenant Remodel - 33 N. Stone	Create add'l office in current space not occupied by PD and remove wall in exist suites for hallway
CFM.XDSBJC	FM - Defense Services Building - Juvenile Courts	Design & Constr 25k sq ft, 2 story office bldg. next to existing on juvenile crt campus. redo fence.
CFM.XDSD01	FM - Development Services Renovation - PWB Floors 1 & 2	Design & construct open office concept for DSD at PWB.
CFM.XEXIMP	FM - Exterior Building Improvements	Unsafe or aesthetically unpleasing areas of plaza addressed.
CFM.XFORSC	FM - Forensics Science Center	New facility south of existing ME bldg. ~34,000 sf, FSC has 2 areas, Office and Autopsy.
CFM.XGCEXT	FM - 130-150 W Congress Facade Improvements	Replace various parts, ancillary components, chiller transformer & MCC in utility tunnel.
CFM.XIIFCW	FM - Interior Improvements - Floors, Ceilings, Walls	Interior improvement of publicly used common facilities in PC bldgs. to current safety standards.
CFM.XJAN8M	FM - January 8 Memorial in El Presidio Park	Design & construct memorial west of old courthouse. Modifications and improvements incl in scope.
CFM.XJCOOL	FM - Minimum Security Facility Cooling Replacement	Remove evap cool system and upgrade to new AC system to match rest facility.
CFM.XKINPG	FM - Kino Parking Garage	Build 6 level parking garage with solar panels, office, and shuttle area.
CFM.XKNYPR	FM - Kino YMCA Pool Restoration	Restoration to pool surfaces
CFM.XLEX20	FM - Library Exterior Improvements - FY20	Library system has 25 branches & project includes exterior improv. like HVAC, paint, roof, etc
CFM.XLIN20	FM - Library Interior Improvements - FY20	Library system has 25 branches & project includes interior improv. like carpet, paint, furniture
CFM.XLPL20	FM - Library Parking Lot Improvements FY20	Library system has 25 branches & project includes repairs for parking lots.
CFM.XLSBPR	FM - LSB Chilled Water Connection	County's main central plant has capacity to provide chilled water to LSB. Feasible piping route.
CFM.XMFIRE	FM - Mission Road Fire Alarm Upgrade	Replace 10 fire alarm panels in multiple bldgs. throughout Mission Rd.
CFM.XMJTPC	FM - Main Jail - Tower Pneumatic Controls	Pneumatic controls will be repl in Mezzanine FY19, tower 4 floors repl FY20.
CFM.XMLBEX	FM - Martha Cooper Library Expansion	Expand existing 7500 sf to add 6-7,000 sf to incl staff area, lgr meet rm, add'l collections space
CFM.XNWHLC	FM - Northwest County Service Center	Purchase 50,000 sf building. Plan, design interior renovation for various functions
CFM.XOCH02	FM - Historical Courthouse - Core & Shell	Interior renov for infrastructure toward planned tenant and bldg. upgrades to extend bldg. life.
CFM.XOCH03	FM - Historical Courthouse - Tenant Improvements	Tenant Imprv to provide Visitor Center & museum space, offices, & storage. Protect historical bldg.
CFM.XPARKA	FM - Parking Lot Paving Rejuvenation	Establish 3-yr cycle for crack sealing, seal coat and re-striping.

CFM.XPCEMS	FM - Public Works Energy Management System	Install Delta Stats at all zones, provide/supply sensors, relays & switches to control HVAC remotely
CFM.XPTMMB	FM - Pre-Trial Mail Modular Building	Install underground utilities,new 2880 aq triple wide modular,east end. Abate & demolish current SSA
CFM.XRRIMP	FM - Rillito Racetrack Building Improvements	Electrical Assessment & upgrade systems to meet current code.
CFM.XSBLIB	FM - New Sahuarita Branch Library	Design & construct 20,000 sq ft library in town of Sahuarita
CFM.XSELIB	FM - Southeast Library	Construct 10,000 SF regional library, connect to Loop, w/YMCA facility at UA Tech Park in Rita Ranch
CFM.XTRHSB	FM - Jail Mail and Pre-Trial Services New Buildings	Demolish old, construct new 22,000 sq ft, 2-story bldg. for adult detention/court matters.
CFM.XVLCHL	FM - Valencia Library Chiller Replacement	Valencia library chiller to be replaced
CFM.XWLIBR	FM - Wilmot Library Roofing	Replace existing lower built up roofing sections to include 4" poly-iso roof insulation, 3-ply sys.
CFS.XAWSFI	FS - Ajo Way Fuel Island	Replace underground fuel tank w/above ground double walled tank. Reno of island for updates & codes.
CFS.XHRDFI	FS - Houghton Rd Fuel Island	Relocate fuel island to west side of Fleet Serv Bldg to imporive vehicle access.
CFS.XINAFI	FS - Ina Road Fuel Island	Repl 2 undergrd fuel tanks w/above grd dbl wall tanks. dispen, protect, & containmnt. reno bathroom
CIT.ACCESS	IT - Access Layer Switch Replacement	Replacement of newtwork ports in offices across county offices.
CIT.ACSSWT	IT - Access Switches (Convert Lease to Purchase) - Fund 6000	14k network access switch ports will be replaced.
CIT.AJOWLS	IT - Ajo Wireless - Fund 6000	Replacement of over 400 individual WAPs), provide better reporting and tracking systems
CIT.ASLM21	IT - PC Attorney Storage Lifecycle Mgmt FY 20/21 - Fund 6013	Replace all PC Attorney server and storage equipment. Current leases will end 3/2021.
CIT.ASLM26	IT - PC Attorney Storage Lifecycle Mgmt FY 25/26 - Fund 6013	Replace all PC Attorney server and storage equipment.
CIT.CLMP20	IT - Cabling Lifecycle Management Plan FY 19/20 - Fund 6000	Route 144 strand fiber cable throughout PC bldgs. Connection from Ajo Complex, Mission, Benson FY20
CIT.CLMP21	IT - Cabling Lifecycle Management Plan FY 20/21 - Fund 6000	Route 144 strand fiber cable throughout PC bldgs. Northwest corridor and Redundancy Points FY21
CIT.CNEQ20	IT - Cisco Network Equipment FY 19/20 - Fund 6000	Replace PCSD network equipment
CIT.DATCSR	IT - Data Center Switch Replacement - Fund 6013	Data center switch replacement. Other related systems will be upgraded or replaced in future years.
CIT.F5LB20	IT - F5 Load Balancer Equipment FY 19/20 - Fund 6013	Replace load balancers in PC data centers.
CIT.HYPE20	IT - Hyper Converge Server/Storage FY 19/20 - Fund 6013	Architect a solution that addresses challenges with HPE and modernizes appl. delivery through IaaS
CIT.HYPE21	IT - Hyper Converge Server/Storage FY 20/21 - Fund 6013	Architect a solution that addresses challenges with HPE and modernizes appl. delivery through IaaS
CIT.LIBERA	IT - Library Network Lifecycle	Upgrade networking infrastructure for Library District via next generation hardward updates, etc.
CIT.MPLSDC	IT - MPLS Project (Distribution and Core) - Fund 6000	14k network access switch ports will be replaced.
CIT.PCSDSS	IT - PC Sheriff's Department Server & Storage Replacement	Phase 1 - Spillman servers and storage being replaced
CIT.PHONES	IT - Phone System Replacement - General Fund	Replace all PC desktop phones
CIT.SDBR20	IT - PCSD Backup Recovery Tape Library FY 19/20 - Fund 6013	Replace current backup solution in PCSD data center.
CIT.WIFI22	IT - WiFi Refresh FY 21/22 - Fund 6000	Replace over 400 WAPs throughout PC with more efficient and secure models.
CIT.WIFI25	IT - WiFi Refresh FY 24/25 - Fund 6000	Replace over 400 WAPs throughout PC with more efficient and secure models.

CIT.WINNBU	IT - PCWIN Network Backhaul Upgrade	Phase 1 of 10 yr network backhaul upgrade plan to replace existing microwave equip with new.
CIT.WRLSAP	IT - Wireless Access Point Replacement	Replacement of wireless access points in offices across county offices.
CKS.KSCSSC	KSC - Kino South Sports Complex	Phase 1 to develop 12 soccer fields and connect with use at North fields.
CMA.81S001	BOS - Willow Ridge Commons	RLRRP - Marana
CMA.81S002	BOS - Cortaro Ranch	RLRRP - Marana
CMA.81S003	BOS - Hartman Ten	RLRRP - Marana
CMA.81S004	BOS - Hartman Vistas	RLRRP - Marana
CMA.81S005	BOS - Countryside Ridge	RLRRP - Marana
CMA.81S006	BOS - Sombra Del Tecolote	RLRRP - Marana
CMA.81S007	BOS - Oasis Hills II	RLRRP - Marana
CMA.81S008	BOS - The Pines Phase I	RLRRP - Marana
CMA.81S009	BOS - Parcel 7 Continental Ranch	RLRRP - Marana
CMA.81S010	BOS - Parcel 9 Continental Ranch	RLRRP - Marana
CMA.81S011	BOS - Parcel 10 Continental Ranch	RLRRP - Marana
CMA.83S001	BOS - San Lucas Block 2	RLRRP - Marana
CMA.83S002	BOS - San Lucas Blocks 3-4	RLRRP - Marana
CMA.83S003	BOS - San Lucas Block 5	RLRRP - Marana
CMA.83S004	BOS - San Lucas Blocks 6 (61-115)	RLRRP - Marana
CMA.83S005	BOS - San Lucas Block 7	RLRRP - Marana
CMA.83S006	BOS - San Lucas Block 8	RLRRP - Marana
CMA.83S007	BOS - San Lucas Block 9	RLRRP - Marana
CMA.83S008	BOS - San Lucas Block 11	RLRRP - Marana
CMA.83S009	BOS - San Lucas Block 12	RLRRP - Marana
CMA.83S010	BOS - Gladden Farms Block 9	RLRRP - Marana
CMA.83S011	BOS - Marana Estates	RLRRP - Marana
CMA.83S012	BOS - Stone Ridge (1-76)	RLRRP - Marana
CMA.83S013	BOS - Continental Reserve Block 1 & 7	RLRRP - Marana
CMA.83S014	BOS - Continental Reserve Block 7 & 8	RLRRP - Marana
CMA.83S015	BOS - Continental Reserve Block 9	RLRRP - Marana
CMA.83S016	BOS - Continental Ranch Active Adult Community	RLRRP - Marana
CMA.83S017	BOS - Continental Ranch Sunflower Phase II	RLRRP - Marana
CMA.83S018	BOS - Continental Ranch Sunflower Phase III	RLRRP - Marana
CMA.83S019	BOS - Continental Ranch Sunflower Phase IV	RLRRP - Marana
CMA.83S020	BOS - Continental Ranch Sunflower Phase V	RLRRP - Marana
CMA.83S021	BOS - Continental Ranch Sunflower Phase VI	RLRRP - Marana
CMA.83S022	BOS - Continental Ranch Sunflower Phase VII	RLRRP - Marana
CMA.83S023	BOS - Saguaro Bloom Block 8B	RLRRP - Marana
CMA.8LABOR	BOS - Marana FY2018 Labor	Local Road Repair Program Labor Tracking for FY 17/18.
CMA.91S008	BOS - The Villages at Dove Mountain	FY 18/19 RLRRP - Marana
CMA.91S009	BOS - The Villages at Redhawk	FY 18/19 RLRRP - Marana
CMA.91S010	BOS - The Villages III at Dove Mountain	FY 18/19 RLRRP - Marana
CMA.91S011	BOS - The Villages IV at Dove Mountain	FY 18/19 RLRRP - Marana
CMA.91S012	BOS - Quail Crossing	FY 18/19 RLRRP - Marana

CMA.91S013	BOS - Quail Crossing II	FY 18/19 RLRRP - Marana
CMA.91S014	BOS - Bluffs at Dove Mountain	FY 18/19 RLRRP - Marana
CMA.91S015	BOS - Tortolita Reserve	FY 18/19 RLRRP - Marana
CMA.91S018	BOS - Parcel 8 Continental Ranch	FY 18/19 RLRRP - Marana
CMA.91S021	BOS - Continental Ranch Parcel 50	FY 18/19 RLRRP - Marana
CMA.91S022	BOS - Continental Ranch Parcel 51	FY 18/19 RLRRP - Marana
CMA.91S023	BOS - Continental Estates Parcel 52C	FY 18/19 RLRRP - Marana
CMA.93S010	BOS - Marana Vista	FY 18/19 RLRRP - Marana
CMA.93S012	BOS - Sunset Acres II	FY 18/19 RLRRP - Marana
CMA.93S013	BOS - Silverbell Hills Estates	FY 18/19 RLRRP - Marana
CMA.93S014	BOS - Sonoran Moon	FY 18/19 RLRRP - Marana
CMA.93S015	BOS - Desert Traditions I	FY 18/19 RLRRP - Marana
CMA.93S016	BOS - Desert Traditions II	FY 18/19 RLRRP - Marana
CMA.93S017	BOS - Acacia Trails	FY 18/19 RLRRP - Marana
CMA.93S018	BOS - Cancion De La Luna	FY 18/19 RLRRP - Marana
CMA.93S019	BOS - El Rio at Continental Ranch	FY 18/19 RLRRP - Marana
CMA.93S020	BOS - Sonoran Vista	FY 18/19 RLRRP - Marana
CMA.93S021	BOS - Los Morteros Estates	FY 18/19 RLRRP - Marana
CMA.93S022	BOS - Silver Moon	FY 18/19 RLRRP - Marana
CMA.93S023	BOS - Twin Peaks Highland	FY 18/19 RLRRP - Marana
CMA.93S024	BOS - Twin Peaks Subdivision	FY 18/19 RLRRP - Marana
CMA.93S025	BOS - Sunset Ranch Estates	FY 18/19 RLRRP - Marana
CMA.93S030	BOS - Continental Reserve Block 10	FY 18/19 RLRRP - Marana
CMA.93S031	BOS - Continental Reserve Block 12	FY 18/19 RLRRP - Marana
CMA.93S032	BOS - Continental Reserve Block 14	FY 18/19 RLRRP - Marana
CMA.93S033	BOS - Continental Reserve Block 15	FY 18/19 RLRRP - Marana
CMA.93S034	BOS - Continental Reserve Block 16A	FY 18/19 RLRRP - Marana
CMA.93S035	BOS - Continental Reserve Block 16B	FY 18/19 RLRRP - Marana
CMA.93S036	BOS - Continental Reserve Blocks 17-19	FY 18/19 RLRRP - Marana
CMA.93S037	BOS - Parcel 11 Continental Ranch	FY 18/19 RLRRP - Marana
CMA.93S038	BOS - Continental Ranch Parcel 12A	FY 18/19 RLRRP - Marana
CMA.93S039	BOS - Continental Ranch Parcel 12B	FY 18/19 RLRRP - Marana
CMA.93S040	BOS - Continental Ranch Parcel 15 The Villas	FY 18/19 RLRRP - Marana
CMA.93S044	BOS - Parcel 23 Continental Ranch	FY 18/19 RLRRP - Marana
CMA.93S045	BOS - Parcel 26 Continental Ranch	FY 18/19 RLRRP - Marana
CMA.93S046	BOS - Continental Ranch Parcel 27A	FY 18/19 RLRRP - Marana
CMA.93S047	BOS - Continental Ranch Parcel 27B	FY 18/19 RLRRP - Marana
CMA.93S048	BOS - Parcel 28 Continental Ranch	FY 18/19 RLRRP - Marana
CMA.93S049	BOS - Continental Ranch Parcels 38 & 40	FY 18/19 RLRRP - Marana
CMA.93S050	BOS - Continental Ranch Par (36-38, 40) Phase II	FY 18/19 RLRRP - Marana
CMA.93S051	BOS - Continental Ranch Phase III Par. 36-38, 40	FY 18/19 RLRRP - Marana
CMA.93S052	BOS - Continental Ranch Copper Moon	FY 18/19 RLRRP - Marana
COV.81R001	BOS - Arrowsmith Dr (RV to Woodburne)	Crack & chip seal for Oro Valley's Year 1 RLRRP. Pima County to manage& final inspec / OV daily ins
COV.81R002	BOS - Arrowsmith Rd (RV to end of Pavement)	Crack seal for Oro Valley's Year 1 RLRRP ; Arrowsmoith Rd. PC manage & final inspec / OV daily inspe
COV.81R003	BOS - Calle Concordia (Loma Linda to Oracle Rd)	Crack seal Oro Valley's Year 1 RLRRP ; Calle Condcordia. PC manage & final inspec / OV daily insp

COV.81R004	BOS - Egleston Dr (Desert Sky to Linda Vista)	Regional Local Road Repair Program, Town of Oro Valley
COV.81R005	BOS - Palisades Rd	Regional Local Road Repair Program, Town of Oro Valley
COV.81R006	BOS - Calle Concordia (Oracle Rd to Marne Pl)	Regional Local Road Repair Program, Town of Oro Valley
COV.81R007	BOS - Cool Drive (Northern Av to Oracle Rd)	Regional Local Road Repair Program, Town of Oro Valley
COV.81S001	BOS - Desert Willows Subd	Regional Local Road Repair Program, Town of Oro Valley
COV.81S002	BOS - Lambert Acres Subd	Regional Local Road Repair Program, Town of Oro Valley
COV.81S003	BOS - Lambert Lane Subd	Regional Local Road Repair Program, Town of Oro Valley
COV.81S004	BOS - RV NH 10 W (1-36) Subd	Regional Local Road Repair Program, Town of Oro Valley
COV.81S005	BOS - RV NH 5 PAR C Subd	Regional Local Road Repair Program, Town of Oro Valley
COV.81S006	BOS - RV NH 5 PAR T Subd	Regional Local Road Repair Program, Town of Oro Valley
COV.81S007	BOS - RV NH 7 PAR H Subd	Regional Local Road Repair Program, Town of Oro Valley
COV.81S008	BOS - RV NH 7 PAR K & C Subd	Regional Local Road Repair Program, Town of Oro Valley
COV.81S009	BOS - Rancho Catalina (1-221)	Regional Local Road Repair Program, Town of Oro Valley
COV.81S010	BOS - Rancho Feliz (353-389)	Regional Local Road Repair Program, Town of Oro Valley
COV.81S011	BOS - RV NH 7 PAR F	Regional Local Road Repair Program, Town of Oro Valley
COV.81S012	BOS - Rivers Edge (1-69 & 103-120)	Regional Local Road Repair Program, Town of Oro Valley
COV.81S013	BOS - RV NH 7 Unit 1	Regional Local Road Repair Program, Town of Oro Valley
COV.81S014	BOS - Tangerine Terrace	Regional Local Road Repair Program, Town of Oro Valley
COV.81S015	BOS - Palisades South (Skywire Way)	Regional Local Road Repair Program, Town of Oro Valley
COV.81S016	BOS - Catalina Shadows	Regional Local Road Repair Program, Town of Oro Valley
COV.81S017	BOS - Catalina Shadows Estates	Regional Local Road Repair Program, Town of Oro Valley
COV.81S018	BOS - Catalina Shadows Estates PH 4	Regional Local Road Repair Program, Town of Oro Valley
COV.81S019	BOS - RV NH 2 PH 1 & 2	Regional Local Road Repair Program, Town of Oro Valley
COV.81S020	BOS - RV NH 7 PAR G	Regional Local Road Repair Program, Town of Oro Valley
COV.81S021	BOS - Rancho Feliz (442-647)	Regional Local Road Repair Program, Town of Oro Valley
COV.81S022	BOS - Shadow Mountain Estates	Regional Local Road Repair Program, Town of Oro Valley
COV.81S023	BOS - Shadow Mountain Estates East	Regional Local Road Repair Program, Town of Oro Valley
COV.81S024	BOS - Sunnyslope (3-59)	Regional Local Road Repair Program, Town of Oro Valley
COV.81S025	BOS - Fairhaven Village	Regional Local Road Repair Program, Town of Oro Valley
COV.8LABOR	BOS - Oro Valley FY2018 Labor	Local Road Repair Program Labor Tracking for FY 17/18.

CPR.PR36TH	PR - 36th Street Desert Haven Natural Resource Park	Install newnatural resourses park incl trail dev, riparian vegetation & restoration, ramadas, etc.
CPR.PRBARN	PR - Rillito Racetrack Barn 2019	install 40 stall "mare motel" south of existing barn.
CPR.PRBFSP	PR - Brandi Fenton Splash Pad Update 2020	Replace existing aged toys, remove & replace top surface of pad, update controls, new fencing
CPR.PRCRTH	PR - Canoa Ranch Tradesman House	Provide new tenant improvements to allow NRPR to start utilizing the transman house at historic prop
CPR.PRHFM4	PR - Farmer's Market Ramada 4	Installation of 4th ramada to match others, as originally engineered.
CPR.PRLNPL	PR - Los Ninos Pools Rehab 2020	Remove & replace plaster surface for main pool & wading pool at park
CPR.PRMTLM	PR - Mount Lemmon CC Improvements	complete portion of list of items to update community center on Mt Lemmon till more funds found.
CPR.PRRLIT	PR - Rillito Park Lighting - Field 10	Install newMusco Green sports lighting for field 10 at Rillito Park.
CPR.PRSGLT	PR - SERP Shotgun Range Lighting	Enhancement to install lighting for evening use for two fields & parking,
CPR.PSPTPK	PR - Sports Park Upgrades 2017	update Sports Park land for parking, ADA, utility and other improvements to enhance operations.
CPW.PWPPEP	PW - Amado Youth Center	New 40x60 bldg. to incl office, storage, restroom, and fexible space for group activities.
CPW.PWSNST	PW - Sunset Campus Entry	Install 2 main entries - a loop road & main mall, along w/utilities, etc. for future bldg. pad site.
CPW.PWVMOP	PW - Veterans Memorial Overpass Painting	Repaint existing public art at overpass to the original color scheme, use better paint product.
CPW.RAYABF	PW - 162d Air Guard Munitions Storage Area	purch appr 55 acres for AZ ANG munitions storage facility + 1.2 acres future expan aero pkwy
CPW.RWRART	PW - RWRD Public Art Program	Public art programs controlled by PW
CSU.ATLANO	SUS - Anza Trail - Llano Grande Campsite	Provide a trailhead at about the location of the Anza Expedition Llano Grande campsite.
CSU.SUNARC	SUS - Sunset Campus Archaeology	2nd Phase of archaeological clearing (trenching) of 3' deep soil cap to be used by RFCD.
CSU.TUMAMO	SUS - Tumamoc Hill Acq	Tumamoc Hill and Desert Laboratory have unique value as open space important to Pima County.
CTR.4AERO2	TR - Aerospace Pkwy Nogales Hwy - Vicinity of World Vw Entr	Install 4-lane pkwy expansion along Aerospace Pkwy from Nogales Hwy to 3800 LF east of Raytheon Pkwy
CTR.4AJOAP	TR - Ajo Airport Perimeter Security Fence	Design & install of approximately 17,500 lineal feet of 6 ft high chain link w/3-strand barbed wire.
CTR.4BBECC	TR - Broadway Blvd Euclid to Country Club RTA17 (portion of)	Widen Broadway Blvd to six or eight lanes from Euclid Avenue to Country Club
CTR.4BUSTX	TR - Bus Stop Improvement 2 Program	Improve bus stops in incorporated Pima County with bus shelters, benches, sidewalks, curbs, etc
CTR.4CFCOT	TR - Cortaro Farms Rd Cmno de Oeste to Thornydale	Widen Cortaro Farms Road, to 4 lanes with multi-use, outside curbs, storm drains and landscaping.
CTR.4DIFSY	TR - 2017-2018 Development Impact Fee Study	Development of land use assumptions, impact fee serv areas, etc. Roads over 10 yr period fee study
CTR.4DRXXL	TR - Benson Hwy at Drexel Intersection Improvements	New intersection modifications for safety improvements.
CTR.4GUARD	TR - Guard Rail Program	Review and construction of guardrails at initially 9 locations, not to exceed $1,785,000
CTR.4HRCCS	TR - Houghton Road City-County Shoulders	Add 6' shoulders along both sides Houghton Rd from Andrada to I-10. Chip & Fog seal, some overlay.
CTR.4HRSTV	TR - Houghton Rd I-10 to Golf Links Rd RTA 32 (portion of)	Widen Houghton Rd to 4-lanes, between Old Vail and Golf Links Roads to 6-lanes.
CTR.4HSBSP	TR - Spdwy Blvd - Painted Hills Rd to Cmo de Oeste	Design & construct 1.6 mi of 6 ft. paved shoulders along Speedway between Pnted Hills & Cmno Oeste
CTR.4INASW	TR - Ina Rd-Shannon Rd to La Cholla Blvd Sidewalk	Includes design and construction of concrete sidewalk and curb access ramps to provide ADA access
CTR.4KCTHP	TR - King Canyon Trailhead Parking	Improving intersection sight distances and cutting back the existing slope N side Kinney Rd

CTR.4KINAC	TR - Kinney Rd Improvements	Mill existing AC pavement and overlay Kinney Rd from Alexandrite Ave to Bopp RD w/ new AC.
CTR.4KINBO	TR - Bopp Rd - Sarasota Blvd at Kinney Rd Improvements	Bopp realigned to connect woth .16 mil extension of Sarasot Blvd south of Kinney.
CTR.4KINOP	TR - 22nd St I-10 to Tucson Blvd Improvements	Construct an overpass for Kino Blvd over 22nd St and ramps from Kino at-grade to 22nd St.
CTR.4KSCSD	TR - Kolb Road: Sabino Road to Sunrise Drive	Reconstruct and widen approx. 1.9 mi of Kolb from 2-lane to 3-lane, multi-use, etc.
CTR.4LCBOT	TR - La Cholla: Overton to Tangerine	Widening approx. 3.5 mi of La Cholla from Overton to Tangerine.
CTR.4PPP18	TR - Arterial / Collector - Pavement Repair & Rehabilitation	Repair & rehabilitate arterial and collector roads in unincorporated Pima County.
CTR.4PPP19	TR - Pavement Repair and Rehabilitation, FY19	Rehab existing urban arterial & collector streets with various degrees of deterioration.
CTR.4PPP20	TR - Arterial / Collector - Pavement Repair & Rehab, FY20	rehabilitate existing urban arterial & collector streets experiencing varied degrees deterioration
CTR.4REPSW	TR - El Paso SW Greenway	Install a portion of the EPSW Greenway of South Tucson segment at 29th st for 1500 LF.
CTR.4RTVWE	TR - Valencia Rd Wade Rd to Ajo Highway	Improve Valencia Rd. from Wade Rd. to Mt. Eagle Rd.
CTR.4SAFTY	TR - Safety Improvements 1997 Bond Funded	The HURF Revenue Bond includes $19 million for traffic safety improvements in various areas.
CTR.4SAHWI	TR - Sahuarita Rd & Wilmot Rd Intersection Improvements	Intersection improvements incl intersec control, add turn lanes, ADA compl & drainage improv.
CTR.4SBPCP	TR - Systematic Bike and Pedestrian Crossing Improvement Pla	Review and short / long term master planning to crossings at merge locations.
CTR.4SHRWD	TR - South Houghton Road Widening	widen Houghton Road from I-10 south to approximately the Andrada Polytechnic High School.
CTR.4SRRIV	TR - Sunset Rd: I-10 to River Rd	New 3-lane roadway and bike lanes on Sunset Rd from I-10 to River Rd.
CTR.4SSWPI	TR - White Pistor	provide sidewalk, curb and curb ramps for continuous ADA sidewalks.
CTR.4SUNTE	TR - Skyline Dr at Sunrise Dr Intersection Improvements	Adjusting left & right turn lanes, add stop control, add 2 street lights, add ADA curbing, signs,etc
CTR.4TRSPR	TR - Sign Panel Replacement	Inventory and determine retro reflectivity of all signs on roadway owned by Pima County.
CTR.4TVTVL	TR - Tanque Verde Rd at Tanque Verde Loop Rd	Install traffic signal & improve lighting, bike lanes and sidewalks/ADA access.
CTR.4UASFS	TR - Speed Management Study	Study over 2 calendar years to collect data w/ADOT and UAfor speed enforcement options.
CTR.4VHOST	TR - Valencia Rd Extension: Houghton Rd to E Old Spanish Tr	Construct new 2-lane road and bridge connecting Valencia Rd to Old Spanish Trail. Developer driven.
CTR.4WVDME	TR - Wilmot: Valencia to DMAFB entrance	Widen Wilmot Rd from Val to DMAFB entrance to accommodate staging of commercial veh
CTU.85R001	BOS - Santa Cruz Ln & Starr Pass Bl	Regional Local Road Repair Program, City of Tucson
CWW.3AI195	WW - ADOT - W Ajo Way & I-19 Sewer Modifications	Relocate or modify existing sewer mains due to major interstate improvements I-19-Ajo Way
CWW.3ANOMX	WW - Anammox Treatment Process	Modifications to TRWRF process for long term compliance,chronic ammonia limits for permit renew'l
CWW.3ASC15	WW - Old Nogales Interc. Aug - New Aerospace Corr Sewer	Provide additional conveyance capacity for anticipated future development in Aerospace Corridor (ASC
CWW.3BBUMP	WW - Tres Rios WRF Nutrient Recovery Project	Design and construct a nutrient recovery facility to reduce costs and increase recovery capacity.
CWW.3CFS15	WW - Continental Ranch Pump Station - Second Force Main	Install a second force main to convey sewage from the Continental Ranch Regional Pump Station to Ina
CWW.3CRS05	WW - CRRPS Facility Modifications	Repair/replace mechanical, electrical & odor components at the Continental Ranch Pump Station.
CWW.3DRSIT	WW - Facilities Modification - IPS Mobile Implementation	convert breakroom into Crew Work area w/network access for paperless work order system.

CWW.3FGS17	WW - PC Fairgrounds WRF Connection to Existing Conveyance Sy	Existing Fairgrounds WRF will be connected to gravity sewer system at S. Rita Road & 1-10
CWW.3GAS18	WW - TRWRF Biogas Cleaning & Utilization Project	Site the proposed gas cleaning facility in the Tres Rios WRF property.
CWW.3II105	WW - ADOT - Ina Rd & I-10 Sewer Modifications	Relocate or modify existing sewer mains due to major interstate improvements Ina & I-10
CWW.3MMP20	WW - Sewer Utility Minor Modification Projects 2019/20	Minor Modification to the sanitary sewer system is required due to roadway improvements
CWW.3MR220	WW - Sewer Manhole Rehabilitation #10	Planned rehabilitation of the conveyance system for manhole #10.
CWW.3MRP19	WW - Minor Rehabilitation Projects FY 18/19	Minor rehabilitation projects -- fixing cracked pipes, relining manholes, and general maitenance.
CWW.3MRP20	WW - Minor Rehabilitation Projects FY 19/20	Minor rehabilitation projects -- fixing cracked pipes, relining manholes, and general maitenance
CWW.3NWO19	WW - Northwest Outfall Siphon at the Santa Cruz River Rehab	Remove & repl existing inlet and outlet manhole structures at the NWO crossing of SCR.
CWW.3OPR19	WW - Prince Rd Sewer Replacement - Oracle Rd West	Replace 428 ft of 24-in diam sewer Prince Rd from Oracle to alleviate capacity, odor & deterioration
CWW.3RAYAG	WW - Raytheon Augmentation	Install approx. 2500 ft gravity line along Aero Park Blvd to 18" interceptor near Nogales Hwy inters
CWW.3RI105	WW - ADOT W Ruthrauff Rd & Interstate 10 Sewer Modifications	Relocate or Modify sewer mains due to major interstate improvements Ruthrauff & I-10
CWW.3SAC15	WW - Speedway Bld Area Capacity Augmentation Alignment Study	Provide additional conveyance capacity for future development by UA /Private near Speedway/Campbell
CWW.3SNI19	WW - SCADA Network Implementation	maintain existing Wide Area Network communications for RWRD facilities vs. lease
CWW.3SR863	WW - ADOT SR86 Valencia Rd to Kinney Rd	Existing sewer mains in the vicinity of SR86 will be relocated or modified due to HWY improvement.
CWW.3TPBBS	WW - Twin Peaks - Blue Bonnet Road Gravity Sewer	Install 4 mi of gravity sewer near Twin Peaks Rd and tangerine Rd south to Linda Vista Blvd.
CWW.3TRP20	WW - System-Wide Treatment Rehabilitation Program	Minor rehab to correct defective components or replace obsolete equipment in treatment facilities
CWW.ARTBAR	WW - Barometers	Visual pedestrian and bicyclist counts stations will be installed at two locations along loop.
RFM.33RR20	FM - 33 N Stone, Restroom Renovation (4-5 Floors)	Renovate restrooms of 33 N. Stone, except 6th fl, and add'l 4-5 fl incl repl finishes, floors, walls
RFM.97FC20	FM - 97 E Congress HVAC Fan Coil Units	Maintain HVAC system and improve energy efficiency with repl 35 fan coil units
RFM.ADTS20	FM - PC Adult Detention Replace 4 Auto Transfer Switches	Replace 4 auto transfer switches
RFM.AE1R20	FM - Admin East 1st Floor Remodel	Remodel Admin 1st floor for public use and BOS, prep print shop for expansion move.
RFM.AW3R20	FM - Admin West 3rd Floor Remodel	Reconfigure 3rd floor to keep staff together in functional areas
RFM.EVNT20	FM - Event Center Mechanical and Roof Replacement	Replace roof and mechanical system (HVAC) for event center on Ajo Way
RFM.EXTB20	FM - Exterior Building Improvements	Rehab to preserve county bldg. assets like HVAC, paint, roof, etc.
RFM.INTB20	FM - Interior Building Improvements	Interior improv of publicly used common facilities like bathrooms, lobbies, etc. in county own bldg
RFM.MR1120	FM - Mission Road Building 11 Tenant Improvements	Remodel office space to accom staff consolidation from bldgs. 9, 10, 11 into 11.
RFM.PARK20	FM - Parking Lot Improvements	Maintain existing parking lots using crack seal, seal coat and re-striping. repl asph as needed
RFM.SCFL20	FM - Superior Courts Common Area Flooring Replacement	Repl common area floor on several floors
RFM.SCPE20	FM - Superior Court Prisoner Elevator Replacement	Repl elevator to transport prisoners. KONE inspection indicates immed repairs needed
RFM.SNHU20	FM - 97 E. Congress TI - Furniture-Fiber for SNHU	Tenant Improvements, furniture reconfig, fiber and control relocation for SNHU tenant

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Appendix 4

Gila topminnow as vector control:
Updated Green Pool stocking list

1 page

Appendix 5. Topminnow vector control stocking list

STOCKING DATE	SOURCE OF FISH	STOCKED BY	NUMBER STOCKED	SOURCE OF WATER	CLOSED SYSTEM	DISEASE CERTIFIED	UTM 12S COORDINATES	NOTES ON STOCKING SITE
6/8/2017	PCHD	Cynthia Bennett	10	Municipal Water Supply	Yes	Yes	516019E, 3574905N	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 notices, warrant obtained.
7/12/2017	PCHD	Cynthia Bennett	22	Rainwater	Yes	Yes	518260E, 3566992N	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 notices, warrant obtained.
9/26/2017	PCHD	Cynthia Bennett	12	Municipal Water Supply	Yes	Yes	518536E, 3564256N	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 notices, warrant obtained.
9/26/2017	PCHD	Cynthia Bennett	12	Municipal Water Supply	Yes	Yes	494853E, 3579153N	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 notices, warrant obtained.
12/4/2017	PCHD	Gregg Bustamante	20	Municipal Water Supply	Yes	Yes	519521E, 3563004N	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 notices, warrant obtained.
1/4/2018	PCHD	Kathleen Walton	18	Municipal Water Supply	Yes	Yes	501422E, 3583839N	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 notices, warrant obtained.
* 9/9/2019	PCHD	Gregg Bustamante	15	Municipal Water Supply	Yes	Yes	502083E, 3590594N	Pond on Golf Course. Topminnow placed in pond only. No mosquito larvae was present at time of stocking. Observed Topminnow swimming around once placed in the pond. OB Sports Golf Management granted permission to place Topminnow in the pond. Received complaints of adult mosquitoes on the property from the pond.

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Appendix 5

Parcel list of allocated MSCP mitigation lands
(same as 2018 annual report)

3 pages

PARCEL NUMBER	NAME	ACRES (GIS)
Bingham Cienega Natural Preserve		
20521002D	BINGHAM CIENEGA	267.81
Cienega Creek Natural Preserve		
30516002A	CIENEGA CREEK NATURAL PRESERVE	37.18
30516002B	CIENEGA CREEK NATURAL PRESERVE	0.37
305122650	CIENEGA CREEK NATURAL PRESERVE	192.05
305122630	CIENEGA CREEK NATURAL PRESERVE	7.25
305110200	CIENEGA CREEK NATURAL PRESERVE	78.17
305122660	CIENEGA CREEK NATURAL PRESERVE	24.39
305122670	CIENEGA CREEK NATURAL PRESERVE	17.66
30511024D	CIENEGA CREEK NATURAL PRESERVE	214.13
30511024D	CIENEGA CREEK NATURAL PRESERVE	47.62
30517006B	CIENEGA CREEK NATURAL PRESERVE	161.14
30517001A	CIENEGA CREEK NATURAL PRESERVE	25.34
30516001C	CIENEGA CREEK NATURAL PRESERVE	12.74
30516001D	CIENEGA CREEK NATURAL PRESERVE	3.49
30516001A	CIENEGA CREEK NATURAL PRESERVE	18.55
30517001B	CIENEGA CREEK NATURAL PRESERVE	68.37
305170020	CIENEGA CREEK NATURAL PRESERVE	147.57
30517001C	CIENEGA CREEK NATURAL PRESERVE	0.91
30604001A	CIENEGA CREEK NATURAL PRESERVE	51.50
30604001A	CIENEGA CREEK NATURAL PRESERVE	0.47
30604001A	CIENEGA CREEK NATURAL PRESERVE	49.60
30517003A	CIENEGA CREEK NATURAL PRESERVE	16.16
30517003B	CIENEGA CREEK NATURAL PRESERVE	6.17
30604001B	CIENEGA CREEK NATURAL PRESERVE	32.87
30604001A	CIENEGA CREEK NATURAL PRESERVE	0.13
30604001B	CIENEGA CREEK NATURAL PRESERVE	0.12
30601021H	CIENEGA CREEK NATURAL PRESERVE	0.50
30601021H	CIENEGA CREEK NATURAL PRESERVE	1.42
305170020	CIENEGA CREEK NATURAL PRESERVE	0.71
30601026E	CIENEGA CREEK NATURAL PRESERVE	10.19
30601026E	CIENEGA CREEK NATURAL PRESERVE	13.74
30518005B	CIENEGA CREEK NATURAL PRESERVE	2.01
30601026E	CIENEGA CREEK NATURAL PRESERVE	0.23
30601021G	CIENEGA CREEK NATURAL PRESERVE	26.41
306050010	CIENEGA CREEK NATURAL PRESERVE	83.68
306050020	CIENEGA CREEK NATURAL PRESERVE	3.17
306050040	CIENEGA CREEK NATURAL PRESERVE	27.13
306080010	CIENEGA CREEK NATURAL PRESERVE	48.32
306090020	CIENEGA CREEK NATURAL PRESERVE	1.12
306090020	CIENEGA CREEK NATURAL PRESERVE	24.55

306090040	CIENEGA CREEK NATURAL PRESERVE	12.39
306080030	CIENEGA CREEK NATURAL PRESERVE	26.66
306080020	CIENEGA CREEK NATURAL PRESERVE	2.73
306090020	CIENEGA CREEK NATURAL PRESERVE	5.51
30609505A	CIENEGA CREEK NATURAL PRESERVE	1.60
306090080	CIENEGA CREEK NATURAL PRESERVE	4.66
30616001B	CIENEGA CREEK NATURAL PRESERVE	11.75
30616001A	CIENEGA CREEK NATURAL PRESERVE	253.30
30618004A	CIENEGA CREEK NATURAL PRESERVE	166.59
30615002A	CIENEGA CREEK NATURAL PRESERVE	75.77
30618504A	CIENEGA CREEK NATURAL PRESERVE	0.02
30588014C	CIENEGA CREEK NATURAL PRESERVE	71.32
306090030	CIENEGA CREEK NATURAL PRESERVE	0.90
30607002A	BAR V RANCH	150.08
30615001A	BAR V RANCH	160.30
306080040	CIENEGA CREEK NATURAL PRESERVE	303.82
306060010	CIENEGA CREEK NATURAL PRESERVE	93.42
305122640	CIENEGA CREEK NATURAL PRESERVE	23.25
30601021J	CIENEGA CREEK NATURAL PRESERVE	897.50
30601026E	CIENEGA CREEK NATURAL PRESERVE	15.15
305122680	FLAP 1227	8.19

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Appendix 6

Pima County Aquatic Species Management Plan
Executive Summary

1 page

Executive Summary for 2019 Aquatic Species Management Plan

Preparation of an Aquatic Species Management Plan (Plan) is a requirement of the Pima County Multi-species Conservation Plan (MSCP). The primary goals of the Plan include maintaining existing populations of target species and their habitats, and identifying areas with potential habitat for future releases of target species. The Plan focuses on the following target species:

- Gila topminnow (*Poeciliopsis occidentalis occidentalis)*
- Gila chub (*Gila intermedia)*;
- Longfin dace (*Agosia chrysogaster*);
- Desert sucker (*Catostomus clarki*);
- Sonora sucker (*Catostomus insignis*);
- Chiricahua leopard frog (*Lithobates chiricahuensis*)
- Lowland leopard frog (*Lithobates yavapaiensis*)
- Northern Mexican gartersnake (*Thamnophis eques megalops*)
- Huachuca water umbel (*Lilaeopsis schaffneriana* var. *recurva*)

The plan supports implementation of Arizona Game and Fish Department's (AZGFD's) priorities from their Santa Cruz Watershed Management Plan, as well as recovery objectives established by U. S. Fish and Wildlife Service (USFWS). The Plan was reviewed and approved by USFWS in July 2019.

The Plan provides a baseline population status and habitat condition assessment at sites (streams, springs, stock tanks, and a few other large ponds) managed for conservation by either Pima County or Pima County Regional Flood Control District (RFCD). Sites were sorted into three tiers of management priority based on the type of water source, environmental conditions, and other considerations.

The Plan identifies opportunities for releasing target species where they do not (as of 2019) currently occur; the number of sites for releases varies among species. Species with the most release opportunities are the Gila topminnow (15 sites) and Huachuca water umbel (14 sites). The most widespread target species on County conservation lands is the lowland leopard frog; there are eight additional sites available for future releases of this species.

The Plan does not direct, authorize or fund any particular action on land owned or managed by Pima County or RFCD. Implementation will depend on partnerships with AZGFD and other conservation partners over the 30-year term of the MSCP. Additional site evaluations and permissions may be needed before releases occur. Additional inventories of above-ground metal or concrete stock tanks are ongoing.

As part of this planning effort, USFWS has prepared guidelines for construction of wildlife-friendly water features. These guidelines may be of interest to private property owners who wish to maximize benefits and minimize risks to Arizona's wildlife.

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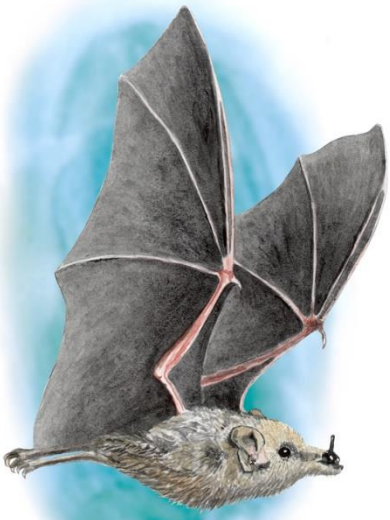
Appendix 7

Pima County 2021 Proposed Bat Monitoring Protocol and 2018 Monitoring Report

80 pages

Pima County Ecological Monitoring Program

2021 Proposed Bat Monitoring Protocol and 2018 Monitoring Report



Mexican long-tongued bat
(*Cheronycteris mexicana*)

Townsend's big-eared bat
(*Corynorhinus townsendii)*

Lesser long-nosed bat
(*Leptonycteris yerbabuenae*)

California leaf-nosed bat
(*Macrotus californicus*)

Prepared by Pima County Office of Sustainability and Conservation Staff:
Jeff M. Gicklhorn
Ian W. Murray

Recommended Citation:
Gicklhorn, J.M. & I.W. Murray. 2020. 2021 Proposed Bat Monitoring Protocol and 2018 Monitoring Report. Ecological Monitoring Program, Pima County Multi-species Conservation Plan. Report to the U.S. Fish and Wildlife Service, Tucson, AZ.

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Abstract

Pima County's Multi-species Conservation Plan (MSCP) and Ecological Monitoring Program outline commitments that Pima County has made to monitor four species of cave and mine-roosting bat species covered under the MSCP - California leaf-nosed bats (*Macrotus californicus;* MACA), lesser long-nosed bats (*Leptonycteris yerbabuenae;* LEYE), Mexican long-tongued bats (*Choeronycteris mexicana;* CHME), and Pale Townsend's big-eared bats (*Corynorhinus townsendii pallescens;* COTO). Using available data on prior bat species surveys and the County's database of known cave and abandoned mine features, County staff chose ten sites to include in a bat monitoring effort in 2018. Pima County worked with Tucson Audubon and Sandy Wolf of Bat Research and Consulting to implement a variety of monitoring techniques at these features to assess bat species occupancy, site condition, and relevant management recommendations. We documented CHME roosting at two sites, both of which are likely maternity roosts. We documented MACA using two sites and included a winter roost exit count for one of the sites, which is the most important known local roost for this species. We report on COTO using two sites, including a maternity roost. This monitoring effort also yielded a number of recommendations for sound management, including highlighting two priority projects to potentially install and repair already existing bat-friendly gating at two sites. Pima County is continuing to build on its inventory and understanding of subterranean features that are used by bats and it is not unexpected that monitored sites may change as the County gains new information, or as bat use of particular sites changes over time. Moving forward, final recommendations identified here include changing the suite of sites to be monitored in subsequent rounds of bat monitoring to better address the four species of interest here. Pima County will continue to work with the USFWS to develop a strong bat monitoring program, including substituting some sites monitored in this effort for a proposed region-wide census of soil-piping cavities, caves, and abandoned mines in Cienega Creek Natural Preserve and Colossal Cave Mountain Park targeted at gaining a better understanding of CHME status in these preserves and the conditions and availability of roosts for this species.

Acknowledgements

We would sincerely like to thank the Tucson Audubon Society and Sandy Wolf (Bat Research and Consulting) for their efforts in inventorying all identified monitoring sites in 2018 and developing the survey specific methodology for the four bat species covered in this document. We are also particularly indebted to Pima County Natural Resources, Parks and Recreation staff Iris Rodden and Don Carter for inventorying hundreds of abandoned mine features and for their efforts that have led to a much better understanding of what bat species occur where, and for their ongoing stewardship of Pima County's bat resources. Brian Powell provided guidance and contributed substantially to field efforts. We also thank Colossal Cave Mountain Park staff for accommodating access and monitoring at Colossal Cave. Keith Hughes, BLM provided permits to access and monitor mine sites on Pima County's BLM lease lands. We thank Shawn Lowery, AZGFD, for helpful review and comments.

Background & Objectives

Pima County's Multi-species Conservation Plan (MSCP) covers six species of bats of conservation concern: 1) the Mexican long-tongued bat (*Choeronycteris mexicana*, CHME), 2) Pale Townsend's big-eared bat (*Corynorhinus townsendii*, COTO*),* 3) California leaf-nosed bat (*Macrotus californicus*, MACA), 4) Lesser long-nosed bat (*Leptonycteris yerbabuenae*, LEYE), 5) the Western red bat (*Lasiurus blossevillii*), and 6) the Western yellow bat (*Lasiurus xanthinus*). The first four species are subterranean obligates, meaning that they require subterranean caves and mine features to roost, while the last two species are tree-roosting obligates. The County's MSCP ensures that the County remains in compliance with its Section 10 incidental take permit that it has been issued from the U.S. Fish and Wildlife Service (USFWS).

As part of the MSCP, Pima County has agreed to monitor occupancy and site condition for the first four bat species (i.e., the cave and mine dwelling covered bat species) for ten sites combined, on County conservation lands as one part of Pima County's Ecological Monitoring Program (Pima County 2016). This protocol covers the various approaches that will be used to monitor caves, mines, and adits for occupancy of the four subterranean obligate bat species during the 30-year life of the MSCP. The individual bat monitoring protocols included here (i.e., live capture, internal mine surveys, exit counts, etc.) as well as the first round of bat monitoring results have been provided and carried out by bat biologist Sandy Wolf, working through Tucson Audubon.

Pima County conservation lands have numerous known caves and abandoned mine features, many of which provide potential habitat for the subterranean obligate bat species. These features range from naturally occurring caves to abandoned mine features to eroded soil piping crevices and cavities. The number of sites available for bat monitoring changes as new information becomes available concerning previously documented sites, or as entirely new sites are inventoried. Numerous factors can affect bat species occupancy of these sites, including feature type, season, surrounding habitat, structure, and integrity and volume of human visitation. Prior to development of this protocol Pima County staff spent much time reviewing records and inventorying cave and mine features to assess what information was available concerning bat occupancy status and safety considerations for many of these features. Though this inventory now includes hundreds of features, the County continues to document additional features as well as gather information on how bats use already known features.

Availability of sites also varies according to land ownership. Many of these locations are on lands that the County holds the grazing lease for, but that are owned by the Arizona State Land Department or U.S. Bureau of Land Management, rather than County-owned fee lands. All of the sites covered in this monitoring effort were either located on lands that Pima County owns, or if on leased lands, were on lands leased from the BLM. Additionally, many features represent a safety hazard to humans due to their dangerous and instable nature. Pima County continues to document these features, and after assessments may install warning signage, fencing, or gating for site on those lands that the County owns and manages. Where possible we recommend that any mines that are assessed follow a process compatible with that of the Arizona State Mine Inspector's office evaluation, and that these data are

included in relevant State databases. Other land managers such as the BLM and Arizona State Mine Inspector's office also inventory and manage abandoned mines to reduce risk to human health and protect bat roosts and may close or install bat-friendly gating on some mines and has funded prior efforts to census abandoned mine features and make recommendations for site closure or gating on BLM lands in the Altar Valley. For example, the BLM has installed steel cable net across some features on Rancho Seco. Ongoing abandoned mine assessments by Pima County as well as other land managers that are meant to mitigate the risks that these features pose to human health may also secondarily provide important information on bat species use, which could be leverage by the County's monitoring program.

Pima County's bat monitoring objective is to monitor the occupancy, site condition, and associated management needs of a subset of roosts used by the Mexican long-tongued, Lesser long-nosed, California leaf-nosed, and Pale Townsend's big-eared bats on Pima County open space lands. Monitored roosts will be those roosts that have particular importance to the local population of these four bat species. The County will also work towards documenting all of the known roosts sites for these species that are located on County lands, though not all will be chosen for additional monitoring efforts. Where possible and relevant, results from these inventory and monitoring efforts will be used to guide the management (i.e., gating) and/or restoration of key features that will benefit these and other bat species.

Monitored bat species

Mexican long-tongued bat (*Choeronycteris mexicana*)

The Mexican long-tongued bat is a nectarivorous bat that occurs in southernmost California and Texas (very few records that likely represent extralimital individuals), as well as southern Arizona and southwestern New Mexico extending south throughout large portions of Central America. Individuals range in size from 81 to 103 mm and weigh from 10 to 25 g (Arroyo-Cabrales 1987). CHME tend to roost in small colonies (usually < 10 bats) and individuals do not cluster tightly while roosting (Arroyo-Cabrales et al. 1987; Cryan and Bogan 2003). Most documented roosts in southeast Arizona occur near water and riparian vegetation located more broadly within desert grassland or Madrean evergreen woodland plant communities (Cryan and Bogan 2003). Females and males roost separately, and evidence suggests that only the females migrate north into southern Arizona and southwestern New Mexico to form maternity colonies, while adult males do not range into the United States (Cryan and Bogan 2003). Consequently, most roosts documented being used by this species in Pima County between May and July are likely to be maternity roosts. CHME will often roost within portions of mines or caves where there is some penetration of light either because the feature itself is shallow, or due to roosting closer to the entrance of a mine or cave.

This species produces a single pup between June to July, and in southern Arizona typically migrates south into Mexico between October and November, returning in early May, following the flowering cycles of their preferred food sources, agave, yucca, and columnar cacti (Hevly 1979; Carter and Peachey 1996). In eastern Pima County, Carter and Peachey (1996) found that the majority of pollen in bat guano samples collected between May and early September was from saguaro cactus and Schott's

agave, while October samples yielded primarily Palmer's agave pollen. This work also documented pollen from *Caesalpinia pulcherrima* and *Agave americana* in CHME guano, both common landscape plants in the Tucson area. Through stomach content analyses, Hevly (1979) showed that CHME largely fed on *Agave* sp. and columnar cactus pollen, but that relative to LEYA, CHME contained a greater diversity of pollen types. In CHME collected during summer and early fall in Arizona, this included pollen from plants such as *Yucca* sp., sotol, Chenpodiaceae, *Amaranthus* sp., and pollen from grasses. The latter three types of plants are wind pollinated and how pollen from these sources was ingested is not known. During a population study at Colossal Cave Mountain Park and Cienega Creek Natural Preserve (1994-1996), no CHME were noted in any of the monitored roosts later than November 13 (Carter and Peachey 1996). However, other observations, indicate some individuals may overwinter in this area.

CHME readily feeds from hummingbird feeders, and the AZGFD conduct citizen science-based monitoring of this species and the lesser long-nosed bat by recording the seasonal timing of hummingbird feeder use in both species (https://www.azgfd.com/wildlife/backyard-bats/). Mexican long-tongued bats have been found in roost sites located on the following County open space lands: Buehman Canyon, A7 Ranch, Cienega Creek Natural Preserve, and Colossal Cave Mountain Park (Appendix D). The species is considered a species of concern by BLM and the U.S. Forest Service.

Pale Townsend's big-eared bat (*Corynorhinus townsendii pallescens*)

The pale Townsend's big-eared bat is one of five subspecies of Townsend's big-eared bat that occurs broadly throughout the western United States into western Canada and central Mexico. All Arizona populations of this bat are considered to be this subspecies (AZGFD 2003). COTO is an insectivorous bat feeding heavily upon moths and tends to roost from open ceilings, such that guano located in open areas of a mine (i.e., not at the sides of a feature against the wall) in circular patches may be from this species (AZGFD 2003). Individuals range in size from 90 to 112 mm total body length weigh between 5 to 13 g (Kunz et al. 1982; Pierson et al. 1999). In southern Arizona this species does not migrate (though they occupy different roosts seasonally), but rather they hibernate in abandoned mines or caves with stable and cool temperatures. COTO generally overwinter singly or in small groups, whereas during summer females may form maternity colonies of 12 – 200 bats; males roost apart from females and evidence suggests they are mostly solitary (Kunz 1982; AZGFD 2003). Key conservation needs include protecting and minimizing disturbance of sites identified as hosting small maternity colonies by closing these sites to human access.

On Pima County conservation lands, COTO have been found in roost sites on Rancho Seco, M Diamond Ranch, Cienega Creek Natural Preserve, Diamond Bell Ranch, Marley Ranch, Old Hayhook Ranch, Oracle Ridge, and Colossal Cave Mountain Park (Appendix D). This subspecies is not federally listed, but is currently protected in several other western states. There are two other subspecies of Townsend's big-eared bat that are federally listed as endangered, the Ozark and the Virginia big-eared bats.

California leaf-nosed bat (*Macrotus californicus*)

The California leaf-nosed bat is an insectivorous bat known to occur from the Mojave, Sonoran, and Colorado deserts of the American southwest (southern California, Nevada, and Arizona) and western Mexico. Individuals range in size from 85 to 108 mm total body length and in weight from 12 to 20 g (Anderson 1969). Individuals are largely sedentary (though they do move between roosts as their seasonal thermoregulatory needs dictate) and are active year-round, relying on the ability to access winter roosts that are relatively warm. MACA frequently roosts near the roost opening, where there is some degree of illumination. MACA prey on relatively large arthropods such as grasshoppers and caterpillars, primarily gleaning prey from the ground or vegetation, and feeds on substantial numbers of diurnally active insects (AZGFD 2001). In some portions of its range, it also feeds on cactus fruit (Tuttle 1998). This species often forages in riparian and xeric-riparian environments (i.e., desert washes), and has been photographed at Mission Garden (Tucson, AZ) where they feed on caterpillars and other arthropods gleaned from the Garden's orchard. During the winter MACA requires thermally stable roosts that allow access to warm temperatures. During summer, males and females roost separately, while the sexes roost together during the winter (AZGFD 2001). Some roosts may be occupied year round, particularly those roosts that offer thermally stable and warm winter temperatures. Key needs include a more complete understanding and protection of key winter and summer roosts. Summer censuses may help located smaller roosts within a geographic area, that can then be managed as a unique population cluster.

Across Pima County's preserves, MACA roosts are known from Tucson Mountain Park and Rancho Seco, though they likely occur more broadly (Appendix D). Historically this species also occupied Colossal Cave, though its current status there is not known. This species is a federal species of concern and a wildlife species of special concern in Arizona.

Lesser long-nosed bat (*Leptonycteris yerbabuenae*)

The lesser long-nosed bat is a nectarivorous bat known to occur from southern Arizona and New Mexico (encompassing the northern tip of its overall distribution) into western Mexico and Central America. Individuals can be quite large and range in size from 74 - 90 mm in total body length and 350 to 360 mm in wingspan and weigh from 15 to 29 g (Arita 1999; Cole and Wilson 2006). Individuals undertake a long seasonal migration in order to follow the flowering cycle of their primary food sources, columnar cacti and agave. Large numbers of female LEYE arrive in southwestern Arizona by late April to have their pups and feed on abundant blooming saguaro cacti, leaving these roosts by mid-July, many of them moving east to feed on blooming agave in southeastern Arizona (Cole and Wilson 2006). LEYE is primarily present in eastern Pima County during late summer and early fall, largely feeding on flowering *Agave palmeri*. Most LEYE depart for Mexico by fall after the Agave are done flowering.

There are no known sites on Pima County preserves where this species roosts, though LEYE is known to forage on County lands, such as Sands Ranch and Cienega Creek Natural Preserve. Should a roost be located on Pima County preserve lands, the County will be responsible for annual monitoring of that site (using an exit count protocol) in coordination with AZGFD and USFWS. Before an exhaust system

caused colony abandonment in the 1960s, Colossal Cave hosted a maternity roost of this species. In recent years, LEYE has been captured during bat mist netting surveys at Colossal Cave Mountain Park, Agua Caliente Park, and Cienega Creek Natural Preserve. This species was listed as endangered by USFWS in 1988, however it was delisted in 2018 due to recovery.

Monitoring Sites

Pima County's conservation lands are broad and contain many abandoned mines, caves, and other features that may be used by roosting bats. Though Pima County has documented hundreds of abandoned mines across its lands, the sheer breadth of County lands means that we do not yet have a complete inventory of all features and how they are used by covered bat species (as well as non-covered bat species). Furthermore, given that bats may only seasonally occupy given features based on their life cycle needs, or may abandon or re-occupy particular roosts over time, a one-time survey of a particular feature may not accurately identify what species are potentially roosting there, or how important it may be.

Pima County has committed to monitoring 10 sites for bat occupancy and site condition for the four covered subterranean obligate bat species (combined), every three years. (In the event that a LEYE roost is found on County lands, that roost will be monitored annually.) Sites monitored in 2018 span the range of County conservation lands (both fee and leased lands), from the Las Guijas Mountains southwest of Tucson, to the Santa Catalina and Rincon Mountains to the east (Fig. 1). All selected sites were known to have bat occupancy, however the current species composition, population status, and relative importance (from a biological perspective) were not known for all sites. Below is a brief description of the location and general condition of each monitoring site. Some specific site information is omitted to reduce the likelihood of disturbance to these sensitive species.

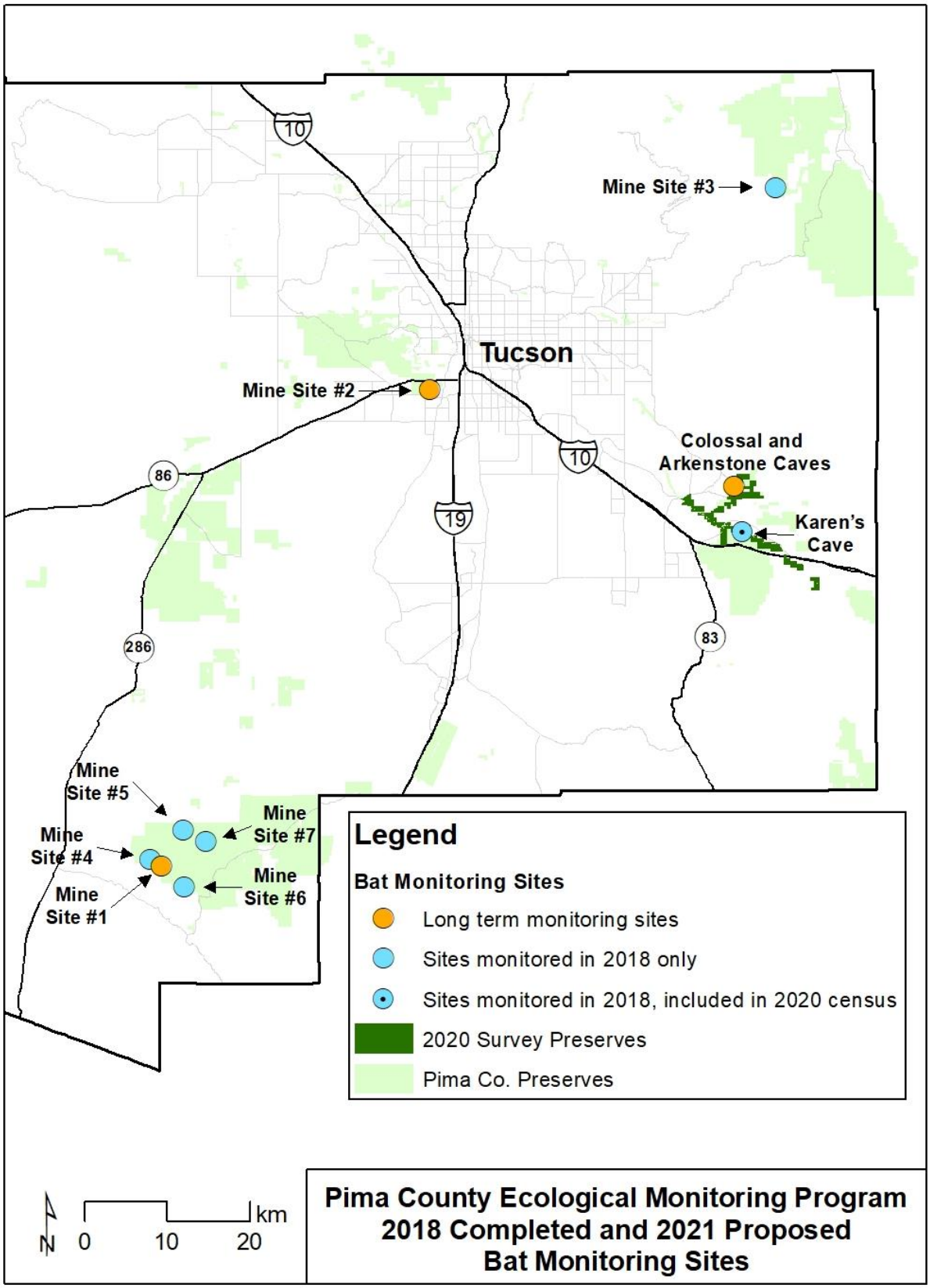

Figure 1. Bat monitoring sites on Pima County conservation lands. Long-term sites denote those sites surveyed in 2018 that were recommended to be surveyed again during the 2021 bat monitoring effort.

2018 Completed Monitoring Sites

We identified 10 sites to include in the bat monitoring completed in 2018. Some of these sites included up to four adjacent and discrete features or subterranean openings that were surveyed during each site visit. The following section provides a general overview of the physical characteristics, ownership, and the basis and/or prior understanding of the potential bat species known or suspected to be using each site.

Karen's Cave

Karen's Cave is a stabilized natural soil-piping feature within the Cienega Creek Natural Preserve. During 2013, both openings to the eroded soil cavern were stabilized with steel culverts in a USFWS Partners for Fish and Wildlife-funded project by Pima County Natural Resources, Parks and Recreation. The interior of the feature has several rooms and passages including the largest room at approximately 20 feet long, 15 feet wide, and 10 feet high at its highest point. Additionally, there are several interior chambers that are not accessible to humans due to small openings that then lead into larger rooms that bats could also roost in. This eroded soil cavity is known to have been a CHME maternity colony (with up to 4 adult and 4 juvenile CHME observed roosting inside) extending as far back as 1996 (Carter and Peachey 1996) as well as being used in the past by small numbers of hibernating COTO.

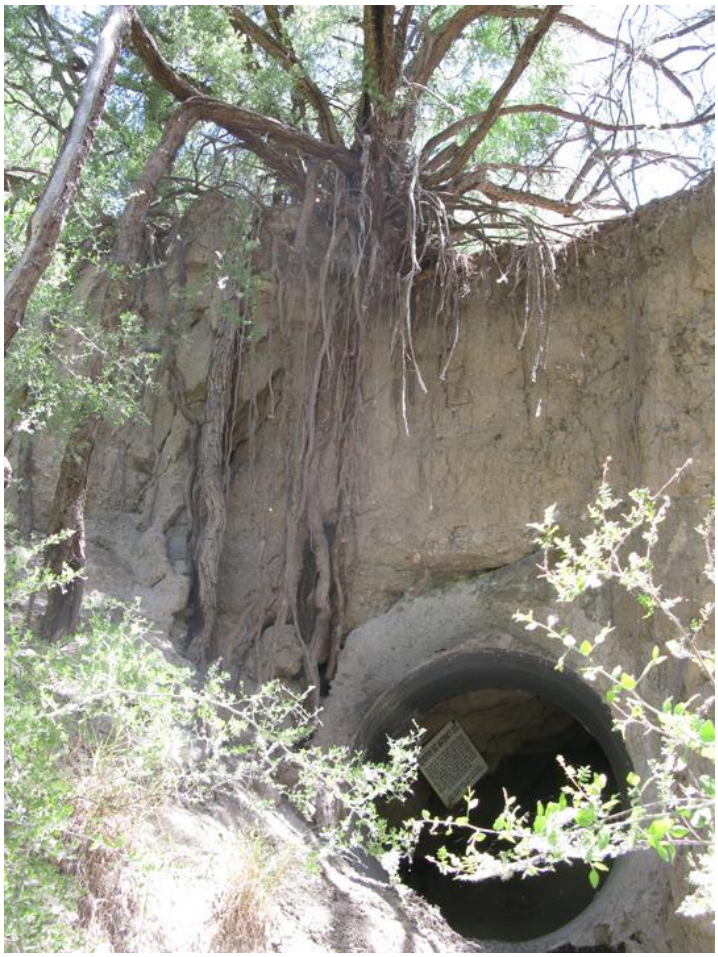

Figure 2. Stabilized entrance to Karen's Cave.

Mine Site #3

Mine site #3 is a mine site located in the Buehman Canyon Natural Preserve on the east side of the Santa Catalina Mountains. The Pima County RFCD owns the surface rights to the land, but the mineral rights are privately held. The site has one main deep, vertical shaft (ca. 8 feet by 12 feet). The shaft is a vertical hole extending downwards to an unknown depth and is fenced by barbed wire and chain link fencing (Figs. 3 & 4). Information provided in a 2017 letter of intent to acquire the mineral claims suggests that in the early 1900s a 130 foot deep shaft with 3,900 feet of drifts over two levels was dug. The site is remote and not readily accessed. Work from this effort as well as from acoustic monitoring in 2016 by Iris Rodden, Pima County Natural Resources, Parks and Recreation suggests that this is a large (> 1000 individuals) summer roost (bachelor or maternity roost) of cave myotis. Due to the sheer numbers of cave myotis recorded exiting on the 2 June 2018 monitoring date, it is not realistic to assess whether smaller numbers of other species may have also been present.

Figure 3. Camera setup at Mine Site #3.

Figure 4. Mine Site #3 shaft.

Mine Site #2

Mine Site #2 is a mine site located at the southern end of the Tucson Mountains within the County's Tucson Mountain Park. California leaf-nosed bats have been known to use this site for many years. In response to vandals entering the site and killing bats, Pima County Natural Resources, Parks and Recreation installed a bat compatible gate to this mine in 2001, that was further updated in 2007 (Wolf and Dalton 2007). Between 2009 and 2011 unknown persons dug out the mine roof just enough above the gate that a 15 inch high gap allows a person to climb over. This site has multiple features with one deep, gated adit (pictured below), several shallow adits, and multiple nearby prospects (Fig. 5). Only the large, gated adit is known to be regularly used by bats. According to prior surveys, the adjacent features are not frequently used, but these other features were not examined during this monitoring session. California leaf-nosed bats are known to roost in the main mine year round, with peak occupancy during the winter months, making this mine a locally important winter roost. There have been a number of monitoring efforts counting bats at this site, particularly during winter, such that future monitoring efforts here could be used to evaluate potential population trends for this site. Furthermore, this site is located near the urban-wild interface, has a high potential for human visitation and disturbance, and the previously installed gating requires further improvements due to vandalism and breaching of the bat gate which can now allow some human ingress.

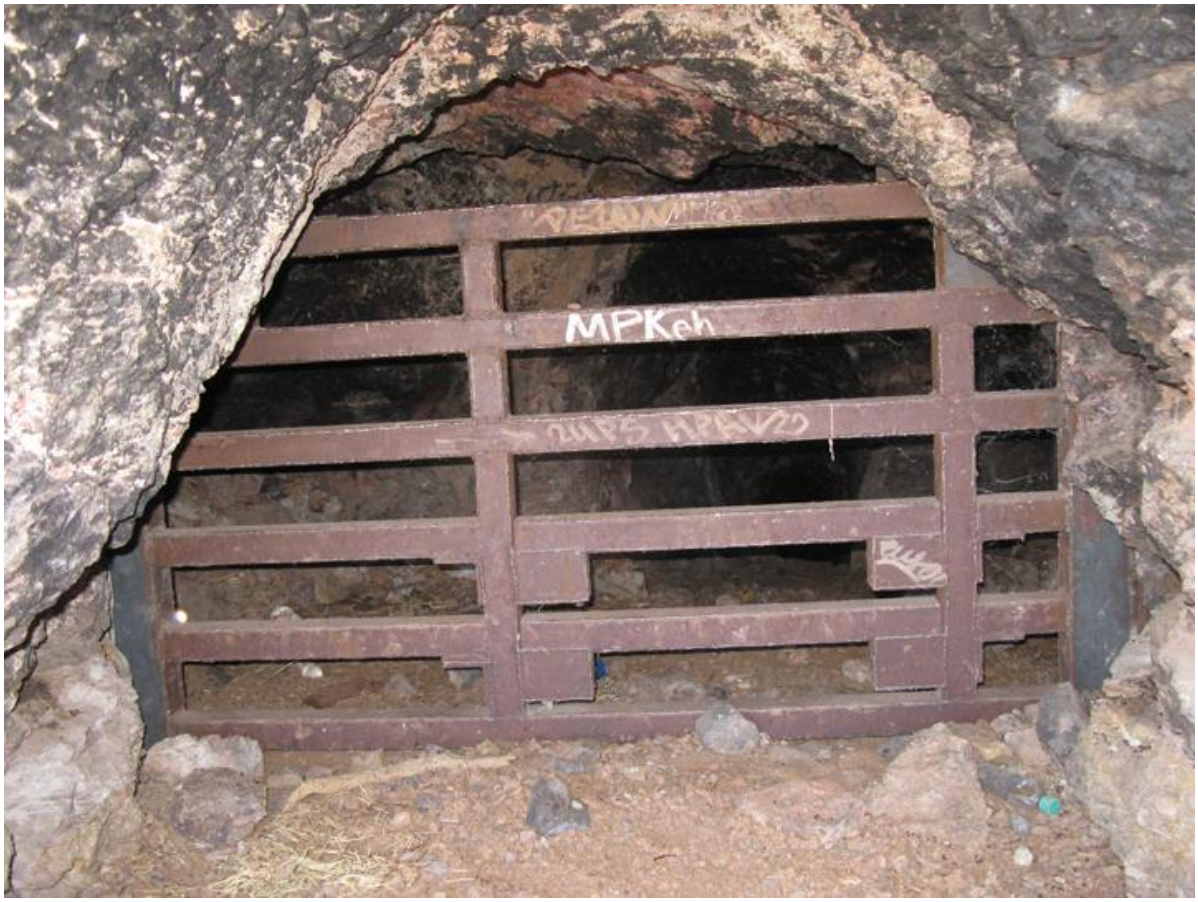

Figure 5. Mine Site #2 with locking gate, installed in 2007.

Colossal Cave

Colossal Cave is a large and complex 'dry' limestone cave located on the west side of the Rincon Mountains within Pima County's Colossal Cave Mountain Park. Estimates suggest that there are about 3 km of passages in this cavern (Brod 1987). This is a large cave system and is known to have at least three entrances within the mountain park (main cave entrance, bat-room tunnel entrance, and Bandit's Escape entrance). Beginning in the 1930s, the Civilian Conservation Corps developed the cave as a tourist experience, including enlarging the main entrance and some passage ways and building walkways and bridges (Brod 1987). At one time Colossal Cave hosted a maternity colony of lesser long-nosed bats (~ 3000 – 5000 bats), but the colony was abandoned (other bat species also largely abandoned the site at this time) after an exhaust fan was installed in 1966. This fan not only altered thermal conditions necessary for the maternity colony (i.e., creating drafts), but also blocked the entrance that this species used to access the cave (Petryszyn 1989). The location of the exhaust fan was changed in 1989 to make the site more compatible to use by bats. Colossal Cave is currently used by Townsend's big-eared bats (2018 capture results) and in the past has been confirmed as a maternity colony for this species (2011 survey data from Sandy Wolf). Pallid bats and cave myotis also use the cave. Lesser long-nosed bats are not known to be using the site, though the possibility remains that LEYE may again re-occupy the site. The cave currently has a commercial cave tour, visitor's center, and other recreational facilities and activities that are all operated by an outside company.

Figure 6. Bat Tunnel entrance, Colossal Cave, outfitted with harp trap.

Arkenstone Cave

Arkenstone Cave is a 'wet' limestone cave located on the west side of the Rincon Mountains within Pima County's Colossal Cave Mountain Park (as a wet cave, strict adherence to White Nose Syndrome protocols are especially important). Discovered in the 1960s, this cave has a single 0.18 m^2 horizontal entrance that is recessed into an entrance pit and is gated. This site is off-limits to the public and therefore has little to no human impact. Prior work has shown that this was a large maternity colony for fringed myotis (a species that today occurs at higher elevations in the Rincon Mountains) during the late Pleistocene, when conditions were cooler and wetter in the immediate area of the cave (Czaplewski and Peachey 2003). Current patterns of bat occupancy of this site are not well known, but earlier surveys documented CHME using this site (Carter and Peachey 1996). Muchmore and Pape (1999) described a new species of troglobytic pseudoscorpion that is only known from this cave highlighting the biological importance of this particular cave.

No site photos of Arkenstone Cave

Mine Site #4

Mine Site #4 is a remote mine site in the Las Guijas Mountains on the County's Rancho Seco property (located on County-owned land). This site consists of two shafts and an adit, all of which are fenced within the same barbed wire fence. Survey work by Don Carter (Pima County Natural Resources, Parks and Recreation) shows that these features are interconnected underground in a complicated and deep network of drifts and winzes. There are many other shafts and adits in the general area as well, many on BLM lands which the County holds in its Rancho Seco grazing lease. Monitoring efforts led by Natural Resources, Parks and Recreation have shown that this feature is an important cave myotis maternity colony, and that smaller numbers of species such as Townsend's big-eared bats also use this mine as a day roost during some times of the year.

Figure 7. Mine Site #4, one adit visible.

Mine Site #1 Complex

Mine Site #1 Complex is a series of shafts and adits in the Las Guijas Mountains on BLM land that Pima County holds as a grazing lease as part of its Rancho Seco property. Some or all of these features include private patented claims. We identified four nearby shafts (some of which may be interconnected) to survey in this monitoring effort based on findings reported by a BLM-funded Bat Conservation International survey effort in 2014-2015. This past survey effort canvassed seven mine features within about 220 m of one another and located a substantial maternity roost of Townsend's big-eared bats in one of them. The monitoring reported here located what is likely the same maternity colony of COTO in a nearby adit, and COTO probably use all of the features during some part of the year. Analysis of the DNA in sampled bat guano also showed use of at least two of these adits by cave myotis and big brown bats.

Figure 8. Mine Site #1 adit (one of four monitored in this effort).

Mine Site #6

Mine Site #6 is a series of shafts and adits in the Las Guijas Mountains on the County's Rancho Seco property. These features are on lands that the BLM owns and that Pima County holds the grazing lease on. Bat Conservation International's BLM-funded surveys included many adits and shafts around Mine Site #6, including the particular adit identified for Pima County's monitoring effort, picture below, an adit about 54 m long with at least one stope near the end. The mineral ownership is not known for this feature, but it may be a private claim. During a 2014 internal survey, one cave myotis was observed in the adit shown below, as well as guano from cave myotis and Townsend's big-eared bats. The surveyors concluded that this feature was likely a cave myotis day roost, and a COTO night roost.

Figure 9. Mine Site #6 adit entrance.

Mine Site #5 Complex

Mine Site #5 Complex is a series of shafts and adits between the Cerro Colorado Mountains and the Las Guijas Mountains. These features are on lands that Pima County holds the grazing lease for as part of Rancho Seco, and that are owned by the Bureau of Land Management. The BLM also likely holds the mineral rights to these features, but this has not been confirmed. Bat Conservation International surveyed at least 15 shafts and adits in this area, and two of these, one pictured below (situated about 200 m apart), were chosen for Pima County's monitoring efforts because MACA had been observed using both features as day roosts during the earlier 2014 surveys that BCI completed. Both sites were occupied by MACA during September surveys reported here.

The openings for both selected features are small, and internal surveys show that there has been a substantial amount of collapse through a large part of the length of one of the features. For example, both monitoring reported here, as well as the prior monitoring done by BCI shows that one adit is a relatively shallow feature showing signs that collapsing rock has blocked much of its former length. The other feature is about 58 m long, though in the monitoring reported here the surveyors were not able to completely survey its length due to its use as a rattlesnake hibernacula in winter and the presence of MACA closer to the entrance during the September survey. Though this second adit is only 'moderately' deep, there would be benefit to ascertaining if MACA uses this feature in the winter. Both sites are fenced with barbed wire and warning signs. During the County's 2018 monitoring effort, an additional three adjacent adits were noted, but not surveyed (two were covered with steel cable netting, and one was occupied by an active beehive, precluding entry).

Figure 10. Mine Site #6 adit (one of two surveyed).

Mine Site #7

Mine Site #7 is a series of shafts and adits in a complex of rocky hills west of the Cerro Colorado Mountains on the County's Rancho Seco property. These features occur on BLM lands. Bat Conservation International surveyed many of these features, one of which was selected for monitoring during Pima County's 2018 efforts. This adit is about 30 meters long and has two stopes. The ownership of the mineral rights at this feature is not known. The prior survey during 2014 noted guano from cave myotis, MACA, and COTO, though no bats were observed. Consequently, surveyors posited that this was a night roost.

Figure 11. Mine Site #7 adit.

2021 Recommended Monitoring Sites

County and USFWS staff have previously discussed the fact that the specific suite of County bat monitoring sites may change over time due to differences in how the covered bat species may use particular sites, as well as due to improvements in our inventory of potential bat roosts across County lands and the species that may use them. Results from the first round of bat monitoring in 2018 showed that some sites either showed little evidence of use by covered species, or were sites that may have been used by covered species but were primarily roosts for other species of bat not included on the MSCP and that would be logistically difficult to monitor and differentiate small numbers of covered bat species from thousands of individuals of other species (Table 1). Monitoring efforts targeted at three of the 'sites'- Mine Site #5, Colossal Cave, and Mine Site #1 - also required substantially more effort to monitor on each visit because these sites include 2, 3, and 4 discrete openings that need to be assessed for bat occupancy and exit counts.

Subsequently, Pima County recommends that only a subset of the sites monitored in 2018 continue to be monitored during the second round of bat monitoring to be done in 2021 (Table 1). These sites are Mine Site #2, Colossal Cave, and Mine Site #1 adits. We also recommend that Pima County's next round of bat monitoring include updated site assessments and bat occupancy status of all of the known soil piping features in Cienega Creek Natural Preserve (14 known in 1996), as well as status and bat occupancy of the nine cave, crevice, and mine features assessed by Carter and Peachey during their 1996 CHME monitoring effort in Colossal Cave Mountain Park (Carter and Peachey 1996)(Table 1). Pending any additional available discretionary resources, we also tentatively identify Mine Site #5 adits and Mine Site #3 as features that are of lesser priority, but that could also benefit from targeted surveys at particular times of the year to gather additional information concerning bat use of those sites. These sites would not be included in the list of committed monitoring sites for Pima County's next round of bat monitoring. We also do not recommend monitoring Mine Site #6 adit, Mine Site #7 adit, Mine Site #4, and would only re-visit Arkenstone Cave and Karen's Cave if snap shot status assessments of all CHME roosts in Cienega Creek Natural Park and/or Colossal Cave Mountain Park were undertaken (Table 1).

Table 1. Bat species documented at monitoring sites on Pima County preserve lands in 2018, and 2021 monitoring site recommendations. Some site names have been censored due to species sensitivity.

Site Name	Covered Species	Non-Covered Species	Site Substitution	Justification
2018 Monitoring Results				
Karen's Cave	Mexican long-tongued bat	N/A	No	Monitor as part of census of all known CHME roosts in Cienega Creek Natural Preserve
Mine site #1	Townsend's big-eared bat	Cave myotis Big brown bat	No	Reliable maternity colony
Arkenstone Cave	Mexican long-tongued bat	N/A	No	Monitor as part of census of all known CHME roosts in Colossal Cave Mountain Park
Colossal Cave	Townsend's big-eared bat	Cave myotis	No	Recent maternity colony for COTO; accessible site
Mine site #2	California leaf-nosed bat	N/A	No	Important winter roost
Mine site #3	N/A	Cave myotis*	Yes	Large roost of probable cave myotis; inaccessible
Mine site #4	N/A	Cave myotis*	Yes	Large roost of cave myotis; inaccessible
Mine Complex #5	California leaf-nosed bat	Cave myotis*	Yes	Small numbers of MACA; unstable site structure
Mine site #6	N/A	Cave myotis	Yes	No recent evidence for covered species use; frequent visitation
Mine site #7	N/A	N/A	Yes	Beehive – no internal survey
Proposed Substitutions				
Cienega Creek CHME roosts	Mexican long-tongued bat	Any other species	In lieu of dropped sites	Assess condition and occupancy of ~14 soil piping features
Colossal Cave CHME roosts	Mexican long-tongued bat	Any other species	In lieu of dropped sites	Assess condition and occupancy of ~9 rock and mine features

*Bats were not captured at these sites, but based on acoustic and trapping (at mine site #4) data collected in previous years by Pima County Natural Resources, Parks and Recreation staff, as well as exit behavior observed in this monitoring, the majority of bats observed at these sites are assumed to be cave myotis.

Colossal Cave

There are three entrances that bats in this cave could exit from and recording video at all of them for exit counts, as well as analyzing the video is a substantial undertaking such that a complete monitoring effort at this site is equal to that of at least two smaller sites. We will discuss with USFWS biologists whether considering a complete and accurate monitoring round at Colossal Cave Mountain Park may be considered equal to monitoring two sites given the complexity of this site.

Monitoring method

1. Capture emerging bats (bat room tunnel entrance) in late July to assess use as a Townsend's big-eared bat maternity colony.
2. Concurrent video emergence counts of the three exits to assess bat abundance and exit patterns as well as cave tour operation impacts
3. Work with Colossal Cave Mountain Park staff (i.e., cave tour leaders, management staff) to receive important observations of bat presence or behavior as well as emphasize bat friendly procedures, lighting, and tour reroutes where feasible. Assess impacts of management and tour-related actions on bat species

Additional opportunities given available resources or interested partners

1. Encourage efforts that address how cave tour operations impact spatial and temporal patterns of bat species use at the site, and robustly evaluate how these patterns may change in response to any changes in cave management and tours implemented in the interest of bat stewardship.

Mine Site #1

Mine Site #1 consists of four nearby adits. Given the number of adit openings, and the resources required to monitor all of them, we recommend treating this complex as two different sites. Pending location of additional known or suspected bat roosts located elsewhere, the County may consider substituting newly discovered sites for the sites at this complex, with input from USFWS staff.

Monitoring method

1. Concurrent video emergence counts of the four features if feasible, otherwise consecutive emergence counts of the features (i.e., video two openings on one night, and two on another night). If resources are limiting, the shallow approximately 23 m long adit identified by prior surveys (XX4 in the attached report) as a likely bat night roost can be internally surveyed relatively easy and not included in a videoed emergence count.

Additional opportunities given available resources or interested partners

1. Pima County should remain vigilant for opportunities to secure the subsurface mineral rights here as a means to permanently protect the site.

Mine Site #2

Mine Site #2 is a single feature accessed by a single, gated entrance. This site is most important as a major winter roost for MACA, and winter occupancy is best assessed through exit counts as determined from evening bat emergence captured on infra-red video.

Monitoring method

1. Winter (November – January) emergence counts through infra-red video
2. Assess status of bat gate and work with Pima County Natural Resources, Parks and Recreation for any site-specific management needs.

Additional opportunities given available resources or interested partners

1. Video September emergence to assess potential LEYE use
2. Consider working with others to outfit female MACA at this site with transmitters to locate additional maternity roosts that may be in the area.

Mine Site #3 – discretionary site

This deep, vertical mine shaft is not being included in future committed bat monitoring efforts. However, pending any available discretionary resources or interested partners it would be useful to assess its use as a seasonal LEYE roost through a video exit count in late September as the species is known to be in the area at this time. During September most or all summer cave myotis roosts would likely be vacated, making it easier to assess LEYE presence on an exit video.

Monitoring method

1. This site will not be included in regularly scheduled monitoring commitments during upcoming bat monitoring.

Additional opportunities given available resources or interested partners

1. Mid to late September emergence counts through infra-red video to assess potential LEYE use of the site.
2. Pima County should remain vigilant for opportunities to secure the subsurface mineral rights here as a means to permanently protect the site.
3. Consider options for bat-friendly securing of the site to prevent human injury as well as other wildlife from falling into the feature.

Mine Site #5 – discretionary site

Mine Site #5 includes two nearby mine adits. Small numbers of MACA were noted using both sites in September. This site is not being included in the list of committed monitoring sites chosen for future efforts, though if there are any available discretionary resources it may be useful to more thoroughly describe their use by MACA (particularly the deeper of the two adits) during summer and winter.

Monitoring method

1. This site will not be included in regularly scheduled monitoring commitments during upcoming bat monitoring.

Additional opportunities given available resources or interested partners

1. Assess whether this is a MACA maternity roost by surveying earlier in the summer (before pups are born) by netting and examining female reproductive status (i.e., avoiding unnecessary entry into the feature).

2. Complete internal survey during winter of SHH2 or if unable to safely enter the feature use videoed exit counts.
3. Monitor both adits for site conditions (vandalism, portal collapse).

New monitoring sites for the 2021 effort

Pima County proposes to substitute approximately 23 additional potential bat roosting sites in its second round of monitoring to be completed in 2021, in lieu of some of the sites monitored during 2018, in coordination with USFWS input. These proposed substitutions are discussed below.

Status and bat occupancy of soil piping caves in Cienega Creek Natural Park

Between 1994-1996 William Peachey and Don Carter (Pima County Natural Resources, Parks and Recreation surveyed all of the known eroded soil piping features in Cienega Creek Natural Park that were occupied by Mexican long-tongued by bats and documented 13 distinct features (12 of which are on County owned land) that were being used by CHME. Occupancy of Cienega Creek Natural Preserve by CHME is largely during the summer and early fall, and is mainly made up of females with young. The highest number of CHME counted on any particular day surveying all of these features was 57 (38 adults and 19 young)(Carter and Peachey 1996).

During the next round of Pima County's bat monitoring efforts we propose a one time (potentially recurring on undetermined cycle as subsequent findings or management needs may dictate) re-evaluation of all of the potential soil piping features within Cienega Creek Natural Park that may host CHME (or other bat species such as COTO). This also includes two additional soil piping features that had been reconstructed in a USFWS Partners Grant to Pima County Natural Resources, Parks and Recreation. Relative to when these features were first surveyed in 1994-1996, there may be some that have eroded to the extent that they are no longer bat habitat, and there may also be additional features that are now suitable for bats. Given the potentially unstable nature of some of these features, surveyors will use utmost care when assessing a particular site and gauging its suitability for an internal survey. Sites will not be surveyed internally when there has been recent rainfall in the vicinity, or if there are signs of recent collapse of substrate near or at the entrance of a feature. All sites will also be surveyed by at least two people and will not be entered if the surveyors deem them to be possibly unstable.

An approach such as is described above is well suited to monitoring CHME within a region given the fact that this species tends to roost in very small groups, in sometimes rather small or shallow sites (see Appendix A). A onetime re-evaluation of all of the known roosts for this species within Cienega Creek Natural Preserve, as well as documentation of any additional roosts is an important part of the management plan for this area, as well as providing a more relevant snapshot of the status of CHME in this area.

Monitoring method

1. Internal surveys and site assessment during summer (approximately two days of field work).

Additional opportunities given available resources or interested partners

1. Work with Natural Resources, Parks and Recreation to evaluate condition and any management needs associated with already completed projects targeting soil piping stabilization efforts targeting bat habitat.
2. Work with the property owners whose land the Amber Adit (an adit within a limestone cave adjacent to Cienega Creek Natural Preserve) is situated on to evaluate its use by LEYE and CHME (it is a known CHME site).

Status and bat occupancy of caves and crevices in Colossal Cave Mountain Park

Carter and Peachey (1996) also monitored all of the known CHME roosts in Colossal Cave Mountain Park, and documented nine features (8 caves or rock crevices and 1 mine) that were being used by CHME (maternity roosts). The highest number of CHME counted on a particular day was 26. Two of these features are those that were included in the County's 2018 bat monitoring effort (Colossal Cave and Arkenstone Cave), but the others were not included in the 2018 monitoring effort. This proposed effort would provide an update to the census produced in 1996. Whether it is prudent to repeat this snapshot view of the status of CHME at these sites every three years (the Pima County bat monitoring interval) would need to be determined. Updating the population status and roost conditions of these sites in Colossal Cave Mountain Park and Cienega Creek Natural Preserve represents a substantial investment of resources, and we proposed that together with the already described recommended sites for the 2021 bat monitoring effort, that this more than satisfies the County's monitoring obligation for these bat species.

Monitoring method

1. Internal surveys, targeted video exit counts (Arkenstone Cave), and site assessment during summer (approximately two days of field work).
2. As resources allow, consider netting Bat Tunnel Exit in late July to assess whether the site is a COTO maternity colony (to be done in 2021 to prevent overly frequent netting at a single site given that it was netted in 2018).

Additional opportunities given available resources or interested partners

1. As opportunity allows, work with the Cave operators to ensure operations minimize disturbance to bat use of the cave. Continue to work towards a bat-compatible gate of the Bandit's Escape Exit to allow bats unimpeded use of the Bat Tunnel Entrance (i.e., Cave tours would then be routed through the Bandit's Escape, rather than the Bat Tunnel).

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Appendix A: 2018 Final Monitoring Report

BAT MONITORING IN PIMA COUNTY

Final Report

April 26, 2019

Sandy Wolf

Bat Research and Consulting

sandyawolf42@gmail.com

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FINAL REPORT ON MONITORING BATS IN CAVES AND MINES IN THE PIMA COUNTY PRESERVE SYSTEM, 2018

Sandy Wolf, Bat Research and Consulting

INTRODUCTION

As part of Pima County's commitments outlined in the County's Multi-species Conservation Plan, the county is responsible for implementing the Pima County Ecological Monitoring Program. One element of the program is to monitor site occupancy for 4 bat species at 10 sites (site list and access were provided by Pima County based on data collected by previous field efforts) within the Pima County Preserve System, and to monitor site condition. The 4 species are Townsend's big-eared bat (*Corynorhinus townsendii*, COTO), California leaf-nosed bat (*Macrotus californicus*, MACA), Mexican long-tongued bat (*Choeronycteris mexicana*, CHME), and lesser long-nosed bat (*Leptonycteris yerbabuenae*, LEYE). All 4 species are subterranean-obligates, which means they require caves or mines to survive. Pima County has not yet finalized selection of the 10 caves/mines; staff is inventorying and evaluating potential sites for use by the 4 targeted species as well as other bat species. We (Bat Research and Consulting) were contracted to assist with the monitoring effort.

OBJECTIVES

1. Survey 10 sites 2 times (approximately) between 15 April and 31 December, 2018 for bat use and site condition. Identify species of bat, number of individuals, and observed threats to the site (e.g., vandalism, evidence of human visitation, collapse of portal/internal workings).
2. Develop protocols for field methods for inventorying and monitoring bats, including internal survey of mine features, infrared video-recordings of bat evening emergences, bat captures, and DNA analysis and species determination of bat guano.

METHODS

We used different methods for monitoring sites based on each site's attributes, and what was previously known about the site and bat use of the site (data from Pima County and BLM). Methods included internal surveys, video-recording evening bat emergences, capturing bats, and deploying guano sheets to collect guano for analysis to determine species. Monitoring protocols for each survey method are discussed in detail in the Protocols for Field Methods for Inventorying and Monitoring Bats in Caves and Mines included in this report. Specific methods used for each site are given in Appendix A: Site Reports. Methods were selected and implemented so that disturbance to bats, when present, was minimized while obtaining necessary data. All methods are standard practices and discussed in the American Society of Mammalogists guidelines (Sikes et al. 2011) and the "bible" of bat research methods (Kunz and Parsons, 2009).

We held a scientific collecting license from Arizona Game and Fish Department (SP619854). We notified the appropriate Pima County, Colossal Cave Mountain Park, Border Patrol, and Bureau of Land Management personnel as necessary before going out to each site.

We cleaned gear after each field trip, following the most recent decontamination protocols for white-nose syndrome from the U.S. Fish and Wildlife Service.

Collected guano was sent to the Bat Ecology and Genetics Lab at Northern Arizona University for analysis.

RESULTS

Between May and December, 2018, we visited 10 sites at least one time: Arkenstone Cave, Colossal Cave, Karen's Cave, Mine Site #3, Mine Site #2, Mine Site #4, Mine Site #1, Mine Site #5, Mine Site #7, and Mine Site #6. Sites #1 and 5 had multiple features. We observed 3 of the 4 targeted species: Townsend's big-eared bats at 2 sites (Colossal Cave and Mine Site #1), California leaf-nosed bats at 2 sites (Mine Sites #2 and 5), and Mexican long-tongued bats at 2 sites (Arkenstone and Karen's Caves). We did not observe or find evidence of use by lesser long-nosed bats at any of the sites. We observed cave myotis (*Myotis velifer*) at Colossal Cave, and what were most likely cave myotis at 4 additional sites (Mine Sites # 3, 4, 5, 6). We collected guano for DNA analysis at Karen's Cave, Mine Site #1, and Mine Site #6. Analysis of this guano confirmed use by cave myotis at Mine Site #1 and 6, and use by big brown bats at Mine Site #1. Guano results from Karen's Cave indicated Mexican long-tongued bat use.

We were unable to survey 3 features: Mine Site #7 and two additional adits near Mine Site #5. There were bee hives at the portals of Mine Site #7 and one of the adits near Mine Site #5, and one adit near Mine Site #5 was closed with cable netting.

We observed and recorded the condition of each site's physical structure and evidence of human visitation or vandalism. All abandoned mines are subject to natural deterioration and some showed more signs of instability than others. Except for Colossal Cave, sites had unrestricted/unenforced access. We saw very little evidence of recent human visitation in the form of trash or tire tracks. Fortunately, most sites are in locations that do not receive much visitation. One of the most vulnerable is Mine Site #2, which is near to houses; the gate installed in 2007 was breached and needs repair. Another is Mine Site #6 in the Rancho Seco area, where there was evidence of rock-hounding. Prior field efforts by Pima County staff have also encountered people exploring the interior of this feature (Ian Murray, personal communication). We observed some trash from migrant use near the trail to Mine Site #4.

Results for each site are given in Appendix A: Site Reports.

DISCUSSION/RECOMMENDATIONS

Discussion and recommendations for each site are in the Appendix A: Site Reports. See below for a brief summary of site-specific monitoring strategies.

MONITORING SITES AND SELECTION STRATEGIES

Of the 10 sites we monitored, we think Mine Site #2, Colossal Cave, and Mine Site #1 are the best choices for permanent, long-term monitoring. Mine Site #2 and Colossal Cave have been occupied by California leaf-nosed bats and Townsend's big-eared bats, respectively, for many years, and therefore are stable colonies. Although the COTO colony in Mine Site #1 was first observed rather recently (in 2014), maternity colonies tend to be site faithful, and our observation of the colony again in 2018 provides evidence that the colony is stable.

Karen's Cave has been monitored periodically by Pima County staff since 1997. Mexican long-tongued bats have been observed from 1997 to the present, including 2018. Townsend's bats have not been observed since 2013 (Pima County data). We collected a bat guano sample (from an insectivorous bat species) that had been deposited at this site after the start of this project, but eDNA analysis of this sample and associated species determination will not be available until after this report is submitted. This site seems to be a good site to monitor CHME (but see discussion in section on Targeted Species under CHME).

Arkenstone Cave, Mine Site #5, Mine Site #6, and Mine Site #7 need additional inventory work on bats using these sites to determine whether they are suitable as long-term monitoring sites. For example, although guano

analysis from Mine Site #6 confirmed use of a non-target species (cave myotis), it is possible that other species use this site; the 2014 survey found evidence of COTO use. These sites are discussed in the next section on Targeted Species.

Mine Site #4, though a biologically valuable site given its status as a large cave myotis maternity site, is not a good choice for monitoring any of the 4 targeted species because of its physical characteristics and its use by large numbers of cave myotis spring through fall. It is not possible to conduct internal surveys or place guano sheets. Video-recording emergences requires 2 cameras and many lights, and does not yield high-quality video or permit species identification. Townsend's bats have been captured on the bench below the shafts (Pima County data), but although the bats were likely roosting in the mine, mist-netting is not a valid method to determine abundance; it can only confirm presence of a species. Mist-netting should be avoided when bats are pregnant or newly lactating (mid-May through early August) and is not likely to be successful in cool months when bats are torpid, so the time period for using mist-netting to document presence is narrow. In addition, failure to capture a targeted species cannot be interpreted as absence of that species in the mine or area. Acoustic data can document presence, but may miss Townsend's bats because of their call characteristics or placement of equipment.

Mine Site #3 is also not a good choice for monitoring targeted species, for similar reasons as those given for Mine Site #4. It seems to be primarily, or solely, a cave myotis summer roost (use by a maternity or bachelor colony is unknown), and is a deep shaft not safe to rappel (collar has loose material). Although it may be difficult to distinguish lesser long-nosed bats from cave myotis either acoustically or by video-recording depending on the proportion of lesser long-nosed bats to cave myotis and total abundance, the site should be surveyed in mid-late September for lesser long-nosed bats (see section on Targeted Species).

More inventory work on caves and mines in the Pima County Preserve system will identify additional sites that are occupied by bats and potential sites that are suitable as permanent, long-term monitoring sites. Multiple potential sites in each geographic area of interest should be surveyed in all seasons and over multiple years to determine how each site is used, when, and in what numbers, by a particular species. A particular site may be important one year and not the next because of changes in temperature and rainfall patterns that affect roost microclimates and prey availability, human disturbance, and the availability of alternate nearby sites. Although such intensive work can be costly and labor intensive, it is crucial that how, when, and in what numbers bats use a particular site is understood in relation to other nearby roosts before a site is selected for long-term monitoring. It is of no value to monitor a site that is used as an ephemeral, transitory, or auxiliary roost by a small number of bats when large numbers of the same species are roosting nearby, or in the same site at a different time of year.

It is much easier to determine abundance accurately, and therefore determine long-term trends, at a single-species roost, so such a roost is preferable to a multi-species roost for permanent long-term monitoring sites. Monitoring multi-species roosts adds to the difficulty of determining abundance, or even presence, of each species. For example, several hundred MACA (large for most MACA colonies) are more difficult to detect and accurately count if they are among thousands of LEYE, even with a high-speed camera and optimal lighting (pers. obs.). It may be impossible if the camera's field of view must be wide to cover a large entrance and species cannot be distinguished.

For a single-species roost, such as Arkenstone Cave, an Anabat Roost Logger acoustic detector can be used to find the time of year when activity is greatest (e.g., when adult numbers in a maternity colony peak before parturition). Abundance can then be obtained through evening bat emergences during that period of time in the future. Deploying a roost logger inside the entrance of a mine or cave for a couple years minimizes personnel time otherwise spent on many survey trips that may not be at optimal times. Batteries can last at

least 2 months; several quick trips to change the batteries will result in long-term data on relative activity throughout the year, and in the long run, will be more cost-effective in determining the best time for a survey.

TARGETED SPECIES

Mexican long-tongued bat (CHME)

The life-history characteristics of Mexican long-tongued bats make it difficult to determine trends in populations over time. Females migrate from Mexico in the spring to form small maternity colonies, often only a few bats (<20), and up to ~50 bats (O'Shea et al., 2018). Colonies are scattered over the landscape in low abundance overall (O'Shea et al., 2018). They frequently roost in the twilight/entrance area, and often fly out of the roost if it is approached by humans, rather than fly farther back into the roost. They are able to use a wide variety of shelters spring through fall, from shallow to deep caves or mines. Some may also overwinter in the Tucson area if they can find sufficiently warm roosts and food resources. Observing sign in unoccupied sites is not always possible because of a colony's small numbers: a few fecal "splats" can easily be lost in the substrate of a mine or cave, or lost in large amounts of similar guano if LEYE also inhabit the site. To determine population size over an area and through time, many roosts would need to be identified and monitored as simultaneously as possible (bats may move from one site to another nearby from day to day or within short periods of time). Even if all 10 of Pima County's chosen monitoring sites were occupied by this species, they would need to be in the same area, such as Cienega Creek Natural Preserve, for interpretation of trends to be valid.

We monitored 2 sites occupied by CHME: Arkenstone and Karen's Caves. In late May, we observed 3 bats in Arkenstone, and 1 in Karen's Cave. In late September, there were 5 bats in Arkenstone and 2 in Karen's Cave, possibly the same adults plus young-of-the-year. Although both sites would work as permanent monitoring sites, interpreting data from surveys at isolated sites every 2-3 years would be impossible. For example, we have monitored a cave in the Rincon Mountains annually since 2005 that always has 2-4 CHME in the same place on our August and September surveys. This past August we saw no CHME. Should we conclude the population of CHME in the area had decreased? As it happened, we observed 1 CHME when we returned in September (and the creek below the site had resumed flowing). In 1999, researchers visited 24 of 39 historical CHME roosts in Arizona and New Mexico and observed bats at 75% of them; the largest number at a site was 17. They were unable to conclude whether the population throughout this area had decreased or increased (O'Shea et al., 2018). These examples illustrate the difficulty of determining real trends in population with both frequent, repeated visits to one site and over time at many sites over a large geographic area.

We suggest that multiple sites in a relatively small area be considered a single long-term monitoring site. For example, in past years, Pima County personnel monitored several soil-piping features along Cienega Creek, including Karen's Cave, that were occupied by CHME. Surveyors would need to survey all sites on the same day but ensure they were not double-counting individuals if bats were flushed out of one site and possibly flew to another. Buehman Canyon is another potential area; multiple mines could be surveyed in one day. The survey would have to be repeated at the same time of year, either before young are born (to count the adult population), or in late summer (which would include young-of-the-year).

Another method would be to monitor bats that feed at hummingbird feeders. Bats are active at feeders in the Tucson area, particularly late in the summer and fall when agaves are finished blooming. They usually start appearing before lesser long-nosed bats arrive, although they may not be noticed by homeowners. A small number of CHME may not drink enough overnight to make the level of sugar water used readily detectable. A few years ago, we set up a feeder by the bat tunnel at Colossal Cave to attract LEYE, and video-recorded both CHME and LEYE at the feeder. Cave personnel maintained the feeder. If a feeder at the cave were maintained again, video-recordings from a night or 2 in September would verify presence in the area, although not provide abundance, and would be at least as valuable as surveying an isolated roost. A strategically placed trail camera

that has high resolution and uses infrared light may be sufficient to record videos throughout the night and identify species if a high-resolution infrared-sensitive camcorder or surveillance camera is not available.

Arizona Game and Fish Department is now maintaining the Bat and Hummingbird Feeder Study website and program (https://www.azgfd.com/wildlife/backyard-bats/), formerly run by the Town of Marana. Most homeowners cannot distinguish CHME from LEYE, but enough pictures are posted that presence of CHME could be verified. Some website contributors have trail-cams; a group of monitors could be solicited from this group and record CHME use after being trained to distinguish between species. Although the monitoring area for CHME would be, for the most part, the north and east sides of Tucson rather than the Pima County Preserve System, it is a large geographic area, and would provide sufficient data to determine presence/absence over time, dates of arrival and departure, and possibly relative amounts of activity from area to area. Although activity at feeders is greatest about the same time as LEYE are present, CHME remain active in some areas well into December and some appear to overwinter. Data from volunteer monitors specifically studying CHME would provide valuable information on how and when this species uses an artificial food source throughout the year.

Townsend's big-eared bat (COTO)

Locating and monitoring maternity colonies is the most effective method of monitoring long-term trends for this species in the Pima County Preserve System. In fall through winter, bats are usually found roosting singly and scattered throughout mines and caves, which makes observations of bats during internal surveys opportunistic. However, maternity colonies abandon their roosts easily if disturbed (Sherwin et al., 2009, O'Shea et al., 2018), so monitoring methods must avoid disturbance. Ideally, maternity colonies should be monitored before adults give birth so that the adult abundance is compared from year to year, rather than later in the season when adults plus volant young-of-the-year are counted. Reproduction and neonate survival is likely more variable from year to year than adult abundance.

The 4 adits of Mine Site #1 in Rancho Seco seem to be a good long-term monitoring site because a maternity colony was observed in 2014 (BLM data from Bat Conservation International surveys) and again in 2018; however, monitoring many entrances simultaneously would be labor intensive. Additional inventory work would determine which adits are used and when throughout the maternity season; the colony seems to switch from one adit to another (XX1 adit in July, 2014 and XX2 in June, 2018). Maternity colonies may use different roosts during pregnancy, birth, and post-birth depending on their physiological needs and the microclimatic conditions of the roosts (O'Shea et al., 2018). Long-term monitoring should consist of video-recording all 4 adits on the same night to ensure that the evening emergence at the occupied adit is captured. Camera images should be of high enough resolution to distinguish COTO from other species that may be present. Surveyors should be aware that XX2 adit probably connects to the vertical pit next to the portal, and XX3 may also connect (BLM data); bats may also exit from these features. Internal surveys in the future are not recommended because of this species' sensitivity to human disturbance. If all entrances cannot be monitored on the same night, we recommend conducting emergence counts at XX1 and XX4 on one night, and XX2, XX3, and the vertical shaft on the next. Guano analysis using eDNA methods from pellets deposited after the start of this study confirmed that samples taken from XX1 were from cave myotis, and samples from XX3 were from big brown bats. Therefore, it is important to distinguish species. On high-quality video, COTO are relatively easy to distinguish from cave myotis and big brown bats because of their large ears.

Colossal Cave is also a good site for long-term monitoring. We confirmed presence of Townsend's bats in early September by capturing 18 bats; 39% (7) were female. Use of the cave by a maternity colony of this species should be confirmed by captures in mid-late July when females are in late-lactation or finished and young are volant. Even though the cave supports other species, it is an easy site logistically to harp trap and capture bats. Bats should not be captured more frequently than once every 2-3 years. Data on abundance requires high-speed, high-resolution cameras at 2 entrances and a camera with good resolution at the Bandit's Escape

entrance. If video-recording all 3 entrances simultaneously is not feasible, the Bandit's Escape entrance could be covered with a tarp or shade cloth so bats use one of the other entrances.

Both Mine Site #1 and Colossal Cave are challenging sites to monitor, in one way or another. Pima County personnel should continue to survey mines and caves to locate additional maternity colonies. If another one or two maternity colonies were located, the easier sites logistically to monitor might be monitored more frequently than the others, depending on scarcity of resources.

California leaf-nosed bat (MACA)

California leaf-nosed bats do not hibernate or migrate; they remain active in an area year-round, moving from roost to roost as their physiological requirements and roost microclimates change through the seasons. The longest distance recorded from a winter to summer roost was 93 km; the longest movement documented was 137 km (O'Shea et al., 2018).

This species can reduce its body temperature somewhat, but cannot hibernate or go into full daily torpor (O'Shea et al., 2018). Winter roosts must be warm enough, and insects must be plentiful enough within a night's flying distance from the roost (<20 km) so that bats can keep a positive energy balance. Colonies can range from just a few individuals to up to hundreds of bats. Summer roosts are often shallow or with multiple entrances and airflow; bats often roost near the entrance (pers. obs., O'Shea et al., 2018). Abandoned mines or caves with a variety of structural characteristics in a relatively small geographic area are therefore crucial to this species for survival.

Mine Site #2 is a historical roost that has been used for decades, and only MACA have been observed there (with the exception of 3 male cave myotis captured in July, 2006; Wolf and Dalton data). Colony size peaks sometime from November through January (not necessarily the exact same time every year) and varies from ~700-900 (Wolf and Dalton data). Bats are present year-round with the fewest numbers (~50) during maternity season (both males and reproductive females present July, 2006; Wolf and Dalton data). The ratio of males to females of 103 bats captured in January 2015 was 52% male and 48% female (Wolf and Dalton data). Therefore, there must be other maternity sites in the Tucson Mountains or nearby areas that are occupied by the hundreds of females that do not remain at the mine. The mine should be surveyed in both winter and summer to monitor trends in both types of use.

Mine Site #5 complex in Rancho Seco may be a good long-term monitoring site, but more inventory work is necessary at all the features in all seasons, and in nearby areas. We observed only small numbers of bats (~25) and in September, when bats were probably between summer and winter roosts. There could well be a roost nearby with larger numbers in either summer or winter.

We recommend that county personnel continue to survey sites for MACA on Pima County lands. Mine Site #7 is not far from Mine Site #5. We were not able to enter because of an active bee hive at the portal, but an internal survey in cold weather would provide recent information, and guano (some was found in the 2014 survey) could be collected and analyzed for species.

Lesser long-nosed bats (LEYE)

We did not observe lesser long-nosed bats, although the species is known to be present in eastern Pima County late-August through mid-October. Colossal Cave was historically used as a maternity roost until the late 1960s when it was extirpated by the installation of an exhaust system. Although the exhaust system was removed in 1988, and other species currently occupy the cave, LEYE have not returned, although they forage in the area in late summer/early fall. Efforts are being made to make the cave more attractive to LEYE; we would consider use of the cave as a late-summer roost as a successful conservation effort.

Arkenstone Cave is probably not inhabitable by large numbers of LEYE because of the small, gated entrance. To our knowledge there are no records of use by large numbers of this species before it was gated, so it is possible it does not provide suitable temperature profiles or structural requirements.

If there are mines or caves within the Pima County Preserve System on lands with patches of agaves, or near agaves, they should be surveyed late July through August, when this species is present in southeastern Arizona to feed on agaves.

Lesser long-nosed bats begin appearing at hummingbird feeders in the Tucson metropolitan area, and at nearby roosts, in mid-late August after agaves have finished flowering in the nearby mountain ranges. They have been found sharing sites and roosting among cave myotis in southeastern Arizona (pers. obs.). For this reason, we recommend video-recording evening emergences of large cave myotis summer roost-sites within about 30 miles of the Tucson metropolitan area in mid-late September, when the LEYE population in this area is greatest. Most or all cave myotis have left maternity/summer bachelor sites by this time, so if LEYE are present, they will be readily distinguishable and identifiable. We recommend that Mine Site #3 be surveyed at this time for LEYE. Mines in Tucson Mountain Park, particularly deep shafts, should also be surveyed mid-late September; in the last several years, LEYE have begun to use hummingbird feeders on the west side of Tucson in the Tucson Mountain foothills and to the west of the Tucson Mountains in the Picture Rocks area. They appear at feeders too early to have flown from known roosts in the Rincon or Santa Rita Mountains; we believe there may be a roost in the Tucson Mountains. Although it is unlikely that LEYE would use a gated site such as Mine Site #2, the mine should also be surveyed with an emergence count in late September. The entrance is small enough (and therefore, the camera can be close or zoomed in) that LEYE and MACA are distinguishable with a camcorder and good infrared lighting.

SITE PROTECTION

The long-term monitoring sites chosen by the county should be protected from human visitation, as should other known roosts of bats that inhabit County lands; otherwise, managers will not know whether a change in abundance or use at a site is due to human visitation at that site, natural changes in the bat population (due to a variety of unknown causes), or changes due to humans at another site used by those bats. Effective measures to protect bat roosts include restricting vehicle access near the site, fencing the site area with high chain-link fencing, and installing a steel “bat-friendly” gate.

Many of the mine features had barb-wire fences across the portal (particularly the adits at Mine Site #1) that had been partially or fully bent back sometime in the past to allow easy access for humans. We do not recommend replacing the fencing. The location of the fences was directly in the flight path of bats entering or leaving the mines and thus a potential danger to the bats. In addition, barb-wire fences are not an effective deterrent to keep people out of adits.

Except for lesser long-nosed bats, the other 3 targeted species adapt well to steel “bat-friendly” gates. To provide the best protection for the roost from human access and allow the most unobstructed flight access for bats, the gate must be well designed for the site’s physical characteristics and anticipated level and type of vandalism, located in the best place, installed at an appropriate time of year to prevent disturbance to bats, and constructed by competent people. The colony should be monitored before and after the gate is installed (at the appropriate season) in addition to the regular monitoring schedule. If the roost is used by other species, these species should be considered in a gating project (e.g., large colonies of cave myotis do not adapt well to gates). We would not recommend adversely affecting a colony of cave myotis in order to gate a roost of another species. Another potential disadvantage of a gate is that it also keeps out other animals that may use the site, such as desert tortoises, javelina, and vultures.

The gate on Mine Site #2 needs an additional top bar to close the space where someone dug out the rock above the gate. At Colossal Cave, the county and cave personnel are interested in re-routing the wild cave tour route to avoid the bat room so that bats can roost undisturbed throughout the year. This would be possible if the gate at the Bandit's Escape entrance was replaced with one that could be easily opened and closed and used as the route's exit point, rather than the bat-room tunnel.

CONCLUSIONS

We observed Townsend's big-eared bats at 2 sites (Colossal Cave and Mine Site #1), California leaf-nosed bats at 2 sites (Mine Site #2, 5), and Mexican long-tongued bats at 2 sites (Arkenstone and Karen's caves). We did not observe or find evidence of use by lesser long-nosed bats at any of the sites. We also confirmed cave myotis at Colossal Cave through capture, and assume that large summer bat colonies at Mine Site #3 and 4 were largely cave myotis. Additionally, through eDNA analysis of bat guano, we confirmed that big brown bats were using at least one of the adits at Mine Site #1 and cave myotis were using a different adit at Mine Site #1 as well as Mine Site #6.

Bats are a difficult group of animals to monitor. Interpretation of data for long-term trends in site occupancy or abundance at a specific site or over a geographic area of interest is difficult. Each species has different natural history characteristics including roost and foraging requirements that change throughout the year and differ between species, age groups, and reproductive condition of individuals. Selecting only 10 sites to monitor 4 very different species is not sufficient to provide good information on each species. In addition, given the geographic extent of the Pima County Preserve System, its diverse ecosystems, and the very small number of monitored sites for each species, the scope of inference for the results of monitoring would not be valid beyond each individual site.

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SITE REPORTS

ARKENSTONE CAVE, Colossal Cave Mountain Park

Bat Surveys, 2018, by Bat Research and Consulting

Location/access: Sensitive information

Participants: Sandy Wolf, Dave Dalton

Objective: Video-record bat evening emergence from cave to determine bat species and abundance

Results summary:

May 30, 2018: 3 Mexican long-tongued bats (*Choeronycteris mexicana*)
September 26, 2018: 5 Mexican long-tongued bats

Methods: The only good place to video-record the emergence at this cave is right next to the entrance pit, looking down at the gate. The ideal position is to view an entrance from the side so emerging bats fly across the field of view, but that is not possible at this site if the goal is to have an image in which species can be identified (providing visual characteristics are unique). Equipment: Axis 1354 camera, 2 near-infrared lights (Wildlife Engineering Model IR6, peak emission 830 nm, spectral bandwidth 15 nm fwhm, 20° dispersion angle, total radiant flux 1.6 W each), Toshiba laptop computer, 2 5-Ah, gel-cell batteries.

Weather data:

May 30: Sunset: 1924 h. Weather at 1924 h: 84°, wind B1, clouds 10%- high, thin. Moon 99% illuminated, rose at 2029 h. Weather at 2100: 77°, wind B1, clouds 0%

September 26: Sunset: 1817 h. Weather at 1830 h: 81°, wind B1, clouds 0%. Moon 98% illuminated, rose at 1936 h. Weather at 1950: 79°, wind B2, clouds 0%

Result details:

May 30: At 1919 h, we saw 2 bats foraging high above the road (likely canyon bats, *Parastrellus hesperus*, which often emerge before sunset). One of us watched the cave entrance continually after the camera was set up, about 1900 h. At 1942 h, we started to record, and recorded until 2055 h. Three bats emerged between 2025 and 2033. Many crickets emerged during our visit, as well as the biggest conenose I have ever seen. We heard one poor-will.

Later, we watched the video and positively identified (100% confidence) 3 Mexican long-tongued bats emerge at 20:25:06 h, 20:26:30 h, and 20:33:30 h. We identified them by the muzzle shape or tail; both characteristics are unique to this species. We were surprised at how late the bats emerged.

September 26: At 1829 h, we started to record, and recorded until 1947 h (all bats were likely to have emerged by this time). Five bats emerged between 1841 and 1931 h. Many crickets emerged during our visit, and at 1937 h, a ringtail went into the cave carrying a rat. The ringtail poked his head out at 1941 h (without the rat) and went back in the cave, then came out at 1944 h without the rat.

Upon watching the video in slow motion, we positively identified 5 Mexican long-tongued bats emerging. We had 100% confidence for identification for 4 of the bats, and about 80% confidence for the fifth. We identified them by the muzzle shape or tail membrane; both characteristics are unique to this species.

Condition of site: There was no sign, including tracks, of recent human activity in the area on either visit. The cave is well protected; the entrance is small, hidden, and gated. The Arizona Trail and road are visible from the site, but the cave entrance is not visible from the trail, road, or hillsides.

Recommendations: Because there are invertebrates in the cave whose status is considered vulnerable, emergence counts are the preferred method of monitoring this site. To fully understand the seasonal use and peak colony size of this cave by Choeronycteris, surveys should occur about every 2 weeks from May through October or November. To determine if lesser long-nosed bats (*Leptonycteris yerbabuenae*) are present, surveys should occur August through mid-October.

We surveyed this cave at the peak of lesser long-nosed b at abundance in the area (26 September) and observed none. We do not expect this species to use the cave except perhaps by an individual or 2; the entrance is small and the gate further impedes access. Lesser long-nosed bats are less maneuverable than Mexican long-tongued bats and roost in much larger numbers; it is unlikely that they would find this site attractive because of the restricted access.

COLOSSAL CAVE, Colossal Cave Mountain Park

Bat Survey, 2018, by Bat Research and Consulting

Location/access: Colossal Cave

Participants: Sandy Wolf, Dave Dalton, Melanie Bucci. Several park personnel and their relatives were present and helped with data recording or observed the capture/processing activities.

Objective: Video-record bat evening emergence from all 3 entrances of the cave to determine number of bats roosting in the cave, and capture bats emerging from the bat-room tunnel entrance to determine species, sex, age, and reproductive condition.

Results summary: September 8, 2018: Captured: 99 Cave myotis (*Myotis velifer*), 18 Townsend's big-eared bats (*Corynorhinus towsendii*). Abundance estimate from video-recordings: including all bats captured, a total of 537 bats (net number out) emerged.

Methods: We video-recorded (from outside the entrances) the main cave entrance, the bat-room tunnel entrance, and the Bandit's Escape entrance. Equipment: Axis 1354 camera, records to Toshiba laptop computer via wired Ethernet, Sony SR11 camcorder, Axis 214 PTZ camera, records to Dell computer via wired Ethernet, 5 near-infrared lights (custom lights using Osram Ostar LED chip arrays SFH 4730, peak emission 850 nm, spectral bandwidth 30 nm fwhm, 32° dispersion angle, total output radiant flux 3 W each), solid state laser with dispersing optics, peak emission 808 nm, spectral bandwidth 2 nm fwhm, ~30° dispersion angle, total radiant flux 5 W, 3 20-Ah lithium-ion batteries.

We captured bats in a harp trap placed a few feet inside the entrance to the bat-room tunnel. Bats were removed from the trap bag and placed in individual cloth bags and taken several yards away to the processing table. Data recorded on each bat included species, sex, age, reproductive condition, and general body condition. Bats were marked with a temporary mark on their head, and released.

Afterwards, equipment was decontaminated according to the most current white-nose syndrome decontamination protocols.

Weather data: Sunset: 1841 h. Weather at 1841 h: 85°, wind calm, clouds 3%. Moon 1% illuminated, set at 1819 h.

Result details: Bats began flying at 1853 h. Recording ended at 2046 h at the main entrance, 2102 h at the bat-room entrance, and 2048 h at the Bandit's Escape entrance.

The first bat captured in the harp trap was at 1848 h. All bats captured until 1935 h were cave myotis, which was when the first Townsend's big-eared bat was captured. The trap was closed at 2015. Although some bats flew around or through the trap without being captured, we captured 99 cave myotis, and 18 big-eared bats. To reduce the time bats were held, we identified most of the cave myotis and some of the big-eared bats at the trap, sexed them, and released them without holding them for further processing. For all cave myotis captured, 40% (40) were female, 60% (59) were male; 37% (7) of the 19 males we examined had descended testes. For big-eared bats, 39% (7) big-eared bats were female, 61% (11) were males; 20% (1) of the 5 males we examined had descended testes.

We counted 502 bats (net number out) emerging from the cave's 3 entrances, plus 35 held for processing, for a total of 537 bats: 86 from the main entrance, 383 from the bat-room tunnel (plus 35 captured and held), and 33 from Bandit's Escape.

Condition of site: The county and cave personnel are interested in re-routing the wild cave tour route to avoid the bat room. This would be possible if the gate at the Bandit's Escape entrance was replaced with one that could be easily opened and closed and used as the route's exit point, rather than the bat-room tunnel. This is not under the scope of the monitoring contract; the county, with our assistance, is currently planning on replacing the existing gate in the near future.

Discussion/Recommendations: We surveyed in September because it was likely to be a time of peak abundance. We assume that most of the 537 bats occupying the cave were cave myotis; 85% of captured bats were cave myotis. According to park staff (Bill Savary, pers. comm.), pallid bats also occupy the cave at times. A harp-trapping session when this species is present would provide information on how pallid bats use the cave.

Previous work in 2011 (Wolf and Dalton) confirmed use by a maternity colony of Townsend's big-eared bats. Our survey this year was too late in the season for us to see epiphyseal gaps in metacarpal-phalangeal joints, which is indicative of juveniles. Resurveying in late July next year would confirm whether this species continues to use the cave as a maternity site.

Data for cave myotis from 2011 showed use primarily by males. The cave myotis occupying the cave in summer therefore may be a bachelor colony. If it were a maternity colony, assuming that each bat gave birth and the single youngster survived, it would be expected that about 75% of the bats would be female; data from this year showed 60% male. Cave myotis migrate in September, so it is possible that the cave is used as by migrating bats as well as the summer colony. Resurveying in late July (before migration) next year would provide more information on the use of the cave by cave myotis.

The harp trap impeded natural exit behavior of bats from the bat-room tunnel so conclusions cannot be drawn from the relative proportions of bats emerging from each entrance (16% from main, 78% from bat-room tunnel, and 6% from Bandit's Escape). In addition, there was a tour along the main tour route that might have affected behavior at the main entrance. Monitoring the entrances on evenings when bats are not captured and there are no tours would provide information on the relative use of each entrance and how it changes throughout the year. Cave Management could then decide whether or not to alter tour times during certain times of the year.

Harp trap, Colossal Cave

Cave myotis, Colossal Cave

Townsend's big-eared bat, Colossal Cave

KAREN'S CAVE, Cienega Creek Natural Preserve

Bat Surveys, 2018, by Bat Research and Consulting

Location/access: Sensitive information

Participants: Sandy Wolf, Dave Dalton

Objective: internal survey of cave, deploy and collect guano sheets

Results summary:

May 29, 2018: 1 Mexican long-tongued bat (*Choeronycteris mexicana*), set 3 guano sheets
September 29, 2018: 2 Mexican long-tongued bats, collected guano sheets, collected insectivorous bat guano from sheet in large room for DNA analysis.

Methods: We used white light for safety because we were unfamiliar with the site (29 May), because snakes or other animals could be present, and to identify bats as quickly as possible (red light is less bothersome to bats but insufficient for safety or quick identification). We used fine mesh bridal veil, laid down and held in place with rocks, to collect guano. We prefer bridal veil to sheets of plastic because it does not affect the airflow and humidity underneath it and therefore minimizes effects on invertebrates and microbiota.

Result details: May 29: We entered the west entrance to the cave using white light. In the first room, we saw a bat flying around. It hung up above us in a high chimney-like area in the ceiling where there was a small grate-like structure reinforcing the ceiling. We identified species with 100% confidence by its long cylindrical muzzle; it took only a few seconds, and then we moved out from under it and did not shine a light near the bat again. We put a large piece of bridal veil underneath the chimney area and across a large part of the room. We surveyed the rest of the cave. Although we saw no guano pellets from insectivorous bats or fecal splats from nectar-feeding bats, we put 2 small pieces of veil down under likely roosting spots near the east entrance where the ceiling was highest. Throughout the cave there was a large amount of scat from pack-rats and mice, as well as javelina and possibly ringtail. There was an old javelina skull outside the west entrance, mostly buried in debris.

September 29: We entered the west entrance to the cave using white light. In the first room, we saw a bat flying around, and then fly into the back part of the cave. We surveyed the rest of the cave. We collected one of the guano sheets near the east entrance (no guano on it); it had been dislodged, and the other one we put down was missing. We heard no bats in the inaccessible room near the east entrance. We returned through the cave and saw 2 *Choeronycteris* (100% confidence for species based on muzzle) hanging up in the big room at the top of the chimney. The large guano sheet in the big room had been mostly moved by water flow and was partly under dried mud. There were a few pellets of guano on it, which we collected for species identification through DNA. Throughout the cave there was a large amount of old scat from pack-rats and mice, as well as javelina. Except for the few guano pellets we collected that looked somewhat fresh, we saw only a couple others that were old. There was no evidence that a colony of an insectivorous bat used the cave, although it is possible that guano was washed away. The old javelina skull outside the west entrance that had been mostly buried in debris in May was washed down a few feet and more visible.

DNA analysis of guano: Pending results from laboratory.

Cave description: This is a soil piping cave that has been stabilized with man-made structures. The west entrance is a metal, corrugated culvert 5 feet in diameter and set in the cliff face. It opens into an oval room about 20 feet long, 15 feet wide, and about 10 feet high at its highest point. At the far end of the room, a metal culvert (30-inch diameter), set at floor level, leads to a narrow, breakdown passage about 40 feet long that

varies in height from about 3- 12 feet high. The passage ends with a metal corrugated culvert, 48 inches in diameter and 5-6 feet long, that stabilizes the east entrance to the cave. Just before the east entrance is a room off to the north. There are 3 holes that lead into this area but are too small for human access. We could see a large open space with a straight vertical wall, but could not see the ceiling, floor, or how big the room was. We listened for bats but did not hear anything. The east entrance is in a large eroded, sinkhole area, and is slightly higher in elevation than the west entrance. Another large sinkhole area to the north has a small hole, about 2 feet wide by 4 inches high, that likely leads to the room we could not get into. We also climbed up the cliff from near the west entrance, went under the fence (the Cienega Preserve boundary), and down to the sinkhole with the east entrance. It is easy to get from one entrance to the other outside the cave, with only a little scrambling.

Condition of site: May 29: The only sign of human activity in the vicinity of the cave was one old plastic water bottle between the cave and the creek.

September 29: There was no sign of human activity in the vicinity of the cave but a large amount of water had come through the area rather recently. The structure of the cave appeared the same as in our previous visit. Soil-piping caves are inherently unstable, but we saw no signs of imminent collapse.

Recommendations: Because there is an area of the cave that humans cannot access, an internal survey cannot provide information on bats' use of this area. Although the entrance to the room is very small, it is possible for a maneuverable bat (e.g., Townsend's big-eared bat) to use it. Emergence counts at times when bats are known to be there are needed to supplement data from internal surveys. Both entrances must be recorded.

It is unlikely that lesser long-nosed bats use this site as a day-roost; we surveyed at the peak time of abundance for this species in the area. We saw no feces from nectarivorous bats. Given the dirt floor, large amount of other scat (rodent, javelina) and evidence of water running through parts of the cave, it is not surprising that we saw nothing if only a small number of Mexican long-tongued bats use the cave. If large numbers of nectarivorous bats (i.e. lesser long-nosed bats) roosted here, I think we would have seen sign in areas where water didn't flow.

Mine Site #3, Buehman Canyon Preserve

Bat Surveys, 2018, by Bat Research and Consulting

Location/access: Sensitive information

Participants: Sandy Wolf, Dave Dalton

Objective: Video-record bat evening emergence from mine to determine abundance

Results summary: June 2, 2018. Over 1,000 bats emerged from the shaft.

Methods: We set up the camera outside the fence on the west side of the shaft, several yards to the west of the fence. The lights were on a U shaped bracket set up at the fence. It's preferable to have the lights with the camera, but the light would have reflected off the fence wires and closed the iris. The size of the shaft meant that the camera's field of view was too wide, and therefore the images of the bats too small, for species identification. Equipment: Axis 1354 camera, records to Toshiba laptop computer via wired Ethernet; 4 near-infrared lights (custom lights using 4 Osram Ostar LED chip arrays SFH 4730, peak emission 850 nm, spectral bandwidth 30 nm fwhm, 32° dispersion angle, total output radiant flux 14 W), 2 20-Ah lithium-ion batteries. Sony SR-11 camcorder.

Weather data: Sunset: 1927 h. Weather at 1927 h: 87°, wind B1-2, clouds 0%. Moon 87% illuminated, rose at 2253 h.

Result details: We saw 2 deer on the hike in. We checked the boiler house and saw no bats, only pack-rat nests and debris. At 1935 h, we started recording when a bat came out and went in (light-sampling). The exit started at 1936 h. Most bats flew over the top of the fence on the north, west, and south sides. Only a few flew over the east chain link fence, and only a few flew through the strands of barbed wire. I hand-held the camcorder and video-recorded the emergence for several minutes until 1958 h. During the emergence, we had to move the Axis camera's view higher; the view through the fence showed bats circling rather than flying out. We stopped recording at 2014 h, after the emergence was over.

We watched the video-recording and estimated at least 1,000 bats exiting (net out). We assume the bats were cave myotis (*Myotis velifer*) based on their exit behavior and acoustic data (Iris Rodden, Pima Co.) from 2016 and 2017.

Mine Description: Shaft is about 8 feet x 12 feet with 2 concrete hoist pillars at the west end. A fence surrounds the ant-lion collar. The east side of the fence is 6 ft high chain link with barbed wire above it. The other 3 sides consist of 6-strand barbed wire. Juniper, hackberry, and mesquite are growing around the shaft. Vegetation partially obstructs access for bats at the east end, inside the fence.

We did not have time to check the double adit above the shaft. Although we allowed plenty of extra time, we used it getting to the site. Neither of the recommended parking areas worked out.

Condition of site: We saw no signs of recent human visitation.

Recommendations: On the north and south sides of the shaft, there are strands of barbed wire about 8 feet high that are an obstruction and potential hazard to bats, particularly juveniles. We were able to remove the strand on the south side because it was unattached and dangling midway along its length. The strand on the north side should be removed the next time county personnel are in the area.

The video did not lend itself to a good count. With more experimentation with camera and light location, we may have found a better view, but would have lost recording part of the emergence. As it was, we moved the

camera angle slightly in the middle of the emergence, which briefly disrupted the recording and changed the view. Placing the lights at the fence prevented reflection off the wires which meant the scene was relatively well lit, but also caused bats to have shadows, which can result in double-counting when it's not clear what is a bat and what is a shadow. To get the best video of an emergence, a site visit and test video (when bats are exiting) are necessary to determine the optimal camera placement, field of view, and light set up. The test video isn't designed to get an accurate count, but is necessary to determine optimal camera placement and view to obtain the most accurate counts in the future.

This site does not seem to be a good one to include as one of the County's 10 monitoring sites. It seems to be primarily, or solely, a cave myotis site, which is not one of the 4 cave/mine-dwelling species targeted for monitoring. Any other species occupying the shaft during the same season as the cave myotis would not be able to be distinguished. However, this site should be assessed during mid-late September (i.e., exit count video) for potential use by lesser long-nosed bats (LEYE). Most cave myotis are gone by then, and with a camera with good resolution and sufficient infrared lighting, LEYE should be distinguishable (lack of tail membrane is diagnostic) if present. It would be difficult to identify species occupying the shaft at other times of the year by video-recording, although if it has never been surveyed during the cooler seasons, it should be. The effort required to get to the site, however, is significant, and might be a factor as to the site's suitability.

Mine Site #2 Tucson Mountain Park

Bat Surveys, 2018, by Bat Research and Consulting

Location/access: Sensitive information

Participants: Sandy Wolf, Dave Dalton

Objective: May 13, 2018: Site visit to design repairs to gate. Opportunistically, determine if bats are present, number and species.

December 23, 2018: Video-record bat evening emergence from cave to determine abundance

Results summary: May 13, 2018: Observed 7 California leaf-nosed bats (*Macrotus californicus*) from outside the gate. December 23, 2018: 738 California leaf-nosed bats
Methods:

May 13, 2018: We arrived at the mine at 0955 h. We approached the gate quietly and sat next to it for several minutes. From past experience, California leaf-nosed bats (*Macrotus californicus*) commonly roost just past the gate in the warmer months. There was sufficient ambient light to see several yards on the other side of the gate.

December 23, 2018: We arrived on site at 1650 h. We set up the camera to the west of the mine entrance, up against the hill. We were ready at 1710 h. Equipment: Sony SR-11 camcorder, 2 near-infrared lights (Wildlife Engineering Model IR6, peak emission 830 nm, spectral bandwidth 15 nm fwhm, 20° dispersion angle, total radiant flux 1.6 W each).

Weather data: December 23, 2018: Sunset: 1925 h. Weather at 1925 h: 65°, wind B0, clouds 3%. Moon 99% illuminated, rose at 1846 h.

Results: May 13, 2018: After a couple minutes, bats flew from farther down the adit and from the alcoves off the adit just past the gate. They flew around, coming right up to the gate, and hung up a few feet from the gate. We saw 7 at the same time. They hung up as individuals, sometimes flapping their wings. This is typical behavior. We are 100% certain these were California leaf-nosed bats; they were only a few feet away, and their ears, face, pelage, body shape, and flight pattern were readily identifiable.

December 23, 2018: Bats began exiting at 1739 h. We recorded from 1739-1840 h. As usual, bats circled around the entrance area, including over our heads and very close to us, as if they were checking us out. We counted a total of 738 bats (net out).

Condition of site: We tested 2 original gate keys and 2 copies; the originals worked, but only one of the copies did.

The gate was installed in spring 2007. Sometime between our visits in December, 2009 and May, 2011, someone dug out the back (roof) of the mine above the gate enough so that a human can climb over the gate and enter the mine. At the widest point, there is a space about 15 inches high above the top bar. We took measurements and designed an addition to the top of the gate to prevent human access, using 3-inch square tube, hardfaced. The addition could be prefabbed to minimize the amount of cutting and welding required on site.

The piece of steel that the County bolted to the gate as a repair was lying in the alcove next to the gate. Some of the gate bars were tagged. Someone had tried to drill a hole in the second bar from the top; this can be

repaired when the additional bar is installed. There was a little trash just inside the gate but did not appear to be recent.

There were water bottles and trash by the entrance to the ungated mine next to this one. Based on surveys in the past, this mine was used infrequently by bats. If future surveys confirm it is still used infrequently, it could be filled in (any bats present would need to be excluded first) or gated to keep people out.

The fence at the parking area was partially knocked down; people can just step over it to go across the wash and up the old road. The road showed no signs of ATV traffic and is getting overgrown. There was no sign of recent ATV traffic at the mine site on either visit, although there is access from the west.

When we got back to the vehicle after each trip, we talked to XXXXXXXX, the homeowner by the parking area. He acts as an unofficial steward and discourages people (successfully) from riding their ATVs through the fence and up the road to the mine. He also has a brush pile near the fence to keep people from breaking down the fence in one area. He said he was interested in talking to county personnel about being an official site steward and being kept informed about activity/work at the mine. I didn't ask for contact information but in 2013 it was XXX-XXXX. We told him we hoped that the gate would be repaired in the spring.

Discussion/Recommendations: Based on previous data from 2005-2009 (Wolf and Dalton, unpublished), abundance seems to be a bit lower than in the past, but we don't have recent data to compare (Table 1). We know that winter (November-January) is the season of peak abundance, but it would take multiple emergence counts over multiple years to narrow down the peak, and determine how variable it is from year to year. We (Wolf and Dalton) have video from emergences in December 2012, December 2013, and January 2014 that are uncounted (we video-recorded for fun and never got a chance to count). If time ever permits, we will count the recordings. At this point we do not know if visitors have disturbed the bats since the gate was breached, although it is likely. Once the gate is repaired, numbers may increase.

Table 1. Abundance estimates of *Macrotus californicus* at Mine Site #2. Data from emergence counts by Wolf and Dalton.

DATE	NUMBER OF BATS
June 28, 2004	14
September 3, 2004	81
September 9, 2004	43
May 25, 2005	49
June 15, 2005	35
November 2, 2005	568
December 24, 2005	624
February 13, 2006	504
November 15, 2006	258
December 15, 2006	883
December 30, 2006	814
January 16, 2007	762
February 15, 2007	661
February 20, 2007	442
March 18, 2007	392
April 25, 2007	346
November 22, 2009	919
December 12, 2009	851
December 23, 2018	738

Mine Site #4, Rancho Seco

Bat Surveys, 2018, by Bat Research and Consulting

Location/access: Sensitive information

Participants: Sandy Wolf, Dave Dalton

Objective: Video-record bat evening emergence from mine

Results summary: June 9, 2018: Total net bats out: ~7,500 Assume bats were all or almost all *Myotis velifer*.

Methods: The mine consists of a large pit on a hillside with a shaft at the west end and an adit above it, and a shaft at the east end. We set up the Axis camera on the north side of the pit looking down and across the west shaft and adit. The lights were on a U shaped bracket on the tripod with the camera. Equipment: Axis 1354 camera, records to Toshiba laptop computer via wired Ethernet; 4 near-infrared lights (custom lights using 4 Osram Ostar LED chip arrays SFH 4730, peak emission 850 nm, spectral bandwidth 30 nm fwhm, 32° dispersion angle, total output radiant flux 14 W), 2 20-Ah lithium-ion batteries. We set up a second camera on the south side of the pit looking north down and across the east shaft. Equipment: Sony SR-11 camcorder, 2 near-infrared lights (Osram, same as above, total output radiant flux 7 W), 1 lithium-ion battery. We started recording a few minutes before bats began to emerge and stopped about 65 minutes later after the exit had ended.

Weather data: Sunset: 1930 h. Weather at 1930 h: 82°, wind B1-2, clouds 20%. No moon. Rain over the Santa Rita Mountains to the east in the afternoon, but none in the Rancho Seco area.

Results: Total net bats out: 7,449 Net bats out from west shaft/adit: 5,231 Net bats out from east shaft: 2,218. Total should be reported as ~7,500 bats.

Two owls exited the west shaft at 2021 h.

Condition of site: We saw one water bottle on the trail not too far from the parking area. There was a rather large pile of water jugs and bottles a few feet off the trail by the wash, where the trail runs along the west side of the wash southeast of the mine. There were 2 metal camp chairs folded up on the bench by the pit that looked weathered and unused in a while. The east side of the pit is fenced on the bench but that is the only barrier. The sides of the pit do not look stable; we took care to stay back from the edge. The shafts and adit are inaccessible without ropes, and even then look pretty sketchy. Don Carter drew a partial map of the features based on his survey, which gives sufficient information to inform future surveyors that this site is best monitored externally through emergence counts, acoustic data, and possibly mist-netting.

Discussion/Recommendations: This is not an easy site to monitor, even with high-speed, high-sensitivity cameras and strong near- infrared lights. The size of the pit meant that it required 2 cameras, and that each camera's field of view was too wide, and therefore the images of the bats too small, for species identification. Some bats flew close to the west shaft camera, and we were able to tell they were not Townsend's big-eared or California leaf-nosed bats, but for most bats, identification isn't possible. In addition, although we placed the cameras at the locations best suited for an accurate count at each shaft, there was vegetation that partly obstructed the fields of view and reflected some of the infrared light. Reflected light caused each camera's iris to close somewhat. The result was that the scene was not as well lit as it could have been. Although we were aware of the problem when we set up, the vegetation was at the very edge of the pit and not where we could safely remove it. In spite of the problems, upon review, it looks like the west shaft recording yielded fairly accurate results. The east shaft was not as easy to count accurately because bats from the west shaft flew into the view, lighting was not as good, and there was more vegetation obstructing the view of bats flying.

We assume all, or most, bats emerging were cave myotis (based on past County data, and our observations). If any of the 4 cave/mine-dwelling species targeted for monitoring by the County were present (or other non-target species), it would be difficult to obtain good data on abundance by video-recording; the site does not lend itself to being able to identify species visually with video.

To positively identify species of bats inhabiting the mine, bats could be captured in mist-nets set on the bench below the pit. On 12 September 2013, 10 Townsend's big-eared bats were captured in addition to cave myotis (Pima County data). Many, possibly most, bats we observed flew high above the bench. To sample them, nets could be placed where we put the cameras; as we sat next to the cameras, we both had bats flying low and directly over our heads. Footing would be unsteady, especially on the rock pile on the south side of the pit, but with care could be done.

This site may not be a good one to include as one of the County's 10 bat monitoring sites. It is not possible to conduct internal surveys or place guano sheets. Video-recording emergences requires 2 cameras and many lights, and does not yield high-quality video or permit species identification. Acoustic data only give presence/absence, and may miss Townsend's bats because of their call characteristics. Capturing bats by mist-netting is feasible but invasive and is safest only on the bench, which is not close to where bats exit. It is likely to be successful only in the warm season. In addition, failure to capture a targeted species cannot be interpreted as absence of that species in the mine.

Mine Site #1, Rancho Seco

Bat Surveys, 2018, by Bat Research and Consulting

Location/access: Sensitive information

Participants: Sandy Wolf, Dave Dalton

Objective: Internal surveys, deploy and collect guano sheets, collect guano for DNA analysis for species identification.

Results summary: June 9, 2018: A small maternity colony with half-grown young (~50 adults and young) of Townsend's big-eared bats (*Corynorhinus townsendii*) in XX. Deployed 2 guano sheets in XX, 3 in XX, 1 in XX.

December 1, 2018: One torpid Townsend's big-eared bat (*Corynorhinus townsendii*) in XX. Collected guano from a guano sheet in XX and from scattered guano in XX.

Guano analysis from XX: cave myotis, from XX: big brown bat

Methods: We conducted internal surveys of the adits. We had descriptions of the features from a previous survey by BCI so we had a general idea of what to expect, although conditions can change greatly in 4 years. Safety gear included hard hats, white light, and a gas detector. We used bridal veil for guano sheets. As we surveyed the adits, we checked for snakes and other animals, guano and insect parts, and hazards. In June, when we encountered bats, we immediately retreated. One of us returned with a camcorder and infrared lights, approached slowly and low to the ground and recorded the colony; no one approached closely enough to cause the bats to fly. Once a group of bats was encountered, we ended the survey in that adit; we did not continue past the bats to prevent them from flying out of the mine or otherwise disturbing them.

Results:

XX1 June: No bats. A trench about 20 ft. long leads to the portal, which is half obstructed by slope creep. The short adit ends in a collapse. One guano pile part way in was old and moldy; we laid a guano sheet over it. December: No bats. The guano sheet we put over the guano pile part way in was gone although the rocks that held it in place were there. There were 2 small areas with scattered guano several feet in from the older pile. We took samples of guano for DNA analysis from the scattered guano and from the edge of the older pile. Later eDNA analysis of this pooled guano sample indicated that it was from cave myotis. Temperature inside the mine was 64° F.

XX2 June: Adit is adjacent to vertical pit. Just a few yards into adit (~25 ft.) was a colony of Townsend's big-eared bats with young. We retreated, came back with video-camera and infrared lights and recorded for a couple of minutes. Ended survey there. Air was blowing into the portal (~97° F outside). The barbed wire fence across the trench just outside the portal was bent back, but there was a wire hanging out into bat flight area. We bent it back and secured it to increase the unobstructed flight area and prevent injuries from bats flying into it. December: No bats seen. Many piles of guano along passage. Some guano was mothy (feels silky smooth from moth wing scales), brown and black, probably Townsend's. Some was more gritty (beetle exoskeleton parts) and similar to that in XX1. We surveyed the adit as far as the ore pile with the winze on the other side and the stope above. It was too dangerous to try to navigate around the winze and continue the survey in the passage beyond the winze (the 2014 BCI survey stopped here also). It would be possible to continue only with additional people and surveyors roped in. Air was blowing, probably from the winze, which probably connects to the vertical shaft nearby. The top of the stope was not visible. There was a wooden ladder leading up to the other stope, which is mid-way between the portal and the winze; the 2014 BCI didn't mention the ladder so

whether it is recent or not is unknown. There was an amazingly large amount of ringtail scat throughout the adit and in the stope.

XX3 June: No bats. Cold air (66° F) blowing strongly out of portal. Going in, first drift to right had small area of large, coarse (beetlely) guano (probably big brown bat guano); we laid down a guano sheet over guano. First drift to left, 18 inch diameter scattering of guano, medium-sized, beetlely (probably cave myotis) under a large flat rock back, put down guano sheet. Largest area of guano (probably Townsend's big-eared bat) between first and second ore chutes, vari-colored, medium-sized, mothy, rather fresh. Put down guano sheet over this area. Air blowing down from stope above fourth (and last) ore chute. Several vulture feathers (white-tipped feathers, immature bird) just past fourth ore chute. Scattering of guano along middle of passage began between second and third ore chute to portal, becoming more continuous and denser towards portal. December: One torpid (ears curled up) Townsend's big-eared bat hanging on the timber on the second ore chute; air was flowing down the stope/chute. Two guano sheets were missing; the one in the first right-hand drift (going in) was present and had a small amount of guano on it. Collected some for DNA analysis. Analysis of this guano sample later confirmed its identity as being from big brown bats.

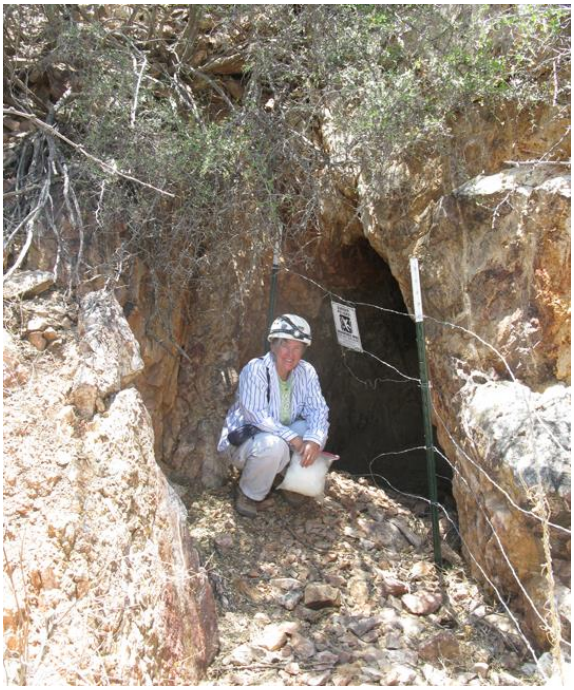
XX4 June: No bats. Half-dozen guano piles plus small scatterings along sill edges near ribs. Laid 2 guano sheets over largest densest piles; one was older and moldy, with small, stained pocket in back above guano; the other guano area was fresher and smaller. Two small black-tailed rattlesnakes. Turkey vulture feather part-way back. December: No bats. One of the 2 guano sheets was missing. The one present had some guano on it with a couple small triangular insect wings, but the guano looked the same as that in XX3 so we didn't collect it. There were also green insect wings inside the portal, indicating use of the mine by night-roosting bats.

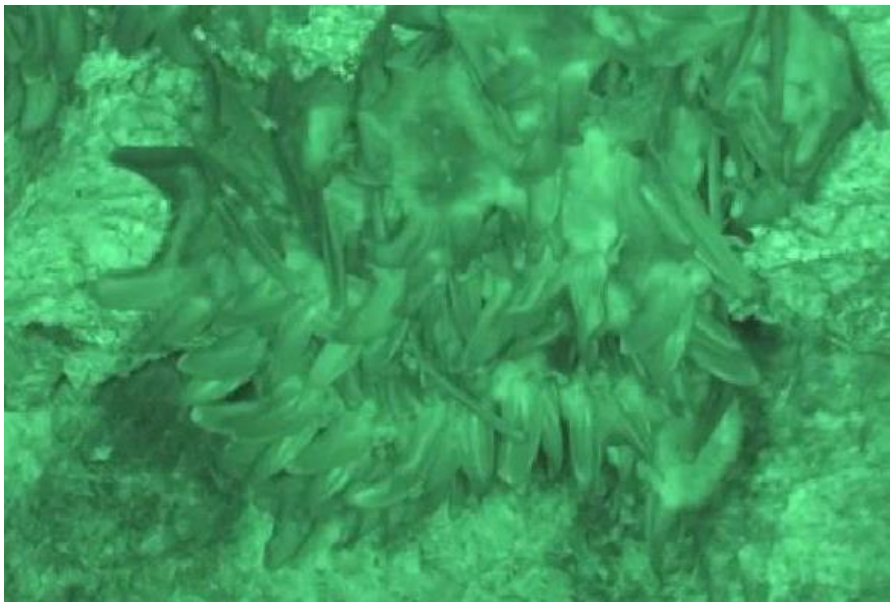
Condition of site: We saw no signs of recent human visitation. Tracks up the hillside between adits and between the highest mine and the wash are well-developed in places but are not continuous, so it is unclear whether they were made by people or javelina. There is debris/equipment left from mining days, but nothing recent. The fences across adit entrances are all partially bent back, which allows easy human access but also allows better bat access. In December, the dirt road leading to the mine from the main east-west road through Rancho Seco was much more overgrown than in June and showed no signs of being traveled on recently.

Discussion/Recommendations: Townsend's big-eared bats likely use all 4 adits at various times as microclimates in the adits and physiological needs of the bats change throughout the year. In 2014, BCI surveyors observed a colony of 150-200 Townsend's bats in XX1 on 24 July 2014. We likely only saw part of the colony and the rest was farther back in the mine. From the guano, cave myotis and big brown bats also inhabit the mine.

Fences were placed very near the portals. To allow for better bat access, they should be moved farther away from the portal, or kept bent back. Townsend's big-eared bats are maneuverable, but youngsters are less so. This species seems to adapt well to steel gates

Some critter (pack rats?) made off with 4 of the 6 guano sheets we put down in June. We searched the mines unsuccessfully for them. Perhaps the bridal veil provided coveted and superior nesting material. It would be worth trying plastic sheeting rather than bridal veil in the future. Although plastic affects the microclimate underneath it, it is not likely to have adverse effects to the mine when used as temporary guano sheeting.


XX2 portal


Townsend’s big-eared bats in XX2

Mine Site #5, Rancho Seco

Bat Surveys, 2018, by Bat Research and Consulting

Location/access: Sensitive information

Participants: Sandy Wolf, Dave Dalton

Objective: Internal survey to determine abundance and species of bats present

Results summary:

September 15, 2018: ~18 California leaf-nosed bats (*Macrotus californicus*) in XX1, 6 *Macrotus californicus* and 2 bats, probably cave myotis (*Myotis velifer*), in XX2.

December 1, 2018: No bats seen. Only partial survey of XX2.

Methods: We conducted internal surveys of the adits. We had descriptions of the features from a previous survey by BCI so we had a general idea of what to expect, although conditions can change greatly in 4 years. Safety gear included hard hats, white light, and a gas detector. Once a group of bats was encountered, we did not continue past the bats to prevent them from flying out of the mine, or otherwise disturbing them.

Result details:

XX1 September: We never entered the adit. Six California leaf-nosed bats (*Macrotus californicus*) hung just inside the portal; they were visible from outside the fence. 100% confidence for species identification (we used binoculars). About 6 m past portal is a collapse with a skylight above it. About 12 California leaf-nosed bats were visible from the surface just below the skylight. A few flew farther back but then immediately returned; the adit may only continue for a meter or so, but an internal survey when bats are not present is necessary to confirm this. December: No bats. Complete internal survey. Adit pinches out about 2 m past the vertical skylight; there is guano and a pack rat nest under the low ledge (~0.6-0.76 m high).

XX2 September: As we approached the portal, we saw 6 California leaf-nosed bats (MACA) just inside; they flew back into the mine so we continued the survey. Two bats, probably cave myotis (*Myotis velifer*, MYVE) based on visual characteristics, hung in a small dome (stained, so likely was repeatedly used by bats) about 15 m in. We did not continue farther. The MACA were flying around this area of the mine; we did not want to push them further or cause them to fly past us towards the portal. From the BCI survey notes, we went about 1/3 of the way. There was a large pile of guano several meters inside the adit and guano scattered throughout, along with lots of varied insect parts, including beetles. There was also an old javelina skeleton and a pack rat with a bowl nest and large pile of greens next to it. There was a muddy area near the portal, and the mine was very humid; slope creep obstructing part of the portal probably contributed to the humidity. December: A medium-large diamondback rattler stopped the survey about 10 m in from the portal. It was crawling towards the portal at a constricted point in the passage. Although we had a snake hook, there was no way to get the snake safely out of the mine because of the partially-collapsed portal that necessitates crawling in and out of. We shone our headlamps down into the adit past the snake and although we did not hear or see any bats, we cannot rule out the presence of bats towards the face of the mine. There were insect parts and guano near the portal.

XX3 September: The entrance is very small. Bees were flying all around the portal so we did not enter. December: No survey.

XX4 September: No survey- the adit and the one adjacent were both covered with steel cable net (~25 cm square, not diagonal). Net looks somewhat recent. December: No survey.

Condition of site: XX1: Fenced and signed. Large pit inside fence in front of adit; old water bottles in pit. XX2: Fenced and signed. First 15 m of adit shows evidence of instability- several large rocks had fallen along the adit. One piece of trash (food wrapper) outside the adit on the bench. XX3: Not fenced or signed. Dirty water bottles outside entrance. XX4: No signs of human activity other than installation of cable net that looks somewhat recent.

Discussion/Recommendations: BCI's description of XX1 is confusing and doesn't quite match our observations. It is unclear from BCI survey notes whether they completed an internal survey of XX3. If the adit opens up past the portal, it may be bat habitat. These sites, especially XX1 and XX2, warrant further monitoring for MACA in different seasons to determine how this species uses the site and when peak numbers occur, and if other species use the features. It seems to be a good site to include on Pima County's monitoring list for MACA.

The portal of XX2 should be monitored for continued collapse. It would be interesting to monitor temperature and humidity, and compare it to other sites occupied by MACA, as the partially-obstructed portal from slope creep likely contributes to microclimatic characteristics favored by this species at certain times of year. Maneuverable species such as MACA do not appear to have problems with small entrances; we have seen them use an entrance a smallish human male had to belly-crawl and squeeze through.

The cable net over XX4 and XX5 appears recent. The size of the net may not prevent use of the adits by maneuverable species that roost in relatively small numbers such as MACA, Townsend's big-eared bats, and Mexican long-tongued bats (*Choeronycteris mexicana*). Unfortunately, the only way to determine use of the site now is by monitoring evening emergences for day-roosting bats and all night long for night-roosting bats, which is inefficient and inconclusive if data are negative. However, monitoring is important to determine if this type of closure is a successful, bat-friendly method for keeping humans out. It may or may not be as "bat-friendly" as a steel gate with horizontal bars.

Mine Site #5 portal. Dave is by skylight.

Mine Site #5 California leaf-nosed bats.

Mine Site #7, Rancho Seco

Bat Surveys, 2018, by Bat Research and Consulting

Location/access: Sensitive information

Participants: Sandy Wolf, Dave Dalton

Objective: Internal survey to determine abundance and species of bats present

Results summary: September 15, 2018: no survey, bee hive at portal

Result details: We were unable to enter the mine because there was a substantial beehive just inside the portal with bees flying all around. They did not seem particularly aggressive, but we did not test this by trying to go past them and into the mine.

Condition of site: Barbed wire across entrance outside drip-line of portal. Grass along 2-track was mashed down due to recent vehicle traffic, but no other signs of recent human activity.

Discussion/Recommendations: This site is worth resurveying, perhaps in winter when bees are gone. The BCI survey (24 July 2014) reported the presence of guano from California leaf-nosed bats (MACA), Townsend's big-eared bats (COTO), and cave myotis, but no bats, and concluded it was used as a night roost. Based on only one survey, that conclusion seems premature. Based on its described length (29.6 m), and our observations that MACA and COTO roost near portals and in small groups at certain times of the year, this site could very well be a day roost.

Mine Site #6, Rancho Seco

Bat Surveys, 2018, by Bat Research and Consulting

Location/access: sensitive information

Participants: Sandy Wolf, Dave Dalton

Objective: Internal survey to determine abundance and species of bats present

Results summary: September 15, 2018: 6 bats, probably cave myotis. Took guano samples for DNA species identification; results confirmed guano was from cave myotis.

Methods: We conducted internal surveys of the adit. We had a description of the feature from a previous survey by BCI so we had a general idea of what to expect, although conditions can change greatly in 4 years. Safety gear included hard hats, white light, and a gas detector.

Result details: Heavy vegetation in deep trench. Some slope creep but portal is a walk-in. Small snake (black-necked gartersnake?) curled up under a piece of metal outside portal. Conducted complete internal survey (BCI survey data: 54 m long). Several small (~ 0.5 m diameter) discreet areas of guano along passage from near portal to face; all areas of guano looked like they were from same species. All but one looked old and were moldy. Took samples for DNA analysis from the one that looked the freshest. Above it were 5 bats with visual characteristics consistent with MYVE. Another bat was flying near the face. We left immediately. Later eDNA analysis of this guano sample confirmed that the sample was exclusively from cave myotis. We saw one sphinx moth wing, which is typical evidence of MACA. There was a 6 ft. step ladder at the stope and a grill from an air conditioner; apparently rock-hounds were collecting and sieving rocks from the stope. The rock at the top of the stope had green and yellow bands of minerals.

Condition of site: Portal used to have chain-link fencing across it, but it has been mostly torn down and pushed aside. Lots of trash near stope: plastic plates and lids, plastic fork, McDonald's Styrofoam cup; looks like people spent some time there. Looks like ATV tracks south of parking spot in road, looks challenging in a few places even for an ATV. Tank was dry and grassy with several cows.

Discussion/Recommendations: This site is worth rechecking in different seasons for California leaf-nosed bats and Townsend's big-eared bats. The site apparently receives rather frequent visitation from recreationalists; the PICO surveyors in December, 2017 met people that had been in the mine. Preventing vehicle/ATV access would be helpful in protecting bats that use this and possibly other mines in the area. Barriers across the portal other than a steel bat-friendly gate are either unlikely to be effective in keeping people out or in allowing bats necessary room for access.

Appendix B: Field Survey Protocols

PROTOCOLS FOR FIELD METHODS FOR INVENTORYING AND MONITORING BATS IN CAVES AND MINES

Sandy Wolf, Bat Research and Consulting

These protocols were written for use by surveyors periodically monitoring bats at cave or mine sites that have already been inventoried and where bats are known to be present or to have been present, and where species and type of use is known. They are not adequate for sites that have not been thoroughly inventoried for bats and other wildlife throughout the year, or where the complete internal structure (including connections to other features), hazards, and resources have not yet been described and mapped.

Regardless of the survey method, there should be sufficient personnel on each visit for safety. Monitoring surveyors should be provided with accurate location data; the datum for GPS coordinates is essential and EPE (estimated precision error) is helpful, particularly for features where entrances are close to each other or cannot be easily seen from a distance. Surveyors should also be given all information from inventory and previous monitoring work; this information will allow them to prepare for the survey and known hazards and conditions, and be better able to interpret changes they observe.

EXTERNAL SURVEY: VIDEO-RECORDED EMERGENCE COUNTS

External surveys, where observers video-record an evening bat emergence, should be used as the monitoring method of choice when bats are known to be present and the objective is to accurately determine abundance. It is the only method that should be used for maternity colonies, and at any time of year for vertical shafts and at sites with large colonies. Emergence counts are more accurate than estimates made during internal surveys where it may not be possible to observe all bats or make an accurate count without disturbing them. External surveys need expertise, particularly at large or complicated sites, but less expertise than internal surveys, or capture and handling of bats. They are also safer for surveyors and bats.

An emergence count produces an estimate of the number of bats in the roost. A census is possible if surveyors conduct an internal survey after the emergence is over to see if any bats remain in the roost. Video-recorded emergences yield important parameters, such as emergence length and peak number of bats out per minute, in addition to total number of net bats out. These can be compared over time and under various circumstances (e.g., installation of a gate). An emergence count is also the only method that can be used to determine the effects of gating on bat behavior.

If multiple species are present, a camera with high resolution and fast shutter speed can be used to identify individuals of easily distinguishable species (e.g., cave myotis and lesser long-nosed bats). Not every individual needs to be identified to estimate the relative proportion of each species. Emergence curves can sometimes be used to determine when the emergence of one species ends and another begins if species typically fly at different times, but this is not reliable without visually identifying as many bats as possible. Acoustic detection of other species that may be present can be conducted at the same time as the emergence count, although the relative proportion of each species cannot be determined.

Camera placement is critically important for good results. Bats on videos can be difficult or impossible to count if bats are flying towards or away from the viewer, or if there is a great amount of swirling

around. Sufficient infrared lighting that is well placed is also essential; bats will be missed in dark areas, and poorly placed lights can create shadows that result in double-counting.

The range of dates for an emergence count should be determined from inventory work. Roosts used during winter, migration, mating, or by transitory or summer bachelor colonies should be monitored at the time of peak abundance. Maternity colonies should be monitored ideally before young are born, but definitely before young are volant, so that the size of the adult population can be compared year to year. Timing is more difficult if births are asynchronous, as is the case with lesser long-nosed bats.

The end-point of an emergence should be standardized for all sites. Bats typically dribble out at the end of the emergence, and particularly at large maternity colonies (e.g., lesser long-nosed bats), they may continue going in and out of the entrance for hours. If the recording is stopped too soon, the abundance estimate will be low. Assuming there are no extenuating circumstances that could temporarily affect an emergence, a possible end-point criterion is: no net bats out for 10 minutes. For large (thousands) maternity colonies of lesser long-nosed bats or cave myotis, we may use an alternate method: when the number of net bats out is <10 for at least 10 minutes.

If capturing bats to determine sex, age, and reproductive condition is necessary, the emergence count should be conducted on a night prior to capture. Capturing bats at a roost will affect their exit behavior on that night, and possibly temporarily after that.

SURVEYOR QUALIFICATIONS

At least one of the surveyors should be familiar with the operation of the equipment and understand photographic principles (e.g., shutter speed, field of view, contrast ratio, depth of field), understand infrared lighting and the camera's sensitivity to same, know what a well-lit scene looks like and how to achieve it (including recognizing and minimizing reflective objects such as vegetation and rocks between the camera and bat flight path), and have experience with where the optimal camera placement is in relation to the physical structure of entrance and bat flight. All of these are necessary to obtain high quality video that yields the most accurate estimate.

All surveyors should be experienced in hiking and navigating in the dark in backcountry. They should be able to recognize and evaluate dangerous conditions on the surface near and above abandoned mines (Pierson et al. 1999).

Familiarity with the behavior of monitored species is helpful. For example, knowing which species are early or late flyers can help one recognize and thus record atypical behavior, and conversely, knowing what is typical behavior can prevent misinterpretation of observations.

EQUIPMENT/MATERIALS

1. Standard field and safety gear for the weather and environment
2. Copies of necessary permits
3. An equipment list: includes monitoring and personal gear to be taken in the field, decontamination materials and possible back-up equipment to be left in the vehicle
4. Standardized data form (and pens, pencils) that includes: date, site name, location, species, observers, sunset time, weather data, equipment used and set up, time recording begins, time first bat out, time recording ends, reason recording ends, if internal survey was conducted after emergence and results, comments (e.g., weather, bat behavior, site condition), room for a sketch of set-up

5. Infrared-sensitive camera for each entrance. Camcorder with internal hard drive and sufficient battery power, or surveillance camera (e.g., Axis P1354) with laptop in waterproof case and Ethernet cable. Although surveillance cameras require the use of a laptop to record the emergence, a long Ethernet cable (50-100 feet) allows the observer to sit away from the entrance and monitor the emergence on the laptop; this avoids the potential disturbance of an observer sitting with a camcorder close to the entrance. Minimum distance depends on the geography of the site, the flight path of the bats, and observer behavior (ability to sit still and be quiet).
6. Enough infrared lights for the size of each entrance, distance from the camera to the entrance, and sensitivity of the camera to infrared light. For example, for a 6 ft. by 6 ft. entrance, and a camera with the sensitivity of an Axis 1534 placed about 15-20 ft. away from the flight path of the bats, 2 WE IR6 lights (Bat Conservation and Management, www.batmanagment.com) are sufficient. Additional lights on a separate tripod may be necessary depending on the entrance; this requires additional skill for placement to avoid shadows that can be double-counted as separate bats.
7. Batteries and power cords for powering cameras and lights, and hardware for attaching lights to tripod. Lithium-ion batteries are lighter (more amp hours per pound) than gel-cell lead acid batteries, but care must be taken not to drop them. Batteries should have enough power to last longer than the expected length of the emergence to avoid having to change a battery and lose recording time
8. Rain protection for cameras (depending on camera model, this may be commercially available, or can be home-made). Bats will fly in the rain and if equipment is protected, monitoring can continue. Especially important if site is logistically difficult to monitor because of distance, terrain, amount of equipment needed to haul, and returning to site another night is costly. If exit behavior is altered by weather, however, another survey should be scheduled.
9. Pan/tilt unit (with a power source) mounted under the camera can be useful if the camera is mounted higher than the surveyor can reach in order to achieve the optimal angle and field of view, or must be remotely operated from recording/viewing laptop.
10. Method for stabilizing tripods for unexpected strong wind (e.g., hang battery or rock from tripod in a cloth bag)
11. As much as possible, a back-up of everything in case of failure
12. Thermometer
13. Watch
14. Headlamps with white light for hiking, red light for use during emergence
15. Camera to photograph equipment set up, site condition, etc.
16. If an entrance must be live-counted, night vision goggles and clicker counters
17. Small pruning shears for clipping grass or trimming vegetation, p-cord for tying back branches
18. Decontamination supplies for use at site after survey and at vehicle- soap, Clorox wipes, alcohol, garbage bags/containers, spare clothes and shoes

FIELD MONITORING PROTOCOL

Before monitoring visit

1. Develop safety plan and contacts for each field visit.
2. Conduct a test emergence count at the site. Determine how long it takes to get to the site to ensure there is adequate time for set-up, determine the best route to take when returning to vehicle in the dark, and check area around site for safety hazards.

A test count is necessary to figure out camera placement and angle (previous video recordings can be used for reference), especially if there are multiple entrances. For sites with multiple entrances, there should be a camera at each entrance.

During the test, move the camera if necessary throughout the emergence to compare views. For abundance estimates, the best camera view is to have bats fly across the screen. All bats exiting must be in the field of view, and large enough to distinguish individuals. Camera placement is best off to the side of the entrance so that it does not interfere with bat flight. For data on behavior at a gate (or at the site of the gate before construction) placement and angle of the camera should ensure that the total gate is in view, at as much of an angle to the gate as possible so that the individual space between bars (or sections of gate) that bats fly through can be distinguished. If this view makes obtaining accurate estimates of abundance more difficult, a different camera can be used outside the entrance with a better view for counting.

During the test video, experiment with the number, placement, and aiming of infrared lights until the optimally lit scene is obtained.

Trim, remove, or tie back vegetation if it obstructs view of the flight path. Vegetation may also reflect infrared light and cause the camera iris to close, darkening areas of the bat flight path and affecting the accuracy of the count.

3. If it is not possible to have a camera at every entrance to a site with multiple entrances, an observer with night vision equipment and supplemental infrared light should monitor the entrance where the fewest number of bats exit. Clicker counters, one for bats exiting and one for bats entering, are used to count bats. Live counts have many disadvantages compared to video-recorded counts, and should be avoided if at all possible.
4. View the test video and count a sample of bats to evaluate the field of view, angle, and lighting. Make notes for any adjustments needed to improve the video.

Before leaving for site

1. Do a full equipment set-up and operation test to ensure everything is working (e.g., batteries are charged), and all hardware and parts are present. Synchronize times on cameras. For surveillance cameras, check that exposure and frame rate are appropriate for the objectives of the visit (i.e. abundance count vs. species identification), and information that will appear on the video (e.g., site name, date, time) is correct.
2. Check items on equipment list as gear is packed and loaded into vehicle to ensure nothing is forgotten.
3. Avoid nights with rain or strong wind; bat exit behavior can be affected.
4. Plan to arrive at the site early enough to be set up and ready before sunset.

On site

1. Be quiet as possible, but do not whisper (higher proportion of ultrasonic sounds). Bats, especially Townsend's big-eared and California leaf-nosed maternity colonies, often roost close to the entrance in the twilight zone, and may be disturbed by noise outside the roost.
2. Set up equipment and check that everything is working, but then turn power off until ready to start recording.

3. Trim, remove, or tie back grass or vegetation in field of view between camera and entrance if necessary.
4. Be ready to begin recording no later than sunset and possibly before in cooler weather. Depending on species, season, and weather, bats may begin flying at or very shortly after sunset. Surveyors should keep an eye on the entrance as they are setting up to ensure atypical behavior is noted, even if it cannot be recorded. We observed several hundred lesser long-nosed bats flying before sunset in the rain in September.
5. Start recording at sunset, shortly before bats are expected to fly (based on past experience), or wait until you see first bat emerge. It is better to start recording early than to miss bats. If recording starts after bats start emerging, write down the number of bats missed. Camcorders do not always record time, so when you start to record, say the time into the camera's microphone as soon as you see the red REC light in the camera's eyepiece or LCD screen. Also say the date and site name. Shut the LCD screen (it uses more battery than eyepiece and produces more light).
6. Record weather data at sunset: temperature, % cloud cover, wind, precipitation. Record significant weather events during emergence that may affect bat behavior (e.g., strong wind, rain). Record weather conditions at end of emergence if significantly different from that at sunset. Note moon phase (% illumination) and moonrise/set time and if visible during emergence.
7. Infrared lights cannot be checked in daylight. Turn lights on when recording starts. Check when dark enough to ensure lights are aimed correctly to produce an evenly lit scene over the entire entrance and flight path. Watch and adjust camera angle, zoom, and lights are capturing the entire flight path of bats once the emergence starts. Depending on where the camera is placed in relation to the entrance, one person may choose to stay at the camera once the emergence starts to check that the set-up is correct and the equipment is operating correctly. If the person is very quiet, still, and does not use any visible light (red or white), this may be less disturbing to bats than to have someone approach the entrance to check equipment periodically.
8. Fill out data form.
9. During the emergence, observers should wait well away the entrance, not in front of entrance or in/near the flight path. They should be as quiet as possible, use red light and only when necessary.
10. Record until the predetermined criteria for the end of recording are met. If no bats exit and there does not seem to be a reason (bad weather, predator at entrance), wait at least 90 minutes after sunset before assuming no bats are present.
11. If possible, do an internal survey after the emergence to determine if, and how many, bats remain.
12. Clean and store gear, according to WNS protocol, and change clothes before entering vehicle.

After field visit

1. Check over equipment and gear and decontaminate according to WNS protocols.
2. Store batteries charged.
3. Watch video-recordings (VLC is a good, free viewer) as slow as is necessary to count accurately. Using a clicker counter, count bats exiting and entering each minute, record on spreadsheet (Figure 1); net number of bats out is estimate. The same person should count all videos for the same evening to standardize bias.
4. If a camcorder is used, download files to a computer and concatenate with a video editor (e.g., AVS Video Editor) to produce a single video for counting.

5. Store video files on a computer (or external hard drive) and back up on an external hard drive.

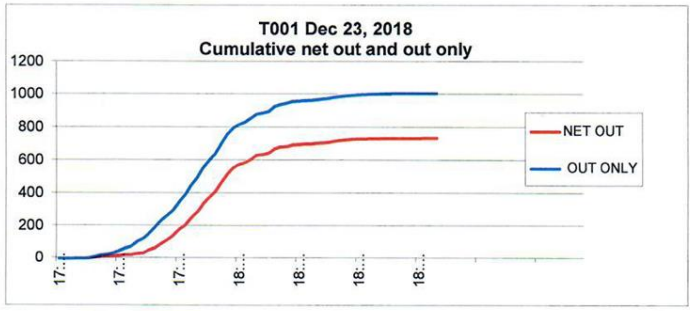
BAT SURVEY DATA SHEET

DATE:	23-Dec-18
NAME:	Dalton and Wolf
SITE:	T001 Tucson Bat Mine
SPECIES:	Macrotus californicus

738 net out total

TIME	#OUT	#IN	OUT-IN	NET OUT	CUMULATIVE OUT ONLY
17:39	1	0	0	1	1
17:40	1	0	1	2	2
17:41	0	0	0	2	2
17:42	1	1	0	2	3
17:43	1	1	0	2	4
17:44	2	0	2	4	6
17:45	7	6	1	5	13
17:46	11	6	5	10	24
17:47	3	1	2	12	27
17:48	9	8	1	13	36
17:49	13	10	3	16	49
17:50	17	13	4	20	66
17:51	13	13	0	20	79
17:52	28	19	9	29	107
17:53	20	18	2	31	127
17:54	30	9	21	52	157
17:55	40	28	12	64	197
17:56	41	13	28	92	238
17:57	29	8	21	113	267
17:58	35	6	29	142	302
17:59	50	11	39	181	352
18:00	44	21	23	204	396
18:01	57	11	46	250	453
18:02	49	12	37	287	502
18:03	58	9	49	336	560
18:04	46	6	40	376	606
18:05	40	4	36	412	646
18:06	58	5	53	465	704
18:07	58	6	52	517	762
18:08	41	1	40	557	803
18:09	21	2	19	576	824
18:10	15	3	12	588	839
18:11	23	3	20	608	862
18:12	27	1	26	634	889
18:13	6	3	3	637	895
18:14	11	1	10	647	906
18:15	28	2	26	673	934
18:16	13	1	12	685	947
18:17	7	5	2	687	954
18:18	11	0	11	698	965
18:19	2	1	1	699	967
18:20	3	0	3	702	970
18:21	2	1	1	703	972
18:22	4	0	4	707	976
18:23	4	1	3	710	980
18:24	3	0	3	713	983
18:25	8	1	7	720	991
18:26	4	0	4	724	995
18:27	4	0	4	728	999
18:28	4	0	4	732	1003
18:29	3	2	1	733	1006
18:30	2	2	0	733	1008
18:31	1	0	1	734	1009
18:32	1	0	1	735	1010
18:33	1	0	1	736	1011
18:34	0	0	0	736	1011
18:35	1	0	1	737	1012
18:36	0	0	0	737	1012
18:37	0	0	0	737	1012
18:38	0	0	0	737	1012
18:39	0	0	0	737	1012
18:40	1	0	1	738	1013 end record
18:41			0	738	1013
18:42			0	738	1013

Notes



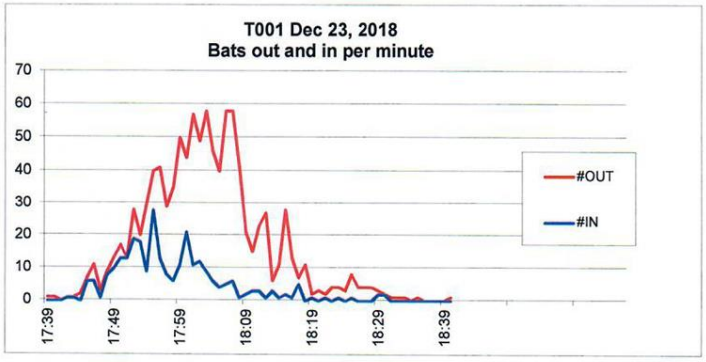


Figure 1. Sample spreadsheet for obtaining an emergence count estimate.

INTERNAL SURVEYS FOR ABANDONED MINES AND CAVES

As an inventory and monitoring method, an internal survey is the best way to determine past, present, and potential future use of a site, and the only way to determine cold season use (hibernating bats) (Sherwin et al. 2009). It is more cost-effective than an external survey because surveys at multiple sites can be conducted in one day, and if a complete survey is possible, results are more conclusive as to whether a site is used or has been used by bats. An internal survey is the best way to collect guano for DNA analysis; bats more often deposit guano under their roosting spots and along passages than at or outside the entrance to a roost.

During an internal survey, surveyors can collect data on environmental conditions (e.g., temperature, humidity, noticeable air flow, standing or dripping water) and will add to our knowledge of conditions associated with use by bats. For mines, data can be collected on the structural condition and stability of the portal and internal workings, noting changes such as slope creep or recent collapses that have occurred since the last survey. Mines will eventually reclaim themselves; data on changes in structural and environmental conditions over time may provide insight on changes in bat use.

At a site where an emergence count is conducted, an internal survey, if possible, provides data on bats remaining after the emergence is over. Without it, the emergence count only provides an estimate of abundance, not a census.

The Pima County Preserve System is comprised of low-mid elevation habitats. It is unlikely there are roost sites suitable for true hibernation for long periods (Townsend's big-eared bats prefer sites <10°C [Pierson et al. 1999]); therefore, an internal survey for the 4 target species at any time of year is likely to find active or temporarily torpid bats. Internal surveys as a monitoring method would be most suitable for fall, winter, or spring surveys where bat use is known to be ephemeral, and based on past inventory work, bat abundance is likely to be low (although migratory cave myotis colonies can number in the hundreds if present with the target species).

If a maternity colony is known to be present in a feature, surveyors should not conduct an internal survey; an emergence count should be used instead. Maternity colonies are easily disturbed; mothers may drop young, move to another area in the roost with less preferable microclimatic conditions, or abandon the roost entirely. If it is necessary to determine if young are present, surveyors can conduct an internal survey after an emergence count; however, great care must be taken not to disturb the young or the adults remaining to babysit them. Young that fall may not be able to be retrieved when the mother returns.

Internal surveys of mine shafts (vertical features) should not be conducted where bat use has been established. Rappelling down a shaft requires multiple people for safety and additional expertise; again, caving experience is not sufficient. An emergence count is safer, and potentially more accurate.

Monitoring caves with internal surveys should probably be avoided unless the objective is to put down guano sheets; emergence counts are more accurate for abundance estimates and safer for surveyors and the cave. Most caves are too complex to survey entirely; even large bat colonies can be missed if not in easily accessible and visible locations. In addition, caves are sensitive environments, often with delicate formations or surfaces easily damaged. If the situation warrants an internal survey, someone familiar with the cave should lead surveyors to ensure a complete survey, and in a manner that

minimizes damage to the cave and prevents anyone becoming lost. Surveyors should wear gloves and avoid touching speleothems; skin oils can damage growing formations.

Those involved in a project that includes internal surveys should ensure that if a rescue is necessary, search and rescue personnel that will be called first to the scene are trained and willing to go underground into caves or abandoned mines.

SURVEYOR QUALIFICATIONS

Surveyors who are not already knowledgeable and experienced in internal surveys as described generally below, and in more detail in Sherwin, et al. (2009), should not survey features unless they are being trained and accompanied by a professional surveyor. A trained professional has the expertise to be able to identify many species visually from a distance, and knows, for each species and type of colony, how best to approach bats, how to evaluate the behavior of the colony, how to balance affecting bats while obtaining necessary data, and when to end the survey if necessary to prevent disturbance.

Surveyors should be experienced and familiar with bats and bat sign for all bats that may be encountered on surveys in that geographic area (i.e. Pima County Preserve System). For example, some species are crevice dwellers and difficult to find even if roosting in groups; they may be in cracks, small domes, and shot holes. Some species roost openly on walls, ceiling, but may still be difficult to find if roosting individually, especially in hard to see areas such as high stopes and ore chutes. Often bats are visible only when approached from one direction and not another. Different species leave different evidence of use behind, for example, California leaf-nosed bats can leave fecal matter on the walls of a mine that do not look typical of bat guano. Nectar-feeding bats leave different guano and odor than insectivorous species. Bats often leave stains indicative of roosting areas; historical roosts of lesser long-nosed bats have a distinctive staining pattern. Surveyors should be able to find small amounts of guano, even a few scattered pellets if present, distinguish bat guano from rodent scat, and should be able to identify the species, or probable species, of the more distinguishable guano.

Surveyors should be trained in looking for, recognizing, and evaluating the numerous hazards that can be present in abandoned mines. Caving experience, no matter how extensive, does not prepare one for the potential dangers of abandoned mines. Surveyors decide when conditions warrant cessation of a survey or abort it before entering the feature. Abandoned mines are not safe, although some hazards can be minimized with training and experience. Proper attitude is important; surveyors must understand and respect the dangers, and recognize when conditions exceed their training or experience (Pierson et al., 1999, Sherwin et al., 2009).

EQUIPMENT/MATERIALS

1. Standard field and safety gear for the weather and environment
2. Copies of necessary permits
3. An equipment list: includes monitoring and personal gear to be taken in the field, decontamination materials and possible back-up equipment to be left in the vehicle
4. Standardized data form (and pens, pencils) that includes at minimum: date and time, site name, location, surveyors, weather, notes on condition of feature, particularly the portal, hazards noticed, water present, air flow, location and type of sign, species observed, how identified, and number, other wildlife present, whether survey was complete, notes on access, evidence of human visitation, photos if taken, room to sketch location of bats/guano
5. Safety gear: MSHA-approved hard hat, multi-gas detector (O2, CO, hydrocarbons, methane sensors), O2-generating self-rescuer, respirator with ammonia and particulate (e.g., dust with potential hantavirus, arenavirus, arsenic or lead-contaminated dust) filters used as necessary

6. Headlamp and 2 backups with powerful white light. Red light is less disturbing to bats, but is insufficient for moving safely through a mine or for seeing bats clearly from a distance. White light is overall less disturbing as it allows identification and estimate of abundance to be done faster and from a greater distance.
7. Probing pole if water is present, waders if necessary
8. An infrared-sensitive camcorder, and supplemental infrared lights and battery. If bats cannot be identified immediately, it is less disturbing to film them from a distance, using the zoom lens and only infrared light. Bats can be identified and counted on the video later.
9. Psychrometer
10. Guano sheet material if deploying, trash bag for collecting used ones
11. Collection vials and materials for collecting guano for DNA analysis, film canisters, ziplocs for collecting skeletal material
12. Still camera
13. Snake hook if experienced in use
14. Small pack to carry gear during survey that can easily be decontaminated
15. Disposable Tyvex suits are an option. However, suits are noisy and hot, and the footies do not have good traction. They should not be worn hiking in between mines.
16. For caves: gloves, and if needed, knee and elbow pads, other standard caving safety gear
17. Plastic bags for hiking backpack to store gear used inside mine and keep separate from other gear in pack, large plastic bags/containers to store potentially-contaminated gear from survey in vehicle
19. Cleaning supplies for on-site decontamination procedures after survey is complete: soap, Clorox wipes, alcohol, garbage bags/containers, spare clothes and shoes

FIELD MONITORING PROTOCOL

This is a general outline only and is not intended to describe everything that must be done to ensure a safe and effective survey.

Before monitoring visit

1. Surveyors should have access to, and be familiar with, all known data about the site, including internal structure, maps, hazards, and previous survey results
2. Develop a safety and communication plan. There should be at least 3 surveyors, 2 who go underground and one who stays on the surface. Sherwin et al. (2009) suggests one person focus only on human safety, the other focus on the biological survey. If a surface monitor is not available and the feature to be surveyed is simple, small, and stable, 2 surveyors can survey the mine with a safety check by phone. The safety check/surface monitor should have the exact location of the feature. Surveyors contact the safety check before entering, giving approximate time of return, and contact again after exiting. In an emergency, the protocol is to call 911 and ask specifically for a Pima County Sheriff Search and Rescue Deputy. That person will determine if a call out to Southern Arizona Rescue Association (SARA) is warranted.
3. Surveys should not be conducted during or after storms. Rain soaking into the ground makes portals and underground workings less stable and prone to collapse.
4. Ensure all safety and survey equipment is functioning correctly.

On site

1. Follow established safety protocol.

2. Assess structural conditions on the surface and at the portal, decide if an internal survey is safe. In Arizona, a common potential hazard is Africanized beehives near the entrances to some features, and this threat should also be assessed.
3. During survey, continuously assess safety conditions, and abort survey if deemed dangerous.
4. Proceed slowly enough to assess safety conditions and search for bats and sign: guano, staining, insect parts, bat carcasses/skeletons.
5. Prevent disturbance to bats by being quiet except for necessary communication.
6. If bats are encountered, identify quickly and estimate numbers. Leave immediately; do not take time staying in the area and shining lights on bats to count individuals. Do not stay in the area to take environmental data. The distance from surveyors to roosting bats before disturbance occurs varies by species and type of colony, physical characteristics of the roost, and surveyors' expertise.
7. Look for other wildlife species and their sign.
8. Collect data on environmental conditions.
9. Look for and make note of structural conditions.
10. Lay down or check guano sheets (probably not useful if surveys are over a year apart). Note amount and type of newly deposited guano. Collect guano for DNA analysis as per protocol.
11. Follow white-nose syndrome protocols after survey upon returning to the surface.

After field visit

1. Store guano samples for DNA analysis as per protocol.
2. Clean and decontaminate all clothing and gear according to the most current white-nose syndrome protocols (see section on white-nose syndrome decontamination).
3. Inspect all personal and safety gear for proper operation and condition.

ROOST LOGGERS

The Anabat Roost Logger (Titley Scientific, www.titley-scientific.com) acoustic detector is a passive detection method for long-term monitoring of bat activity in a roost. It cannot identify species or abundance, but it does document dates, times, and levels of echolocation activity as bats enter or leave the roost. It can be deployed just inside a cave or mine entrance, or at the entrance, which avoids the safety problems of internal surveys. The system is waterproof (but not submersible) and batteries last for weeks or months depending on how it is programmed. Proper placement for optimal results is important, and it is most effective at smaller entrances/passages where distance from the unit to flight path of bats is <10 m (closer is better).

This system is a valuable tool for inventory work or long-term monitoring (depending on the objective of the monitoring). Deploying one for a year at a site where bats or bat sign was observed will give information on which seasons bats use the site, when peak activity (and most likely abundance) occurs, and whether the site is used as a day or night (or both) roost. Although visits to the site are necessary periodically to change batteries, trained bat surveyors may not be necessary depending on the location of the logger, and visits can be done during the day to multiple sites.

Once data are collected, trained surveyors can time visits to determine species and type of use when data show surveys are most likely to produce the best information, thus reducing the number of trips for inventory work. If the roost is occupied by a single species, long-term deployment of a logger can provide valuable data on dates of arrival and departure, and relative abundance, whereas an emergence count once every 2-3 years provides an accurate estimate of abundance for that night only.

BAT CAPTURES

Capturing bats is not appropriate as a periodic, long-term monitoring method; before a site is selected for long-term monitoring, the species, type of use (e.g., maternity, transitory) and approximate size of the colony should already be known. For the 4 target species, it should be necessary only occasionally (e.g., at multi-species roost) to identify species during inventory work; species can usually be determined visually during an internal survey or from a video-recording. Captures are necessary if bats' age, sex, and reproductive condition are needed to determine the type of use in a roost (e.g., maternity vs. bachelor). Bats should only be handled by experienced people with pre-exposure rabies vaccine and up-to-date titer checks, and who hold a current permit from Arizona Game and Fish Department.

Bats should not be captured during late pregnancy or early lactation; capture sessions should be timed to avoid this period (in eastern Pima County, mid-May through early-August for MACA and CHME, May through mid-July for COTO, mid-April through early July for LEYE). The stress of being captured and held on pregnant bats and those with newborns can negatively affect survival of young. The ideal time to confirm maternity use at a site is after young have begun to fly and before bats have started to leave, or others move in from another roost. If a maternity colony roosts in the twilight zone, human activity at the entrance is too disturbing. In this case, bats should be captured away from the entrance.

EQUIPMENT

1. Gloves- thick enough to avoid bites, flexible enough to feel and hold bat safely. May need different gloves depending on species caught.
2. Cotton cloth bags for individual bats, preferably numbered, with string cord-locked closure
3. Mist net and poles, guy lines and tent stakes
4. Harp trap, shade cloth or tarps
5. Scissors for cutting net if necessary to free tangled bat (rare event if nets are adequately tended and bats removed immediately by skilled handlers)
6. Head lamps with red and white light
7. Tub with sticks to hang bat bags on, protected from cold and wind and predators, to hold temporarily until processing
8. Processing equipment in large clipboard- calipers, Pesola scale, data sheets, pen, pencil, bat species key, straw for blowing hair to see nipples on females
9. Plastic trash bags to store used bat bags, used nets, to transport for cleaning and decontamination.
10. Rollup or portable table for processing is helpful if a large sample of bats is anticipated.
11. Supplies for initial cleaning and WNS decontamination in field

PROTOCOL

A harp trap is better than a mist-net for mine or small cave entrances, especially when a large colony is present (Sikes et al. 2011). Spaces around the harp trap can be closed with tarps or shade cloth to keep bats from flying around the trap. A few will probably still fly through the trap, but it is an effective method of capture, and much less stress on the bats. If too many bats are caught, the trap should be moved away from the entrance. Bats can hurt each other if they are too crowded in the harp trap's bag.

If the entrance is too large for a harp trap, bats can be captured in mist-nets set near, but not directly in front of, a roost. Bats must be removed by skilled handlers; it is easy to break a bat's delicate wing

bones. If more bats are caught simultaneously than can be removed immediately, bats get tangled, are more difficult to remove, suffer more stress, and are more likely to be injured. Therefore, the mist-net must be placed in a position far enough away to catch only one or 2 bats at a time, but near enough and in a flight path to catch a sufficient sample for the desired objective. This requires skill and experience. Multiple handlers should be present to remove bats from a net, and the net should be closed when a sufficient number of bats are caught.

1. Do not open nets until just before bats fly to avoid capturing birds.
2. Monitor the mist-net or harp trap continuously, remove bats immediately.
3. Remove bats from the trap's bag or mist net and place in individual cloth bags until they are processed. Hang bags somewhere (e.g., large tub with wooden sticks across top) out of wind, cold, and safe from predators. Ensure bats are hung in the order they are caught.
4. If there are too many bats in the harp trap bag to quickly remove and bag individually, they can be transferred to a holding cage (separate species in different cages) to avoid suffocation/fighting, and another handler can transfer them to individual bags.
5. Close nets or move harp trap as soon as a sufficient sample of bats is obtained.
6. Process bats as soon as possible; other handlers should continue to monitor net/trap. Process bats in the order they were caught. Process bats near the site of capture but not in view of the entrance to avoid lights shining into the entrance or bats being affected by noise. Minimize talking.
7. Release each bat as soon as data is collected. Bats should be held for as short a time as possible, a maximum of 30 minutes (less in cool weather); pregnant or lactating bats should be held only a few minutes.
8. Release by holding bat in an open palm with arm upraised away from processing area and in the dark. Handler should wait until bat flies off on its own; under no circumstances should a bat be tossed into the air to release it.
9. Limit photographs to one or 2 animals and minimize the time a bat is photographed; flash in a bat's eyes temporarily impairs its vision.
10. Clean and decontaminate equipment according to WNS protocol, and store separately from gear not potentially contaminated in vehicle.
11. Do off-site cleaning and decontamination according to WNS protocol.

DNA ANALYSIS OF GUANO

Identifying bat species from their guano is a relatively recent method of determining bat use in a cave or mine. It is an ideal method because bats do not need to be present for surveyors to collect data and there is no disturbance. To collect guano for analysis, material is laid down either over old guano, underneath a known bat roosting area, or near the entrance to the cave or mine. The guano "sheet" can be bridal veil or plastic sheeting. Corners should be weighted down with rocks. Bridal veil is preferable in caves because plastic sheeting can allow moisture to collect under the sheet and affect microclimatic conditions, and in turn, microbiota and invertebrates. In a mine, for which there is generally less interest in the preservation of delicate ecosystems, plastic sheeting can be used, and is less expensive. In addition, plastic may be less attractive to animals. It is also possible to use material already in the mine, such as a board or rock, if old guano has been brushed off. After a specified length of time, surveyors return and collect samples. In addition to identification of the bat species, the time period when bats were present will be known.

Guano samples should be collected and stored according to the protocols provided by the laboratory conducting the analysis. Fresh samples are best. Care must be taken to avoid contamination with other DNA, including the collector's, during collection. Nitrile gloves, sterile tweezers, Ziploc bags, a marker, and alcohol are needed in addition to the collection vials provided by the lab. After collection, samples should be stored on ice in a cooler while in the field, then stored as directed until sent to the lab.

WHITE-NOSE SYNDROME DECONTAMINATION PROCEDURES

White-nose syndrome is a disease affecting hibernating bats that was first observed in a cave in New York in 2006. It is caused by the fungus *Pseudogymnoascus destructans* that attacks the skin, causing physiological changes that make bats come out of hibernation too often, use up energy reserves, and die. It has affected 11 species, resulting in 90-100% mortality of some colonies, and killing millions of bats as it continues to spread throughout the United States and Canada. The fungus spreads primarily through bat to bat contact, but bats can also be infected by contacting fungus on the floors and walls of caves and mines. It is possible for humans to transfer spores on clothing, shoes, or gear from one site to another. (www.whitenosesyndrome.org)

To prevent the inadvertent spread of the fungus by humans, guidelines and decontamination protocols (https://www.whitenosesyndrome.org) have been developed for people who come into contact with bats or their underground environments. The protocol is updated periodically; surveyors should use the most recent version. Surveyors should clean and decontaminate anything that has entered a roost, has been used outside a roost (i.e. emergence count equipment), or has been used to capture or process bats. This includes surveyor clothing and shoes.

Decontamination may not be necessary between each of multiple sites surveyed during the same day if sites are within a small geographic area where bats are likely to move among those roosts. The managing agency has the discretion to determine this amendment to the protocol and the size of the geographic area.

GENERAL GUIDELINES (not a substitute for following the most recent official protocol as posted on www.whitenosesyndrome.org)

1. Prepare for field work by choosing equipment, gear, and clothing that is easiest to decontaminate if choices are possible. Ideally, have certain gear dedicated for use only at a specific site.
2. When a survey is completed, clean as much as possible before packing for transport to vehicle, separate and package gear to keep uncontaminated gear clean during transport.
3. Before entering the vehicle, wash exposed skin, change and bag clothes and shoes. Package potentially-contaminated items to prevent spread to the vehicle.
4. Off-site, clean and thorough decontaminate all clothing and equipment according to protocol.

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Appendix C: Field Data Forms

Sample Emergence Count Spreadsheet

BAT SURVEY DATA SHEET

DATE:	6/9/18	**5,231 total**
NAME:	Dalton and Wolf	**peak 265**
SITE:	XX Mine west shaft	
SPECIES:	Myotis velifer	

TIME	#OUT	#IN	OUT-IN	NET OUT	CUMULATIVE OUT ONLY	Notes
19:35	0	0	0	0	0	
19:36	0	0	0	0	0	
19:37	0	0	0	0	0	
19:38	1	1	0	0	1	
19:39	0	0	0	0	1	
19:40	0	0	0	0	1	
19:41	1	1	0	0	2	
19:42	1	1	0	0	3	
19:43	2	0	2	2	5	
19:44	2	0	2	4	7	
19:45	1	0	1	5	8	
19:46	3	0	3	8	11	
19:47	13	0	13	21	24	
19:48	17	2	15	36	41	
19:49	22	0	22	58	63	
19:50	35	2	33	91	98	
19:51	32	0	32	123	130	
19:52	61	0	61	184	191	
19:53	63	0	63	247	254	
19:54	79	0	79	326	333	
19:55	97	0	97	423	430	
19:56	111	0	111	534	541	
19:57	169	0	169	703	710	
19:58	134	0	134	837	844	
19:59	107	0	107	944	951	
20:00	163	0	163	1107	1114	
20:01	198	0	198	1305	1312	
20:02	232	0	232	1537	1544	
20:03	**265**	0	265	1802	1809	
20:04	259	0	259	2061	2068	
20:05	247	0	247	2308	2315	
20:06	255	0	255	2563	2570	
20:07	247	0	247	2810	2817	

20:08	247	0	247	3057	3064	
20:09	264	0	264	3321	3328	
20:10	234	0	234	3555	3562	
20:11	230	0	230	3785	3792	
20:12	213	0	213	3998	4005	
20:13	162	0	162	4160	4167	
20:14	110	14	96	4256	4277	
20:15	124	5	119	4375	4401	
20:16	139	0	139	4514	4540	
20:17	100	0	100	4614	4640	
20:18	81	0	81	4695	4721	
20:19	80	0	80	4775	4801	
20:20	51	0	51	4826	4852	
20:21	59	0	59	4885	4911	owl out
20:22	60	0	60	4945	4971	
20:23	52	0	52	4997	5023	
20:24	56	0	56	5053	5079	
20:25	41	0	41	5094	5120	
20:26	24	0	24	5118	5144	
20:27	26	0	26	5144	5170	
20:28	17	0	17	5161	5187	
20:29	17	0	17	5178	5204	
20:30	20	0	20	5198	5224	
20:31	9	0	9	5207	5233	
20:32	9	0	9	5216	5242	
20:33	3	0	3	5219	5245	
20:34	8	0	8	5227	5253	
20:35	1	0	1	5228	5254	
20:36	1	0	1	5229	5255	
20:37	1	0	1	5230	5256	
20:38	1	0	1	5231	5257	
20:39	0	0	0	5231	5257	
20:40	0	0	0	**5231**	5257	stop record

Appendix D: Bat species observations on Pima County properties

Table 1. Bat species observation type by County property using available data from AZGFD Scientific Collecting License reporting, Pima County staff monitoring and netting data (i.e., at Agua Caliente Park), BLM-funded Bat Conservation International surveys of abandoned mines, and other available historical data. **Roost** = bat species has a roost site on the property; **Visual** = non-capture observation of a bat species on the property that does not indicate a roost; **Capture** = bat species captured while active, such as by mist net; **Acoustic** = bat species detected acoustically, usually while active and often away from a roost; **Salvage** = specimen salvaged dead and reported to AZGFD; **Historic** = prior records of a species using a site as a roost.

Pima County Property	Bat Species	Observation Type
MSCP covered bat species		
California leaf-nosed bat *Macrotus californicus*	Tucson Mountain Park Rancho Seco Mission Garden Agua Caliente Park Colossal Cave Mountain Park	Roost, Capture Roost Visual, Acoustic Capture Historic
Lesser long-nosed bat *Leptonycteris yerbabuenae*	Agua Caliente Park Cienega Creek Natural Preserve Colossal Cave Mountain Park	Capture Capture Capture, Historic
Mexican long-tongued bat *Choernonycteris mexicana*	A7 Ranch Agua Caliente Park Buehman Canyon Cienega Creek Natural Preserve Colossal Cave Mountain park	Roost Capture Roost Roost Roost
Pale Townsend's big-eared bat *Corynorhinus townsendii pallescens*	Agua Caliente Park Buehman Canyon Cienega Creek Natural Preserve Colossal Cave Mountain Park Diamond Bell Ranch Marley Ranch Old Hayhook Ranch Oracle Ridge Rancho Seco Tucson Mountain Park	Capture Roost Capture, Roost, Acoustic Capture, Roost, Acoustic Roost Roost Roost Roost Roost, Acoustic, Capture Roost, Acoustic
Western red bat *Lasiurus blossevillii*	Cienega Creek Natural Preserve	Capture
Western yellow bat *Lasiurus xanthinus*	Agua Caliente Park Cienega Creek Natural Preserve	Roost, Capture, Acoustic Capture
Non-covered bat species		
Big brown bat *Eptesicus fuscus*	Agua caliente park Arizona Sonora Desert Museum Cienega Creek Natural Preserve Colossal Cave Mountain Park	Capture, Acoustic Capture Capture, Acoustic Capture, Acoustic

Pima County Property	Bat Species	Observation Type
	Diamond Bell Ranch	Roost
	M Diamond Ranch	Acoustic
	Marley Ranch	Roost
	Oracle Ridge	Roost, Acoustic
	Rancho Seco	Roost
	Mission Garden	Acoustic
	Robles Barn	Roost
Big free-tailed bat *Nyctinomops macrotus*	Agua Caliente Park	Acoustic
California myotis *Myotis californicus*	Agua Caliente Park	Capture, Acoustic
	Cienega Creek Natural Preserve	Capture, Acoustic
	Oracle Ridge	Acoustic
Canyon bat *Parastrellus hesperus*	Agua Caliente Park	Acoustic
	A7 Ranch	Acoustic
	Arizona Sonora Desert Museum	Salvage
	Cienega Creek Natural Preserve	Capture
	Colossal Cave Mountain Park	Acoustic
	Oracle Ridge	Acoustic
	Rancho Seco	Acoustic
	Tucson Mountain Park	Roost, Acoustic
	Mission Garden	Acoustic
Cave myotis *Myotis velifer*	A7 Ranch	Acoustic
	Agua Caliente Park	Capture
	Arizona Sonora Desert Museum	Visual
	Bar V Ranch	Acoustic
	Buehman Canyon	Roost, Acoustic
	Cienega Creek Natural Preserve	Capture, Roost
	Colossal Cave Mountain Park	Acoustic, Capture, Roost
	Diamond Bell Ranch	Roost
	Marley Ranch	Roost, Acoustic
	Oracle Ridge	Acoustic
	Rancho Seco	Roost, Capture, Acoustic
	Tucson Mountain Park	Roost, Capture
	Robles Ranch	Roost, Capture
	Mission Garden	Acoustic
Fringed Myotis *Myotis thysanodes*	Oracle Ridge	Acoustic
	Rancho Seco	Acoustic, Capture, Roost
Hoary bat *Lasiurus cinereus*	Cienega Creek Natural Preserve	Capture
	Marley Ranch	Acoustic
	Agua Caliente Park	acoustic
Mexican free-tailed bat *Tadarida brasiliensis*	Agua Caliente Park	Capture
	Cienega Creek Natural Preserve	Capture
	Colossal Cave Mountain Park	Acoustic
	Marley Ranch	Acoustic
	Oracle Ridge	Acoustic
	Rancho Seco	Acoustic

Pima County Property	Bat Species	Observation Type
	Robles Ranch Mission Garden	Roost Acoustic
Pallid Bat *Antrozous pallidus*	Agua Caliente Park Canoa Ranch Cienega Creek Natural Preserve Colossal Cave Mountain Park Oracle Ridge Rancho Seco Robles Ranch Tucson Mountain Park	Capture Roost Capture, Roost Roost Roost, Acoustic Acoustic Roost Roost, Acoustic
Pocketed free-tailed bat *Nyctinomops femorosaccus*	Agua Caliente Park Cienega Creek Natural Preserve Oracle Ridge	Capture Capture Acoustic
Southwestern myotis *Myotis auriculus*	Agua Caliente Park	Capture
Western small-footed myotis *Myotis ciliolabrum*	Agua Caliente Park	Capture, Acoustic
Yuma myotis *Myotis yumanensis*	Agua Caliente Park	Capture, Acoustic
Western mastiff-bat *Eumops perotis*	Agua Caliente Park	Acoustic
Silver-haired bat *Lasionycteris noctivagans*	Agua Caliente Park	Acoustic
Arizona myotis *Myotis occultus*	Agua Caliente Park	Acoustic

Pima County
Multi-species Conservation Plan:
2019 Annual Report

Appendix 8

Pima County Uplands Vegetation and Soils Monitoring Protocol

18 pages

Pima County Ecological Monitoring Program
Uplands Vegetation and Soils Monitoring Protocol

March 2020

PIMA COUNTY
SUSTAINABILITY & CONSERVATION

Prepared by Pima County Office of Sustainability and Conservation Staff:
Jeff M. Gicklhorn

Cover photo: National Park Service and Tucson Audubon field staff monitoring vegetation on Pima County's Six Bar Ranch

Recommended citation: Gicklhorn, J.M. 2020. Uplands Vegetation and Soils Monitoring Protocol. Ecological Monitoring Program, Pima County Multi-species Conservation Plan. Report to the U.S. Fish and Wildlife Service, Tucson, AZ.

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Abstract

Habitat characteristics are the specific suite of resources that a species needs to perform life history functions and survive. These characteristics can vary broadly by species and can be broken into structure and composition components. Upland habitat components include vegetation and soils composition and structure, and repeated monitoring efforts will allow Pima County to detect change in habitat quality and condition over time. The County's Multi-species Conservation Plan covers 44 species native to southeastern Arizona across a broad suite of conservation lands. The species have vastly different life history strategies and specific habitat requirements; therefore, Pima County's Ecological Monitoring Program will repeatedly monitor upland vegetation and soils composition and structure at-large across all County conservation lands to detect and quantify long-term trends in those habitat components for MSCP covered species. Through a partnership with the National Park Service and the Tucson Audubon Society, Pima County Ecological Monitoring Program staff have implemented a protocol developed by the NPS, Sonoran Desert Inventory and Monitoring Network to monitor upland habitat over time across County lands. This protocol discusses 1) the spatial and temporal scope of Pima County's Uplands Vegetation and Soils monitoring efforts, 2) the process for generating a potential sample frame and monitoring plots locations, and 3) the data collection, analysis, and long-term storage methodology and location.

Acknowledgements

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Background and Objectives

Each species has habitat requirements, that when met, allow that species to not only survive but thrive. Habitat characteristics are the specific suite of resources that a species needs to perform life history functions, such as foraging, nesting, mating, and finding refuge (Morrison et al. 1998). Habitat requirements vary by species, and habitat condition and quality can vary broadly based on numerous factors, including land use and climate. Therefore, changes in disturbance or climate regimes may subsequently alter habitat condition or quality.

Habitat characteristics can be broken into structure and composition components, which together determine condition and quality. Habitat characteristics for upland terrestrial species consist of vegetation and soils components. Due to different life history requirements, key supporting habitat characteristics vary from species to species. For example, a generalist species may be able to utilize multiple vegetative communities regardless of composition, while a specialist species may require a specific vegetative composition to persist. Vegetation and soils influence one another and monitoring both is useful for determining if and how changes in habitat characteristics are occurring. For example, changes in soils composition or structure may portend future changes to the overlying vegetative community.

Pima County's Sonoran Desert Conservation Plan (SDCP) defined a biological goal of ensuring "the long-term survival of the full spectrum of plants and animals that are indigenous to Pima County through maintaining or improving the ecosystem structures and functions necessary for their survival." Subsequently, the County's Multi-Species Conservation Plan (MSCP) identified a suite of 44 covered species as high priorities for conservation. Finally, the County's Ecological Monitoring Program (EMP) was tasked with monitoring both covered species directly (via presence or abundance estimates), and the condition and status of their habitat (via repeated monitoring of change to habitat structure and composition). Implementing this monitoring is challenging at a landscape scale, as the County's broad suite of conservation lands totals > 250,000 acres and is spatially disparate and biologically diverse. To address these challenges, County staff will sample a subset of these lands utilizing a statistically robust repeated monitoring approach over the duration of the 30-year MSCP to detect changes in habitat composition and structure.

To this end, Pima County will leverage the Uplands Vegetation and Soils Monitoring Protocol methodology designed and implemented by the National Park Service's (NPS) Sonoran and Chihuahuan Desert Inventory and Monitoring (I&M) Networks (Hubbard et al. 2012). This protocol was designed for implementation on NPS units in the desert southwest; however, vegetation communities on these and Pima County conservation lands share many similar characteristics. This protocol will allow Pima County staff to assess the condition of and changes to habitat generally across the County's broad suite of conservation lands. Furthermore, the County has partnered with NPS, as well as the Tucson Audubon Society (TAS), to implement this protocol on County conservation lands. This approach will allow the County to leverage the expertise and experience of some of those who developed the protocol.

This protocol will be implemented in addition to other long-term vegetation and soils monitoring efforts, including Ecological Site Inventory and Key Area monitoring efforts under the Natural Resources, Parks and Recreation (NRPR) department's Range Management program. Range program monitoring efforts are targeted at assessing range condition in the context of administering the range management program, with the ability to draw inference at the allotment or pasture scale. This is in contrast to the NPS protocol which is used to track long-term changes in habitat composition and structure over time, with the ability to draw statistical inference across the entire suite of County conservation lands. Lastly, NPS protocol monuments monitoring plots and transects with the intention that they be directly repeatable across repeated sampling occasions. Range monitoring efforts monument the general location of transects; however, they are not intended to be directly repeatable across repeated occasions.

The objective of this protocol as implemented by Pima County is to define 1) the spatial and temporal scope of Pima County's Uplands Vegetation and Soils monitoring efforts, 2) the process for generating a potential sample frame and monitoring plot locations, and 3) the data collection, analysis, and long-term storage methodology and location.

Geographic and Temporal Scope

The uplands vegetation and soils monitoring protocol covers the full suite of Pima County conservation lands and spans the 30-year duration of the County's Section 10 incidental take permit, from 2016 to 2046.

Pima County's conservation lands are made up of > 250,000 acres of fee and leased lands (for which the County holds a grazing lease) surrounding the City of Tucson (Figure 1). These lands are located across five major watersheds, which include the Altar/Brawley Wash, San Pedro River, Cienega Creek, and upper and lower Santa Cruz River, and range in elevation from 425 to 1870 meters (1400 to 6130 feet). These conservation properties range in size from 0.1 to 16,500 hectares (0.25 to 41,000 acres) though only properties > 40.5 hectares (100 acre) were included within the monitoring plot sampling frame. Individual properties can vary in elevation by as much as 750 meters (2460 feet).

Assessing habitat across multiple vegetative communities and at multiple spatial scales requires first defining those categories and scales. The NPS protocol (Hubbard et al. 2012) defines uplands elevational strata that roughly correlate to biome-level plant communities (Table 1). Each elevational stratum is then broken down further into three sub-strata by percent rock fragment (Table 1). County conservation lands are distributed within primarily low to mid-elevations, and therefore contain strata levels 100-400 (Fig. 1). Level-500 strata do not occur on County conservation lands.

Repeated monitoring will occur across the 30-year span of the County's Section 10 permit, with all established monitoring plots surveyed once during each five-year panel (i.e., a rotating panel design), for a total of six surveys per plot. This equates to approximately 20 plots either established (panel one) or monitored (panels two through six) per year. The order or year in

which each plot is surveyed within a specific panel is not required to stay consistent, as monitoring data are analyzed per five-year panel rather than per year.

Table 1. Elevational and soil/rock type strata definitions (from Hubbard et al. 2012).

Biome(s)	Elevation		Score
	Feet	Meters	
Desert	<2,500′	<762	100
Thornscrub	2,501–3,700′	762.1–1,127.76	200
Semi-desert Grassland	3,701–4,500′	1,127.77–1,371.6	300
Madrean Woodland & Interior Chaparral	4,501–6,000′	1,371.61–1,828.8	400
Temperate Forest	>6,000′	>1,828.8	500

Rock fragment modifier	Fragment content % by volume	Score
None or adjective (e.g., loam or gravelly loam)	<35	1
"very" or "extremely"	35–90	2
Bedrock or rock outcrop	--	3

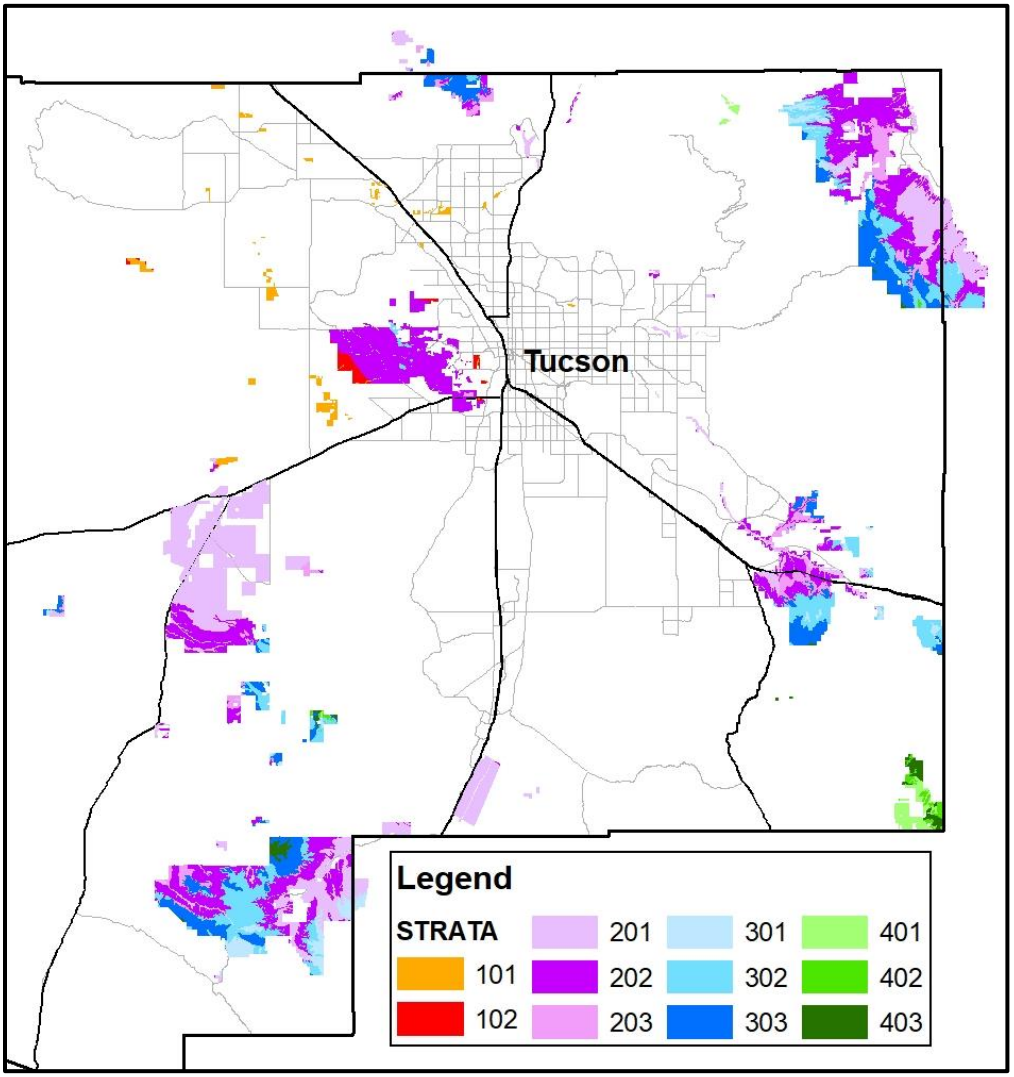

Figure 1. Elevation and rock fragment strata shown across all Pima County conservation lands. The '1', '2', or '3' in the ones unit digit represent percent rock fragment (see Table 1).

Methods

Spatially Balanced Design

Pima County used the random, spatially balanced Reversed Randomized Quadrant-Recursive Raster (RRQRR) method (Theobald et al. 2007) to generate the plot locations spanning across the County's broad suite of conservation lands based on specified criteria used to identify the monitoring plot sample frame (Table 2). Spatially balanced designs represent a probabilistic sampling design that still ensures spatial balance regardless of overall sample size (Stehman 1999). Additionally, these methods allow the ability to drop individual plots (e.g., access constraints) and minimally alter the overall scheme without losing statistical power.

Sample Frame Criteria and Data Sources

The RRQRR process allows users to incorporate their own criteria when developing a monitoring sample frame. The potential sample frame initially included all County conservation land properties > 40.5 hectares (100 acres) which was then reduced based on specific sampling considerations and associated criteria (Table 2). These categories and criteria included eliminating steep slopes due to safety reasons and resource damage concerns, buffering linear features such as roads, trails, fences, property boundaries, and washes, and limiting hike time to ≤ 1 hour from the closest road or access point for efficiency.

Table 2. Categories, criteria and their data sources used to generate the uplands vegetation and soils monitoring data frame through the RRQRR process.

Category	Selection Criteria	Data Source (gislib layer)
Slope	Exclude > 35° for safety reasons	Pima County 3 m DEM
Roads	100 m buffer both sides	County maintained paved and unimproved GIS road layers (STNETALL, STMISC)
Trails	Buffer 50 m, both sides	County maintained trails layer (TRAILS11)
Fence Lines	Buffer 50 m, both sides	County maintained ranch infrastructure layers (NR_FENCE, EMPFENCE)
Preserve Boundary	50 m interior buffer	County maintained preserve layer (PRESERVES)
Water Features	Point features (springs, wells): 50 m buffer	County maintained ranch infrastructure layer (SPRINGS, WELLS)
	Washes: Buffer 75 m, both sides of centerline	County maintained wash dataset (RIP05FC2) for within County, National Hydrography Dataset for outside
Hike Time	Limit to 1 hour from existing roads	GIS Analysis; estimated vegetation resistance and slope

Hike time was generated by combining the distance from the closest road or trailhead and a metric of resistance to hiking for all vegetative communities classified by the Southwest Regional Gap Analysis Project (Fig. 2). The potential sample frame generated from other criteria (Table 2) was then clipped to limit hike times to ≤ 1 hour. An example of how this process created the final sample frame is shown in Figure 3.

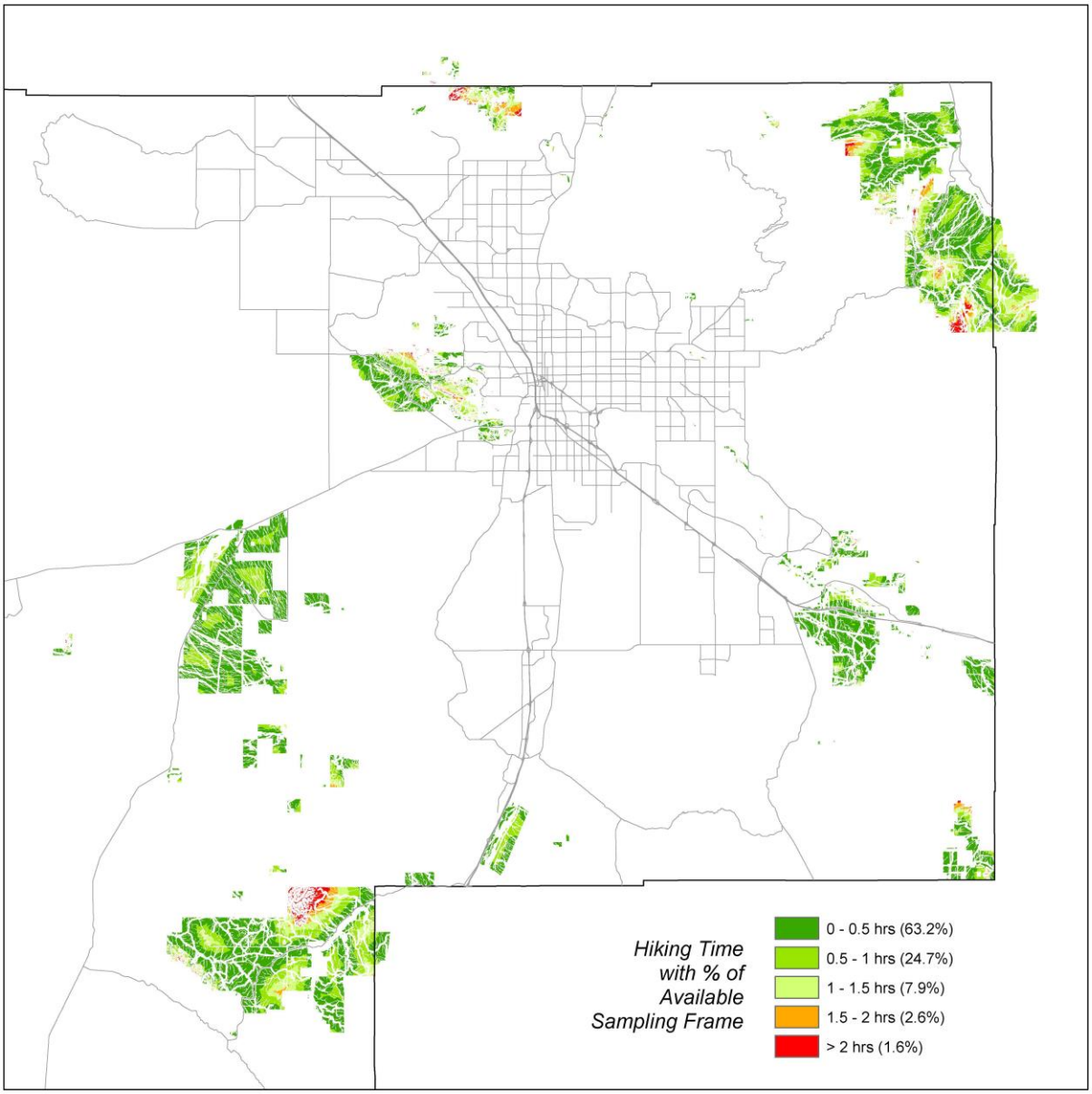

Figure 2. Hike time estimates generated from the nearest road or trailhead. Inputs included vegetation community resistance values and slope.

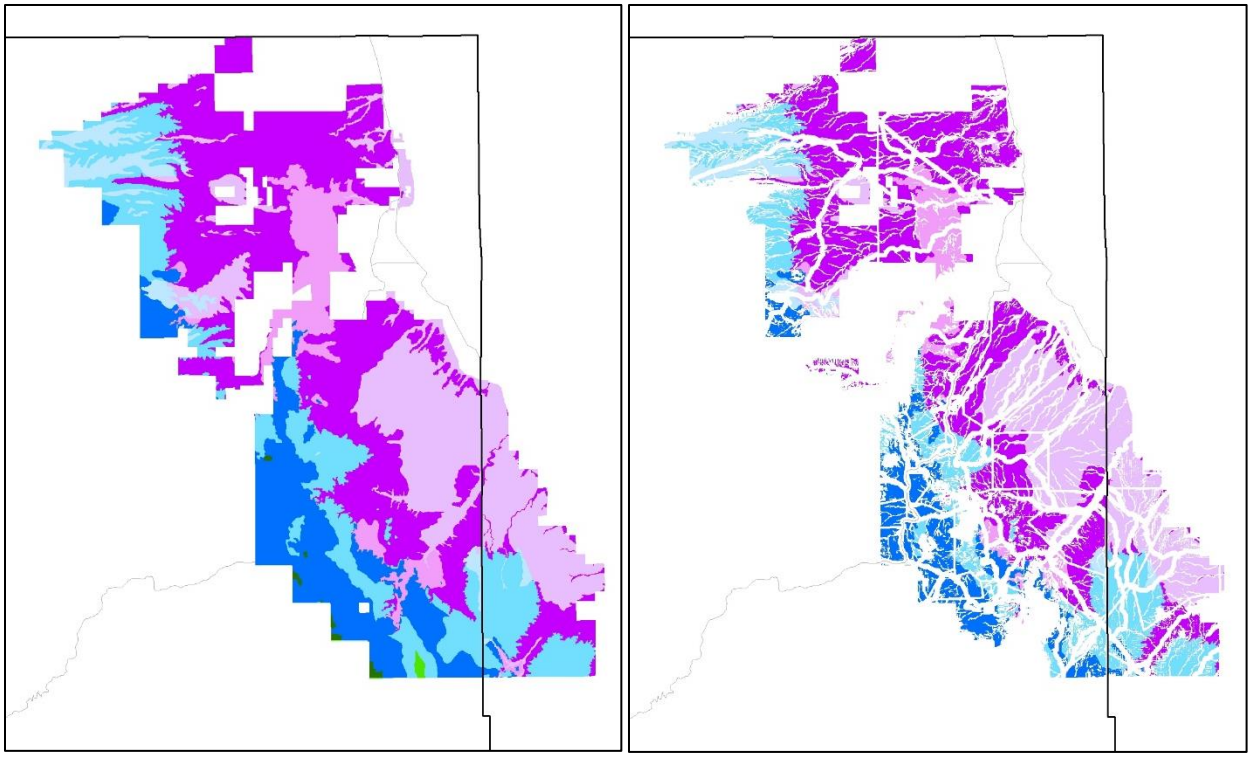

Figure 3. Example of how the potential sample frame was constrained from all available lands (left) to only those lands meeting the specific selection criteria listed in Table 2 (right).

Monitoring Plot Number and Locations

Pima County has committed to establishing a minimum of 100 plot locations for long-term uplands vegetation and soils monitoring across County conservation lands (Pima County 2016). These plots will be distributed among elevational strata, with the final number of plots per stratum approximately in proportion to the percent of total area covered by each stratum and sub-stratum (e.g. more plots located in the larger 201 strata vs. the smaller 303 strata) within the final sample frame. County conservation lands contain primarily elevational strata 200-400, with 100-level strata only constituting 1.74% (sub-strata 101 and 102 combined) of the potential sample frame. Staff elected to remove the 100-level strata from the potential sample frame due to the overall low representation, with the caveat that if deemed important enough future measures could be explored to add these strata back into the sample frame. Additionally, field visits to two properties with sub-strata 401, 402, and 403 in close proximity showed that the overall plant community and physical structure of sub-strata 402 and 403 were similar enough to warrant combining these into one category (sub-strata 4023). In both cases, sub-stratum 401 appeared distinct enough in its plant community and physical structure to warrant remaining as a unique stratum within the sample frame. The final tally of monitoring plots by strata were updated to account for the change in available sample frame from the above decisions.

Lastly, plot numbers for remaining sub-strata with relatively low spatial representation were increased in order to be able to draw statistical inference (Hubbard et al. (2012) recommend that at least 5 plots be established for a particular stratum to maximize the ability to generate

robust results); subsequently, those strata with relatively high spatial representation had their number of plots reduced slightly to compensate. The percentage of the potential sampling frame and subsequent proposed number of final monitoring plots are shown below (Table 3).

Table 3. Total and percent area of conservation lands and final sample frame with number of proposed monitoring plots by elevation and rock fragment strata.

Elevational Strata	Percent Rock Fragment Class	Total Area on Cons. Lands (ha)	Percentage of Total Cons. Lands	Total Area in Final Sample Frame (ha)	Percentage of Class in Sample Frame	Number of Proposed Plots
100	101	1,974.97	0.021	0	0	0 (Dropped)
	102	857.82	0.009	0	0	0 (Dropped)
200	201	0.04	0.000	14,008.05	0.51	23
	202	27,310.15	0.284	15,842.39	0.53	25
	203	29,839.99	0.310	2,530.01	0.47	10
300	301	5,369.90	0.056	2,040.90	0.58	10
	302	3,509.63	0.036	7,379.22	0.55	11
	303	13,473.24	0.140	4,486.90	0.42	9
400	401	10,700.97	0.111	700.23	0.50	6
	402	1,397.64	0.015	708.54	0.37	6 (402 & 403 combined)
	403	667.93	0.007			
	Total	**96,324.83**	**100**	**47,696.23**	**100**	**100**

EMP staff worked with staff from the County's IT/GIS office to generate 215 potential monitoring plot locations located within the final sample frame for strata 200-400. These points consist of primary and alternate plot locations for each sub-strata. Field staff may need to drop designated primary monitoring plot locations due to lack of access, unsafe terrain, or previously unidentified disturbance, so numerous alternates were generated for each sub-strata. Replacing primary plots with alternates does not reduce the statistical power of the study design due to the spatially balanced approach of the RRQRR method, provided the alternate plots are sampled in numerical order. All primary plot locations are plotted below (Fig. 2); however, these specific locations may change once all plots are established in 2021.

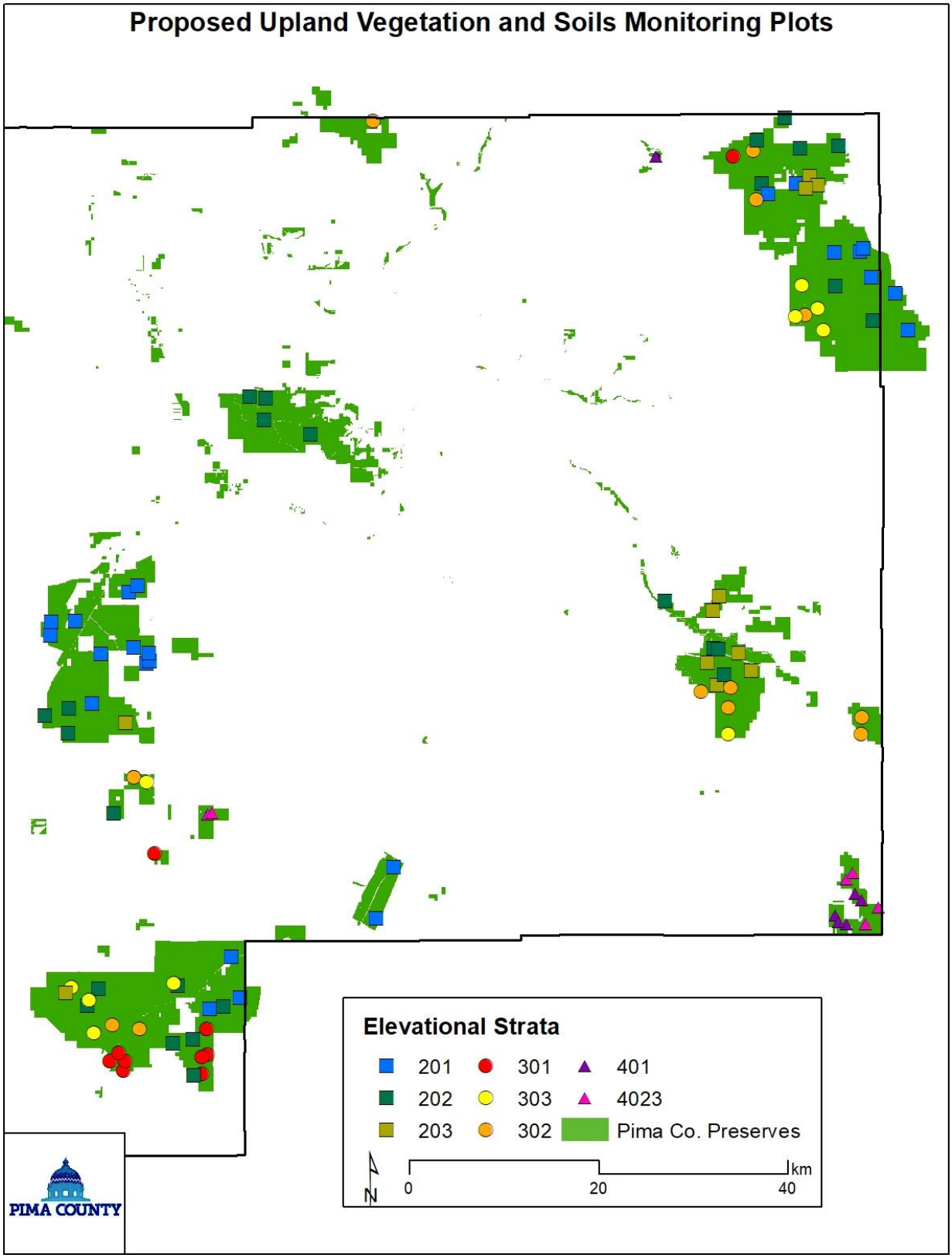

Figure 4. Proposed uplands vegetation and soils monitoring plots displayed by elevational strata with geographic climate regions shown.

Monitoring Plot Design

Uplands vegetation and soils monitoring plots consist of 20 x 50 meter plots containing six 20-meter vegetation transects (Fig. 5).

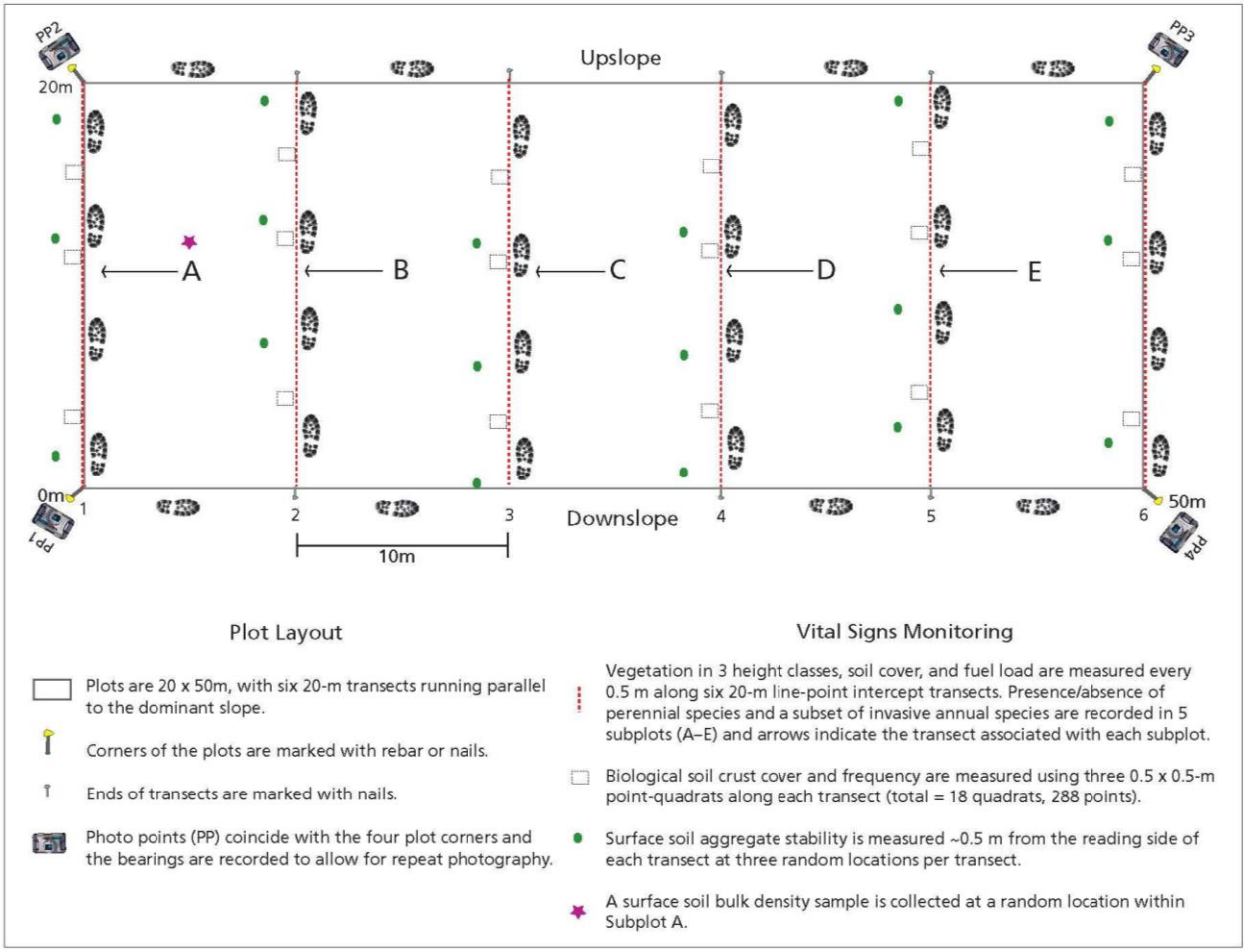

Figure 5. Uplands vegetation and soils monitoring plot design (from Hubbard et al. 2012).

Field Monitoring Methodology

Field monitoring methodology involves rigorously quantifying vegetation and soils composition and structure using a team of 4 or 5 people who are familiar with the protocol. This methodology is described in detail Hubbard et al. (2012), whereas here we briefly summarize the monitoring approach and elements (shown in Fig. 5).

Field staff navigate to the RRQRR generated plot location and determine if that location is suitable. This randomly generated location represents the downslope, left plot corner (PP1 in Fig. 5). If landscape features are present (e.g. shallow wash, excessive slopes, etc) that may preclude the original placement, staff can shift the plot location within a 110-meter radius of the original point (Fig. 6). This can be accomplished by either shifting the plot a short distance or generating a new random location within the specified 110-meter radius. The final placement must have at least one corner of the plot within 50-m of the original reference point. Once the final plot location is identified, all four plot corners and six interior transect end points

are GPS'd with a sub-1 meter accuracy Trimble GPS unit and monumented using capped rebar marked with Pima County identification (plot corners) or landscape 6-8 inch magnetic landscape nails (interior transects) (Fig. 7). These markers allow repeatability of each transect during future monitoring efforts. Staff use tripods to suspend meter tapes along all six vegetation transects to perform vegetation measurements (Figure 8). Additionally, staff only walk on the right side of each vegetation transect to minimize the potential for trampling of vegetation prior to sampling.

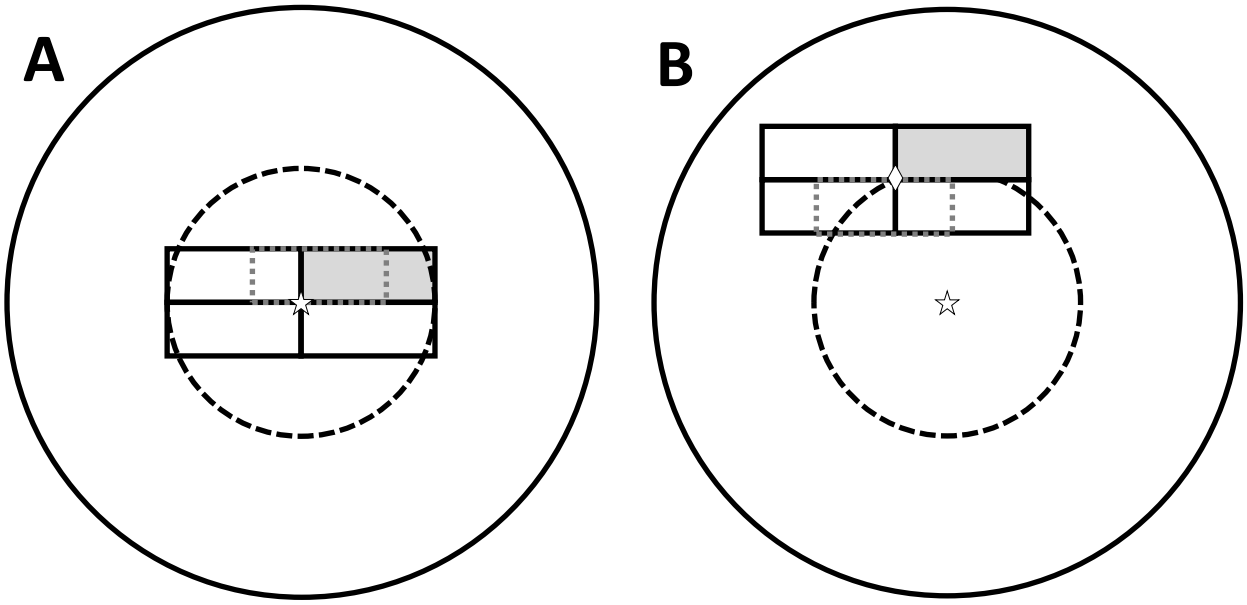

Figure 6. Plot adjustment options. A) Star is original reference point. Dashed circle indicates 50m radius while solid circle indicates 110m radius around reference point. The shaded box indicates plot orientation with no adjustment needed. The boxes to the left and below the shaded plot are extreme adjustments where the point becomes a different corner. The dashed box is an example of shifting the plot such that the reference point remains along the baseline. B) Star is original reference point while the diamond indicates the randomly-generated, new reference point. Dashed circle, shaded box, and hollow boxes represent the same as in option A. The dashed box is an example of shifting the plot such that the new reference point serves as a transect endpoint along the topline (from Hubbard et al. 2012).

Field staff record cover data for all perennial species and non-native annual species at three height classes, soil cover, and fuel loads every 0.5 m along the six 20-meter transects using the line-point intercept method. Presence of perennial species and non-native annual species are also recorded within five subplots (defined by the 10 x 20 space between any two adjacent transects). These data are used to quantify cover by species, species richness and vegetation structure, with repeated measurements over time capable of detecting changes in these values. Biological soil crust cover and frequency and surface soil aggregate stability are both measured at three random points along each transect (18 total per plot). Lastly, a soil surface bulk density sample is collected from a random location within the plot for subsequent lab analysis when establishing that plot; subsequently, a new soil bulk density sample is only collected during a future visit if observations indicate substantial disturbance has occurred on the plot, such as

fire, landslide, or severe erosion. All soils data are used to quantify soils stability and potential erodibility. Repeated measurements over time may detect changes in soils distribution or structure.

Figure 7. Monumented monitoring plot corner.

Figure 8. Tripod used to elevate measurement tapes along vegetation transects.

Data Collection, Certification, and Storage

Field monitoring data is collected via a digital database operating on a ruggedized field tablet or computer (Panasonic Toughbook). Digital data collection minimizes potential transcription errors and increases efficiency for field staff. Hubbard et al. (2012) defines regular backup protocols during field data collection to ensure data protection and redundancy; however, field staff also carry and record plot data (particularly data collected during the initial setting up of a plot) on paper field forms in case of system failure of the field tablet.

Field monitoring data are quality controlled by field staff back at NPS SODN offices, and errors/issues addressed. Once all data for a specific monitoring season are confirmed accurate, the NPS data manager certifies those data and they are added to the master NPS I&M database. Pima County OSC receives an annual download of certified field monitoring data for storage in the County's OnBase data management system. For redundancy, vegetation and soils monitoring data collected on Pima County lands will be stored permanently by both Pima County and NPS.

Data Summaries and Analysis

Field staff produce short, non-technical field summaries/debriefings at the end of each field season, which provide feedback on monitoring protocol implementation and highlight incidental observations, such as potential management concerns, occurrences of new plant species, or comments on field site access. Vegetation and soils monitoring data will also be summarized by year as data are collected. At the end of each five-year sampling period, monitoring data from that period will be used to generate a status and trends assessment which will describe and interpret current conditions and trends from the previous period. These data summaries will be used to help interpret results from other EMP monitoring protocols and efforts.

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Pima County
Multi-species Conservation Plan:
2019 Annual Report

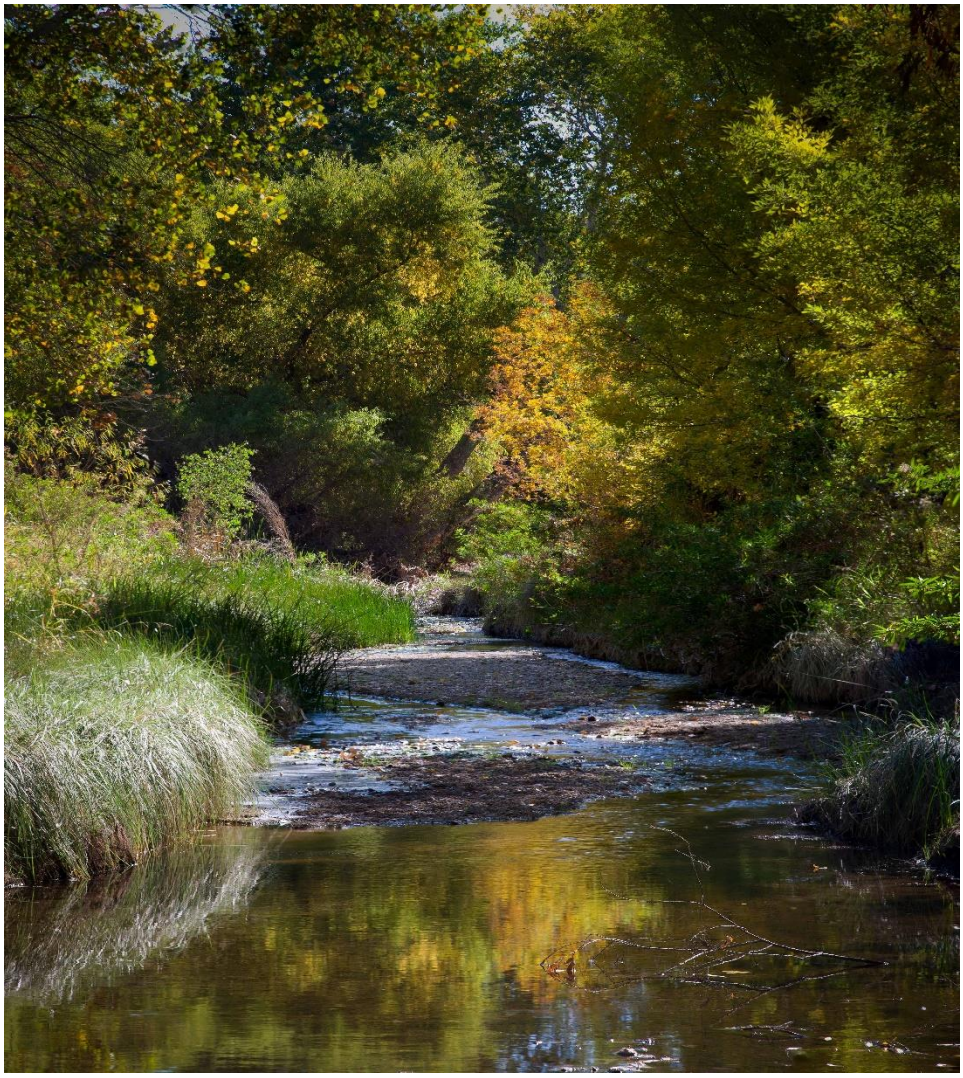
Appendix 9

Pima County Springs and Streams Monitoring Protocol

16 pages

Pima County Ecological Monitoring Program
Springs and Streams Monitoring Protocol

July 2020



PIMA COUNTY
SUSTAINABILITY & CONSERVATION

Prepared by Pima County Office of Sustainability and Conservation Staff:
Ian W. Murray
Jeff M. Gicklhorn

Cover photo: Cienega Creek near Three Bridges within the Cienega Creek Natural Preserve

Recommended citation: Murray, I.W., Gicklhorn, J.M. 2020. Springs and Streams Monitoring Protocol. Ecological Monitoring Program, Pima County Multi-species Conservation Plan. Report to the U.S. Fish and Wildlife Service, Tucson, AZ.

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Abstract

Pima County's wide network of open space lands include a variety of aquatic riparian habitats, from intermittent, but perennial stretches of stream, to small springs and seeps. These aquatic sites, while making up a small proportion of the overall area of the open space lands, have a disproportionately heavy influence on the status and presence of many of the County's Multi-species Conservation Plan's (MSCP) covered species, a number of which are either aquatic or reliant upon aquatic and riparian associated habitats. Pima County's Ecological Monitoring Program includes regular monitoring to track the status and potential management needs of both springs and streams across County lands. This protocol outlines the scope and methods that Pima County will use to monitor its springs and streams. Accurate data describing these resources will play an important role in Pima County's land stewardship and conservation through duration of the MSCP.

Acknowledgements

We thank our colleagues in Pima County Natural Resources, Parks and Recreation and the Regional Flood Control District for assistance with the many seasons of wet-dry mapping data collection that have already occurred, as well as those occurring in the future. Brian Powell, NRPR, deserves especially strong recognition for his many years shepherding monitoring-related inventories and analyses for this and many other elements that are critical to Pima County's ecological stewardship. We also note the heavy influence that his prior reports on aquatic sites on County lands have played in the presentation of this content, and we have incorporated some of his text describing methods into this protocol. We are particularly grateful for the efforts that the Pima Association of Governments has invested in monitoring of Cienega Creek Natural Preserve, and are especially thankful for the quarterly monitoring efforts that PAG staff Melanie Alvarez, Mead Mier, and Ben Hickson organize. We also thank Pima County IT GIS, especially Mike List and Pankaj Jamwal for their ongoing efforts to facilitate data capture, storage, management, as well as for addressing various requests for advice, analyses, and map products. We are grateful to Melanie Alvarez and Mead Mier of PAG, Don Swann of Saguaro National Park, Julia Fonseca and Amanda Webb of Pima County-OSC for critical review that improved this protocol.

Background and Objectives

In arid regions, riparian and aquatic habitats make up a relatively small part of the landscape, yet they hold high species diversity and are important not only for aquatic species, but also for terrestrial species that may depend on riparian systems as important habitats for water, foraging, movement, and shelter. Throughout the development of its flagship Sonoran Desert Conservation Plan (SDCP), Pima County has long recognized the critical role that aquatic habitats play in maintaining healthy ecosystems containing the full spectrum of native plants and animals present in our region and where these habitats occur across the > 250,000 acres of conservation lands that Pima County provides stewardship over (Fonseca et al. 2000; Pima County 2002). The County has, and continues to invest considerably in the acquisition and stewardship of these aquatic and riparian resources where they occur.

Pima County's Multi-species Conservation Plan (MSCP) is the vehicle for which the County remains in compliance with its Section 10 Incidental Take Permit issued by the U.S. Fish and Wildlife Service (USFWS) in 2016 (Pima County 2016). The MSCP covers 44 species of plants and animals (Covered Species), many of which are either obligate aquatic/riparian species or facultative riparian species that rely on aquatic or riparian habitats during some part of their life cycle. The Ecological Monitoring Program, a key part of the MSCP, is tasked with tracking the health of the County's preserve lands and the population status of a variety of the Covered Species that occur on them. One critical monitoring element is the evaluation of the status of streams and springs on County lands. At a minimum, the County has obligated itself to monitoring at least eight springs every two years. Additionally, the County has agreed to monitor perennial stream flow in Cienega Creek Natural Preserve, Buehman Canyon, Davidson Canyon, Youtcy Canyon, and Espiritu Canyon on an annual basis. This monitoring of perennial water resources, or wet-dry mapping, not only provides a means to track the status of these water resources on County lands, but also contributes important information that supports other monitoring elements such as aquatic species (both native and nonnative), as well as provides key information supporting the County's grazing interests under the Range program.

The objective here is to monitor and track the status of important streams, springs, and some un-supplemented stock tanks on County preserve lands.

Since well before Pima County's MSCP was approved by the USFWS and its Section 10 permit issued in 2016, County staff have been monitoring streams, springs, and stock tanks during usually annual wet-dry mapping during June. These efforts have not only resulted in a much better understanding of the status and locations of these resources and the species within them, but have also been synthesized in inventory and monitoring reports (Powell 2011, 2018). Much of the content of this protocol is taken from Powell (2018) and a detailed history of surface water monitoring efforts on County lands may be found there.

In Pima County, June is generally the hottest and driest part of the year, and is often called the foresummer, closely followed by the onsets of the summer monsoons. Estimating surface water extent at this time of year gives insight into what the minimal extent of aquatic habitat is

each year. In this report, we use the term extent to mean physical length, rather than duration of time. Importantly, during the winter rainy season and following summer monsoons, many of these features have substantially more surface water, higher flow volume, and/or greater linear length of wetted flow. Though the majority of the monitoring program's efforts will focus on estimating surface water extent in the hottest and driest part of the year (June), there is also value in collecting data on what the potential length of flow is in perennial stream systems on County lands during spring, particularly after especially wet winters. Information such as this provides for a more complete temporal understanding of a watershed tributary that may be important for better understanding population ecology of some aquatic species, as well as having an important nexus with water rights and mining claims.

Geographic scope and context

Pima County's conservation lands are made up of > 250,000 acres of fee and leased lands (for which the County holds a grazing lease) surrounding the City of Tucson (Figures 1 & 2). Aquatic and riparian habitats on these lands that have permanent or almost-permanent surface water include both supplemented and non-supplemented dirt stock tanks, springs, and stream stretches. These sites occur in both the San Pedro River Watershed (sites on the eastern side of the Santa Catalina and Rincon Mountains) and the Santa Cruz River drainage. See Powell and Fonseca (2019) for a discussion of the value that many of these sites have in the context of native aquatic species covered by the MSCP.

Methods

The primary focusing of this monitoring protocol is to collect data and repeatedly track the extent of surface water at spring and stream sites during the hottest and driest part of the year (i.e., June). This primarily entails collecting data on the 1) physical length of perennial surface water and the distribution of pools in stream features, and 2) the presence and extent of water in spring features. In most cases, monitoring earthen stock tanks is not a priority, but as priorities allow, or as species-specific needs require, water presence and estimated surface extent may also be recorded for these features. Secondarily, there may be triggers that justify discretionary springtime collection of extent of flow in key stream reaches in order to gain a better understanding of flow extent following wet winters to understand the potential maximum aquatic habitat extent of the year.

Monitoring schedule

Pima County's EMP is tasked with tracking the status of a variety of elements, from certain plant and animal species to vegetation and soils (see Appendix Q of the MSCP for a complete list; Pima County 2016). To better balance the realities of limited staff and time resources with the benefit of collecting robust monitoring data, streams and springs on County preserve lands will be monitored on the schedule indicated in Table 1 which was established based on site accessibility and an evaluation of the relative value to MSCP-covered species (at a minimum). Figures 1 and 2 show the distribution of these sites across County preserve lands. Appendix A contains supplementary information, including location and notes, for each monitoring site.

Table 1. Monitoring schedule for spring and streams on County conservation lands.

Site	Annual	Every 2 years	Every 5 years	Opportunistic
Stream Reaches				
Cienega Creek/Davidson Canyon	x			
Buehman/Bullock Canyon	x			
Youtcy Canyon	x			
Espiritu/Soza Canyon	x			
Edgar Canyon	x			
Geesaman Wash				x
Gibb Wash				x
Tanque Verde Creek (downstream – Wentworth Rd.)				x
Agua Verde Creek				x
Springs				
Fundoshi Spring		x		
Agua Caliente Spring		x		
Blacktail Spring		x		
Peck Spring		x		
Turney Spring		x		
Robles Spring			x	
Grapevine Spring			x	
Tennis Spring		x		
Carpenter Spring (Tortolita Mountains)				x
Cliff Spring		x		
Youtcy Canyon Tinajas				x

Pre-monsoon wet-dry mapping

County staff have primarily collected wet-dry mapping data between late May and early July over the many years that this monitoring has occurred. The summer monsoon start date may be variable, occurring between late June and late July. In our area the average start of the monsoon was 5 July (between 1984 to 2009; Crimmins et al. 2011), but during that same time period there were years when it started both substantially earlier (June 17) and later (July 25). The goal here is to complete wet-dry data collection as close as possible to the start of the monsoon, but to finish monitoring all sites BEFORE the first rains start. Safety and logistical concerns also mandate that staff are not walking or driving along some of the necessary back roads and canyon bottoms during or close to large rain events. As such, County staff will strive to complete wet-dry mapping within the first three weeks of June.

Spring wet-dry mapping

There is benefit to having a more complete understanding of the maximal physical extent of surface base flow (i.e., the portion of a stream's flow that is not sustained by precipitation-derived runoff) that may occur in some of the perennial streams on County lands, particularly as it relates to very wet winters (or also very dry winters). Subsequently, this would best be captured in the early spring (March – April), following winters with above average precipitation (or below average precipitation). Monitoring and mapping the extent of flow at these times is a discretionary EMP task that may be complementary to other County activities. The Pima County EMP will collect early spring physical extent of

perennial water opportunistically as conditions may allow and/or in accordance with various needs or priorities that may complement broader management directives. Stream stretches addressed here may include Buehman Canyon, Edgar Canyon, Geesaman Wash, Gibb Wash, Youtcy Canyon, Espiritu Canyon, and Agua Verde Wash.

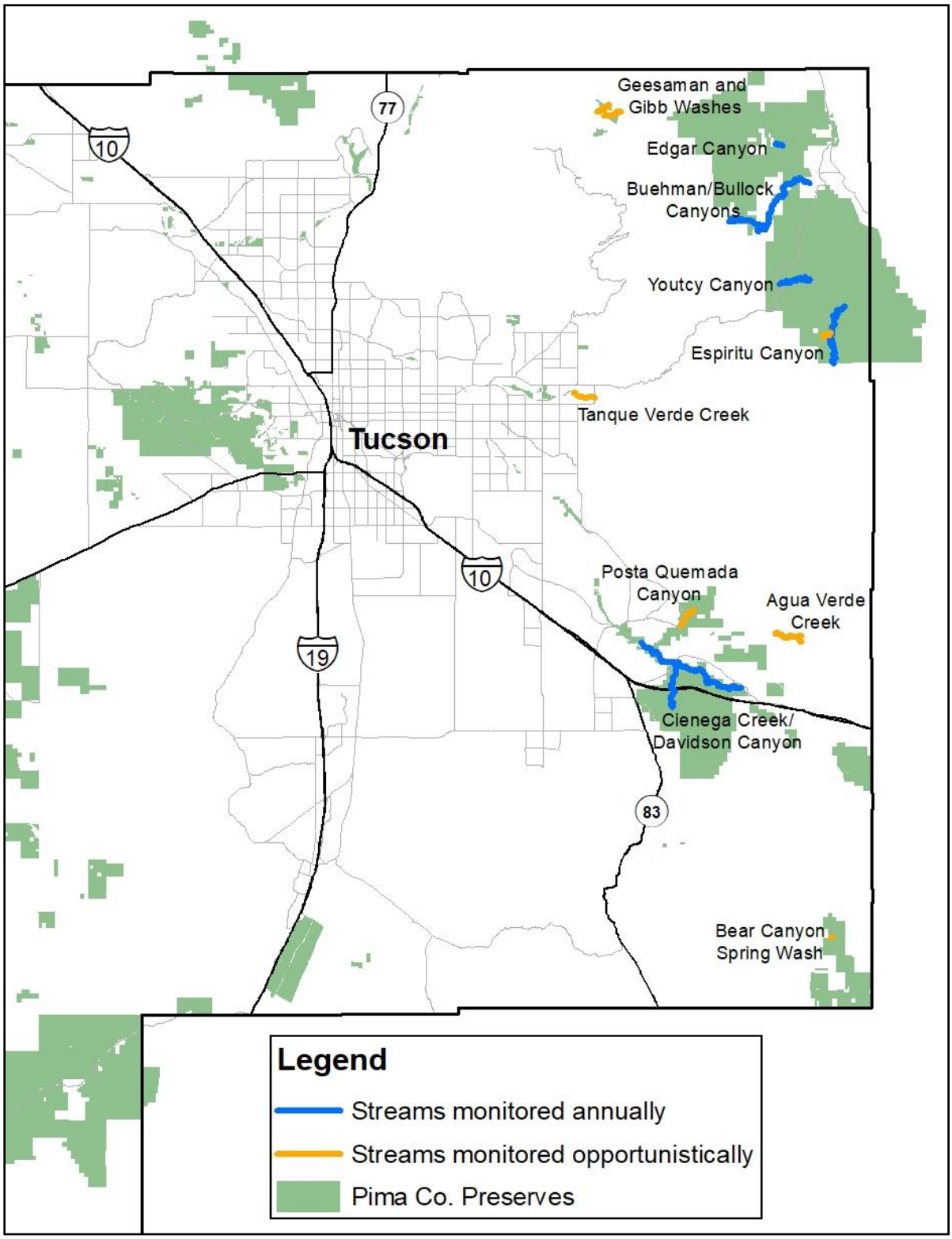

Figure 1. Streams and associated monitoring intervals on Pima County preserve lands.

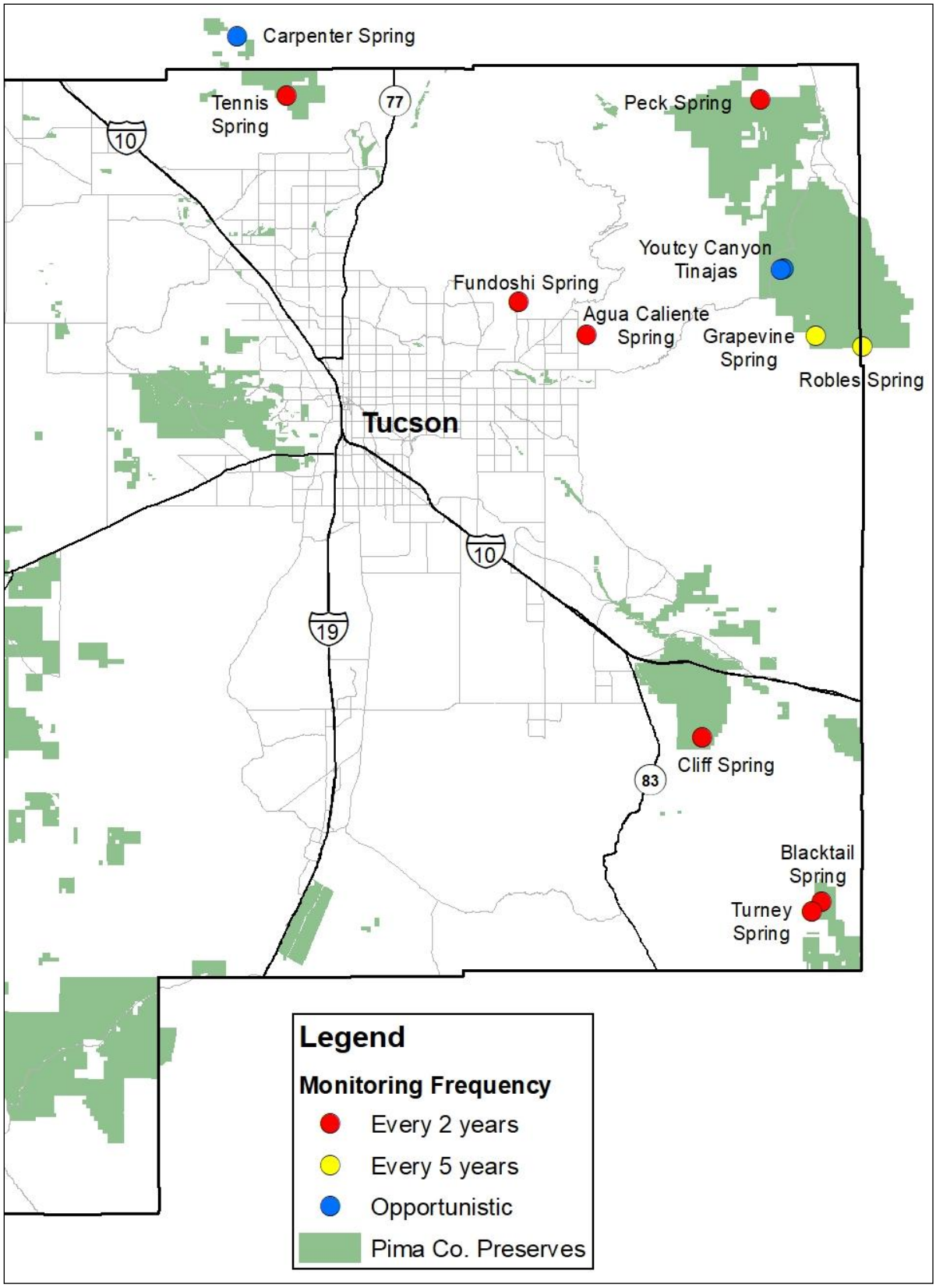

Figure 2. Springs and associated monitoring intervals on Pima County preserve lands.

Field survey methodology

Surveyors record the presence and location of water using hand-held GPS receivers (i.e., Garmin Oregon 450; using datum NAD83) or GPS-enabled field tablets (Panasonic Toughpad FZ-M1). In many cases, surveyors used Toughpads paired with an external GPS receiver (Bad Elf GNSS Surveyor) which led to substantially enhanced economy of battery capacity on the Toughpads. All data collection was made as a single point-based feature. However, surveyors also record a 'track log' in a continually running GPS receiver during a particular survey that can then be exported into a shapefile and archived later. While the Garmin Oregon 450 GPS units (or comparable hand-held GPS units) can give a positional accuracy of 3-5 meters (assuming a clear view of the sky on open terrain), the Bad Elf GPS receivers and the internal GPS receivers on the Panasonic Toughpads are capable of routinely yielding positional accuracies of 1-2 meters or better, given optimal conditions. Data are entered directly into digital datasheets or are collected on a paper form (see Appendix B) and then migrated into a database once back in the office.

For streams, the beginning and ends of every flowing reach were each recorded as a single point. The beginning of the wetted reach was always the upstream end, regardless of which direction the surveyor was walking. Beyond general estimates that may be paired with species observations or qualitative descriptions of a flow segment, depth is not routinely measured. To improve data management and standardization, a point is also recorded for the start and the end of the survey, regardless of whether water is present. Stretches of water that were estimated to be less than 3 meters long were recorded as a pool and marked as a single point (regardless of depth and width), often times with an estimate of dimensions. Any gaps in continuous wetted surface in a stream were treated as a separation between two adjacent stretches of flow, each with an end and beginning point. The Pima Association of Governments (PAG) coordinates wet-dry mapping of Cienega Creek and Davidson Canyon in the Cienega Creek Natural Preserve (CCNP)/Bar V Ranch (e.g., Pima Association of Governments 2017a, 2017b). When processing the data, PAG does not break the flow line if interruptions are < 20 feet long and the soils are wet, under the assumption that the segments were likely connected recently, possibly through diurnal fluctuation in the extent of surface water (e.g., through riparian vegetation transpiration) with higher flows at night. However, they record a GPS point for each break and estimate the length of the break. Similarly, PAG records a single point for any wet feature that is < 20 feet long and estimates its flow length. PAG does not mark any pool that is < 5 feet in diameter or shallower than 4 inches deep unless fish are present (https://www.pagnet.org/documents/water/20FtRuleGuide-2017-01-Draft.pdf). Notes are taken for pools and flowing reaches to indicate if there is evidence of baseflow versus runoff such as clarity or algal presence. PAG gathers average width and maximum depth for each pool.

During opportunistic surveys of earthen cattle tanks surveyors record whether water is present and in some cases width and length of surface water as estimated from GPS track logs. Staff may also use rangefinders (Bushnell Trophy model #202640) to estimate tank dimensions.

PAG routinely takes water quality readings during quarterly wet-dry mapping at CCNP both upstream and downstream of the Davidson Canyon confluence, as well as two sites in Davidson

Canyon (pending water availability). Data collection is based on Arizona Department of Environmental Quality sampling forms. However, Pima County Regional Flood Control District staff estimate flow volume occasionally at these sites during their water sampling efforts. Starting in 2018, EMP staff took at least two water quality measurements (pH, electrical conductivity, total dissolved solids, and water temperature) in most stream stretches using a Hanna Waterproof Tester (HI98129) that is regularly calibrated and cleaned.

During wet-dry mapping surveyors also recorded the location, and often estimates of numbers and life stages, of any MSCP Covered Species, particularly aquatic species such as leopard frogs, longfin dace, Gila topminnow, and Gila chub. Other species of interest, both aquatic and terrestrial, are also often noted and recorded, such as Sonora mud turtles and various raptor species. Any management needs, such as broken fences/trespass grazing, invasive plant observations, or illegal off-highway vehicle use are also noted and given to the appropriate managing department. During PAG's data collection, fish and frogs are recorded as present or absent (indicated to species level if known) for each pool and stream reach. For each pool the average size and different species are recorded.

Taking photographs is not a standardized part of the wet-dry mapping protocol, but is rather used to more generally illustrate the conditions at a particular site, or to capture an observation of a species of interest. The Panasonic toughpads have an integrated digital camera which may be used to link a photograph to a particular point on the digital forms as needed (e.g., to highlight an incidental species observation or to further describe particular aquatic site characteristics). Furthermore, in some cases higher quality images are taken with a DSLR and these images may be uploaded and attached to a point observation from within ArcGIS Collector. PAG has repeat photography points primarily for sites with erosion or drought impact concerns. Several years of past photo records are available. These photos are no longer gathered on a regular schedule.

Data management and analysis

Field data that are recorded using a handheld GPS and paper datasheets are downloaded (the GPS waypoints marking recorded features as well as the surveyors track log) and manually entered into a geodatabase (maintained by Pima County IT GIS) once the surveyor returns to the office, using the ArcGIS Collector app. In cases where data were entered directly into the digital forms on the field tablet, these data are 'synced' with the geodatabase once the tablet has viable wireless connectivity. After data are in the geodatabase, surveyors check the data for any inaccuracies or errors before the data are finalized. Proofed data in the geodatabase are available for County staff and external partners (as relevant) via several mechanisms, including visualization in an Enterprise geodatabase in ArcGIS Portal or sharing of exported shapefiles as necessary.

Here we draw heavily on the methodology already reported in Powell (2018), and much of the below content is from that report. Monitoring data for various streams on County preserve lands have been collected in various ways for many years, and County staff have worked to integrate these data into one database. Montgomery & Associates, in coordination with PAG

collected data on the extent of stream flow in Cienega Creek Natural Preserve in 1975, 1978, 1979, 1982, and 1984-1992. These data are available only in a paper format (M. Alvarez, PAG, personal communication). Wet reaches for Cienega Creek and Davidson Canyon were surveyed by PAG beginning in 1999 and with data provided as shapefiles. Beginning in 2005, PAG started included portions of Davidson Canyon that were upstream of Interstate-10 in quarterly monitoring efforts. PAG's wet reach point features, when processed in the office, were used to clip a consistent stream centerline into flowing and non-flowing reaches. However, over time PAG mapped to different depictions of stream centerlines across survey periods; these data has since been corrected and standardized using a common stream centerline. For example, monitored wet reaches were mapped to 1:24,000 or 1:100,000 scale USGS bluelines, or various versions of the Pima County GIS 'washes' layer during past PAG surveys of Cienega Creek. Data from other monitored streams on County preserve lands were provided by Pima County staff as GPS-collected coordinates for survey start and stop points, wet reach start and stop points, and in-channel point features. It is assumed the GPS-collected data had varying degrees of accuracy. Therefore, there was a need to establish a common depiction of the stream centerlines for comparative measurements over time.

Subsequently, County IT staff transferred all features to a linear referencing system based on the High Resolution National Hydrography Dataset stream centerlines for each respective monitoring stream. A linear referencing data model allows all stream channel features to be stored as table records which in turn reference a *single* GIS layer for stream centerlines. Linear referencing also affords the ability to perform a linear overlay analysis and directly compare the linear extent of surface water present across different monitoring events, as shown below in Figure 3. This method can be then used to create analysis products on an as-needed basis. For example, both automated GIS tools and manual interpretation were used to create linear referencing table measures for stream features for analyses such as for analyzing the degree of water permanence over time within the monitored reaches (Figure 4).

In this work flow, pairs of measures are called events (i.e., a point indicating the start of flow and a point indicating the end of flow). For each stream, all events by type were intersected against each other to create new linear features for both number of times a reach was surveyed and number times flowing water was observed. Finally, surveys and wet reaches were intersected to yield a flow permanence layer – if a reach was surveyed three times and water was present twice, the permanence value is 66% (Figure 4). All event tables and intersect results are stored in an enterprise geodatabase, which allows for data backups, point-in-time recovery, and multi-user editing. See Powell (2018) for an in depth treatment and reporting of these analyses through the year 2017.

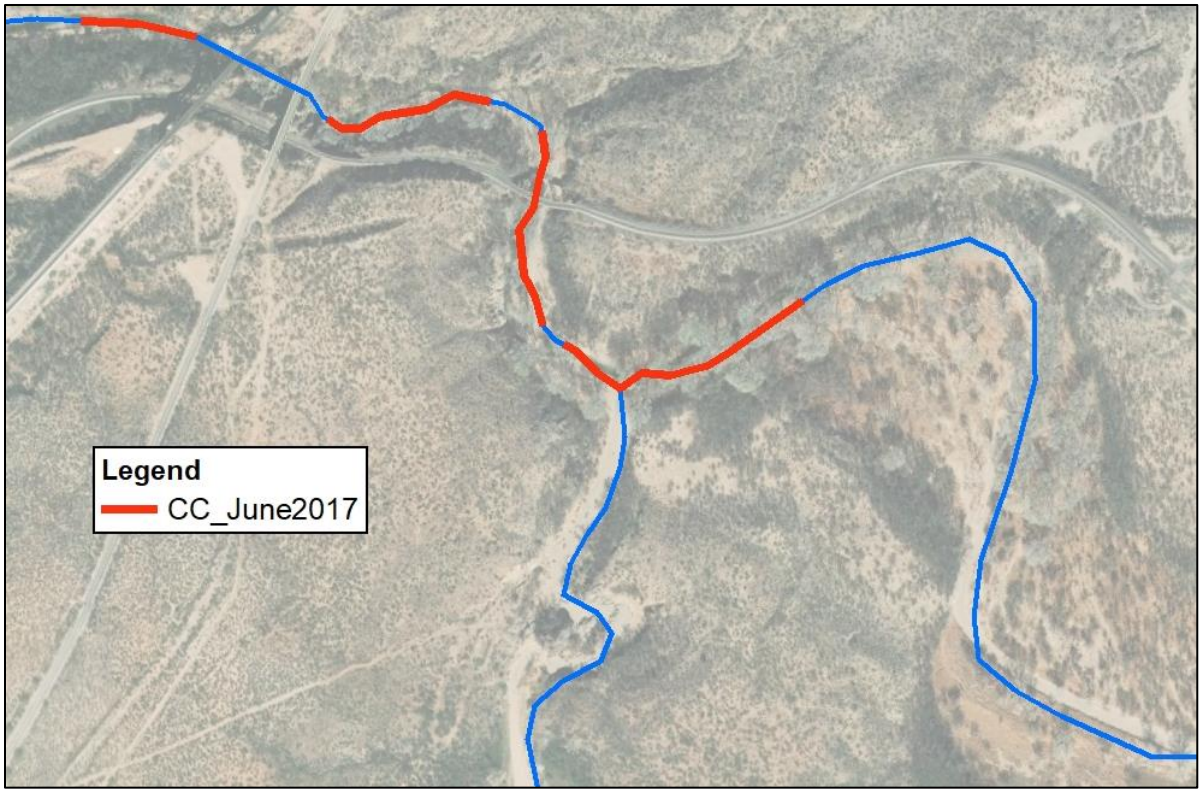

Figure 3. Example of analysis - surface water present in Cienega Creek in June 2017 (shown in red). Area shown includes the Davidson Canyon confluence and Three Bridges.

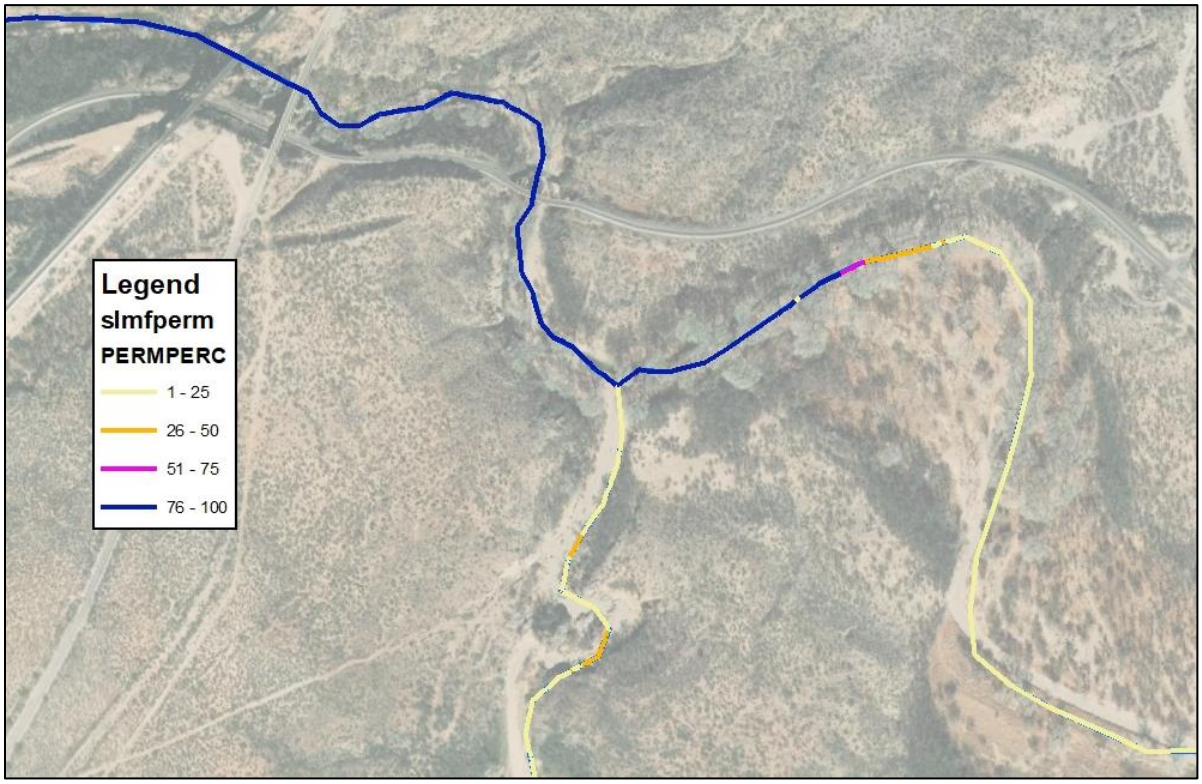

Figure 4. Example of analysis - water permanence in Cienega Creek (shown as percent of surveys when water was present). Color-coded bins in the legend indicate the proportion of survey periods for which a particular stretch had surface water.

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Appendix A: Monitoring site supplementary information

Stream Reaches							
Site	**Frequency**	**Start UTM E**	**Start UTM N**	**End UTM E**	**End UTM N**	**Length (km)**	**Notes**
Cienega Creek	Annual	539756	3540316	530510	3544447	13.16	From Pantano dam to Jungle road crossing.
Davidson Canyon Wash	Annual	533462	3538451	533724	3542487	2.72	Reaches above CC confluence and S of I-10.
Buehman Canyon Wash	Annual	538661	3583396	546081	3586960	12.02	Monitor from FS boundary to bottom of canyon.
Bullock Canyon Wash	Annual	541367	3582447	542172	3583050	1.57	Walk upstream from where Piety Hill Rd. crosses main channel, Buehman Canyon
Youtcy Canyon Wash	Annual	543330	3577644	546108	3578020	4.47	Focus on spring reach in canyon.
Espiritu/Soza Canyon	Annual	548348	3570288	549312	3575559	8.36	Monitor from FS boundary down to above Bar LY, including side canyon. Include Bolt Canyon if time.
Edgar Canyon	Annual	542906	3590592	543615	3590409	0.78	Permanent water upstream of County boundary.
Geesaman Wash	Opportunistic	527134	3593168	528661	3593547	1.83	Park below and hike up and back.
Gibb Wash	Opportunistic	526457	3593502	527577	3594075	1.45	Hike from top to bottom, off of Control Rd.
Tanque Verde Creek (downstream – Wentworth Rd.)	Opportunistic	526270	3567116	524332	3567591	2.12	Be aware of adjacent private property.
Agua Verde Creek	Opportunistic	545365	3544537	545314	3545078	0.65	Be aware of adjacent private property.

Springs				
Site	**Frequency**	**UTM E**	**UTM N**	**Notes**
Fundoshi Spring	2 Years	518963	3574681	Coordinate with RFCD for access.
Agua Caliente Spring	2 Years	525485	3571582	
Blacktail Spring	2 Years	547993	3517158	Check flow below spring box and in Bear Canyon Wash.
Peck Spring	2 Years	542177	3594103	
Turney Spring Complex	2 Years	547168	3516214	Four spring features present.
Robles Spring	5 Years	551951	3570453	Monitor above spring to FS boundary.
Grapevine Spring	5 Years	547456	3571447	Approach road can be exceptionally bad.
Tennis Spring	2 Years	496741	3594437	
Carpenter Spring (Tortolita Mountains)	Opportunistic	492000	3600186	
Cliff Spring	2 Years	536563	3533027	
Youtcy Canyon Tinaja 1	Opportunistic	544361	3577909	
Youtcy Canyon Tinaja 2	Opportunistic	544072	3577786	

Appendix B: Wet-dry mapping datasheet

Pima County Ecological Monitoring Program: **Wet/dry Mapping and Water Availability** Protocol: 2013-1

Location

Property: _____ Site Name/ID: _____

Feature Type (circle one): Stream Reach Stock Tank Spring

Visit

Date: ___/___/___ Observer(s): _____ Visit #: _____

Start time: _____ Stop time: _____ Total search time (minutes): _____

Photograhs taken: Y / N If "yes", file number(s): _____

Survey start: 12R 0 _ _ _ _ _ _, 3 _ _ _ _ _ _ Survey Stop: 12R 0 _ _ _ _ _ _, 3 _ _ _ _ _ _

Notes about features and conditions (including observations of frogs and other riparian species): _____

Datum used (NAD83 preferred): _____

Survey data

Time	Accuracy	UTM Easting	UTM Northing	Water Start/Stop	Notes-include name of feature (if appropriate)
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	
		12R 0 _ _ _ _ _ _	3 _ _ _ _ _ _	Start Stop Pool	

If found, please call (520) 724-9489

Page ___of___

Pima County
Multi-species Conservation Plan:
2019 Annual Report

Appendix 10

Pima County Landscape Pattern Monitoring Protocol

28 pages

Pima County Ecological Monitoring Program
Landscape Pattern Monitoring Protocol

March 2020

PIMA COUNTY
SUSTAINABILITY & CONSERVATION

Prepared by Pima County Office of Sustainability and Conservation Staff:
Julia Fonseca

Cover photo: National Land Cover for the conterminous United States – NLCD program.

Recommended citation: Fonseca, J. 2020. Landscape Pattern Monitoring Protocol. Ecological Monitoring Program, Pima County Multi-species Conservation Plan. Report to the U.S. Fish and Wildlife Service, Tucson, AZ.

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Definitions

Throughout the development of Pima County's Multi-species Conservation Plan (MSCP), monitoring landscape-level parameters of land use and land cover was considered a top priority (RECON Environmental Inc. 2007). *Landscape pattern* is a broad category describing the spatial configuration and extent of land-cover and land-use parameters. *Land cover* is the observed biophysical state of the earth's surface and immediate subsurface; it can be categorized into types of natural vegetation (e.g., forest and grassland) and human uses such as urban development, agricultural fields, mine sites, and roads. *Land use* can involve both the manner that land is manipulated and the intent of that manipulation.

Purpose

The purpose of this protocol is to describe the objectives and tools which are proposed for use in Pima County MSCP's Ecological Monitoring Program (EMP) for detecting and interpreting changes in patterns of land use and land cover over the thirty-year term of Pima County's Section 10 (incidental take) permit. This report responds to the commitments in the MSCP (2016) approved by U. S. Fish and Wildlife Service and builds on previous work of Fonseca et. al. (2009). It attempts to complement the NPScape monitoring effort (Monahan et al. 2012) for the National Park System units in our area.

Objectives

MSCP Objectives for Landscape Pattern Monitoring

Landscape Pattern is one of the five ecological monitoring elements of the Pima County Multi-species Conservation Plan (the other elements being: single-species, habitat, threats, and climate monitoring). Of the five, it is the broadest in extent. Monitoring changes in landscape patterns, including land cover and land use, will help explain observed changes in the habitats used by species covered by the MSCP and anticipate future threats.

MSCP objectives for the Landscape Pattern element fall into two categories: retrospective and prospective analyses.

<u>Retrospective</u>:

1. Document changes in the type and location of *land cover conversion* activities that have occurred during each reporting period, including updating the built environment GIS layer used as a reference for mitigation of County activities under the permit.

<u>Prospective</u>

2. Forecast extent and location of *potential future development* that may result in land cover changes.

Changes in land cover and land use may affect the long-term viability of many of the covered species. Measures of fragmentation of habitat, independent of land cover and land use, can be analyzed at the landscape level or inferred using results from both retrospective and prospective monitoring.

Landscape pattern monitoring results will also provide a useful regional context to supplement the evaluation of permit-related activities every ten years as described in Chapter 9 of the MSCP. We anticipate developing a separate statement with the Science and Technical Advisory

Team (STAT) to guide all of the analyses that will be brought to be bear on the decennial review of the Section 10 permit, separately from this document.

Additional Objectives in Relation to Changed Circumstances

Changed circumstances are "changes in circumstances affecting a species or geographic area covered by a Habitat Conservation Plan (HCP) that can reasonably be anticipated by Plan developers and the [USFWS] and that can be planned for" (50 CFR §17.3). Table 7.1 of the MSCP lists identifiable changed circumstances for the County's permit, and describes potential responses that Pima County may take. Many of the changed circumstances are related to activities of others that could affect species or their habitats covered by the MSCP, for which no response would be needed.

Much of Table 7.1 is evaluated and discussed with USFWS annually, but in the 2016 MSCP Annual Report, we proposed to integrate the reporting frequency for several changed circumstance scenarios with landscape pattern monitoring techniques. These select circumstances are shown below in Table 1. The reporting frequency for changed circumstances that will be addressed through landscape pattern monitoring varies as shown below.

Table 1. Changed Circumstances addressed through Landscape Pattern Element (abstracted from Pima County MSCP Annual Report 2016, Table 6).

Circumstance	Minimum reporting frequency	Reporting mechanism
Central Arizona Project recharge creates aquatic habitat, and expands riparian habitat.	5 years	Landscape pattern analysis in eastern Pima County
Land is graded on County-held grazing leases, County conservation easements, or County-owned mitigation lands for infrastructure or other developments beyond County's control (e.g., condemnation)	5 years for landscape pattern, otherwise as data become available	Landscape pattern in eastern Pima County, supplemented with biennial inspection reports, threats monitoring at site level
Conversion of desert, riparian areas, or grasslands to agriculture in Permit Area or on adjacent tribal lands.	5 years	Landscape pattern monitoring in Pima County
Conversion of desert, riparian, or grasslands to development due to Federal projects or federally authorized projects of others in the Permit area or on adjacent tribal lands	10 years	Landscape pattern monitoring in Pima County
New roads or utilities established in CLS outside Preserves.	5 years	Landscape pattern monitoring in Pima County excluding tribal lands
Reduction in effluent discharge from County treatment facility (below permit issuance baseline) contributes to die-offs of riparian forest and elimination of aquatic vegetation along the Santa Cruz River in Pima County	Discharge annually; Vegetation as new products become available	Annually report change in effluent discharges; examine vegetation using Landscape Pattern monitoring
Wildland fire exceeding 1,000 acres in size occur inside or outside County preserve network. Not all County preserves are affected at same time, but at least one is.	5 years	Landscape pattern monitoring in Pima County, excluding tribal lands

Protocols presented in this document integrate detection of these changed circumstances primarily with retrospective land cover analysis using the National Land Cover Dataset (NLCD) and other sources of information.

Area of Analysis

In general, we prefer to analyze landscape change in Pima County across jurisdictions, where data and analytical resources are available. In some cases, the analysis may be restricted to a smaller area, for instance to satisfy one of the above changed circumstances, or to use high-resolution data sources that do not extend more broadly over Pima County (see Table 1). The permit area is much smaller than Pima County and shrinks with time as areas are annexed. The permitted activities primarily affect eastern Pima County and a small area around Ajo, Arizona. The permit area does not extend onto the Tohono O'odham Nation or other tribal or federal lands.

Permit Baseline

The Section 10 permit was signed in July 2016. The monitoring plan itself has a five-year period for initiation. In general, the baseline or reference conditions for monitoring landscape pattern will be defined based on imagery analyses selected as close to July 2016 as possible. Successive-year analyses such as those supporting the decennial permit review will also be used to establish trends over time.

Component Monitoring Protocols

Protocol Summary

Table 2. Purpose and monitoring frequency for Landscape Pattern component monitoring protocols.

Protocol	Frequency	Purpose
Built environment	Updated as CIP projects occur	Establish new reference layer for more accurate baseline; Maintain reference layer for determining when County projects require mitigation.
National Land Cover Dataset (NLCD)	As NLCD products are released	Detect changes in regional land cover and land use using 2016 baseline to understand trends; monitor and report certain changed circumstances
Large wildland fire impacts	5 years	Detect changes in land cover on County preserves that may be related to fires exceeding 1000 acres in size for changed circumstances affecting covered species
Effluent-reduction analysis for Santa Cruz River	5 years	Detect changes in aquatic or riparian habitat for covered species and evaluate in relation to effluent discharge and other factors
Regional road network	5 years	Detect changes from 2016 baseline that may shape future land use or fragment habitat in CLS for decennial review
Sewer analysis	5 years	Establish 2016 baseline; detect changes that may shape future land use patterns or fragment habitat in CLS for decennial review
Future development	≤10 years	Project how and where future development may affect land cover that support the habitat of covered species for decennial review

Built Environment Analysis

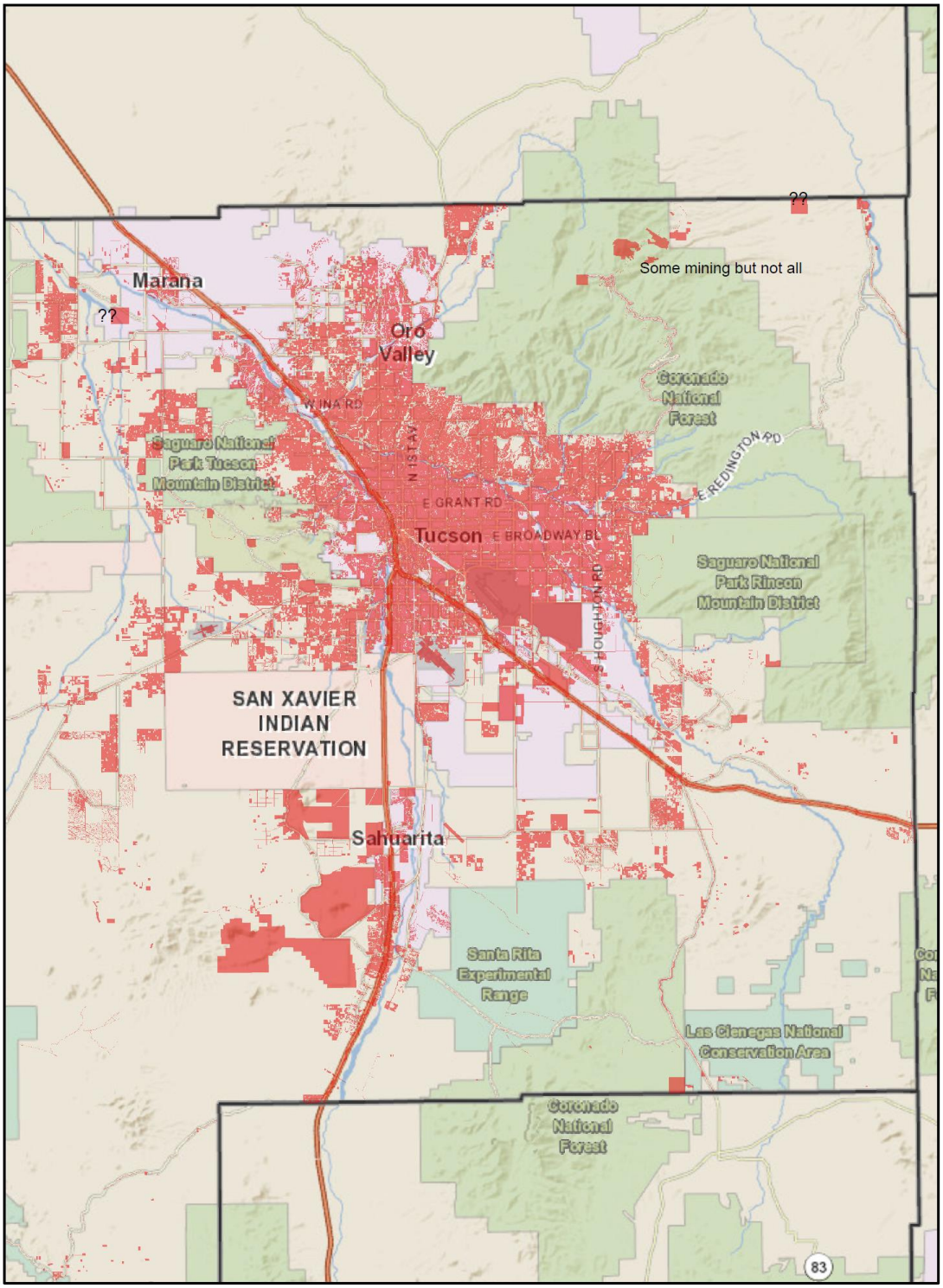
The built environment GIS layer serves one main purpose: to serve as the basis for determining when County construction projects (defined in the MSCP as Capital Improvement Projects or CIP) require mitigation. It is NOT used to track other types of urban growth.

When the permit was issued, Pima County created the geographic information system (GIS) layer known as *CIPBUILT* to determine when Capital Improvement Projects performed by Pima County require mitigation (Figure 1). This layer is continuously edited as CIP projects are completed and after permit issuance become finalized. In other words, each new CIP project redefines the built environment representation against which new CIP projects are measured, to prevent double mitigation. *CIPBUILT* is stored as GIS layer in Pima County's central GIS library.

Like every representation of reality, this layer imperfectly represents the actual distribution of developed areas in 2016 when the permit was issued. Most of the work to represent the built environment was done by the Pima Association of Governments and represented in an earlier layer, *BLT_2008*, prepared eight years before the permit was issued. In addition, the effort did not finely resolve certain land use categories.

As noted in the 2016 and 2017 MSCP Annual Reports, accounting for certain types of CIP projects has been difficult because the original layer from which *CIPBUILT* was derived (*BLT_2008*) did not account accurately for the pre-permit parks and landfills where the County continues to do work. As documented in the 2017 Annual report, USFWS authorized an update to *CIPBUILT* to account for landfills that were in existence at permit baseline, but a similar exercise has not been performed for parks which may have varying compositions of sod, hardscape, natural vegetation, and other land covers but that are otherwise primarily managed for human use and recreation, rather than natural resources.

We seek USFWS permission to perform a similar update to *CIPBUILT* for parks using a detailed classification of imagery dated 2015 to distinguish between natural cover and areas where the ground has been disturbed and cover is largely managed for visual or recreational purposes. Parks are often a mix of natural and developed areas. In 2017, for instance, the lining of an existing pond at Agua Caliente affected an already developed area that was not reflected in the *CIPBUILT* layer. We can anticipate this being a recurring issue in the use of the *CIPBUILT* layer if not otherwise corrected.



Legend

cipbuilt

Figure 1. *CIPBUILT* indicates built up areas and is used to determine whether new capital improvements covered under the permit require mitigation.

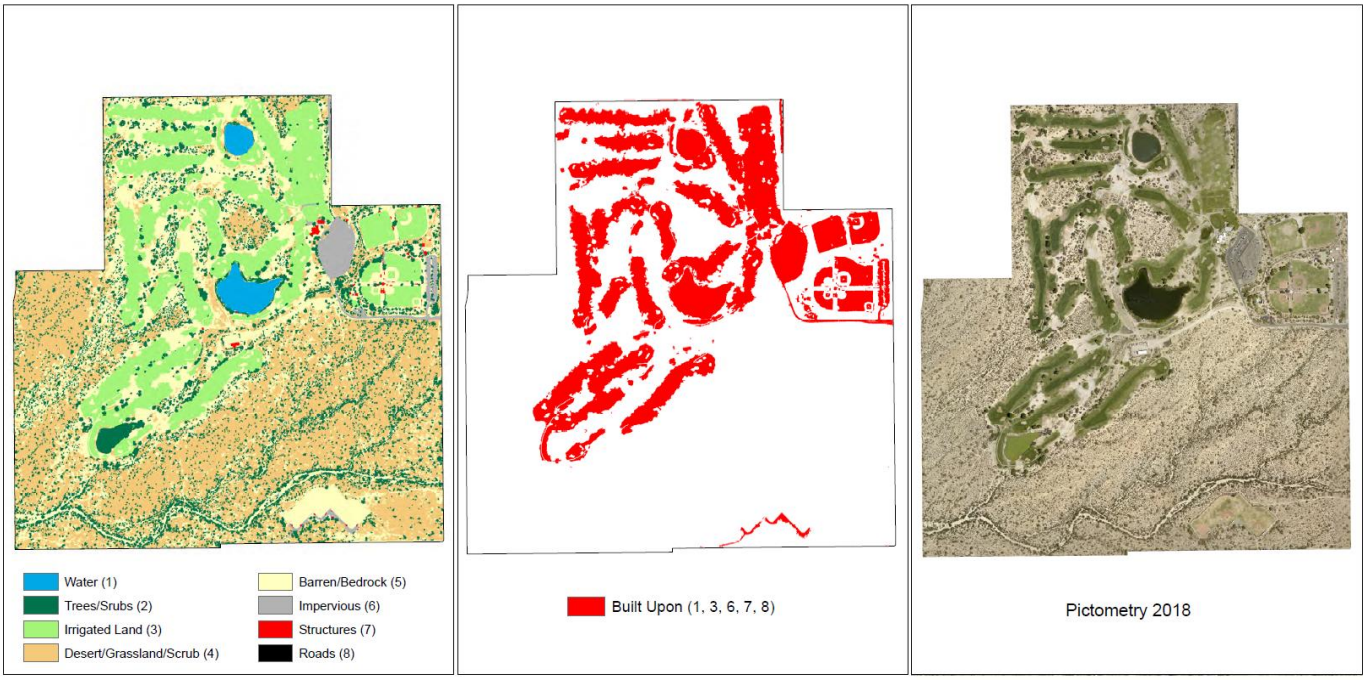


Figure 2. Left, 2015 classification of land cover (*LULC18*). Middle, built environment extracted from 2015 land cover. Right, 2018 aerial imagery for reference.

When we have permission, we will revise the *CIPBUILT* layer to identify areas of natural cover in parks that had been converted to either ponded water, impervious cover, structures, irrigated land (turf) by 2015, when the PAG imagery used for the raster classification called *LULC18* was collected and analyzed. Figure 2 provides an example where substantial areas of irrigated turf and ponded water in a golf course are adjacent to natural open space vegetation. This example highlights the level of detail provided by the *LULC18* classification and its proposed use for improving the classification of the built environment in park lands.

In general, the *LULC18* classification is very good at discriminating changes in land cover, but including the barren/bedrock land cover classification may introduce some inaccuracies because it can conflate areas of natural open ground (bare dirt or bedrock) with some types of human-altered land covers such as bladed ground. As an example, in Figure 2 the poorly irrigated turf sport field in the lower right part of the image is incorrectly classified as barren/bedrock. Since there are natural land covers types described by barren/bedrock throughout many of the scrub lands in the permit area, inclusion of barren/bedrock would pose problems. Our proposal to exclude the land cover category barren-bedrock from the built environment is conservative, in that it will not capture poorly irrigated turf such as the ball field in the southern part of the figure.

NLCD Landscape Pattern Analysis

The National Land Cover Dataset is derived from LANDSAT satellite data, and is intended to provide reliable information on the Nation's land cover and land use change (Yang et al, 2018). The National Park Service has chosen the NLCD for most of its land cover and land use monitoring, and has published detailed instructions for its use (available at irma.nps.gov). The scale of this product is typically 30-meter resolution. The NLCD has been supported by

consistent funding, and iterative updates are then provided at no cost to the public, every five years or so.

The primary purpose of using the NLCD for the EMP, as proposed by Fonseca (2008), is to analyze gross changes in regional land cover that may be responsible for long-term trends in covered species distributions or population trends. The NLCD will also be used to analyze for and report changed circumstances as noted in Table 1 and discussed below.

The NLCD has been used successfully in the detection of land cover change in Arizona (Kepner et. al. 2000), and Pima County (Fonseca 2008). More recently, Shrestha et al. (2012) found that 80% of the "developed, low intensity" and 66% of "open space, very low intensity" areas were correctly classified near Phoenix. In arid regions, NLCD is quite successful in detecting this otherwise difficult land use. In Pima County, Fonseca (2008) and Fonseca et al. (2009) found the NLCD was useful in detecting land cover removal due to dirt road construction in areas of lot splitting.

Grassland classification has been thought to be a notable weakness of the previous iterations of the NLCD (Xian, et al. 2015). Estimates of grassland or other herbaceous cover varied greatly between NLCD 2011 and Wallace et al. (2011) for the Cienega Creek watershed (Powell 2015). Importantly for Pima County's work, the 2016 NLCD dataset now includes improved shrub and grass mapping for southern Arizona and New Mexico, as well as large parts of the western United States (Young 2017). Most of Pima County falls in the shrub and grass categories of NLCD, but there are major areas of evergreen forest, agriculture and developed lands (Fonseca et al., 2009).

NLCD 2016 has just been released (June 2019). Land cover and imperviousness products are available for seven product dates between 2001 and 2016. Land cover and imperviousness products are now spatially and temporally consistent among the various years that NLCD has existed, permitting trend analysis. The 2016 release provides separate fractional vegetation products for download, and these can be incorporated into the land cover for improved accuracy.

Economic and land use changes are important drivers that are expected to change landscape pattern over the term of the permit. The NLCD's change detection products will be used to provide unique information on the conversion of natural land cover types by mining, urban expansion, and agricultural activities within and outside the permit area. This analysis will provide information about trends in these land-use activities, which can affect habitat conditions for covered species.

For our first five-year review period, we will retrospectively evaluate changes in all of the Anderson Level 1 and 2 categories of the NLCD (Table 3) that occurred from 2006 to 2016. This analysis will help us understand and interpret trends that led up to the NLCD 2016 baseline, and inform interpretation of subsequent changes that affect the NLCD 2016 baseline for the first decennial review.

Table 3. Anderson Level 1 (number in first column) and 2 (value in second column) Land Cover Classes in NLCD 2016.

11. Water
12. Perennial Ice Snow (not in Pima County)
21. Developed, Open Space
22. Developed, Low Intensity
23. Developed, Medium Intensity
24. Developed High Intensity
31. Bare Rock/Sand/Clay
41. Deciduous Forest
42. Evergreen Forest
43. Mixed Forest
52. Shrub/Scrub
71. Grasslands/Herbaceous
81. Pasture/Hay
82. Cultivated Crops
90. Woody Wetlands
95. Emergent Herbaceous Wetlands

After the initial five-year review, Pima County will specifically report observed changes using the change detection datasets provided by NLCD. If these are not available at five-year intervals, Pima County may at our discretion use other products rather than wait for another release. In reporting results, we will use the NLCD's categories of land use or land cover (see Table 4) whenever possible, guided by NPS protocols available at irma.nps.gov. If similar regional analyses are available from NPS for the area near Saguaro National Park, we will compare our results to theirs.

Of particular interest is the robustness of any emerging trends in grassland/herbaceous class over time. We will look for further research by others that will elucidate the accuracy of the NLCD classification and trends, and if possible, bring local ancillary data, such as those from Santa Rita Experimental Range, into an evaluation of long-term trends.

Table 4. Reporting Metrics Using NLCD Land Cover Product

Purpose	NLCD-derived Metric and Format
Describe existing land cover	Total area of Level 2 Land Cover class in acres by type and percent area for Pima County for baseline and year of analysis (Table); map of Eastern Pima County and Western Pima County at Level 2
Δ Land Cover	Table of total areal change (-/+) for each Level 2 land cover class from 2016 baseline to year of analysis in Pima County; supporting map showing dominant changes
Conversion of desert, riparian areas, or grasslands to agriculture in Permit area or on adjacent tribal lands (changed circumstance)	Table of acreage lost from 2016 baseline Level 1 Shrubland, Grassland, or Wetland (Woody and Emergent) to any type of Developed or Barren class; a sample is then spot-checked with high-resolution aerial photographs to determine if change occurred
Agriculture (changed circumstance)	Map of change from 2016 baseline any Level 1 natural land-cover type except Barren to Pasture or Cropland in Permit Area or tribal lands; these are then verified with high-resolution aerial photographs to determine if change occurred
Wildland Fire (changed circumstance)	Conversions at Level 1 within areas of previous fires on County mitigation properties (see protocol below)
New roads or utility incursions in CLS, outside Preserves (changed circumstance)	Map showing conversions to Level 1 Barren or Developed in CLS outside Preserves that have been verified with street network or other ancillary data
Federally authorized project incursion (changed circumstance)	Map showing locations of conversions from Level 1 natural land cover types to Agriculture, Barren, Urban or Open Water; verified with high-resolution aerial photographic or other evidence
CAP recharge creates aquatic habitat or expanded riparian habitat (changed circumstance)	Map showing locations of conversion from a Level 1 non-water cover type to a wetlands cover type near CAP recharge areas; verified with high-resolution aerial photographic evidence

Wildland Fire Analysis

The monitoring objective is to detect large fires that cause long-lasting alterations of habitat for covered species in County preserves. If there is a wildland fire meeting the size and proximity criteria, it will be reported as a potential changed circumstance, subject to later analysis for habitat alteration. The distribution of fires and their long-term effects on distribution of broad classes of vegetation community structure will thus be available in the decennial review.

Pima County will screen for wildland fires exceeding 1,000 acres in size that have occurred inside or outside the County preserve network using fire perimeters reported to the MTBS (Monitoring Trends in Burn Severity) multiagency program (MTBS 2017). The GeoMAC (Geospatial Multi-Agency Coordination) Wildland Fire Support will not be consulted because it is not comprehensive.

Figure 3 compares the two databases for the period 2000 to 2016. Most fires before the permit was issued occurred on lands outside the County preserve network. Many fires in Pima County were not reported by GeoMAC, and our comparative analysis showed that every fire that was on GeoMAC was also on MTBS. A record of pre-permit polygons from both MTBS and

GeoMACwill be maintained to support decennial analysis. The pre-permit baseline for this effort will include MTBS perimeters for fires that either occurred within Pima County or had part of their perimeter located within a four-mile buffer from Pima County dating back to 1984. It will reside in Pima County's GIS library as a shapefile and as an Enterprise Geodatabase feature class showing the number of times a given polygon has burned between 1984 and 2016.

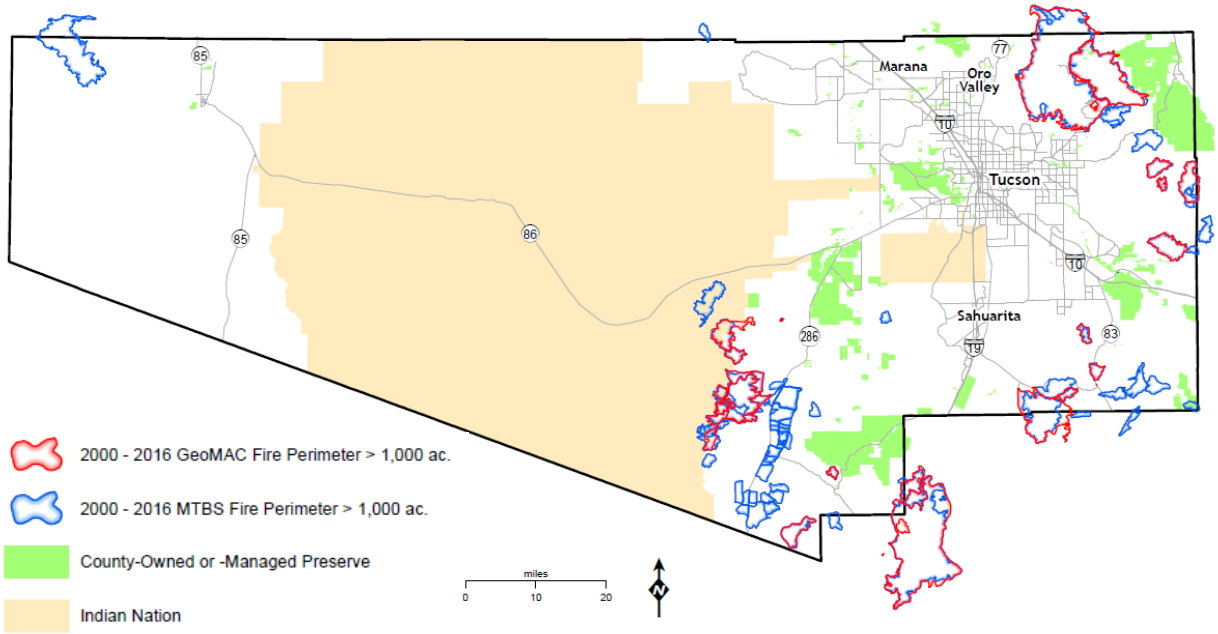


Figure 3. Fire perimeters from the period 2000 to 2016 from two different data sources. MTBS seems to report fires more reliably than GeoMAC in Pima County.

MTBS provides data on fire perimeters of 1,000 acres or greater, including prescribed fires (MTBS 2017). It seems that there is a lag time of about 18 months for successive years' release of data (e.g. the 2016 data were released on August 3, 2018). MTBS data are also free and consistent over time, since they are based on Landsat imagery. There is a high likelihood that this program will be maintained in the future, making it useful for the Landscape Pattern Monitoring element of the EMP. If MTBS is not continued, then Pima County will rely on GeoMAC or another federal successor program.

MTBS will be queried every five years to identify the location of new (post-permit) fire perimeters relative to County preserves. Additionally, any large fires that occur on County preserves would likely be reported in that particular year's MSCP annual report to the USFWS. If direct mortality of covered species or impacts to covered species habitats due to wildfire has been verified by field observations, we will also advise USFWS of this in our reporting of the changed circumstance in the County preserve or preserves.

Assuming there is no direct observation supporting mortality of covered species, we will review evidence for long-lasting habitat impacts. If MSCP mitigation land or potential mitigation lands are affected and the total acreage of the fire appears to exceed 1000 acres in size, an analysis of land cover impacts will be performed using remote sensing products described below, when those are made available. Because some fires will not result in vegetation or soil changes that

are apparent or persistent enough to be considered a change in land cover by remote sensing, it is not anticipated that a changed circumstance will be confirmed each time a County mitigation property is burned.

The fire effects occurring on MSCP mitigation land or potential mitigation land will be analyzed and reported using MTBS. The MTBS dataset is developed by first compiling fire occurrence data from federal and state land management agencies in order to identify candidate fires. For fire events that meet MTBS' 1,000-acre minimum, corresponding Landsat scenes are selected based upon the reported location and ignition date. Pre- and post-fire scenes are then evaluated. The burned area boundary is delineated manually by an analyst who looks for any detectable fire area based on the base reflectance imagery as well as the differenced Normalized Burn Ratio (dNBR) and relativized dNBR (RdNBR) burn severity values derived from the prefire and postfire scenes. Thus the perimeters will be different and presumably more accurate than the GeoMAC-derived perimeters which are not estimated in this manner. The MTBS program also publishes burn severity data for each fire.

The perimeter data from MTBS will be used in conjunction with changes in NCLD Land Cover to evaluate significant changes in vegetation structure during ensuing years. A gross change in NLCD Level 1 classification for any portion of the total burn polygon area, such as a conversion of woodland to grassland or grassland to bare ground, will be evaluated for a potential changed circumstance if it persists for five years or longer. Changes will be evaluated in light of the ecological site state-and-transition models for the locations, and their effects on covered species. Pima County will discuss any potential changed circumstances with USFWS in the context of covered species distributions and habitat impacts to determine whether an actual changed circumstance has occurred.

If a new post-fire NLCD Land Cover product is not available at each five-year review period, then LANDFIRE data may be used. A significant change in the overall composition of the Existing Vegetation Types (*EVT_Order* in LANDFIRE) for any portion of the burn polygon will be considered a potential changed circumstance warranting further discussion with USFWS. In the first five-year reporting period (2021), if neither product is available, we will examine pre-permit fires located in the MSCP mitigation properties (mainly Sands/Clyne Ranch) to see if previous fires have caused persistent effects to the 2016 baseline.

Effluent-reduction Vegetation Analysis along the Santa Cruz River

The objective of this analysis is to detect certain changes in vegetation related to decreased discharge of treated sewage (effluent) discharged downstream of the Agua Nueva wastewater treatment facility. The effluent discharge helps to support some of the most extensive riparian vegetation and the longest and largest perennial flows of water in the permit area. Extensive upgrades to the County's sewage treatment facilities were completed before the Section 10 permit was issued, resulting in a higher quality of effluent discharge, and changes in the ratio of discharges at the two treatment facilities.

In 2019, City of Tucson began diverting their effluent from Agua Nueva to a discharge location downtown. This discharge is not a County action and is not part of this monitoring protocol. However, any uses or diversions from the Agua Nueva or Tres Rios facilities by effluent owners have the potential to reduce effluent discharge to the Lower Santa Cruz River. Continued

discharges of effluent to the river depend on actions by various entities, principally City of Tucson and U. S. Bureau of Reclamation.

The drivers of vegetation structure and composition along the effluent-dependent Santa Cruz River are flood-related erosion and deposition, discharge of effluent, groundwater pumping and land use history (particularly mechanical disturbance) (Pima County Regional Flood Control District 2013). In the absence of disturbances such as erosion, dredging or other mechanical disturbance, floodplain sand and gravel bars become progressively more stabilized by vegetation. Such vegetation can be important for covered species such as Abert's towhee and Bell's vireo, though the text of the changed circumstance points to riparian forests that might eventually serve as habitat for covered species such as the cuckoo, and aquatic covered species such as Gila topminnow, which were detected and reported to USFWS in 2017.

Pima County will use information from Pima County's Effluent Generation Report to identify and report post-2016 reductions in effluent discharge from County treatment facilities to the Santa Cruz River on an annual basis. Calendar year 2016 provides a cumulative permit issuance baseline discharge of 41,789.42 acre-feet from the treatment facilities (33,678.13 from Tres Rios, and 8111.29 from Agua Nueva).

Effluent reductions have occurred since the permit was issued. We know that the effluent discharged to the Santa Cruz River was reduced at both Agua Nueva and Tres Rios in 2017, to 39,590.10 acre-feet. For example, there were 67 dry days at Trico Road (a location downstream of both water treatment facilities) in water-year 2016 versus 109 days for water-year 2017 (the 2016 water year ended September 30). The Regional Flood Control District (Pima County 2017) identified no change in June base flow length for flow downstream of Agua Nueva, and a reduction in flow length downstream of Tres Rios. These reductions may have reduced available habitat for the Gila topminnow in the Tres Rios reach (downstream of Ina Road).

One explanation for the reduction of discharge since 2016 (the permit baseline) is that total inflows of untreated sewage diminished by about a thousand acre-feet (Pima County 2017). This explains about half of the reduced discharge. Water-efficient appliances installed by consumers and businesses are thought to be responsible for the observed long-term trend in reduced indoor consumption of water, and hence sewage production (Mayer 2017). When the decline in water consumption and sewage inflows first began, the reductions upended expectations that sewage volumes would always expand with population growth. Now the question is when this trend of diminishing inflows tied to increasing appliance efficiency will end. Other factors such as diversion of flows to constructed recharge or reclaimed water lines also reduce the discharge to the river.

Effluent discharge has decreased, and will probably continue to do so, but this does not mean a changed circumstance has occurred for vegetation according to the terms in Table 7.1 of the MSCP. If effluent discharge continues to decline, we will evaluate aerial photographic imagery against a baseline to interpret whether riparian forest loss has occurred, and whether this can be linked to reduction of effluent discharge that occurred after 2016.

Vegetation loss can result from other factors such as channel-bed clearing, removal of vegetation, increased infiltration rates, or decreases in natural runoff due to recent floods or drought. A combination of factors will be likely sources of increases or decreases in vegetative

cover classes along the Santa Cruz River. Pima County will report a changed circumstance when a decrease in area of riparian forest below the baseline is thought to be primarily driven by reduced discharges at the two County treatment facilities, rather than flood flows or other factors.

The NLCD 2016 was tested as a baseline for land cover class change from or to emergent herbaceous wetland, water and woody wetlands along the Santa Cruz River from Grant to Trico Roads. Although previous testing of 2011 and earlier NLCD datasets detected subtle changes in woody wetlands (Fonseca 2008, 2009), NLCD 2016 proved to be insensitive to many obvious reductions in water and woody wetlands based on comparison with high-resolution aerial imagery collected by Pima Association of Governments for similar time frames, at least for the time period 2011 to 2016. Thus, 2016 NLCD will not be used as a baseline to evaluate the changed circumstance.

We also evaluated the LANDFIRE Existing Vegetation Type dataset as a baseline for the effluent-dependent Santa Cruz River downstream of Agua Nueva. The North American Warm Desert Riparian Forest and Woodland class name in LANDFIRE *EVT* appeared to capture this type in the Cienega Creek Natural Preserve, but the vegetation classes along the effluent-dependent Santa Cruz River were classified as herbaceous or shrub, and appeared relatively insensitive to forest or woodland types. This data source was therefore rejected for a baseline.

In 2018, Pima County Regional Flood Control District and the Chesapeake Conservancy (Chesapeake) team classified imagery and LiDAR from 2015 and 2016 into a GIS layer known as LULC2018. The classification uses the following land cover classes: water, trees/shrubs, irrigated lands, desert, barren-bedrock, impervious, structures, and roads. We will use the tree/shrub class as our baseline for interpreting vegetation changes along the Santa Cruz River, and then evaluated changes based on successive PAG or other aerial imagery posted to PimaMaps. If RFCD elects to repeat their land use/land cover analysis based on Chesapeake's algorithms (Allenby and Phelan, no date), we will report changes from that source as well, when it becomes available.

Changes in Regional Road Networks

The primary purpose of regional road network analysis is to detect changes relative to fragmentation of the Maeveen Marie Behan Conservation Lands System by major roads, and to consider the trajectory of potential urban growth during the decennial review. This protocol will not be used to determine changed circumstances relating to grading of roads inside Preserves. The latter will be addressed at a more granular level through biennial inspections, threats monitoring and ongoing ranch road inventories and reported at a gross level through the NLCD analyses.

Changes in the regional road network will be identified for Pima County every three to five years (Table 5). The 2021 analysis will use 2016 as a baseline. Figure 4 presents the baseline road network for 2016. The baseline road network consists of data layers maintained by Pima County, supplemented with information from other sources. At present, our baseline will use the layers Street Network (*stnetall*) and Street Miscellaneous (*stmisc*). Street Network is maintained daily; Street Miscellaneous is maintained whenever there is a change or addition to unnamed streets in Pima County.

Table 5. Road Network Analyses for Pima County MSCP

Analysis	Rationale
Incursion of new roads into the Maeveen Marie Behan Conservation Lands System, relative to unincorporated and incorporated areas	The CLS guidelines are intended to minimize post-permit incursions into the CLS, but land-use authority of Pima County applies mainly in unincorporated Pima County
Location of post-permit CIP road projects relative to the Maeveen Marie Behan Conservation Lands System	The permit authorizes road work undertaken by Pima County in areas outside its land-use authority
Paving of unpaved roads since permit baseline, intersected with County Preserves and MSCP Restricted Covenants	The permit authorizes road paving by Pima County, but MSCP RCs forbid it except in limited circumstances.

To support the decennial review, analyses of core NPScape metrics (NPS 2013) such as road density, distance from roads, and roadless areas will also be considered by Pima County at its discretion, and with input from the STAT.

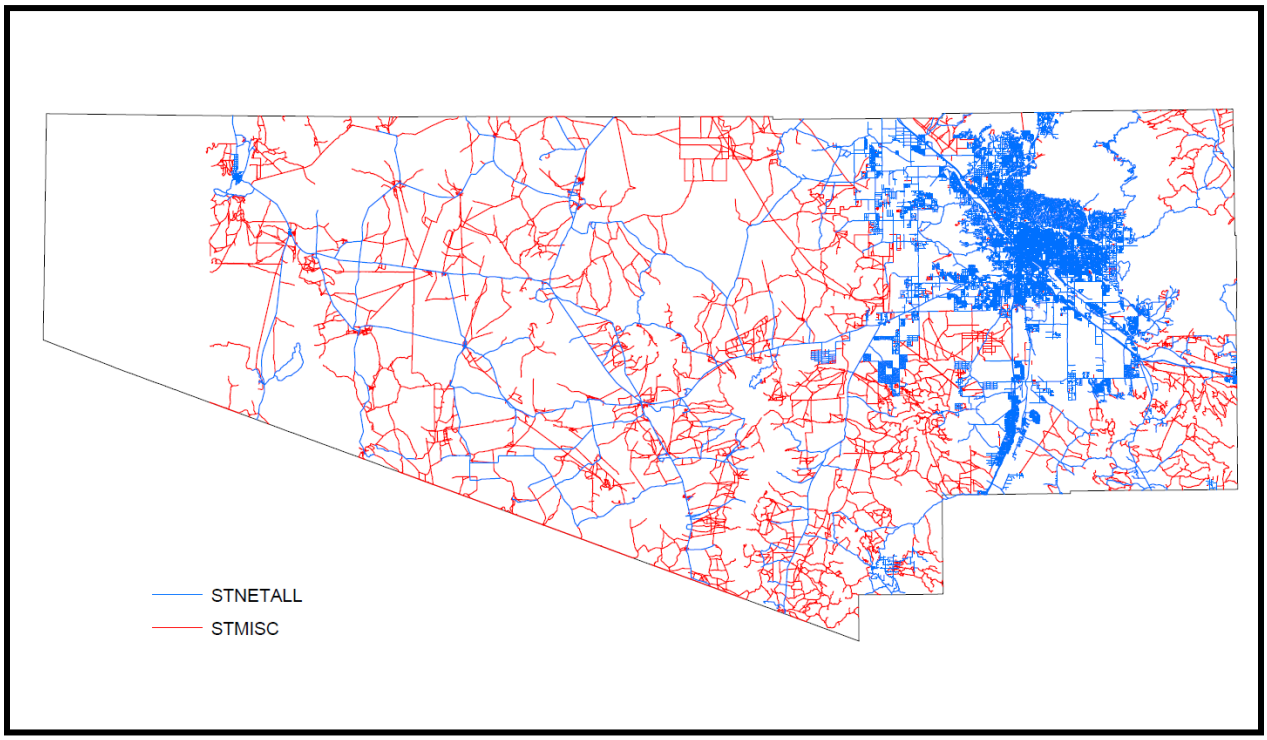


Figure 4. The 2016 baseline for the road network in Pima County, Arizona is comprised of two different GIS layers (*stnetall* and *stmisc*).

Changes in Sewer Networks

The primary purpose of sewer network analysis is to detect changes relative to intensification of land use in the Maeveen Marie Behan Conservation Lands System (CLS) during the decennial review. Sewered areas support much higher density development than do unsewered areas. To the extent that the County Board of Supervisors keeps the sewer system out of the CLS via exercise of its discretion during land-use planning authorities, the fragmentation of the reserve design will be minimized. Thus, the results will be useful for both retrospective as well as prospective views of land-use change in relation to Pima County's strategic investments in this important urban infrastructure.

Retrospective analyses

Pima County IT maintains the sanitary sewer network (*wwm_sn*) on a daily basis at a scale of 1:200. A copy of the 2016 sanitary sewer network (*ssn_cl*) has been created and archived. This is represented in Figure 5, relative to the CLS. Figure 6 shows development of the sewer network over time. The sewer baseline does not include systems owned by other entities such as Marana or those operated by private entities (Robert Shay, RWRD personal communication, Dec 2018). Incursions of the CLS by these authorities are beyond discretion of the Board. Abandoned portions of the sewer system are also not included in the baseline.

The baseline shapefile *ssn_cl* will be intersected with the current County sewer network every three to five years, and any post-permit incursions into the Maeveen Marie Behan Conservation Lands System will be reported retrospectively.

Prospective analyses

For the prospective analysis, the current Pima County RWRD Service Area (GIS layer *sewr_bnd*) will be intersected with the CLS. This shapefile is not maintained every year, as it changes slowly. The scale is also coarser, 1:24,000. Post-permit incursions of the RWRD Service Area into the CLS will be reported for decennial analyses. Changes in County sewer service area will also be compared at five-year intervals in between the decennial reviews.

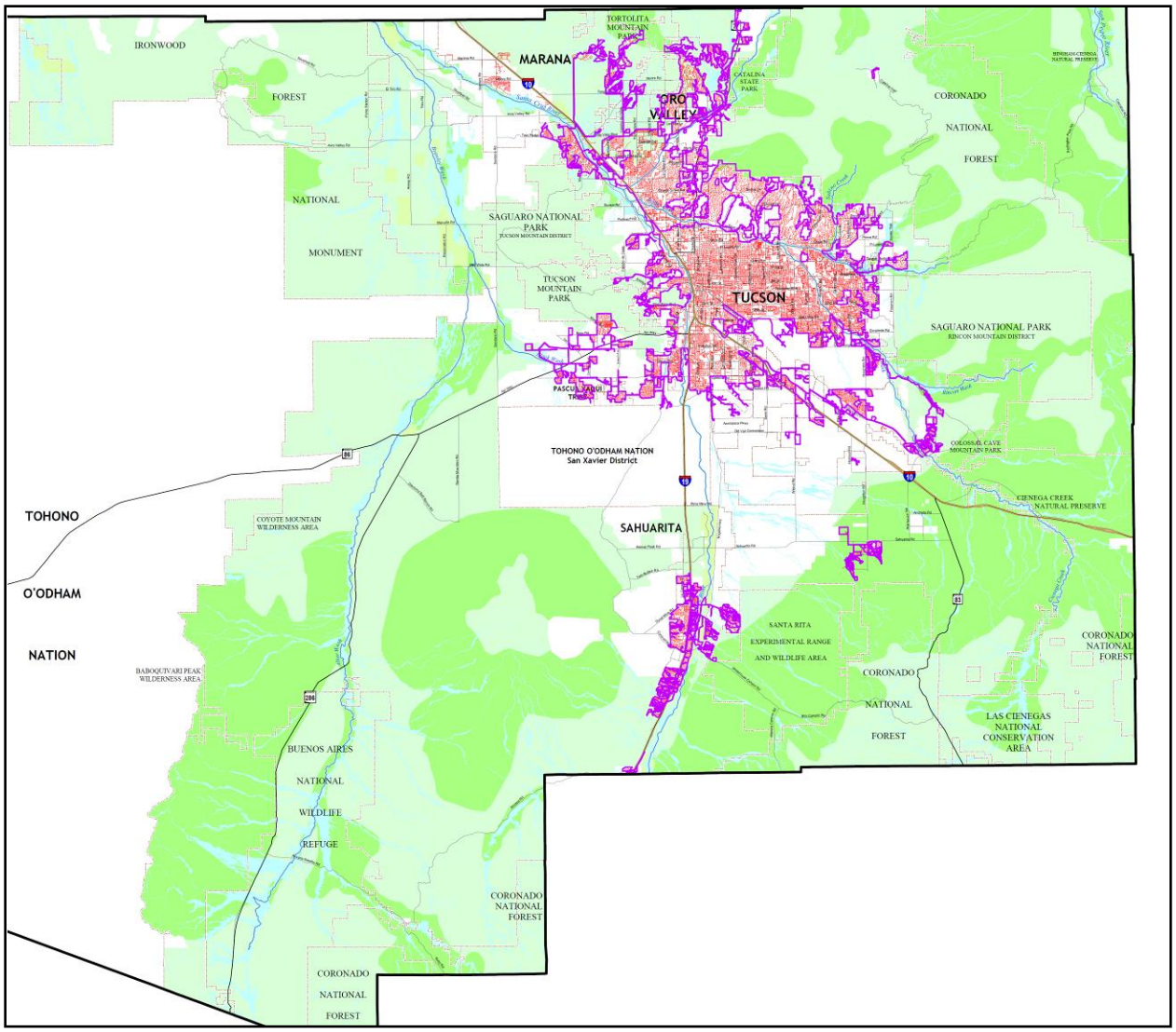


Figure 5. Area enclosed by the purple line (*sewr_bnd*) represents the sewer service area baseline in 2016 (*ssn_cl*). Red lines show the sewers within the service area as of 2016. Principal incursions in the CLS (light and dark green) are in the Corona De Tucson area, and the Tortolita piedmont.

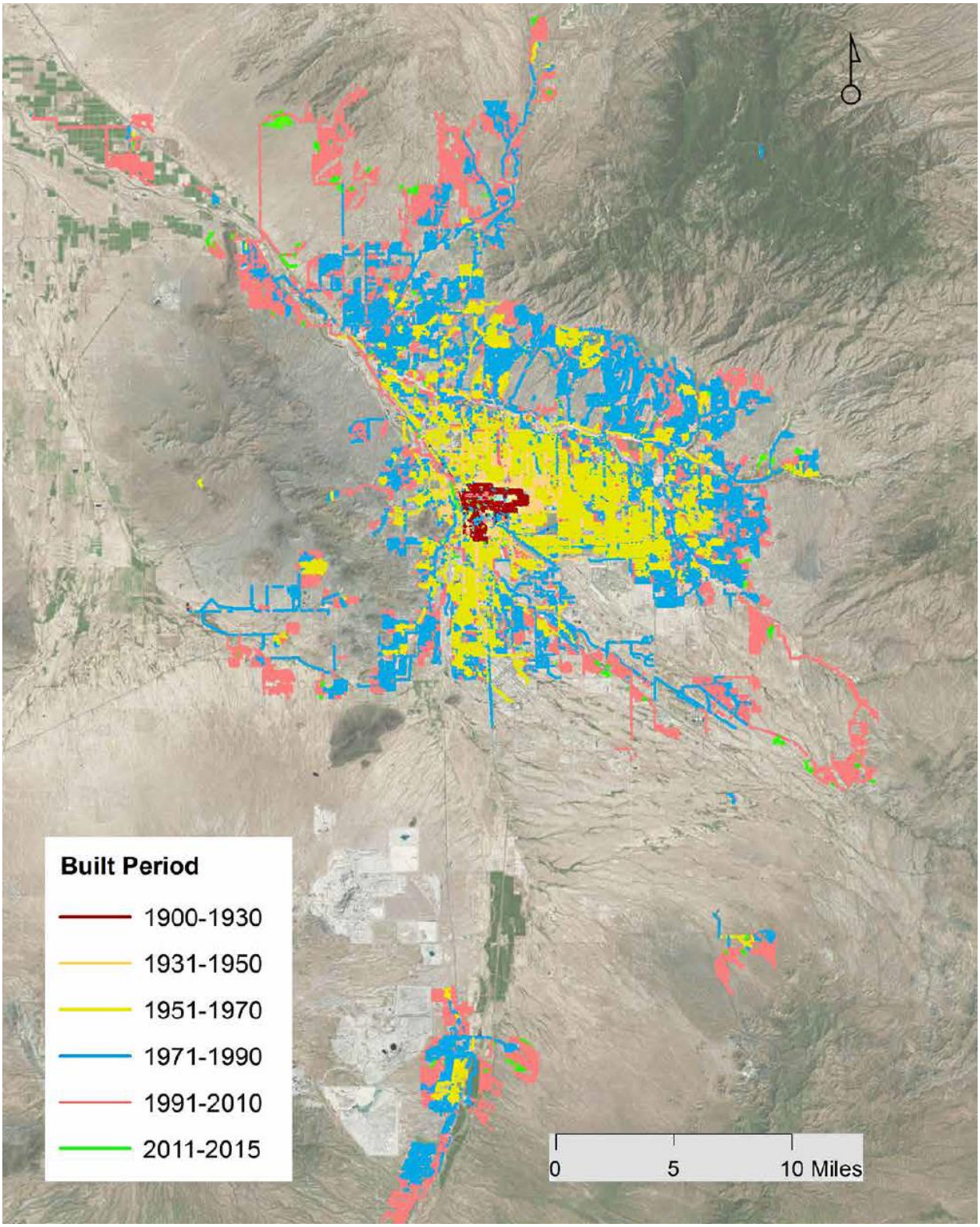


Figure 6. Sewer development prior to issuance of the Section 10 permit, 1900-2015 (map from Pima County 2016).

Future Development

The purpose of forecasting the location and extent of future development is to understand how future development may affect land cover that may support the habitat of covered species. This look at the direction of change will help inform the decennial reviews, including outside peer review.

Pima County will either use 1) population density projections and transportation plans provided by Pima Association of Governments (PAG) or 2) an updated land use model to measure and forecast development-related activities for the decennial analyses. Pima County's Comprehensive Land Use Plan growth areas will also be depicted relative to the CLS and analyzed relative to species PCAs. Other supplemental analyses will be at Pima County's discretion.

The baseline for population density distribution is provided by the 2045 PAG Regional Mobility and Accessibility Plan (RMAP). The RMAP was adopted by the regional governments on May 26, 2016. Existing and projected population densities for 2045 are shown below (Figure 7). For the most part, future patterns of growth are similar with a significant increase in density in the urban core, and large increases in population density near Houghton Road projected in the City of Tucson's Houghton Area and Esmond Station Plans. PAG is planning to complete the next update of the RMAP by 2020, and again in 2024 per federal regulations.

The update cycle begins with state population projections. The Arizona Department of Administration has recently updated population estimates for each county through 2055. The state projects a population of 1.28 million by 2055 for Pima County. This is a significant decrease of 250,000 from the future population projection used to develop PAG's 2045 RMAP. PAG's Population Technical Subcommittee is evaluating how population growth may be distributed across the county's landscape using updated information about land use, employment and demographics. PAG's modeling group will develop a revised scenario of changes in land use and regional development patterns to inform recommendations for addressing future transportation needs.

In developing the currently adopted 2045 RMAP, PAG considered three different future land use scenarios arranged along a continuum from lowest to highest density. Each of the scenarios considered the same number of future jobs and population, but evaluated different patterns of their distribution. New land developed varied from 98 to 315 square miles. The official growth scenario chosen is based on the general and comprehensive plans of each jurisdiction in Pima County adopted as of 2013. Under this scenario, an additional 234 square miles would come under development, including some portions of biological core management area lands (CLS land category with high biological value) south of the Interstate 10 along the axis of Houghton and Sahuarita Roads (Figure 9; lower right portion).

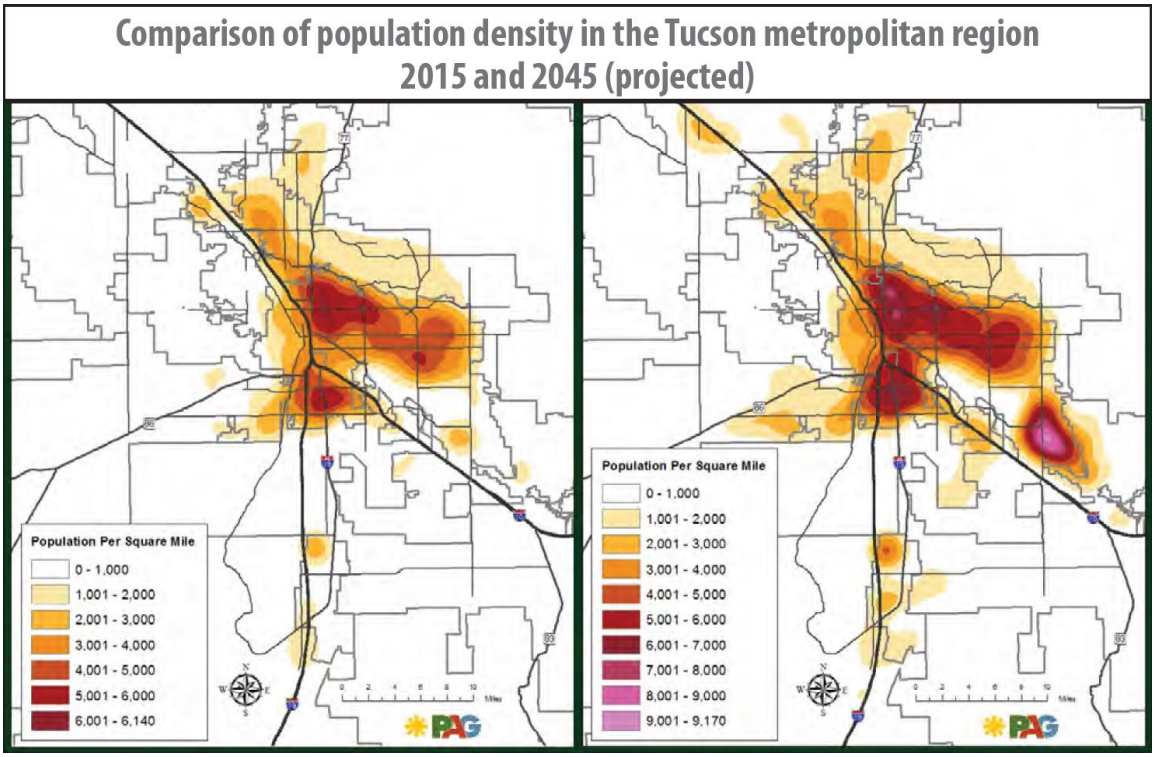


Figure 7. PAG's population density maps for 2015 and projected for 2045

The 2020 effort will be an update to the 2016 RMAP and will not undergo the extensive scenario modeling that PAG conducted as part of the 2016 adopted RMAP. The official growth scenario that we will use for this update will again reflect the adopted general and comprehensive plans of each jurisdiction in Pima County current as of 2017.

As part of the project selection and analysis phase of the 2016 RMAP, PAG mapped the list of preferred projects to be included and superimposed the project map over the regional biological resources identified in the Sonoran Desert Conservation Plan (see Figure 8 below). Of particular concern is the Sonoran Corridor State Route 410 through Pima Pineapple Cactus habitat, since most of the route is new, but it has the advantage of being located entirely out of the CLS. The other plans that affect CLS are for improvements to existing roadways in the CLS, in particular the Sandario Road through the Tucson Mitigation Corridor, and the roadways in the Rocking K Valley.

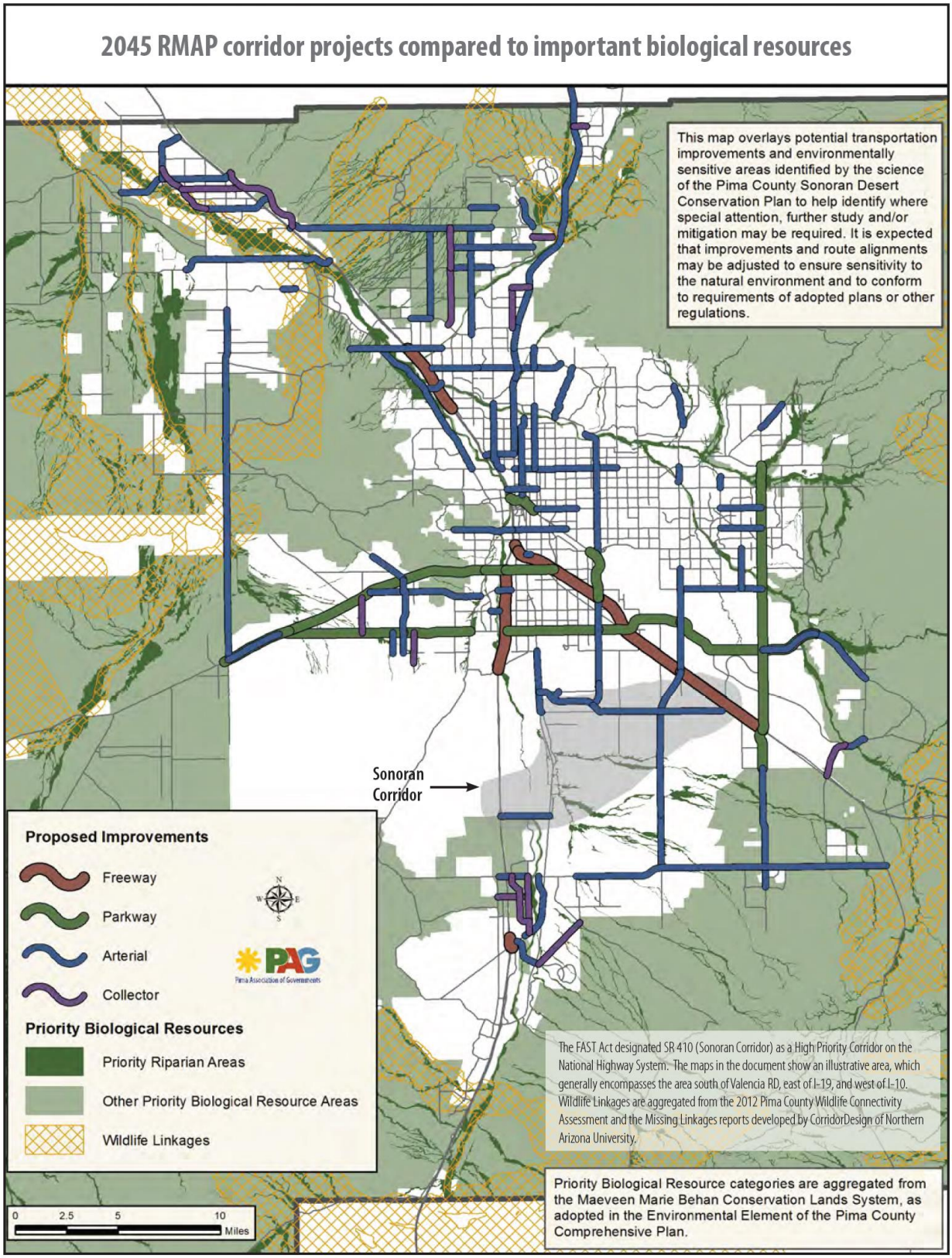


Figure 8. Location of projects relative to Maeveen Marie Behan Conservation Lands System categories (categories combined; gray-green color) and wildlife corridors (yellow checks). Map by PAG.

In addition, the proposed Interstate 11 has the potential to affect human population distribution, and alter wildlife connectivity. A Tier 1 Environmental Impact Statement (EIS) released early in 2019 recommends an alignment to bypass long-haul truck traffic around Tucson, but doing so could greatly affect the trajectory of future development along its path. The proposed alignment runs through State trust land west from Interstate 10 along the south boundary of the San Xavier District and north more or less along the Sandario Road parkway alignment shown on the RMAP figure. It cuts through the Tucson Mitigation Corridor, which was secured as mitigation for the wildlife connectivity impacts caused by the Central Arizona Project for Saguaro National Park and Tucson Mountain Park. An alternative alignment runs along the existing Interstate Highway 10, and this would not affect regional wildlife connectivity.

Figure 8 also reflects a general location for the future Sonoran Corridor that is consistent with the Congressional designation of the Sonoran Corridor as a High Priority Corridor on the National Highway System. No specific alignment was selected as part of the RMAP process so as not to bias the outcome of the current Tier 1 Environmental Impact Statement (EIS) process being conducted by ADOT. The study, which should conclude in 2020 will identify a single Preferred Alternative Corridor that is expected to be 2000 feet in width. The future roadway alignment would then be located within that 2000 feet as determined by additional studies and design work, either as a whole or in separate projects. More information on the Tier 1 EIS can be found on ADOT's website https://www.azdot.gov/planning/transportation-studies/sonoran-corridor-tier-1-environmental-impact-statement/overview).

Every ten years or so, Pima County is required to complete a revision of its Comprehensive Land Use Plan per state statute. As part of this plan, the County must identify to the state areas that it wishes to target for growth or re-development. Pima Prospers, which was completed in 2015, is the baseline for the Section 10 permit, but was not included in the 2016 RMAP. Figure 9 summarizes the areas where Pima County is focusing investments in infrastructure that are intended to foster growth or re-development. All areas are outside the CLS except for a portion of biological core and certain Important Riparian Areas southwest of Tucson. Avoidance and minimization of IRAs is accomplished through the Floodplain and Erosion Hazard Management Ordinance and the Floodprone Acquisition Program. Pima County also purchased and restricted some parts of the biological core management unit lands from development.

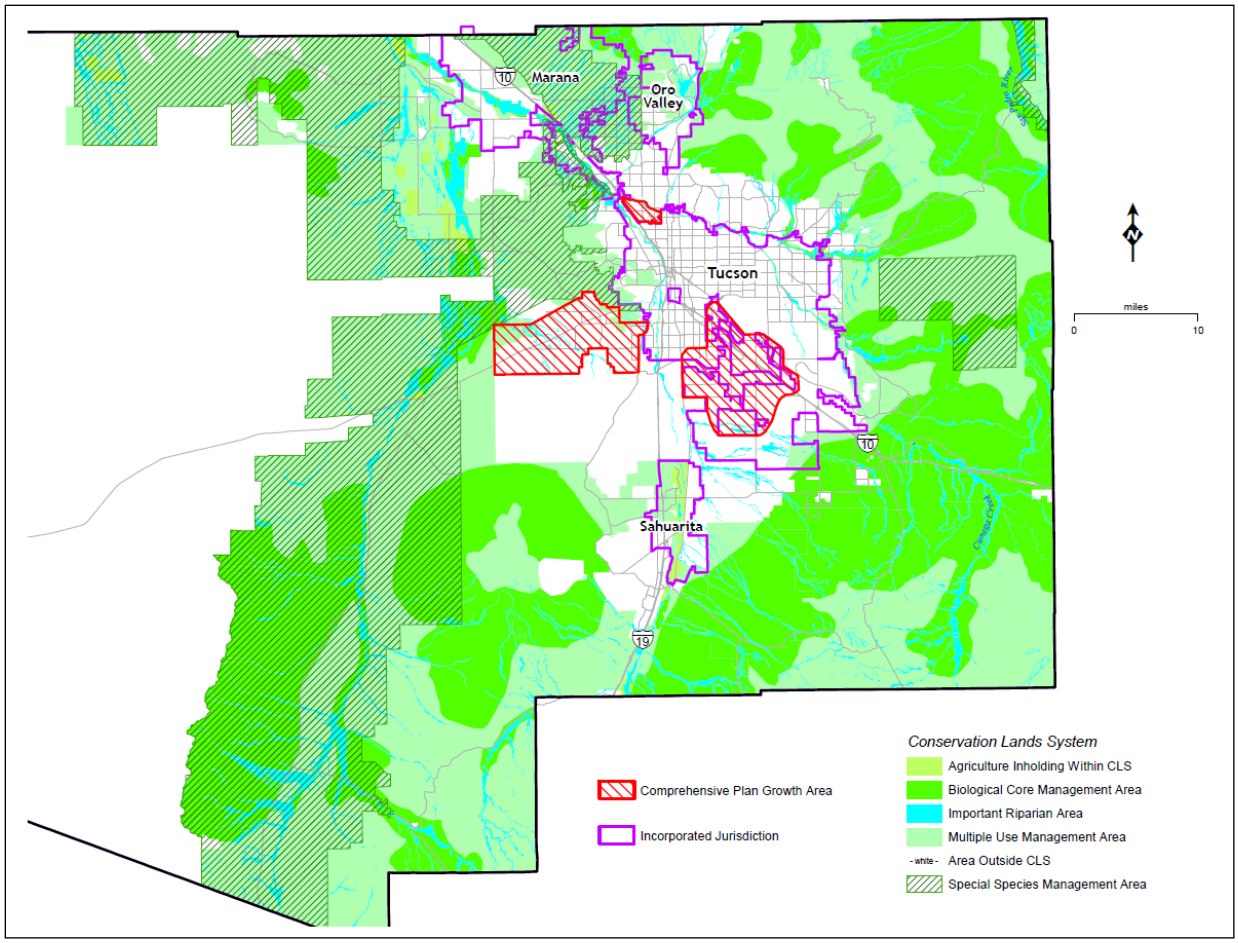


Figure 9. Growth areas (red) identified in Pima County's Comprehensive Land Use Plan relative to the Maeveen Marie Behan Conservation Lands System categories and incorporated boundaries.

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Pima County
Multi-species Conservation Plan:
2019 Annual Report

Appendix 11

Pima County Monitoring Protocol for Tracking Invasive Plant Occurrences

68 pages

Pima County Ecological Monitoring Program's Monitoring Protocol for Tracking Invasive Plant Occurrences

June 2020

PIMA COUNTY
SUSTAINABILITY & CONSERVATION

Prepared by Pima County Office of Sustainability and Conservation Staff:
Amanda D. Webb

Cover photo: Fountain grass (*Pennisetum setaceum*) fills in spaces among native plants in Espiritu Canyon on A7 Ranch in the Santa Catalina Mountains, Pima County, Arizona.

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Executive Summary

Pima County, part of a larger region known for its high biodiversity, harbors many unique species and ecological communities across its iconic landscapes. These natural resources are threatened by invasive, nonnative plants that out-compete native plants, alter ecosystem processes, and degrade wildlife habitat. The Pima County Multi-Species Conservation Plan (MSCP) outlines conservation measures that the County is undertaking to preserve and enhance 44 plant and animal species of conservation concern and their habitats. The MSCP commits Pima County and the Regional Flood Control District (County collectively) to collect monitoring observations on and prepare a database for 15 to 20 of the most important invasive plant species that all appropriate County staff and cooperators should be able to identify during vegetation monitoring occurring in the Preserve network. This protocol provides information on 25 invasive plants that are a priority for monitoring and management across Pima County conservation lands, and lays out a process by which the County will monitor them. Recommendations for prioritizing management actions are also included.

The purpose of this protocol is to create a process by which Pima County can:

1. **Detect the spread of the most harmful invasive plants into new areas;**
2. **Detect new invasions early when they can be controlled more easily;**
3. **Store and share data on invasive plant occurrences across departments in a geodatabase that can be used to inform the development of management plans and the coordination of invasive plant control efforts, where appropriate and feasible.**

To narrow down the long list of invasive plants known to occur in and around Pima County into a short list of the most important species for monitoring and management, we consulted with partners within and external to Pima County departments to get feedback on selected species, and reviewed other available resources including reports, field guides, and other databases. As part of our justification, we focus largely on invasive plants that are the most likely to impact vegetation and ecological processes such that they can lead to an ecosystem type conversion (e.g., buffelgrass increases fine fuel loads and increases fire frequency, which leads to the mortality of native vegetation while perpetuating the spread of buffelgrass, thus changing the ecosystem from desert or thornscrub to a nonnative-dominated grassland). Our assumption is that the conversion of ecosystem types would trigger direct and indirect negative impacts to covered species and their habitats. We also incorporate all 10 focal species of the Sonoran Desert Cooperative Weed Management Area (SDCWMA), a partnership led by the Arizona-Sonora Desert Museum that strives to focus on species that local partners are concerned about the most. Finally, several species included in this protocol are designated as noxious weeds by the state of Arizona.

Pima County's ecological monitoring program (EMP) supports the MSCP by tracking ecological conditions, stewardship effectiveness, and the status of covered species across the County's conservation lands. Under the MSCP, the EMP is required to develop a protocol that addresses

surveillance for the presence of invasive plants. The EMP will accomplish this by: leveraging data collected at long-term plots for soils and vegetation monitoring; collecting invasive plant data opportunistically while carrying out other monitoring protocols, property assessments, and other operations in-the-field; utilizing data collected by other organizations that are freely available online; through regular communications with partners at the local, state, and federal levels.

Although the EMP collects data in support of the MSCP, other Pima County departments, primarily the Pima County Regional Flood Control District (RFCD) and Natural Resources, Parks and Recreation (NRPR), also collect data on invasive plant occurrences. The EMP does not directly implement invasive plant control. In contrast, both RFCD and NRPR have invasive plant management responsibilities with multiple on-going projects across the County lands that they manage. To help facilitate data sharing (i.e., get EMP's observations to NRPR and RFCD so managers can use those data to implement control strategies) EMP is developing a geodatabase where these data can be stored and viewed. Furthermore, the EMP is working with the County's GIS technical team to create an automated script that will make these data available to the relevant managers on a daily basis. These procedures and processes are meant to ensure that County land managers are kept up to date on the most current status of invasive plant occurrence on County lands, particularly as it relates to any emerging threats warranting rapid response.

Our recommendations to managers include developing a strategic management plan for tackling invasive plants. Treating new infestations early is likely to save time and money in the long run. Plans should have clearly defined objectives, but be flexible to allow for improvements when new information becomes available. Partnerships, cross-boundary collaboration, and volunteers will likely continue to be critical elements of success. We recommend maintaining an ad hoc, interdepartmental working group focused on invasive plants to help provide a forum for discussion among staff at OSC, RFCD, and NRPR.

To help County managers develop robust control strategies, we present information about each of the invasive plants highlighted in this report, what ecosystems they are known to invade, what their general status is, as well as particular County conservation lands where they have been observed. We also describe the key resources associated with several covered species, and which invasive plants may pose the most immediate threat to their habitats. Other portions of this protocol which may be of use to managers are a list of operational and logistical considerations for prioritizing treatments, and the identification of existing resources on developing invasive plant management plans and criteria for selecting the highest priority species on which to focus. The bibliography also provides some additional management resources that may be useful.

Acknowledgements

I thank my colleagues in Pima County for their past, current, and future due diligence in their reporting of species of interest on Pima County open space lands. I thank Ian Murray and Julia Fonseca for their valuable input on multiple aspects of this protocol. I thank Jeff Gicklhorn for his significant contributions toward the development of data management strategies, and for producing the maps herein depicting documented locations of buffelgrass and fountain grass on Pima County conservation lands. I thank Jennifer Becker, Carianne Campbell, and Gita Bodner for their thoughtful reviews of this document. I thank Brian Powell, Doug Siegel, and Rachel Loubeau for input on the species included in this protocol, their impacts, and their whereabouts on County conservation lands. Marisa Rice provided sustained input on elements ranging from relevant invasive species to development of digital datasheets and data management. I thank Don Swann for his comments on invasive species in the region that are important for monitoring. I also thank Pima County IT GIS, especially Mike List, Elisabeth Van Der Leeuw, Becky Steinnecker, and Pankaj Jamwal, for their continual efforts to build and improve the ecological monitoring program's geodatabase, as well as for assisting the monitoring program with other GIS-related needs like producing map products and providing assistance with digital data collection best practices and hardware.

Background

Nonnative invasive plants and their detrimental impacts on naturally functioning ecosystems across the landscape are an increasing threat to native plants and wildlife worldwide. They can out-compete native plants, alter ecosystem processes such as fire and nutrient cycling, and affect food web structure. Invasive plant infestations can also bring about economic impacts by affecting recreational experiences, agricultural production, and increasing fire hazards in housing developments, industrial areas and on military bases. Pima County has highlighted management of invasive plants, specifically buffelgrass, as critical to the conservation of the diverse and unique ecological communities of the region. Monitoring is needed to inform management. It is the means by which County staff can detect invasive plants, track their movement over space and time, and assess the threats they pose to valued resources. This document lays out the protocol that Pima County staff will follow as it carries out its commitments for invasive plant monitoring, as described in the Pima County Multi-Species Conservation Plan (MSCP). Furthermore, this protocol provides land managers in Pima County with information intended to help them make effective management decisions given the large scope of the invasive plant problem, the vast area covered by County preserves, and the limited resources available to apply towards this issue.

By implementing the MSCP, Pima County remains in compliance with the Endangered Species Act through its Section 10 Incidental Take Permit issued by the US Fish and Wildlife Service (USFWS) in 2016 (Pima County 2016). The MSCP covers 44 species (covered species) that are federally listed as threatened or endangered, or otherwise recognized as species of conservation concern due to factors such as their limited distribution and risk of rapid decline due to threats like habitat destruction. The MSCP was developed as part of Pima County's broader Sonoran Desert Conservation Plan (SDCP), in which a stated goal is to ensure that the full range of native plants and animals continue to occur on the County's conservation lands. The species covered under the MSCP include amphibians, birds, fish, mammals, reptiles, and plants. For many of these species, invasive plants and their associated impacts are a major threat to their persistence.

Pima County's ecological monitoring program (EMP) is a crucial part of the MSCP because it allows the County to track ecological conditions, the effectiveness of its stewardship, and the status of covered species across County conservation lands. Under the MSCP, the EMP is required to develop a protocol that addresses surveillance for the presence of invasive plants across County conservation lands. Additionally, Pima County's MSCP identifies a set of changed circumstances that could potentially arise and that would impact covered species or their habitats (Table 7.1, Pima County 2016). Several of these changed circumstances are related to the potential impacts caused by invasive plants. Changed circumstances will be discussed in further detail later in this report along with the County's potential responses to these problems.

As stated in Table A-2 of the MSCP, the EMP has committed to developing a database for recording species observations for 15-20 of the most important invasive species that all appropriate County staff and cooperators should be able to identify. These invasive plants are

to be surveyed for in and around all long-term monitoring plots at the same time as vegetation monitoring. Furthermore, the County has committed to assisting local, state, and federal partners in Pima County with mapping and monitoring buffelgrass. This protocol addresses these commitments, but also goes beyond them by: including additional opportunities for collecting field data; utilizing field data collected by other individuals and organizations; providing an assessment of 25 species that are a high priority for management; providing a list of key resources and associated geographic areas that are critical for MSCP covered species and should ideally be protected from invasive plants; and providing a list of operational and logistical considerations to help inform prioritization of management projects. The EMP is providing these additional data, recommendations, and considerations in an effort to assist the County's orchestration of a management response to invasive plants on more than 250,000 acres of conservation lands and other County-owned properties, which is very difficult given limited resources. As conditions change on-the-ground and new information about the impacts of invasive plants on MSCP covered species are discovered, this protocol may, and should be, updated.

Purpose

The purpose of this protocol is to create a process by which Pima County can:

1. **Detect the spread of the most harmful invasive plants into new areas;**
2. **Detect new invasions early when they can be controlled more easily;**
3. **Store and share data on invasive plant occurrences across departments in a geodatabase that can be used to inform the development of management plans and the coordination of invasive plant control efforts, where appropriate and feasible.**

Ecosystems of Pima County

The ecological requirements for the persistence, spread, and harm posed by invasive plants varies from species to species, and are dependent on site-specific conditions. To help guide treatment and monitoring efforts, it is helpful to understand what ecosystems occur in Pima County, and which of them an invasive plant is most likely to impact. The table below summarizes major ecosystems that occur in Pima County (Dimmit 2000). The upland systems are considered biomes, as described by Dimmit (2000). The riparian zone includes many different riparian vegetation communities owing to the great diversity of vegetation types that occur in riparian zones across elevations and latitudes (Dimmit 2000). The upland ecosystems have been stratified by elevation as a proxy for biome-level plant communities to structure vegetation and soils sampling in NPS's long-term monitoring protocol for parks in the Sonoran Desert Network (Hubbard *et al.* 2012), which Pima County has adapted for its own use (Gicklhorn 2020). This design will allow the County to analyze change over time in each upland ecosystem type individually (Figure 1). While these broad delineations are helpful for analyzing vegetation change in the context of other environmental factors (e.g., climate, land use, etc.), the reality on-the-ground is that plant communities are more complex, with transition zones of overlapping vegetation types that do no adhere to strict elevation boundaries. For finer-scale classifications of ecosystem types, see Ecological Site Descriptions produced by the Natural

Resources Conservation Service (https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/desc/).

Table 1. Ecosystems of Pima County with notes on the elevations at which they are typically found, vegetation characteristics, and natural disturbance regimes.

Ecosystem	Approximate Elevation (ft)	Plant Community Characteristics	Disturbance Regimes
Desert	0 – 2,500	Cacti; annual grasses and forbs; some shrubs (mesquite, acacia, creosote bush) but not dense	Low fire frequency, drought maintains considerable open space around most plants
Thornscrub	2,500 – 3,700	Shares many of the same species found in Desert but with more succulents, more shrubs, and fewer herbaceous species and annuals; agave, yucca, and paloverde more common	Low fire frequency, drought-resistance is high
Semi-desert grassland	3,700 – 4,500	Perennial short- and mid-grasses; annuals; occasional shrubs and trees	High frequency fire is important for maintaining grassland characteristics, drought reduces perennial grass cover, infrequent prolonged freezing can affect mesquite
Interior chaparral	3,700 – 4,500	Dense shrubs including manzanita and shrub live oak	Fires are stand-replacing and occur on average every 125 years (Fryer et al. 2012), drought can exacerbate fire
Madrean evergreen woodland	4,500 – 6,000	Oak, pinyon pine, juniper; perennial grasses	Low severity fires common with stand replacing fires occurring every 65 years on average (Fryer et al. 2012), drought can exacerbate fire
Xeric riparian	0 – 6,000	Some species similar to adjacent uplands but more dense and robust life forms; woody species may include mesquite, desert willow, netleaf and desert hackberry, paloverde, oak, and desert broom	Intermittent flooding; fire regimes influenced by those in adjacent uplands and the plant-scouring action of flooding that may decrease fuel continuity; drought
Mesic riparian	0 – 6,000	Variable; may be herbaceous-dominated (sedges, cattails), woody-dominated (cottonwood, Goodding's willow, mesquite, velvet ash, walnut, netleaf hackberry), or mixed	Seasonal or more frequent inundation with flooding common; fire regimes highly variable depending on vegetation structure and composition, and influenced by fire regimes in adjacent uplands; drought effects are moderated by available water including shallow groundwater where present

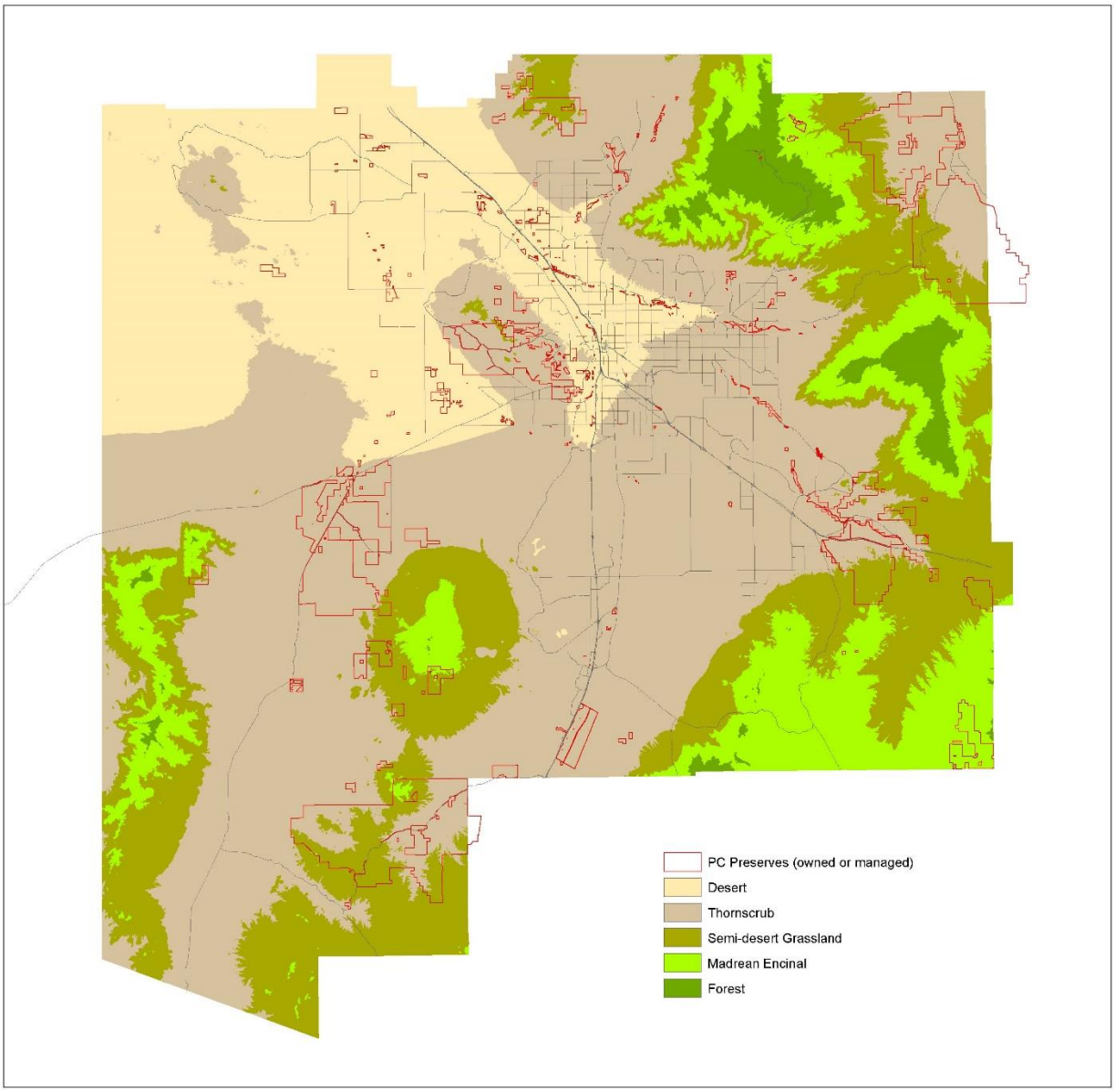

Figure 1. Geography of terrestrial biomes across eastern Pima County. Categorization uses elevation as a proxy for biome, as presented in Hubbard et al. (2012). Corresponding elevations are listed in Table 1. For information on riparian areas in Pima County, see RFCD's Regulated Riparian Habitat Mitigation Standards and Implementation Guidelines (https://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Environmental%20Quality/Water/Stormwater/2011_RFCD_RiparianHabitatProtectionMitigationGuidelines.pdf).

Assessment of Current Management Programs and Procedures

While the Conservation Science Division of Pima County's Office of Sustainability and Conservation houses the EMP and is responsible for compliance monitoring under the MSCP, the management of invasive plants on County conservation lands is undertaken by other Pima County departments. The Natural Resources, Parks and Recreation (NRPR) department manages most of the County-owned parks, trails, preserves, rangelands, and grazing leases.

Among many other responsibilities, staff at NRPR coordinate and lead invasive plant removal projects on the lands they oversee, primarily on fee-lands. For example, NRPR is currently developing a long-term strategic plan for invasive plant species management across County open space lands, including a summary of the invasive plant efforts of County open space lands over the last 20 years, creation of an application targeting real-time reporting of invasive species mapping, removal, and monitoring, as well as creation of a functional, accessible, and long-term central database for management and monitoring of invasive species. Additionally, the Pima County Regional Flood Control District (RFCD) engages in invasive plant monitoring and removal projects in their efforts to protect and enhance floodplain function across a sizeable network of floodplains, constructed restoration projects, and open space lands. Projects are generally focused on minimizing flood and fire risk while providing habitat for native species and passive recreational opportunities for people. The District is currently developing a floodplain management plan for unincorporated lands in Pima County. Among many objectives, the plan includes invasive species management.

Due to the complex nature of designing and implementing floodplain projects and limitations on staff resources, RFCD accomplishes much of its restoration project work with professional contractors, but uses NRPR Operations Division staff, contractors, and groups such as the Arizona Conservation Corps and the Pima County Summer Youth Group for land management actions including invasive species removal. Just recently, the RFCD received a large grant from the Arizona Department of Forestry and Fire Management for invasive plant species control on County-managed lands, particularly targeting monitoring and re-treatment of known infestations.

In addition to work organized and done by County field staff, NRPR regularly engages the public in volunteer projects. For example, a stakeholder citizen group called the Sonoran Desert Weedwackers meets three times per month to conduct invasive plant removal in and around the Tucson Mountain Park. NRPR staff provides tools and equipment, education on plant identification and safe removal techniques, and works with the group in-the-field on projects taking place on County property. Pima County collaborates with Tucson Clean and Beautiful to allow volunteer groups access to County-owned lands for invasive species removals, but these groups must demonstrate trained expertise and function relatively autonomously. As with RFCD, NRPR also hires youth corps work groups (i.e., Arizona Conservation Corps) that spend a portion of their time on invasive plant removal.

Despite the opportunities County staff seize to engage in invasive plant removal, staff availability for this is limited as they have multiple responsibilities and a large geographic area with substantial area of remote and rough terrain. Although the County actively seeks funding opportunities that can support invasive plant removal, such as the grant mentioned above, challenges related to limited staff availability and the large scope of the invasive plant problem will most likely remain, making sustained progress slow and difficult. Nonetheless, efforts are being made to improve strategies for managing invasive plants on County lands.

Many agencies, individuals, and organizations in Pima County are struggling with invasive plants, which spread in response to ecological conditions and without regard to jurisdictional or land ownership boundaries. The Southwest Vegetation Management Association (SWVMA) is a statewide organization that focuses on invasive species ecology, inventory, and management. The Sonoran Desert Cooperative Weed Management Area (SDCWMA) is a partnership that responds to the need for better coordination of invasive plant management across the local landscape. Pima County is one of several entities partnering with the SDCWMA.

In addition to on-the-ground removal tactics and monitoring, the County has other tools to help address the threats posed by invasive plants. Since the development of the SDCP, Pima County has implemented a number of policies and plans for protecting native plant communities *in situ* as well as those that address invasive plants. These policies avoid and minimize disturbances, promote use of native species in landscaping, institutionalize processes for monitoring and managing invasive plants, and give the County authority to take action in instances where invasive plants on private land create a public health hazard.

The SDCP policies and plans can be divided into two categories: those that address threats monitoring and response in the County's preserve network, and those that outline procedures for avoidance and minimization of impacts associated with County projects outside of the preserve network (Table 2).

Table 2. Formalized rules and procedures for addressing invasive plants in unincorporated Pima County.

Title	Summary	More Information
Threats monitoring and response inside the preserve network		
Buffelgrass Control: Standard Operation Procedure No. 2009-02	Outlines procedures County staff shall follow to detect, map, and treat buffelgrass.	See Appendix A
Cienega Creek Natural Preserve Management	Currently under revision. Existing plan calls for the development of a cooperative program that includes monitoring for invasive plants and wildlife.	https://webcms.pima.gov/cms/one.aspx?pageId=65706
Floodplain Management Plan	Development of this plan is currently underway. The plan will integrate riparian habitat preservation and restoration into operations designed to protect public safety and prevent flood damage.	https://webcms.pima.gov/cms/One.aspx?portalid=169&pageId=450475

Title	Summary	More Information
Range Management Standards and Guidelines	Describes standards, guidelines, and procedure for how the County will manage ranch properties sustainably and as an important part of MSCP implementation.	https://webcms.pima.gov/cms/one.aspx?portalId=169&pageId=41864
Restoration Plans	RFCD has and continues to develop restoration plans at several sites within and outside of the County's Conservation Lands System.	https://webcms.pima.gov/cms/one.aspx?portalId=169&pageId=57629
Avoidance of disturbance and minimization of impacts associated with County projects outside the preserve network		
Plant Materials Salvage and Selection for Pima County Projects: Administrative Procedure No. 51-3	Establishes a procedure for plant selection and salvage for projects constructed by Pima County to ensure compliance with state and local requirements, and to provide a unified approach for use of native plants. Directs staff to SOP 2009-02 for management and control of invasive plants, including fountain grass and Sahara mustard.	https://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Administration/Administrative%20Procedures/51-3%20Plant%20Salvage,%20Selection%20for%20County%20Projects.pdf
Buffelgrass Control: Standard Operation Procedure No. 2009-02	Outlines procedures County staff shall follow to detect, map, and treat buffelgrass.	See Appendix A
Noxious and Invasive Vegetation on DOT Projects: Standard Operation Procedure No. 201-01	Provides a cost effective procedure for removing buffelgrass, fountain grass, and other target invasive plants in areas of the right-of-way for all transportation Capital Improvement Program (CIP) projects regardless of size.	https://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Transportation/Standard%20Operating%20Procedures/SOP201-01_Noxious_and_Invasive_Vegetation_on_DOTProjects.pdf
Community Participation and Mitigation: Pima County Zoning Code Chapter 10.56	Requires that all transportation projects include the application of the Environmentally Sensitive Roadway Design Guidelines. Guidelines include a list of invasive plants that are not allowed for use in post-construction revegetation.	https://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Transportation/Roadway%20Design/EnvironmentallySensitiveRWY/ESR-WebsiteDocumentGuidelineswith4dmemo.pdf
Native Plant Salvage on DOT	Outlines a procedure by which Pima County DOT will minimize impacts to	https://webcms.pima.gov/UserFiles/Servers/Server_6/Fil

Title	Summary	More Information
Projects: Standard Operation Procedure No. 809-01	existing vegetation and provide opportunities for native plant salvage. Requires the removal and disposal of invasive plants prior to salvage where they will be impacted by salvage activity.	e/Government/Transportation/Standard%20Operating%20Procedures/SOP809-01_NativePlantSalvage_on_DOTProjects.pdf
Private Landscaping Additions to the Right-of-Way: Standard Operating Policy and Procedure No. 670.03	For private landscape additions on public right-of-ways, requires private entities to include in their landscape plans the approximate locations of invasive species, treatment schedule, and treatment type.	Appendix B
Removal of Rubbish, Trash, Weeds, Filth and Debris: Pima County Code, Title 7, Chapter 33; Ordinance No. 2008-117	Identifies buffelgrass as a weed subject to regulation. Allows 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.	http://www.deq.pima.gov/Regulations/pdf/ORD2008-117BUFFELGRASS.pdf

Invasive species of interest

One commitment that Pima County has under the MSCP is to develop a database for recording observations of 15-20 of the most important invasive species. Below are descriptions of 25 invasive plant species of interest. To help ensure that these species are the most important, we have consulted with partners within and external to Pima County departments in an effort to get feedback on the selected species, as well as reviewed resources readily available online. All invasive plants included in this protocol are nonnative species.

A majority of the species in this protocol are important because they have been documented to lead to ecosystem type conversions by triggering changes in ecosystem processes that mediate habitat for plants, or have characteristics that suggest this is a possibility in the ecosystems they invade. In many cases, this is most evident in the way invasive plants alter fuel structure and fuel loading, accompanied by shifts in fire characteristics (Figure 2); for example, some invasive species increase fire frequency, size, and intensity (Rice et al. 2008; Webb et al. 2019). Fires can expedite the spread of invasive species that is already happening due to climate change and natural resource management. For a few species included in this protocol, although they appear unlikely to result in ecosystem type conversions, there remain concerns about how they alter vegetation structure and overtake native species, which may also have detrimental effects on MSCP covered species.

The invasive species in this protocol overlap with the focal species of the Sonoran Desert Cooperative Weed Management Area (SDCWMA). The SDCWMA is a partnership led by the Arizona-Sonora Desert Museum and made up of several organizations that work on invasive plant issues in Pima County. The partnership's list of focal species was developed in response to feedback from partners regarding what species they work on and are concerned about the most. All ten of the SDCWMA focal species are included in this protocol.

Figure 2. Buffelgrass burning in Marana, Pima County, Arizona.

As another indication of their importance, several invasive plants in the descriptions below are designated as noxious weeds by the state of Arizona due to the hazards they pose to native ecosystems, agriculture, and public health and safety. These plants are identified as Regulated, Restricted, or Prohibited in the state of Arizona, as defined under state administrative codes R3-4-244 and R3-4-245. The full list of Arizona noxious weeds can be found on the Arizona Department of Agriculture website (https://agriculture.az.gov/pestspest-control/agriculture-pests/noxious-weeds). Where applicable, we note the designation of a noxious weed in the table and species descriptions below.

Table 3. Invasive plants highlighted in this protocol are listed in the table below. They are divided into two categories: watchlist species for which intensive management may be avoided if infestations can be addressed early, and high priority species for management that are more established, and in some cases, widespread.

Scientific Name	Common Name	Functional Group	Eco-systems Invaded	Status in Pima Co.	AZ Nox-ious Weed	SDCWMA Focal Species
Watchlist Species: Undetected, uncommon, or newly emerging in Pima County						
Ailanthus altissima	tree-of-heaven	tree or shrub	Mesic riparian	Spreading in urban and riverine areas	Yes	No
Asphodelus fistulosus	onion weed	annual or perennial forb; flowers in winter/spring	Thornscrub; semi-desert grassland; xeric riparian; mesic riparian	Uncommon	Yes; also federally listed	No

Scientific Name	Common Name	Functional Group	Eco-systems Invaded	Status in Pima Co.	AZ Nox-ious Weed	SDCWMA Focal Species
Bothriochloa ischaemum	yellow bluestem	warm season perennial grass	Semi-desert grassland; xeric riparian	Spreading; present in urban Pima County and recently emerging on range lands	Yes	No
Matthiola parviflora	small-flowered stock	annual forb; flowers in winter/spring	Thornscrub, xeric riparian, mesic riparian	New; uncommon; spreading in Tucson metro	No	No
Oncosiphon piluliferum	stinknet	annual forb; flowers in spring	Desert; thornscrub; xeric riparian	New; uncommon; spreading rapidly in metro Tucson, Phoenix and S. CA	Yes	Yes
Vinca major	periwinkle	herbaceous vine; flowers in spring/ summer	Mesic riparian	Uncommon	No	No
Volutaria tubuliflora	volutaria	annual forb; flowers in winter/spring/ summer	Mojave desert	Not yet detected	No	No
High Priority Species for Management: Widespread, common, or established species						
Arundo donax	giant reed	warm season perennial grass	Mesic riparian	Spreading in washes	Yes	Yes
Brassica tournefortii	Sahara mustard	annual forb; flowers winter/spring	Desert; thornscrub; xeric riparian	Spreading	Yes	Yes
Bromus rubens	red brome	cool season annual grass	Desert; thornscrub; chaparral; Madrean woodland; mesic and xeric riparian	Spreading; common in Arizona	No	No
Centaurea melitensis	Malta starthistle	annual or biennial forb; flowers in spring/summer	Desert; thornscrub; mesic riparian; xeric riparian	Spreading	Yes	Yes

Scientific Name	Common Name	Functional Group	Eco-systems Invaded	Status in Pima Co.	AZ Nox-ious Weed	SDCWMA Focal Species
Centaurea solstitialis	yellow starthistle	annual forb; flowers summer/fall/early winter	Thornscrub; semi-desert grassland; chaparral; Madrean woodland	Spreading	Yes	No
Enneapogon cenchroides	soft feather pappusgrass	annual or perennial grass; non-seasonal	Desert; thornscrub; xeric and mesic riparian	Spreading; current distribution appears to be mainly in Pima County	No	No
Eragrostis curvula	weeping lovegrass	warm season perennial grass	Desert; thornscrub; xeric riparian	Widespread within and beyond Pima County	No	No
Eragrostis echinochloidea	African lovegrass	warm season perennial grass	Desert; thornscrub; grassland;	Spreading; current distribution appears to be mainly in Pima and Cochise counties	No	No
Eragrostis lehmanniana	Lehmann lovegrass	warm season perennial grass	Semi-desert grassland; thornscrub; xeric riparian	Widespread within and beyond Pima County	No	Yes
Euryops multifidus	sweet resinbush	subshrub; flowers in winter/spring	Thornscrub; semi-desert grassland	Spreading; present elsewhere in Arizona but not widespread in Pima County	Yes	No
Melinis repens	natal grass	perennial or annual grass; may flower for much of the year; intolerant of hard frosts	Semi-desert grassland; thornscrub	Spreading	Yes	Yes
Pennisetum ciliare	buffelgrass	warm season perennial grass	Desert; thornscrub; xeric riparian	Widespread within and beyond Pima County	Yes	Yes

Scientific Name	Common Name	Functional Group	Eco-systems Invaded	Status in Pima Co.	AZ Nox-ious Weed	SDCWMA Focal Species
Pennisetum setaceum	fountain grass	warm season perennial grass	Desert; thornscrub; xeric riparian; mesic riparian	Widespread within and beyond Pima County	Yes	Yes
Searsia lancea (formerly *Rhus lancea*)	African sumac	tree or shrub	Xeric and mesic riparian	Spreading out from urban and suburban areas	No	No
Setaria adhaerens	bur bristlegrass	warm season annual grass	Mesic and xeric riparian	Spreading; present in far NE Pima County and beyond	No	No
[1]*Sorghum halepense*	Johnsongrass	warm season perennial grass	Mesic riparian; moist ditches	Widespread within and beyond Pima County	Yes	Yes
Tamarisk chinensis; T. ramosissima	Salt cedar	tree or shrub	Mesic riparian; xeric riparian	Common	Yes	Yes

Grasses

Arundo donax (Giant reed)

Giant reed is a perennial grass from Asia and Africa that was introduced as an ornamental plant and planted for erosion control in drainages. In Pima County, giant reed is largely confined to mesic riparian areas. It has been found in a few County-owned areas at Cienega Creek Natural Preserve, and along Agua Verde Creek and Santa Cruz River. Currently, it is not widespread in these areas. There are a few small patches and occasional singular plants along waterways, and in particular there may be dense patches in areas along the middle Santa Cruz River. Along Tanque Verde Creek, however, it is spreading rapidly. It is considered a Class B noxious weed in Arizona, meaning it is still spreading as opposed to being established. Giant reed is a focal species of the SDCWMA.

Giant reed is large and fast-growing, reaching up to 30 feet tall, and has the potential to affect water availability due its very high use of water for transpiration relative to native plants (US Forest Service 2014a). Chemical compounds in giant reed can inhibit growth of other species,

[1] Monitoring will also include *Panicum antidotale* (blue panic grass) which is often mistaken for Johnsongrass due to its visual similarity and occupation of the same mesic niche.

and the decay of dead plant material can impact water quality when it results in the creation of toxic ammonia (US Forest Service 2014a).

While populations appear somewhat constrained in Pima County at this time, in other parts of the southwestern United States, giant reed has displaced native plants in rivers and flood control channels, including woody species, and has spread to form dense monocultures. Were this to occur on County conservation lands, several covered riparian birds that depend on trees and shrubs could be impacted. Giant reed in flood control channels could lead to a build-up of materials, reducing flood capacity and slowing water in floodways, and thus increase flood risk in upstream and adjacent areas. Furthermore, the longer giant reed is in a location, the harder it can be to remove, particularly if it experiences repeated flood events that bury its roots in successive layers of sediment. Pieces of plants that break away can wash downstream and establish new infestations.

The presence of giant reed can increase fuel loads and continuity, thus increasing fire risk in riparian areas. In fact, observations in California suggest that streams dominated by giant reed can act as conduits for fire spread, allowing fires started in uplands to spread across water bodies and continue burning on the other side (Coffman et al. 2010). Fires promote further dominance of giant reed; nutrient levels observed post-fire suggest nutrients increase around burned giant reed plants and not around burned native plants (Coffman et al.2010).

Bothriochloa ischaemum (Yellow bluestem)

Yellow bluestem is a warm season perennial grass native to southern Europe and Asia (Coyne and Bradford 1985). It was in the United States by the early 1900s when there was interest in Old World bluestems as good forage for livestock (Celarier and Harlan 1955). Today, it is a noxious weed in Arizona, categorized as a Class B Weed, meaning that it is known to occur, but of limited distribution in the State and may be a high priority pest for control or mitigation. According to the NRCS Plants Database (https://plants.sc.egov.usda.gov/), current distribution includes the southern United States. In Pima County, it is likely to primarily be an issue in semi-desert grassland, xeric riparian areas, Madrean evergreen woodland, and also potentially thornscrub. It has recently been observed on County-owned and leased lands at Sands Ranch, Davidson Canyon, and King 98 Ranch. As with other invasive grasses in thornscrub habitats, it may contribute to the threat of ecosystem conversion to grassland, and could thus threaten MSCP covered species through the demise of the native plant communities on which they depend. A study in Texas demonstrated that where yellow bluestem dominates, species richness and diversity of perennial herbaceous species are lower than areas where it does not occur (Gabbard and Fowler 2007). This may be due to direct or indirect effects of allelopathic compounds released by yellow bluestem (Greer et al. 2014). Furthermore, yellow bluestem has been found to grow in a wide variety of conditions (Gabbard and Fowler 2007).

Bromus rubens (Red brome)

Red brome is a cool season annual grass (Figure 3) from the Mediterranean region that was introduced as forage. It has been reported in many places across southern Arizona and Pima County, including Cienega Creek Natural Preserve and Tucson Mountain Park. It was highlighted

Figure 3. Red brome can invade a wide range of ecosystem types that occur in Pima County.

as a species of concern for implementing the Sonoran Desert Conservation Plan (Pima County 2002).

Red brome can invade desert, thornscrub, interior chaparral, Madrean evergreen woodland, and riparian areas, both xeric and mesic. It is known to invade overgrazed rangelands and lands that are otherwise disturbed. Germination of red brome requires relatively little rainfall. Like many other on-native invasive grasses, it increases fire risk, which can lead to the demise of fire-sensitive species while increasing dominance of red brome (US Forest Service 2017b).

Enneapogon cenchroides (Soft feather pappusgrass)

Soft feather pappusgrass is native to Africa and southern reaches of mainland Asia (Barkworth et al. 2007). It may grow as an annual or a perennial (Natural Resources Conservation Service n.d.). Information about this species in the United States is scarce, although plant inventory records indicate that soft feather pappusgrass seeds were presented to the US Department of Agriculture in 1942 (US Department of Agriculture 1951). Based on observations recorded in SEINet and iNaturalist (https://www.inaturalist.org/), the primary area of infestation lies in and around Tucson with a few observations to the south and east. Soft feather pappusgrass has also been detected in Organ Pipe National Monument where it has been described a potentially serious invader (Felger et al. 2014), and it is a concern in Saguaro National Park (NPS 2019). In Pima County, staff have observed this species in Tucson Mountain Park, as well as in

widespread floodplain areas and County-managed ranches on the east side of the Santa Catalina Mountains, such as A7 and M Diamond Ranches.

The information available about this species in Arizona suggests that soft feather pappusgrass invades primarily thornscrub and semi-desert grassland, with some potential to occur in xeric riparian situations. This suggests that it is one of multiple invasive grass species that are likely contributing to the loss of native vegetation and conversion to grassland. Therefore, multiple desert and thornscrub species that depend on native plant communities, such as Sonoran desert tortoise, are at risk of losing their habitats. While more information on the distribution of soft feather pappusgrass would be helpful for making an informed assessment of the potential for control, existing information suggests the infestation covers a smaller area of the Southwest than most other invasive grasses in this report, indicating that it may be possible for soft feather pappusgrass to be greatly limited in its spread if there are opportunities for aggressive management.

Eragrostis curvula (Weeping lovegrass)

Weeping lovegrass is a warm season bunchgrass native to Africa. It was planted in the United States for erosion control, and was seeded in Arizona as recently as 1990 (Gucker 2009). The Natural Resources Conservation Service still hosts a plant fact sheet online that describes considerations and benefits of seeding weeping lovegrass (Natural Resources Conservation Service 2002). It is an apomictic plant, meaning it can clone itself through seeds (Carballo et al. 2019). Weeping lovegrass is present in several states. On Pima County conservation lands, it is known to occur on Bar V Ranch and Oracle Ridge. It invades multiple ecosystems, including desert, thornscrub, semi-arid grassland, and xeric riparian areas. Weeping lovegrass in desert, thornscrub, and xeric riparian may contribute to an increase in fine fuel loads caused by invasive grasses, contributing to fire risk and the potential for ecosystem conversion to grass-dominated vegetation types. Loss of desert and thornscrub habitat would likely be detrimental to several covered species that rely on native vegetation structure, such as cactus ferruginous pygmy owls and Sonoran desert tortoise. While eradication of weeping lovegrass may not be possible, controlling it in areas inhabited by MSCP covered species is advisable.

Eragrostis echinochloidea (African lovegrass)

This perennial grass is native to Africa, and was grown in at least one Tucson nursery in the mid-1940s (Reeder and Reeder 1985). It is possible that African lovegrass started out as an urban invader that later spread into surrounding areas that were less developed (Reeder and Reeder 1985). Based on observations available in SEINet (http://swbiodiversity.org/seinet/) at the time this report was written, the distribution within the United States appears limited to Arizona, with the most observations reported within eastern Pima County, several in Santa Cruz and Cochise counties, five in Pinal County, and two in Maricopa County. A few other records exist for Sonora, Mexico. Very little information is readily available online regarding the ecology of African lovegrass.

Pima County staff from NRPR report that African lovegrass is spreading and that it invades multiple ecosystems types including desert, thornscrub, semi-desert grasslands, xeric riparian

areas, and mesic riparian areas. A few African lovegrass observations in SEINet are from elevations above 5,000 feet, suggesting that it may also spread into Interior chaparral and Madrean woodlands. African lovegrass may pose a threat to MSCP covered species, particularly in thornscrub and desert areas where it alters vegetation structure and provides a source of fine fuels for wildfires. More information about the ecology of this species in Arizona would be helpful for informing management.

Eragrostis lehmanniana (Lehmann lovegrass)

Lehmann lovegrass is a perennial bunchgrass that is native to South Africa. It was brought to the southwestern United States in the 1930s and planted for livestock forage and erosion control (Uchytil 1992; US Forest Service 2014b). Lehmann lovegrass was also planted widely for restoration after wildfires and highway construction projects (US Forest Service 2014b). Nowadays, it is widespread in Pima County and other parts of southeastern Arizona where it is a common invader of semi-desert grasslands, thornscrub, and xeric riparian areas.

Impacts of Lehmann lovegrass on MSCP covered species are not well-documented. It may be that negative impacts are more likely in thornscrub than in semi-desert grasslands because of a greater departure from vegetation structures typical of thornscrub and an increase in fine fuel loads that can lead to mortality of native plants such as agaves and saguaros. Regardless, the propensity of Lehmann lovegrass to form dense monocultures may increase the likelihood of fire-related mortality of Pima pineapple cactus (*Coryphantha sheeri* var. *robustipina*) and needle-spined pineapple cactus (*Echinomastus erectocentrus* var. *erectocentrus*), even where they occur in grassland settings. Additionally, a substantial body of work shows that while dense stands of this grass may benefit a small number of grassland bird and rodent species (Litt and Steidl 2016), there is a primarily negative impact on arthropod biomass, heteromyid rodent abundance, and on habitat use of some, but not all, species of grassland sparrows (Litt and Steidl 2011; Andersen et al. 2018; Titulaer et al. 2018; Andersen 2019). Although it may not be possible to eradicate Lehmann lovegrass on a large scale, management actions that ensure native grasses are still part of the invaded grassland community may help minimize negative impacts to native species.

Melinis repens (Natal grass)

Natal grass is native to South Africa that is an annual or perennial depending on conditions. Even though it is listed as a noxious weed in Arizona, there is a limited amount of information readily available on this species. It has been documented as spreading rapidly in Sonora where it has displaced native grasses and may achieve high enough biomass levels to be a fire risk (Van Devender and Reina 2005). Natal grass is a focal species of the SDCWMA, and on their website they describe this as mainly an invader of grasslands, and while also present in thornscrub, it does not grow densely enough to pose a serious fire threat and is not likely to contribute to a vegetation conversion (SDCWMA n.d.). However, because it has shown potential in the region to spread quickly and displace native grasses, in combination with other invasive grasses, it could possibly degrade habitat for MSCP covered species that depend on native grasslands. This

grass is relatively intolerant of harsh frosts, highlighting the fact that warming trends may enhance its ability to spread into areas and elevations where it currently cannot persist.

Pennisetum ciliare (Buffelgrass)

Buffelgrass was imported from Africa and planted for erosion control and forage for cattle by the United States government. A noxious weed, buffelgrass is widespread in Pima County, and occurs on County-controlled properties including Tucson Mountain Park (Figure 4). Buffelgrass is one of ten focal species of the SDCWMA.

This drought-tolerant, perennial grass is a very urgent and serious threat in desert, thornscrub, and xeric riparian ecosystems of Pima County where it crowds out native plants and spreads rapidly. By creating a carpet of fine fuels in vegetation communities where there is usually lots of space around individual plants, buffelgrass increases fire risk, intensity, size, and frequency. This can be a concern in neighborhoods as well as wildlands. Native Sonoran desert plants did not evolve to be fire-adapted, so when a buffelgrass-fueled fire occurs, it leaves in its path widespread mortality of native plants, including saguaros, other cacti, and MSCP covered plants. In addition to direct mortality from fire, because buffelgrass leads to the destruction of native vegetation communities, several species of MSCP-covered wildlife are at risk of losing their habitats and food sources.

It should be noted that, although buffelgrass is not considered a major threat in mesic riparian systems, by increasing fuel loads in adjacent uplands it can increase fire risk in the riparian zone, especially where buffelgrass-invaded uplands abut riparian areas that are infested with other invasive plant species that increase fire risk. Therefore, potential impacts exist to covered species that are riparian-obligates even if they don't use uplands as habitat.

Pima County has an official Standard Operating Procedure (Appendix A) for addressing buffelgrass on County-controlled lands. Current methods for addressing buffelgrass are limited mainly to manual removal and foliar herbicide application at times when it is photosynthetically active (e.g. "green"). Therefore, planning for herbicide treatments generally involves tracking rainfall patterns as buffelgrass greens up when recent rains trigger active growth, which in Pima County is primarily during the summer monsoon season (Wallace et al. 2016).

Pennisetum setaceum (Fountain grass)

Fountain grass is a perennial native to parts of Africa and Asia. It has been widely sold in nurseries and used as an ornamental grass for landscaping. Having escaped from gardens and yards, fountain grass is now widespread in Pima County, designated as a noxious weed in Arizona, and a priority of the SDCWMA. Fountain grass typically grows in xeric riparian areas as well as adjacent uplands. Large numbers have been observed at Pima County preserves such as Tucson Mountain Park, A7 Ranch, Rancho Seco, as well as other areas (Figure 4).

Though fountain grass is commonly observed invading canyons and xeric riparian areas, it can also be found in mesic riparian habitats and in upland desert and thornscrub. This dense bunchgrass spreads rapidly, crowding out native species, including the grasses and forbs that

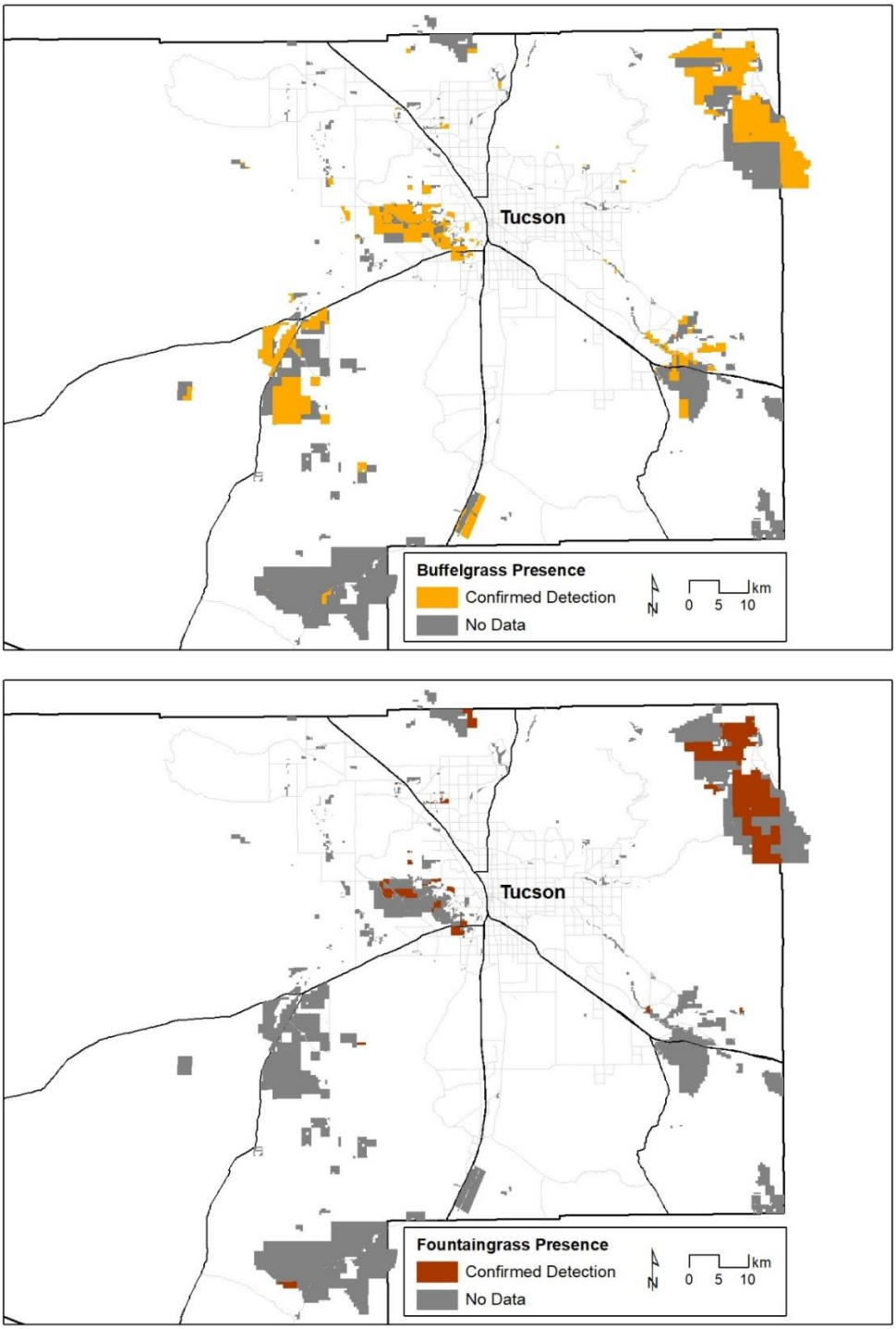

Figure 4. Maps highlighting parcels on Pima County conservation lands where observations of buffelgrass (top) and fountain grass (bottom) presence have been documented. These species likely occur in many areas colored gray, but records were not available in sourced data. The northeastern boundary of Pima County is visible as a black line. Plant data sources include EMP incidental observations, NRPR observations, and EDDMaps data (https://www.eddmaps.org/; accessed 28 February 2020). Note that highlighted parcels do not indicate abundance or severity of infestations. Instead, they are meant to generally indicate how widespread these grasses are on County conservation lands, based on data available to Pima County, and are largely a reflection of where County staff have done ground assessments.

provide forage and other resources for a variety of MSCP covered species. Similar to buffelgrass, fountain grass invasions result in ample fine fuels that increase fire-related mortality of native plants, including cacti (US Forest Service 2017a).

The presence of fountain grass in riparian zones increases the potential for fire to carry in these areas, which can rapidly change vegetation characteristics through mortality of native trees and shrubs. Subsequently, fountain grass can preemptively colonize the open spaces available post-fire. Therefore, several covered species that depend on riparian shrubs and trees could be impacted by fountain grass. Any fire in a mesic riparian zone has the potential to affect covered aquatic species through direct mortality as well as through fire effects on the physical environment, such as impacts to water quality. Fountain grass is not a desirable range species for livestock grazing because mature plants are not very palatable or nutritious (US Forest Service 2017a).

Setaria adhaerens (Bur bristlegrass)

Bur bristlegrass is an annual grass native to parts of Europe and the Middle East (CABI 2020). While present in neighboring regions of the Southwest and Sonora, it is not yet widespread in Pima County where it invades mesic and xeric riparian areas. The seeds of this plant are easily picked up and carried on fabric and animal fur, highlighting the caution that County staff should take when working in known areas of infestation to minimize the possibility of serving as a vector (i.e., thoroughly remove seeds adhering to shoes, socks, and pant legs). There is limited information readily available about this species. Pima County staff have reported that the initial phases of the infestation came on very quickly, and that it has been seen inhabiting both wet and dry locations. Bur bristlegrass is particularly widespread in portions of the lower San Pedro River Valley, but within the Tucson Basin, its current distribution appears to be restricted to certain areas, suggesting that addressing this species in the near term could greatly minimize its spread. A new infestation at the Swan Wetlands restoration project was eradicated with vigilant attention during 2015-2017. If it continues to spread, bur bristlegrass has the potential to impact MSCP covered species that utilize riparian areas such as mesquite bosques.

Sorghum halepense (Johnsongrass)

Johnsongrass is a perennial species from the Mediterranean region (Howard 2004) that was introduced to the eastern United States in the early to mid-1800s (US Department of Agriculture 2015c) and was planted in Arizona as forage for livestock despite the fact that it sometimes produces deadly prussic acid (Anderson et al 1952). It now occurs in nearly every state in the United States. In Arizona, it is listed as a Class C noxious weed, meaning that it is widespread but may be recommended for active control based on risk assessment.

In Pima County, Johnsongrass is usually found in mesic riparian areas, in ditches, and along roadsides. Along Cienega Creek, for example, there are large swathes of Johnsongrass along the riparian corridor in some stretches where it is dense and dominates ground cover. In this way, it could impact MSCP covered species in riparian by altering vegetation structure and composition. Although there is little information available about the effects of Johnsongrass on

fire regimes, like other invasive grasses, it may provide ample fine fuels to increase flammability and fire spread, and could potentially carry flames into the canopy (Webb et al. 2019).

Monitoring will also include *Panicum antidotale* (blue panic grass) which is often mistaken for Johnsongrass due to its visual similarity and occupation of the same mesic niche. Blue panic grass (*Panicum antidotale*) has displaced most of the Johnsongrass in Pantano Wash, and it is now prevalent in the Rillito and elsewhere around Tucson (J. Becker, personal communication, February 14, 2020).

Forbs

Asphodelus fistulosus (Onion weed)

Onion weed is an annual or short-lived forb native to the Mediterranean region (Winston et al. 2014). It may be that onion weed was brought from naturalized populations in Mexico and sold in Texas in the 1980s (APHIS 2008). It is sometimes planted as an ornamental (APHIS 2008). Onion weed is listed as a noxious weed in Arizona and federally in the United States (https://plants.usda.gov/java/noxious). It is reported that plants in Arizona have been found from about 2,000 to 4,500 feet in elevation (APHIS 2008), making onion weed a likely invader of thornscrub, semi-desert grasslands, xeric riparian areas in Pima County. Along Rincon Creek in Saguaro National Park, it is a common invader of mesic riparian areas, often occurring in and right next to water (D. Swann, personal communication, February 25, 2020).

Onion weed is avoided by livestock, which may reinforce its presence, and burning may help facilitate its spread (Winston et al 2014; NatureServe 2019a). Where it forms dense patches, onion weed can crowd out native species and result in changes in vegetation structure (NatureServe 2019a). There is limited information about the ecology of onion weed in Pima County, and so it is difficult to speculate on potential impacts to MSCP covered species. Evidence suggests that in lower elevation desert areas it may be moisture-limited. However, it appears to be currently a relatively uncommon plant on Pima County conservation lands, and addressing any infestations early may minimize future impacts and costs associated with control.

Brassica tournefortii (Sahara mustard)

Sahara mustard is an annual forb native to the Mediterranean region and the Middle East that was likely introduced to the United States in shipments of date palms sent to the Coachella Valley of California in the early 1900s (Barrows and Allen 2007). Since then, Sahara mustard has become a notorious invader in the Sonoran and Mojave deserts. Sahara mustard is listed as a noxious weed in Arizona and is a focal species of the SDCWMA. In Pima County, it invades desert, thornscrub, and xeric riparian ecosystems. While it is not yet widespread on County conservation lands specifically, it has been observed in and around the area of Tucson Mountain Park as well as various low-lying lands that the RFCD manages.

Sahara mustard is notorious for using up available moisture in the early spring and crowding out native plants in the Mojave desert and other regions. Monocultures can form, and when the plants dry up, they become a fire risk that threatens native plants and infrastructure (US

Department of Agriculture 2015b). Because of this, it is a serious threat to MSCP covered species, and its presence on the landscape could facilitate an ecosystem type conversion as native cacti and other food plants for wildlife are destroyed. Research shows that larger plants may produce more seeds than smaller plants. This suggests control efforts that reduce density in an area but do not remove all individuals may actually result in increased seed production when the plants that were not removed grow larger in response to reduced competition (Trader et al. 2006). Mature individuals can produced up to 9,000 seeds (US Department of Agriculture 2015b). Although this species is widespread in some areas of the Sonoran desert, its presence has been limited in Pima County until recently. It is suspected that plentiful monsoon rains help to destroy the seedbank in the Sonoran desert region. Sahara mustard has become an increasingly concerning problem in Avra Valley. Working with partners to minimize its spread on County and neighboring lands could help avert serious impacts to native biota.

Centaurea melitensis (Malta starthistle)

Malta starthistle is an annual forb native to the Mediterranean region. It is listed as a noxious weed in Arizona and is a focal species of the SDCWMA. It is believed to be in the early stages of colonization in Pima County where it invades desert, thornscrub, mesic riparian areas, and xeric riparian areas (Grissom n.d.). Malta starthistle can form dense stands and displaces native vegetation. A large infestation at the Arroyo Chico Park Avenue Basin flood control and mitigation project was eradicated with vigilant attention during 2014-2018.

Malta starthistle poses threats to livestock due to the sharp spines found on seed heads (US Department of Agriculture 2015a). These spines and the prolific production of seeds make it easy for Malta starthistle to spread via vehicles, machinery, people and wildlife, including seeds transported by birds that eat them (USDA 2015). Malta starthistle is a suspected cause of "chewing disease" in horses, a neurological disorder that has no cure (USDA 2015). Therefore, Malta starthistle has the potential to have negative impacts on native vegetation relied upon by MSCP covered species, but also may impact livestock on the County's ranches and leased lands.

Centaurea solstitialis (Yellow starthistle)

Yellow starthistle is a winter annual forb native to Eurasia that was introduced to the United States in the mid-1800s via imported seed that was contaminated (US Department of Agriculture 2014b). It is listed as a noxious weed in Arizona. Yellow starthistle is a potential invader of thornscrub, semi-desert grasslands, chaparral, Madrean woodlands, and mesic riparian areas (US Department of Agriculture 2014b; Zouhar 2002). In Pima County, it may not be as widespread as it is in other parts of Arizona and California, but County staff report recent increases in populations. This highlights the importance of monitoring this species given its impacts on native plant communities and livestock.

Yellow starthistle displaces native species and has been identified as a particularly serious concern for rangelands and grasslands where it can form dense monocultures (Randall et al. 2017). It has a deep taproot that can grow to over 1 meter long (Randall et al. 2017) making it an intense competitor for available moisture. Fire exclusion in grasslands and oak woodlands may help facilitate spread of yellow thistle, and its dominance may alter fuel structures and

therefore impact fire regime characteristics (Zouhar 2002). This raises a red flag about the ability of yellow starthistle to degrade grassland conditions and potentially impact MSCP covered species that occur there. Yellow starthistle can have a number of negative impacts on livestock, and it is toxic to horses (DiTomaso et al. 2006).

Matthiola parviflora (Small-flowered stock)

Small-flowered stock is an annual forb native to the Mediterranean. It was first discovered in the Western Hemisphere at the Desert Laboratory on Tumamoc Hill in 2008 (Horst et al. 2014). In one location where it was found, there were 576 individuals in an area of about 150 meters squared; in 2010, there were 4,018 individuals in the same location (Horst et al. 2014). Small-flowered stock was found in Saguaro National Park in 2015 (Walton 2015). In 2016, it was found on Pima County's Cienega Creek Natural Preserve. This species emerges in the spring in response to winter rains.

Research suggests that Pima County is ideal habitat for small-flowered stock, and that it will probably continue to spread (Horst et al. 2014). Because it is new to the western hemisphere, it is difficult to anticipate impacts of small-flowered stock on MSCP covered species, but a reduction in native plant diversity seems likely based on its rapid spread across the Desert Laboratory. This species has been observed spreading rapidly throughout large parts of the Tucson metro area, and there is evidence that this plant can invade thornscrub, xeric riparian, and mesic riparian ecosystems. However, given its recent introduction, its potential to spread to other ecosystems is unknown, underscoring the importance of monitoring for this species. Early, proactive management of this species before it spreads over large areas would be advisable to minimize adverse impacts and costs associated with control.

Oncosiphon piluliferum (Stinknet)

Stinknet (Figure 5) is an annual herb from South Africa that was introduced to central Arizona as a landscaping plant. Over the last 20 years, it has spread rapidly in Maricopa County, now infesting hundreds of areas and continuing to spread southwards. It was confirmed in the Tucson area in 2015. Stinknet infestations are found on County lands along the Chuck Huckelberry Loop near Prince Road (Appendix E), Three Points, plus there are more isolated occurrences around metro Tucson and Vail. It has the potential to spread extensively at lower elevations. Stinknet was newly added to the list of Arizona noxious weeds in January 2020, and is focal species of the SDCWMA.

Stinknet germinates and grows in response to cool season precipitation. It can form dense mats of ground cover in desert, thornscrub, xeric riparian areas, and disturbed areas such as roadsides and fields. Because of this, it threatens food sources for Sonoran desert tortoise, and could spread to invade habitats where Pima pineapple cactus and needle-spined pineapple cactus are found. When patches of stinknet dry out, they become flammable, and could increase fire risk in native habitats where fires are typically rare events. The smoke from burning stinknet is caustic.

Figure 5. Photos of stinknet when it is young (left) and mature (right).

Fortunately, this emerging threat is on the radar of organizations in Tucson and around Arizona. After witnessing the rapid takeover of this species in Maricopa County, the Arizona Native Plant Society initiated a Tucson-area effort to educate local jurisdictions, landscape contractors, and the community in general about stinknet. This has included numerous training sessions on the identification, ecology, and control of stinknet. Early detection and eradication is important due to the way stinknet can grow in layers, with older plants shielding younger plants from herbicide application.

Vinca major (Periwinkle)

Periwinkle is a perennial, herbaceous vine native to the Mediterranean region. With lovely purple-blue flowers, this semi-evergreen species has been popular as an ornamental groundcover for centuries, and continues to be promoted as such today (Stone 2009). In Arizona, periwinkle invades mesic riparian areas. On Pima County conservation lands, it has been found and treated in the Cienega Creek Natural Preserve. It is not likely to pose a widespread threat, but has the potentially to impact key riparian sites. Periwinkle forms dense mats that cover the ground, excluding other plants that might otherwise sprout and grow, and thus impacting vegetation structure and diversity. Where it grows along streams, it can alter hydrogeological processes (NatureServe 2019b).

Asexual reproduction is very important for this species (Stone 2009). It reproduces largely by rooting stolons, and plant fragments carried away by floods, people, or wildlife may result in plants becoming established in new areas. This capability also makes removing periwinkle very difficult, requiring many repeat visits and the complete removal of plant material. The potential impact of periwinkle on riparian vegetation is a concern for the MSCP covered species that rely on native plants for habitat. Due to the difficultly of removing this species, and its uncommon occurrence on County lands, addressing infestations early may be the most prudent course of action.

Volutaria tubuliflora (Volutaria)

Volutaria is an annual from the Mediterranean region. It appears to be a relatively new invasive plant in the United States, initially discovered in California's Mojave desert in 2011 in the Borrego Springs area. Volutaria, to our knowledge, has not yet been detected in Arizona or

Pima County. However, its rapid spread in southern California has triggered an alarm in the conservation and restoration community there, with practitioners sending information out to neighboring areas (https://anzaborrego.ucnrs.org/wp-content/uploads/2018/02/Volutaria-Threats-and-Management-UCCE-McDonald.pdf). Volutaria is also a growing problem in the Great Basin desert (C. Campbell, personal communication, February 19, 2020).

Volutaria may outcompete native plants (plants can grow quite large, up to 5 feet high), and could be toxic to some livestock. Early detection of this species, should it be discovered in Pima County, could greatly increase the chances of cost-effective control. In southern California, volutaria typically germinates in response to winter rains, but has also been observed germinating after summer rains and in response to irrigation.

Woody plants

Ailanthus altissima (Tree of heaven)

Tree of heaven is a native of China that was first introduced to the United States as an ornamental plant. In the southwestern United States, it invades mesic riparian areas and moist drainages. It is listed as a Class C noxious weed in Arizona, meaning that it is widespread but may be recommended for active control based on the risks it poses. In Pima County, tree of heaven has been documented on the Coronado National Forest on southern, northern, and eastern slopes of the Santa Catalina Mountains (iNaturalist; SEINet) and in the lower reaches of Madera Canyon in the Santa Rita Mountains. It has also been observed in the Santa Rita foothills east of Helvetia (SEINet), and in towns and urban areas. Though most of these locations range in elevation from approximately 4,500 to 5,100 feet, tree of heaven has also been observed at lower elevations in other counties, including along the lower San Pedro River in Pinal County.

Tree of heaven could pose a risk to MSCP covered species that rely on native riparian vegetation. If detected on County conservation lands, treating the infestation early may be the best course of action. Tree of heaven is fast-growing and can develop dense thickets of trees cloned from root sprouts (Fryer 2010; US Department of Agriculture 2014). A single tree can produce up to 300,000 seeds per year, although seeds are short-lived and persist for only one or two years (US Department of Agriculture 2014a). Many plant parts contain allelopathic chemicals, including seeds, which can inhibit growth of native plants (US Department of Agriculture 2014a). Following fire, tree of heaven can regenerate by resprouting or by seed (Fryer 2010).

Euryops multifidus (Sweet resinbush)

Sweet resinbush is a subshrub native to South Africa that was introduced to the southwestern United States for erosion control and range improvement by the United States Soil Conservation Service in 1935 (Pierson and McAuliffe 1995). It invades thornscrub and semi-desert grassland. It is a Class A noxious weed in Arizona, meaning it is a plant not known to exist or of limited distribution in the state and is a high priority for quarantine, control, or mitigation. One well-known and problematic infestation is located on Frye Mesa in Graham County southwest of Safford, Arizona (Pierson and McAulliffe 1995). In Pima County, sweet resinbush

has been observed in the area of Sabino Canyon on the Coronado National Forest on the outskirts of Tucson (Pierson and McAuliffe 1995), and was still being actively managed by the Sabino Stewards at least as recently as the late 2010s (C. Campbell, personal communication, February 14, 2020).

In southern Arizona, sweet resinbush is of particular concern in semi-desert grasslands where it can dominate vegetation (Gornish and Howery 2019). Sweet resinbush has been observed to replace native grasses and native woody species while also increasing exposure of bare soil, leading to higher erosion rates (Pierson and McAulliffe 1995; US Department of Agriculture 2017b). Also, it may be toxic to livestock and wildlife (US Department of Agriculture 2017b).

Searsia lancea (African sumac)

African sumac grows in the form of a shrub or tree and is native to Africa. It is commonly promoted in landscaping within the Sonoran desert because it can grow large enough to provide shade and is a low water use plant. Hardy as it is, it has escaped cultivation and can now be found in washes and canyons throughout Tucson and in the surrounding landscape. Furthermore, it produces copious amounts of allergenic pollen and vigorously sprouts and volunteers where it is not wanted in the landscape, which also highlights that the species is a nuisance. Current records of African sumac in SEINet and iMapInvasives show a similar pattern around Phoenix, with observations seeming to radiate out from the city.

African sumac can displace native woody species that MSCP covered species depend on, such as mesquite, cottonwood, and willows. Therefore, it has the potential to alter how flood waters move through the system, which could trigger additional problems. In fact, it was called out specifically in the MSCP as a species of concern. In 2005, the Arizona Wildlands Invasive Plant Working Group labeled African sumac as a medium threat, meaning that is has substantial impacts on ecosystems, biota, and vegetation structure, and well as medium to high rates of dispersal (AWIPWG 2005). More information about the ecology of African sumac in Arizona would be helpful for informing management.

Tamarix spp. (Salt cedar)

The genus *Tamarix* includes several species, including at least five that are known to occur in the southwestern United States (*T. aphylla*, *T. chinensis*, *T. gallica*, *T. parviflora*, and *T. ramosissima*). However, they are often grouped together in various combinations because there is dispute over their taxonomy, some are very difficult to distinguish from one another, and they are known to hybridize (Gaskin and Schaal 2002; US Department of Agriculture 2017a; Zouhar 2003). For the purposes of this protocol, we focus on *T. chinensis* and *T. ramosissima* and their hybrids because they are most commonly implicated as invasive threats in the region, and we henceforth refer to them as salt cedar.

Salt cedar is a large shrub, native to eastern Europe and Asia, that was introduced to the United States in the mid-1800s (Tellman 1998). It quickly escaped cultivation, and moved into riparian areas, where it spread quickly during the mid-1900s with an increase in dam construction and associated interruption of natural flood regimes (Tellman 1998; Zouhar 2003). Salt cedar now

occurs in riparian areas across much of the western United States. In Pima County, it can be found in mesic and xeric riparian areas, including along Cienega Creek, the Santa Cruz River, and in many ephemeral washes. Salt cedar is listed as noxious weed in Arizona and is a focal species of the SDCWMA.

As drought and water management have altered environmental conditions along southwestern streams, salt cedar has taken advantage of the negative effects of these drivers on native riparian plants. Salt cedar now dominates or co-dominates vegetation in many places. This has led to increased risk of more frequent and more intense fires that lead to widespread mortality of native species while concurrently favoring greater dominance of salt cedar (Webb et al. 2019). Salt cedar can provide nesting opportunities for some birds, such as the southwestern willow flycatcher, an MSCP covered species. However, the overall impact of the replacement of cottonwood-willow riparian woodlands with invasive species is a decline in biodiversity, which could impact MSCP covered species through pathways that impact ecological communities at multiple trophic levels (Webb et al. 2019).

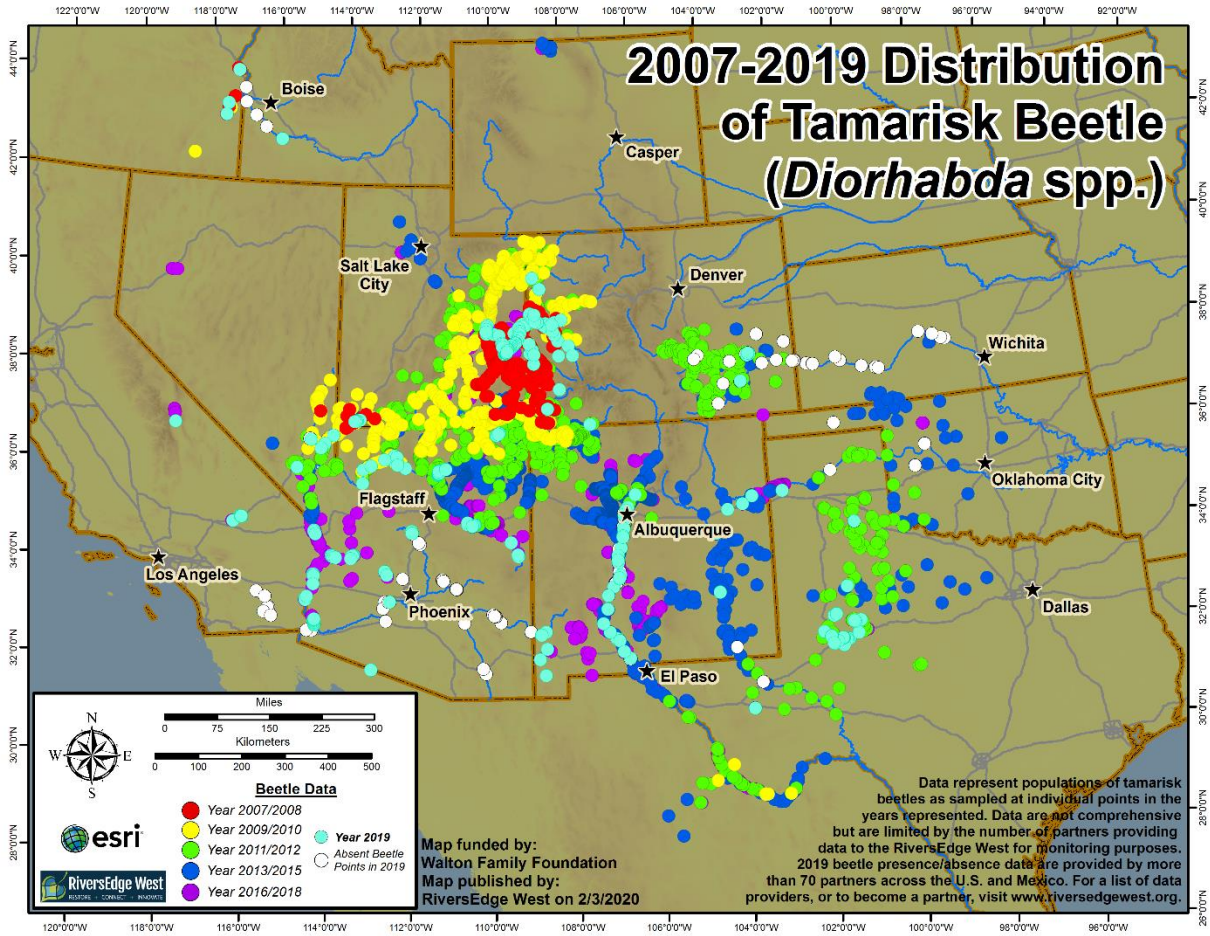

Figure 6. Tamarisk beetles have spread along streams throughout much of the southwestern United States. This map shows them present in the Gila River basin, which includes the Santa Cruz River and Cienega Creek. Map courtesy of Ben Bloodworth, RiversEdge West.

An additional emerging concern in Pima County is the continued expansion of a biological control agent, tamarisk beetles (*Diorhabda* spp), which is reported on annually (Figure 6) through a beetle monitoring program conducted by RiversEdge West (https://riversedgewest.org/events/tamarisk-beetle-maps). Tamarisk beetles are introduced insects that are native to the same regions as salt cedar. When the beetles feed on salt cedar, fire risk may be temporarily elevated while dead leaves persist on branches (Drus et al. 2012). Then, after the salt cedar is dead, there may be concerns about what plants will move into the new open space. A case is to made for preemptively removing and replacing salt cedar with native species in stages prior to the arrival of tamarisk beetles to minimize the effects of habitat loss for nesting birds when the beetle arrives (Coulson et al. 2016). Where salt cedar is affected by beetle herbivory, active management may be needed to ensure desirable species fill in the new available space instead of other invasive species. On the Upper Gila River, the Gila Watershed Partnership has been engaged in a multi-year restoration project in anticipation of the arrival of tamarisk beetles to mitigate the impacts of herbivory on southwestern willow flycatchers and other riparian species (https://arcg.is/1zuarL).

Methods

We (Pima County EMP) will monitor invasive plants by leveraging existing plot-based vegetation monitoring efforts as well as collection of incidental observations during staff time in the field spent on a variety of other monitoring protocols. We will collect data using a digital data form (Appendix C) using ArcGIS Collector that includes quantitative and qualitative fields that were developed in consultation with multiple departments within Pima County that are involved with detection and management of invasive plants.

To help guide data collection efforts by County staff, cooperators, partners, and volunteers, we have developed a subset of invasive plant species (provided in the previous section) that occur or could spread into the area and are considered high priority for monitoring and detection. This is intended to focus data collection on the species that pose the highest risk to MSCP covered species and their habitats. However, Pima County has a more extensive list of invasive plant species that are also included on the digital data form and that will also be tracked opportunistically. This list was borrowed from a compilation by the Arizona Wildlands Invasive Plant Working Group (Appendix D; https://www.swvma.org/wp-content/uploads/Invasive-Non-Native-Plants-that-Threaten-Wildlands-in-Arizona.pdf).

Field Survey Methodologies

Uplands vegetation and soil monitoring

As part of the monitoring requirements committed to under the MSCP, we will leverage existing upland vegetation and soils monitoring plots as part of the invasive plant monitoring protocol. These are long-term, geo-referenced plots (20 m by 50 m) that are monitored using a rotating panel design that ensures each plot is monitored once in each 5-year term for a total of 6 times through the 30-year span of the County's Section 10 permit (Gicklhorn 2020; Hubbard et al. 2012). Pima County has committed to establishing a minimum of 100 plots (Gicklhorn 2020).

Sampling locations are designed to capture conditions in all of the upland biomes that occur on Pima County lands (see Table 1).

Surveyors of upland vegetation plots are trained field technicians skilled in plant identification (Figure 7). Field monitoring data is collected via a digital database operating on a ruggedized field tablet or computer (Panasonic Toughbook). The EMP receives an annual download of certified field monitoring data for storage in the County's OnBase data management system. At the end of each field season, field staff provide summaries that highlight, among other things, occurrences of new plant species. These observations will be input directly into the database by EMP staff using Collector on a desktop computer. EMP staff will quality check the data, which will then be post-processed by the database manager.

Figure 7. Field staff from the National Park Service and Tucson Audubon Society monitor uplands vegetation on Pima County's Six Bar Ranch.

The data collected can be used to analyze changes in plant community structure and species diversity over time, including the presence and relative abundances of some invasive plant species. Though not an explicit goal of this particular monitoring element, these efforts are also capable of contributing to the ability to detect new invasive plant populations (in those areas where plots are established). For more details about the County's upland vegetation and soils monitoring protocol, see Gicklhorn (2020).

Incidental observations made during other operations

In addition to monitoring efforts described above, EMP staff will collect incidental observations of high priority invasive plants during field operations, including while implementing monitoring protocols for other species or threats, and conducting general property inventories and assessments. Observations will be collected via a digital database operating on a ruggedized field tablet or computer (Panasonic Toughbook). In the office, EMP staff will sync data collected on the tablet with the Incidental Observations geodatabase. Afterwards, staff will quality check the data, which will then be post-processed by the database manager.

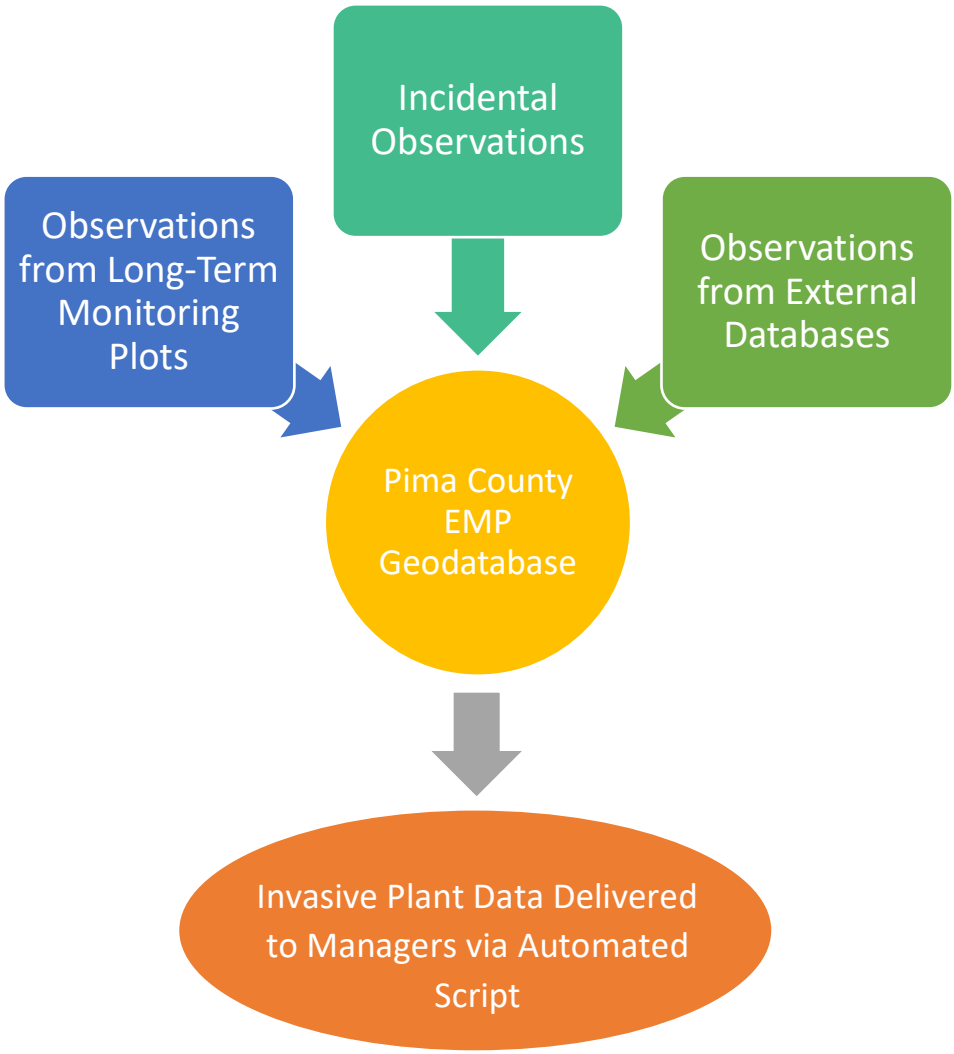

Figure 8. Conceptual diagram summarizing sources of invasive plant data, and how data will be stored and shared.

Utilization of external databases

County staff will utilize four external databases that may contain observations of interest to the County that have been recorded by other organizations or individuals:

- SEINet (http://swbiodiversity.org/seinet/index.php), which serves as a gateway to access herbariums specimens and other collections with a focus on Arizona and New Mexico;
- iMapInvasives (https://www.imapinvasives.org/), which is maintained by Arizona Game and Fish Department as part of its Heritage Data Management System;
- Early Detection and Distribution Mapping System (EDDMaps; https://www.eddmaps.org/), which was developed by The University of Georgia's Center for Invasive Species and Ecosystem Health;
- Nonindigenous Aquatic Species (NAS; https://nas.er.usgs.gov/), a repository for spatially referenced biogeographic accounts of introduced aquatic species.

On iMapInvasives, EDDMaps, and NAS, EMP staff will set up monthly alerts to receive emails about high priority species detected within a specified geography. County staff will follow up on reports to confirm species identification and presence, as needed. When confirming reports, staff will collect data on the field tablet and include it in the Incidental Observations database, following the quality check and post-processing process described above. Other data collected externally, if credible, will be input directly into the database using Collector on a desktop computer.

Data sharing for management of Pima County mitigation lands

There is a need for the data collected using the methods described above to be compiled and made available for use by other Pima County departments (Figure 8), including NRPR, RFCD, and DOT. The EMP is currently devising a process by which invasive plant data collected and stored in the Incidental Observation database can be shared with other Pima County departments to support their control efforts. While still in development, the goal is to create a system that automatically makes invasive plant data, along with other data, available to managers on a daily basis. If there is a new invasive plant observation that is a concern because of the potential for rapid spread, such as with stinknet, EMP staff will communicate with other departments about the observation by email within one week of the date observed to ensure managers are aware of the observation.

The data collected in this effort will also be of value for management planning in general, such as in the development of site-specific management plans. The data will be available for Pima County staff to view and use in their own analyses, allowing for a data-informed approach to incorporating management of invasive plants into management planning across landscapes. Furthermore, the EMP staff who have collected and compiled the data will themselves be valuable participants in management planning as stewards of this information.

Communication with external partners and keeping up to date on current threats

Informal communication and networking with local, state, and federal agency partners is also a valuable means to keep abreast of notable observations of invasive plants that could potentially impact County lands. Pima County EMP staff regularly communicate with various external partners who may have work or research activities on or near County conservation lands, including biologists with Arizona Game and Fish Department, USFWS and BLM biologists, staff from various non-profit organizations (i.e., Sonoran Institute and The Nature Conservancy), and researchers from the University of Arizona. Staff also work with the local SDCWMA and the statewide SWVMA, which are additional venues for information-sharing. Regular communications with all of these entities are another means by which EMP staff may become aware of, and follow up on if needed, observations of invasive plants on County lands. Conversely, these are also opportunities for EMP staff to share notable observations with other agencies and organizations who may have a role in addressing threats and impacts of invasive plants. These interactions will be important for determining if and when new species should be added to this protocol.

Training

Many Pima County staff in departments that manage lands currently receive training on invasive plant identification and removal. As relevant, EMP staff will participate in trainings on invasive plant identification and ecology. For example, more than 50 members of the staff at Pima County, including EMP staff, attended a stinknet awareness session orchestrated by the Arizona Native Plant Society and Pima County Native Plant Nursery in early 2020. Other relevant educational opportunities may arise with the SWVMA and SDCWMA.

Recommendations for the Prioritization of Invasive Plant Management

The best defense against invasive plants is often maintaining an intact community of native plant species and the ecological processes that provide their habitats. Preventing or quickly eradicating new infestations of invasive plants is likely to be the most cost-effective form of control in many situations, especially for long-term ecosystem management (McCrea and DiSalvo 2001). Monitoring and early detection are key to prevention and the development of a rapid response. The monitoring outlined in this protocol will help support early detection and management, but in some areas of County lands, additional scouting or monitoring may be needed both for early detection and for developing robust control strategies. Partnerships, cross-boundary coordination, and volunteers can help support these efforts.

Best management practices for developing invasive plant strategies begin with having short- and long-term objectives that are clearly defined (Flint et al. 2003; Federal Integrated Pest Management Coordinating Committee 2018; McCrea and DiSalvo 2001; US Fish and Wildlife Service 2006). Management should be implemented based on the best available science and technologies, and plans should be flexible to allow improvements based on new information (Flint et al. 2003). Control treatments and other management actions should be supported with monitoring protocols designed to track the effectiveness of management. To help foster the sharing of knowledge and coordination of efforts, we recommend that Pima County create an ad hoc, interdepartmental working group (NRPR, RFCD, and OSC) to provide a forum for discussion. Such discussions would also help determine when updates of this monitoring protocol are needed to account for newly emerging risks from invasive species and to better integrate operations across Pima County departments.

Changed circumstances that would affect species or lands covered by the MSCP and that are realistic and can be planned for must be assessed to meet USFWS requirements for all habitat conservation plans. Potential changed circumstances are listed in Table 7.1 of the MSCP (Pima County 2016), some of which are related to the introduction of invasive plants, their effects on biotic communities, and climate change (which influences invasive plants). The invasive plants database may help aid discovery of changed circumstances. For example, if new non-native plants are identified on County lands, this information could be used to help determine if a new species has become commercially available for landscaping. In this scenario, if it was confirmed that a new species of landscaping plant was being sold in the region, EMP would report the occurrence(s) to senior officials in OSC. These officials would then coordinate with the County's

Development Services Department to update lists of species that are not allowed to be used in County construction and right-of-way projects.

Another aspect of developing a robust invasive plant strategy is identifying areas that are high priorities for management and monitoring. Below is a list of key resources (Table 4) that support MSCP covered species, and where management of the invasive species highlighted in

Table 4. Associations of covered species and invasive plants in the habitats where they occur. This table is not intended to be comprehensive, but to highlight invasive plants that may pose the most immediate threats to key resources used by some MSCP covered species, and therefore might warrant a high level of consideration for active management.

Covered Species	Key Resources	Geography	Invasive Plants
Talussnails	Talus slopes and rocky outcrops	Occur at multiple elevations but of most concern in thornscrub due to buffelgrass	Buffelgrass Fountain grass
Sonoran desert tortoise	Rocky slopes and washes	Thornscrub	Buffelgrass Fountain grass Red brome Stinknet Sahara mustard
Pima pineapple cactus	Areas of known occurrences	Thornscrub and semi-desert grasslands in the Altar Valley and on County conservation lands in the Santa Cruz Valley and Bar V Ranch	Lehmann lovegrass Buffelgrass Weeping lovegrass African lovegrass
Cactus ferruginous pygmy-owl	Large saguaros and mature xeric riparian vegetation (mesquite, palo verde, ironwood)	Thornscrub and semi-desert grasslands; Altar Valley	Buffelgrass Sahara mustard Weeping lovegrass
Aquatic and riparian species (frogs, fish, birds, reptiles)	Water quantity, quality, and hydrological regimes; mesic riparian vegetation structure	Streams, springs, and cienegas	Buffelgrass Fountain grass Giant reed Johnsongrass African sumac Salt cedar Stinknet
Nectar feeding bats	Saguaros plus Palmer's and Parry's agave	Thornscrub and semi-desert grasslands	Lehmann lovegrass Buffelgrass Fountain grass Stinknet Natal grass

this protocol may be required to maintain and promote habitat availability and quality. Priority areas for treatments should also include areas important for wildlife species' movements and maintaining ecosystem function. In addition to the geographically specific areas listed below, high priority areas for treatment include those driven by partnerships where the combined efforts of multiple entities can have a significant impact and where partnerships can be leveraged to bring in more resources for control efforts. County conservation lands in the San Pedro Valley may require additional assessment beyond what is provided here. Vector control should be assessed and considered to help maintain efficacy of control operations. For vector control, treatment may be needed in areas of any biological value where movement of people, wildlife, wind, or water could serve as vectors to spread invasive plants into a highly valued area.

In addition to biological values, there are several operational and logistical considerations that should be taken into account when prioritizing sites and species for management. They include (listed in no particular order):

A. What is the management status of the land in question? Fee lands should be prioritized over leased lands, which the County does not have full management discretion over. Management ability will vary by location.

B. Are there newly emerging invasive plant species, or new infestations of known species, where concerted action could stop a damaging and costly invasion later?

C. Does the invasive plant species represent a measurable risk to a federally listed covered species or secondarily, any MSCP covered species? Includes risk to key or necessary habitat components.

D. Does the invasive plant represent a measurable risk to adjacent property or development, public health and safety, recreational and aesthetic values, or educational opportunities?

E. What are logistical considerations in terms of ease of access?

F. Is there a nexus with County ranch operations? Are invasive plants making ranch operations more difficult or expensive?

G. What is the restoration potential of the site?

H. Are there areas of high biological value that are mostly pristine where some amount of effort could help prevent encroachment of invasive plants?

I. Where can we build on existing work and collaborative partnerships to control invasive plants?
    a. Building on existing work where there has already been a significant investment in management and/or where progress has already been made (both internally

and regionally) could be a consideration, as well as the synergy of coordinated efforts by multiple organizations in the geographic area

b. Leveraging outside funding opportunities

J. Are there seeps, springs, or high value riparian areas that are at risk from invasive plants?

K. What is the cost-benefit analysis of action versus no action? Is doing nothing now likely to be more expensive or otherwise unacceptable in the long-term?

L. Where an infestation crosses jurisdictional or private property boundaries, will most or all affected parties work to control the invasive species of interest to achieve effective management?

In this protocol, we have provided input on which species are high priorities for management, what biological values may be at risk (Figure 9), and where they are located geographically. However, we recognize that developing a robust invasive plant management strategy for Pima County, which we recommend undertaking, is a larger endeavor that goes beyond what we have covered here. There are multiple organizations that have produced guidance to help aid the development of invasive plant management plans and set priorities. We list several such documents below, and include a couple of examples of invasive plant management plans from other parts of Arizona. Also, we encourage utilization of the bibliography in this protocol as a resource for managers to easily access information about appropriate control methods, and the ecology and management of individual invasive plant species.

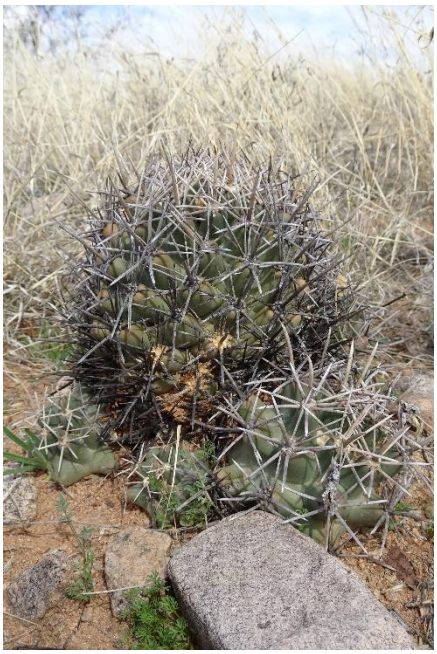

Figure 9. The range of the Pima pineapple cactus is small, occurring mainly in Pima County, as well as Santa Cruz County and in northern areas of Sonora, Mexico.

Guides for developing invasive plant management strategies:

- Invasive Plant Management Planning: Technical Considerations (Dingman et al. 2018) https://irma.nps.gov/Datastore/DownloadFile/612495
- Land Manager's Guide to Developing an Invasive Plant Management Plan (US Fish and Wildlife Service and California Invasive Plant Council 2018) https://bugwoodcloud.org/mura/mipn/assets/File/USFS/2019%20Invasive%20Plant%20Mgmt%20Planning_BMP_USFWS.pdf
- Guidance for Invasive Species Management in the Southwestern Region (USDA Forest Service 2014) https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3801891.pdf

- An Invasive Species Assessment Protocol (Morse et al. 2004) https://www.natureserve.org/sites/default/files/invasive_species_assessment_protocol.pdf
- Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands (California Exotic Pest Plant Council and Southwest Vegetation Management Association 2003) https://www.cal-ipc.org/docs/ip/inventory/pdf/Criteria.pdf
- 2018 Invasive Plant Treatment Prioritization (Grunberg et al. 2018) https://dffm.az.gov/2018-invasive-plant-treatment-prioritization

Example plans from other organizations:

- Navajo Nation Integrated Weed Management Plan (Fred Phillips Consulting n.d.) https://www.bia.gov/sites/bia.gov/files/assets/public/pdf/idc2-060709.pdf
- Verde River Cooperative Invasive Plant Management Plan (Fred Phillips Consulting 2011) https://verderiver.org/wp-content/uploads/2017/12/verde-river-cooperative-invasive-plant-management-plan.pdf

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Appendix A: Pima County's Buffelgrass Control Procedure

Pima County
Public Works Departments
Standard Operating Procedures

Subject: **Buffelgrass Control**	**SOP No.: 2009-02**
Approved By: **John M. Bernal, Deputy County Administrator**	**Effective Date:** **November 10, 2009**

A. STATEMENT OF PURPOSE

The vision of the Pima County public works departments for buffelgrass is to preserve our communities and our natural resources and to be recognized as the regional leader of a comprehensive and aggressive program to coordinate, manage, control the spread of, and where possible, to eliminate, buffelgrass on Pima County rights-of-way and county owned property.

Buffelgrass (*Pennisetum ciliare)* is a fire-prone non-native perennial grass that grows in dense stands, crowds out native plants and can fuel frequent and devastating fires in both natural open space and established neighborhoods. It is predicted that without a concerted and sustained effort to control further spread and eliminate buffelgrass where possible, the Sonoran Desert will be modified, thus losing native desert environments and creating increased exposure to potentially deadly urban fires.

These standard operating procedures are agreed upon by the involved Pima County departments to optimize the opportunity for application of identified human and financial resources in the most cost-effective manner. The commonly desired approach to buffelgrass identification, eradication, and monitoring described herein is not a commitment of specific departmental resources but provides a guide for departmental actions when apply any such resources.

B. DEFINITIONS

1. **Buffelgrass**: *Pennisetum ciliare* a shrubby bunch grass 1.5 feet tall, and 1 to 3 feet wide.
2. **Treatment**:
   a. Chemical Herbicide: Glyphosate herbicides in a 2 percent solution. Aquatic areas require further regulator compliance, and may require a different product; and
   b. Manual: Pulling or digging out the whole plant.
3. **Proper disposal**: Bagged grass is to be delivered to a Municipal Solid Waste Landfill. When this is not feasible due to remote conditions the material can be mounded and held in place with rock to adequately minimize seed dispersal.
4. **Monitoring**: Surveillance and documentation of conditions and efforts at identified locations.

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C. PROCEDURE

This Standard Operating Procedure (SOP) ensures the goal of the Pima County public works departments to develop and support an aggressive program to control the spread of buffelgrass.

All public works departments will develop and implement a program to address buffelgrass on rights-of-way and properties under their control. The lead department for this collective effort will be Natural Resources Parks and Recreation Department (NRPR). NRPR will be responsible for training of public works departments' key staff in the identification and control options for buffelgrass. The trained key staff within each department will be responsible for training their own respective agency staff. NRPR staff will advise and assist with training any public works department when requested. The Public Works Geographic Information Services Office will be the lead for the development of uniform Geographic Information System standards for capturing the mapped buffelgrass data. Each public works department will maintain information regarding control efforts/options and time commitments and will make such information available as part of the buffelgrass interagency working group and Pima County Invasive Species Working Group.

D. DETECTION, MAPPING AND TREATMENT

Properties under a public works department control should be surveyed for the presence of buffelgrass. Areas found to have a presence of buffelgrass should be subject to increased inspections and assessments regarding proper management options. It is easier and more effective to aggressively address the initial appearance of buffelgrass than to wait until it establishes a firm presence.

Treated sites should be resurveyed to evaluate effectiveness of control efforts or expansion of the infestation following the primary growing season. Staff should be trained to distinguish dormant (yellowish) from active (green) buffelgrass so inspections can be done year round. Maps of surviving buffelgrass and survey forms should be generated for the following season use.

The Public Works Geographic Information Services Office shall maintain a common GIS database for public works. Where possible, Pima County MapGuide ortho photos of the property should be utilized to record the location of buffelgrass. Standard survey forms should be filled out for each property or portion of a property surveyed and treated. Copies of the maps and survey forms shall be entered into the GIS buffelgrass database by each department on a monthly basis or as warranted by inspection findings.

E. TREATMENT AND CONTROL TECHNIQUES

Buffelgrass is a persistent perennial grass that has a long-lived seed bed. Current work indicates the seed bed can survive for at least 3-5 years following control efforts. There are two primary methods of control, herbicide application and/or manual pulling. The growth period for buffelgrass depends on rainfall or the availability of supplemental water. The primary regional growth period corresponds to the summer/monsoon rains and can be as little as a 2-6 week window, typically starting after mid-July. A spring time growth period may happen in February or March. Efforts to control buffelgrass should be planned well ahead and put into action as the growth period becomes evident.

1. **Chemical control:**
    - Buffelgrass must be green and actively growing for herbicides to be effective.
    - Try to spray before the buffelgrass develops seed heads or just as they are forming seed heads.
    - Herbicides will be most effective when at least 50% of the buffelgrass plant is green material.
    - The current herbicide recommended for use is a 2% solution of glyphosate. As the dry portions of the plant reach closer to 50%, then a higher concentration may be more effective but do not exceed more than a 5% solution. If the spray

treatment is in an area where revegetation isn't anticipated or desired, a pre-emergent can be added to the glyphosate mixture.

- Follow all label directions for the herbicide(s), include use of foaming agent in large spray tanks and a dye marker in mix to more effectively target spray on all buffelgrass present and away from non-target plant species.
- Take precautions to not spray non-target species of native plants. Use a pre-emergent additive only where the native seed bank will not be hampered from recolonizing the treated area.
- All spray units used by county staff should be operated under immediate supervision of a licensed sprayer and according to state law.
- Volunteers should not be allowed to use spray equipment on county lands unless specifically allowed by written agency procedures and state law.
- When spraying plants, put enough chemical on plants to coat all leaves but not enough to run off.
- Do not spray in rain, threat of rain or excessively windy conditions.
- Buffelgrass killed by herbicides can be removed or left to decompose in place.
- Chemical control sprays can be applied by hand, vehicle mounted units or other approved methods.

2. **Manual control:**
    - Mowing is not an effective control method by itself. It can be used in some cases just before the active growing season when followed by application of herbicide.
    - Mowing can sometimes stimulate buffelgrass to put out more green growth in the growing season and be more susceptible to herbicide applications, but don't mow if mowing will potentially spread seed to adjacent non-infested areas
    - The whole buffelgrass plant, including root rhizomes, must be removed for manual efforts to be effective; any portion of the root ball left behind can re-sprout.
    - Generally, buffelgrass has a defined and readily extractable root ball. Smaller buffelgrass plants in moist soil can be pulled by hand. For larger plants and in dryer soils utilize a digging bar or long-handled pick hammer to go in under the root ball at an angle and pop it out; utilizing the digging tool is more effective if two person teams work together.
    - Once grass with a root ball is removed from the ground, it should be put into large plastic bags with tie closures before removing from site for disposal in a landfill, whenever feasible. In remote areas, piling up the removed grass and rocking it in place to prevent seed dispersal is acceptable but will require additional/more frequent monitoring. Do not shake or disturb seed-heads, to minimize broadcasting of seed.
    - Buffelgrass cannot be used for mulch. Buffelgrass composting is highly discouraged, and would require intensive monitoring efforts in receiving areas.
    - If large areas of buffelgrass are detected that require manual control efforts beyond capabilities of an agency, NRPR can be contacted to assist with coordination of volunteer control projects.
    - Use of volunteers to control buffelgrass should be conducted in a way to ensure compliance of volunteers with the Public Works SOP, county risk management requirements, any applicable agency volunteer program procedures and state law.

F. MONITORING

All treated roadsides or treated patches of buffelgrass infestation should be monitored for new growth for at least 3 consecutive years. If new growth is detected, continue treatment efforts. Once no presence of buffelgrass is detected for three years, maintain a monitoring schedule of one site visit during the growing season every 3 to 5 years thereafter

Apply the same procedures initially used for surveying and mapping for routine monitoring of treated areas. Monitoring is best done during the active growth period.

Monitoring reports should be retained by each Department to track efforts and effectiveness of control strategies. A cost and time estimate by property or program should be developed at the end of every treatment period or fiscal year by responsible agency. A copy of all records will be submitted to ITD for a central database.

Appendix B: Private Landscaping Additions to the Right-of-Way

PIMA COUNTY
TRANSPORTATION

STANDARD OPERATING
POLICY AND PROCEDURE

Subject:	Number:	Page:	Effective Date:
Private Landscaping Additions to the Right-of-Way	670.03	1 of 6	09/26/19

Approval: Ana M. Olivares, P.E., Director *Ana M. Olivares*

PURPOSE:

To establish standards and requirements for the design, installation, and maintenance of private landscaping placed within public right-of-way by any person, entity, corporation, company, subdivision, or organization.

BACKGROUND:

Landscape additions must meet standards of public safety, environmental and economic sustainability, and fit aesthetically within the context of the surrounding area. This procedure outlines requirements for landscape additions that fulfill one or more of the following goals:

- Increasing shade and vegetative cover
- Creating and improving neighborhood identity at subdivision entries and along roadsides
- Providing stabilization and erosion control
- Increasing visual interest and creating "sense of place" in roadside and median areas devoid of vegetation
- Taking advantage of excess roadway stormwater runoff by creating water harvesting areas, and
- Fulfilling mitigation requirements of Title 18.72, the Native Plant Preservation Ordinance (NPPO) and Title 16.30, Riparian Habitat Protection.

DEFINITIONS:

Landscape is defined as all vegetation (both naturally occurring native and introduced vegetation), irrigation, and hardscape elements, such as decorative paving, benches, rocks, boulders, and decorative walls. It includes native grasses and other understory native plants, in addition to the plants on the Arizona Department of Agriculture's Protected Native Plants List *(1)*.

PROCEDURE:

1. Landscape additions not required by the NPPO shall be identified on a planting plan and submitted as part of the Right-of-Way Use Permit. The plan shall adhere to Section 3 of this procedure, be drawn to scale and include the following:

   - Bar scale and north arrow
   - Location Map
   - Right-of-way line
   - Pavement, including existing curbs and paths
   - Utility locations-overhead and underground
   - Topography – existing and proposed
   - Structures in vicinity – i.e. walls, utility boxes, building, signs
   - Street names
   - Limits of disturbance used in constructing project
   - Sight visibility triangles
   - Drainage structures- i.e. curb inlets, drainage basins, culverts, etc.
   - Existing vegetation in and adjacent to the project area
   - Existing washes
   - Proposed plant types, including scientific name, container size, and quantities
   - Lighting
   - Existing Regional Flood Control District (RFCD) riparian areas (if applicable)
   - Method of irrigation (if applicable)

2. Landscape additions that are required by the NPPO shall be shown on the project's landscape plans submitted with the Tentative Plat or Development/Site Construction Plan. A separate landscape plan for the right-of-way is not required. All proposed landscaping shall adhere to Section 3 of this procedure.

   - Landscape plans shall be reviewed by Development Services Department (DSD) staff assigned to review NPPO submittals and/or by RFCD staff assigned to review riparian habitat disturbance. Landscape mitigation shall be designed to be compatible with adjacent landscape bufferyard plantings.
   - Landscape mitigation plans shall indicate watering methods that will insure long-term survival of plants. If an automatic irrigation system is used, an irrigation plan shall be submitted along with the landscape plan. Cacti generally do not require automatic

irrigation systems, while irrigation systems are typically recommended for tree plantings. See Section 3 (II) for irrigation requirements.

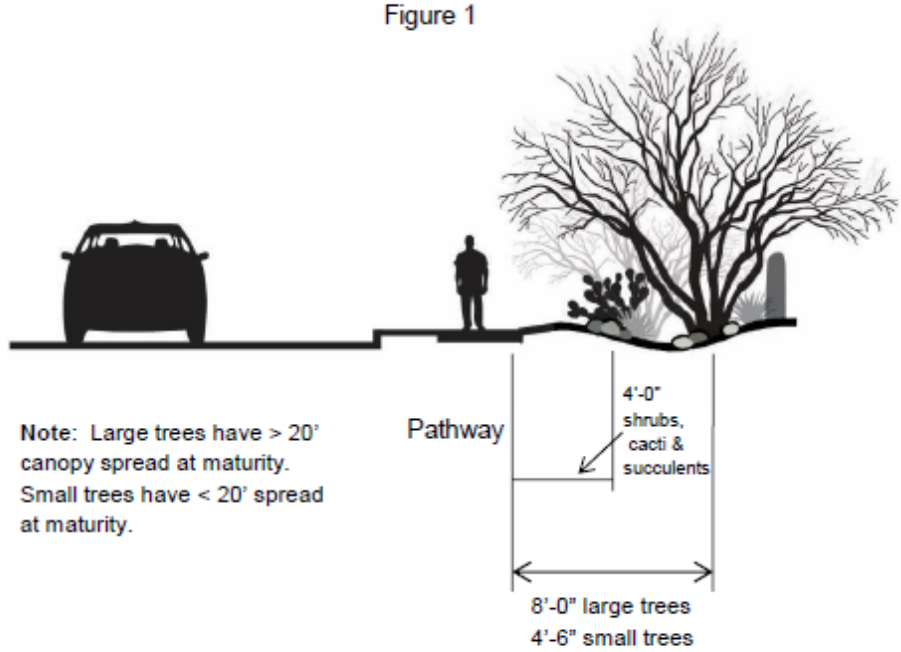
3. Landscape Guidelines

I. All proposed landscape plantings shall follow these requirements:

- Required setbacks

Plant Type	Requirement
Large Tree (Greater than 20' canopy spread at maturity)	8'-0" minimum from edge of shoulder or pedestrian path
Small Tree/Large Shrub	4'-6" minimum from edge of shoulder or pedestrian path
Small Shrubs/Cacti/Accents	4'-0" minimum from pedestrian path, face of curb, or edge of paving

Figure 1



Note: Large trees have > 20' canopy spread at maturity. Small trees have < 20' spread at maturity.

- Plant selections:

  a. Native plants observed growing in the immediate site vicinity or found historically within the project area should be used.
  b. When a wider selection of plants is desired, plants shall be selected from the Low Water Use Drought Tolerant Plant List *(2)*.
  c. Plants not meeting the recommended setback distances require more frequent pruning and maintenance.
  d. Consideration should be given to placing appropriate shrubs and small trees within clear zone limits. No individual part of the plant shall be larger than 4" in diameter at mature size. Trees and shrubs that are twiggy in character with multiple branches are appropriate. Many desert trees could be classified as large shrubs and can be used in the clear zone.
  e. Trees shall be selected that are multi-trunk or low branching and do not require staking. This form is typical of native desert trees. Planting structurally stable trees that do not require staking is preferred. If staking is used, it shall comply with American Nursery Association standards.

II. Invasive Non-Native Species: If invasive non-native species are present, the landscape plan will show the approximate locations of the invasive, state the schedule for, and type of treatment.

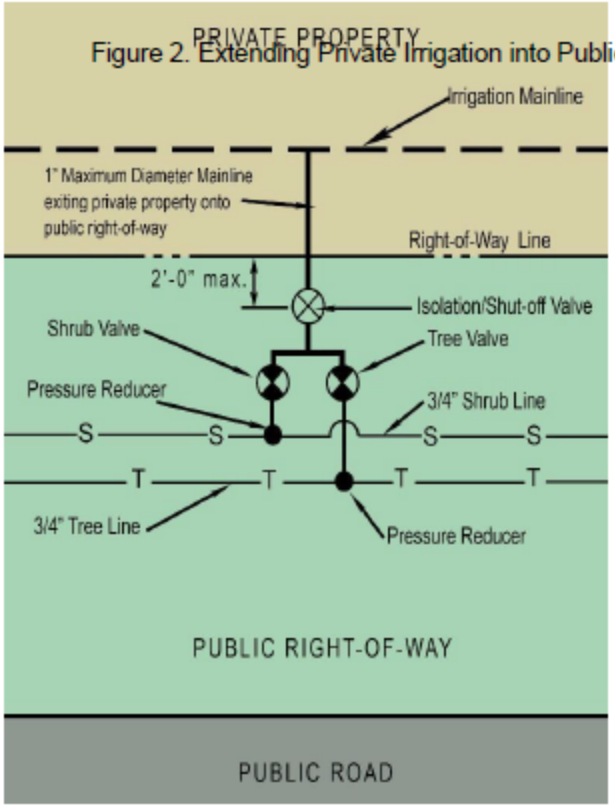
III. Irrigation: The method of watering new plantings is to be identified in the planting or landscape plan. Proposed plantings of cacti and succulents may not require supplemental irrigation depending on what time of year they are planted. Natural rainfall may be supplemented with drip irrigation system when necessary. Irrigation methods may include one or a combination of the following:

- If the landscaping in the right-of-way requires only minimal irrigation, emitter lines may be extended from the adjacent private property's irrigation system into the right-of-way and shall meet the specification for emitters under 808-2.13 of the Pima Association of Governments (PAG) Standard Specification for Public Improvements or unless approved otherwise by the County.
- If a more extensive irrigation system is required, an irrigation system either within the right-of-way with its own dedicated water meter and shut-off or outside of the right-of-way on private property in conformance with Figure 2

may be used. In either case, approval from Pima County Department of Transportation (PCDOT) is required.

- Landscape irrigation system installed within the right-of-way shall adhere to the latest requirements specified in the PAG Standard Specification for Public Improvements.
- Stormwater and rainwater harvesting may be incorporated in order to take advantage of natural stormwater runoff and rainfall. Basins shall be shown on the landscape plan. Maximum depth of basins = 1 foot with a minimum of 3 inches of freeboard. Guidance on stormwater harvesting basins can be found at Low Impact Design and Green Infrastructure Guidance Manual (3).
- Truck, hand, or other manual watering methods may be used.

Figure 2. Extending Private Irrigation into Public Right-of-way



- Irrigation plans for the development shall be provided with the submittal.
- All irrigation piping within the right-of-way shall be PVC Schedule 40.
- The portion of the irrigation system extending into the right-of-way shall be accessible to PCDOT in accordance with the diagram at left.
- An isolation valve shall be installed within the right-of-way to enable the system to be shut off by PCDOT when necessary.

IV. Maintenance:

- The person, entity, corporation, company, subdivision, or organization installing plantings in the right-of-way is responsible for the first year of landscape establishment. PCDOT shall assume landscape maintenance responsibility after one year for all landscape enhancements that have been approved under this Standard Operating Policy and Procedure. Privately installed plantings that mature to establish growth outside of the right-of-way on private property may be trimmed or removed by PCDOT.
- All landscape additions in which plants non-native to the Tucson region are selected or that are planted closer than recommended distances shall be maintained in perpetuity by the applicant.
- Maintenance activities performed within the right-of-way by the applicant are to be identified in a License Agreement with the County.

V. Disclaimer:

It shall be recognized as a condition of the license agreement that PCDOT may remove or trim plants in the County right-of-way at any time for road or shoulder widening or any purpose deemed necessary for the health, safety, and welfare of the public.

REFERENCES

1. Arizona Administrative Code, *Appendix A. Protected Native Plants by Category*, Title 3. Agriculture, Chapter 3. Department of Agriculture-Environmental Services Division, Article 1. Arizona Native Plants, pages 44 – 51, March 31, 2016.

2. Arizona Department of Water Resources, *Low Water Use Drought Tolerant Plant List*, Tucson Active Management Area, March 2007. 400 W. Congress, Suite 518, Tucson, Arizona, 85701.

3. Pima County/City of Tucson, *Low Impact Development and Green Infrastructure Guidance* Manual, March 2015.

Appendix C: Digital data form fields

Property Name

Survey Date

Time

Observer

Class (select one)

- Cultural
- Herb
- Bird
- Plant
- Invertebrate
- Mammal
- Fish
- **Invasive Plant**
- Invasive Animal
- Infrastructure
- Threat
- Other

Type (select one)

- Invasive plant species names appear in this field when Invasive Plant is selected for Class. For a list of species, see Appendix D.

Sub-type (select one)

- Isolated
- Localized
- Extensive
- Overrunning

Number

File Upload (select one)

- Yes
- No
- NA

Notes

Attachments

Appendix D: Invasive plants included in Pima County's digital data form

Excerpted from Appendix of the Regulated Riparian Habitat Mitigation Standards and Implementation Guidelines entitled, "Appendix E: List of noxious & invasive plant species & best management practices."

Pima County Regional Flood Control District. 2011. Regulated riparian habitat mitigation standards and implementation guidelines. Supplement to Title 16 Chapter 16.30 of the Watercourse and Riparian Habitat Protection and Mitigation Requirements Ordinance No. 2010 FC5, November 2011.

Arizona Wildlands Invasive Plant Working Group: Invasive Species Plant List

The following list was developed by the Arizona Wildlands Invasive Plant Working Group and adopted by the Arizona Invasive Species Advisory Council under EO 2007-07. The list was created to address invasive, non-native plant species that pose an ecological threat to wildlands in Arizona, and is divided into three categories, indicating the severity of ecological impacts on plant communities by invasive species. Plant species listed shall be controlled within disturbed and mitigated area(s) to prevent the spread into surrounding areas.

The entire document can be viewed at:

http://www.swvma.org/InvasiveNon-NativePlantsThatThreatenWildlandsInArizona.pdf

Hard copies of this document are available at our customer service counter, located at 97 E. Congress Street, 3rd floor.

Native Plant Species with Weedy Growth Habits

In certain areas, in particular, floodplains, specific native plant species can become invasive. While native species that are invasive in nature tend to be few, they can still affect the success of a mitigation area. For example, Palmer's Amaranth, an annual that germinates during the summer months, tends to form monotypic stands, competing with other native species for water and nutrients. Native weedy species should monitored and thinned as necessary to ensure success of the mitigation area.

Excerpted from the Regulated Riparian Habitat Mitigation Standards and Implementation Guidelines

Arizona Wildlands Invasive Plant Working Group: Invasive Species Plant List (continued)

Scientific Name	Common Name
High	
Acroptilon repens	Russian knapweed
Arundo donax	Giant reed
Bromus rubens	Red brome
Bromus tectorum	Cheatgrass
Centaurea solstitialis	Yellow starthistle
Eichhornia crassipes	Water hyacinth
Elaeagnus angustifolia	Russian olive
Eragrostis lehmanniana	Lehmann lovegrass
Euphorbia esula	Leafy spurge
Euryops multifidus	Sweet resinbush
Lepidum latifolium	Perennial pepperweed
Myriophyllum aquaticum	Parrot's feather
Myriophyllum spicatum	Eurasian watermilfoil
Pennisetum ciliare	Buffelgrass
Pennisetum setaceum	Fountain grass
Salvina molesta	Giant salvinia
Tamarix chinensis	Fivestamen tamarisk
Tamarix parviflora	Smallflower tamarisk
Tamarix ramosissima	Saltcedar
Medium	
Alhagi maurorum	Camelthorn
Avena fatua	Wild oat
Brassica tournefortii	Sahara mustard
Bromus diandrus	Ripgut brome
Bromus inermis	Smooth brome
Cardaria chalapensis	Lenspod whitetop
Cardaria draba	Whitetop
Cardaria pubescens	Hairy whitetop
Carduus nutans	Musk thistle
Centaurea biebersteinii	Spotted knapweed
Centaurea diffusa	Diffuse knapweed
Centaurea melitensis	Malta starthistle
Chondrilla juncea	Rush skeletonweed
Cirsium arvense	Canada thistle
Conium maculatum	Poison hemlock
Convolvulus arvensis	Field bindweed

List of Noxious & Invasive Plant Species

Watercourse and Riparian Habitat Protection and Mitigation Requirements
Mitigation Standards and Implementation Guidelines
E-4

Excerpted from the Regulated Riparian Habitat Mitigation Standards and Implementation Guidelines

** *Oncosiphon piluliferum* (Stinknet) is a High Severity threat that has emerged since the development of this list.

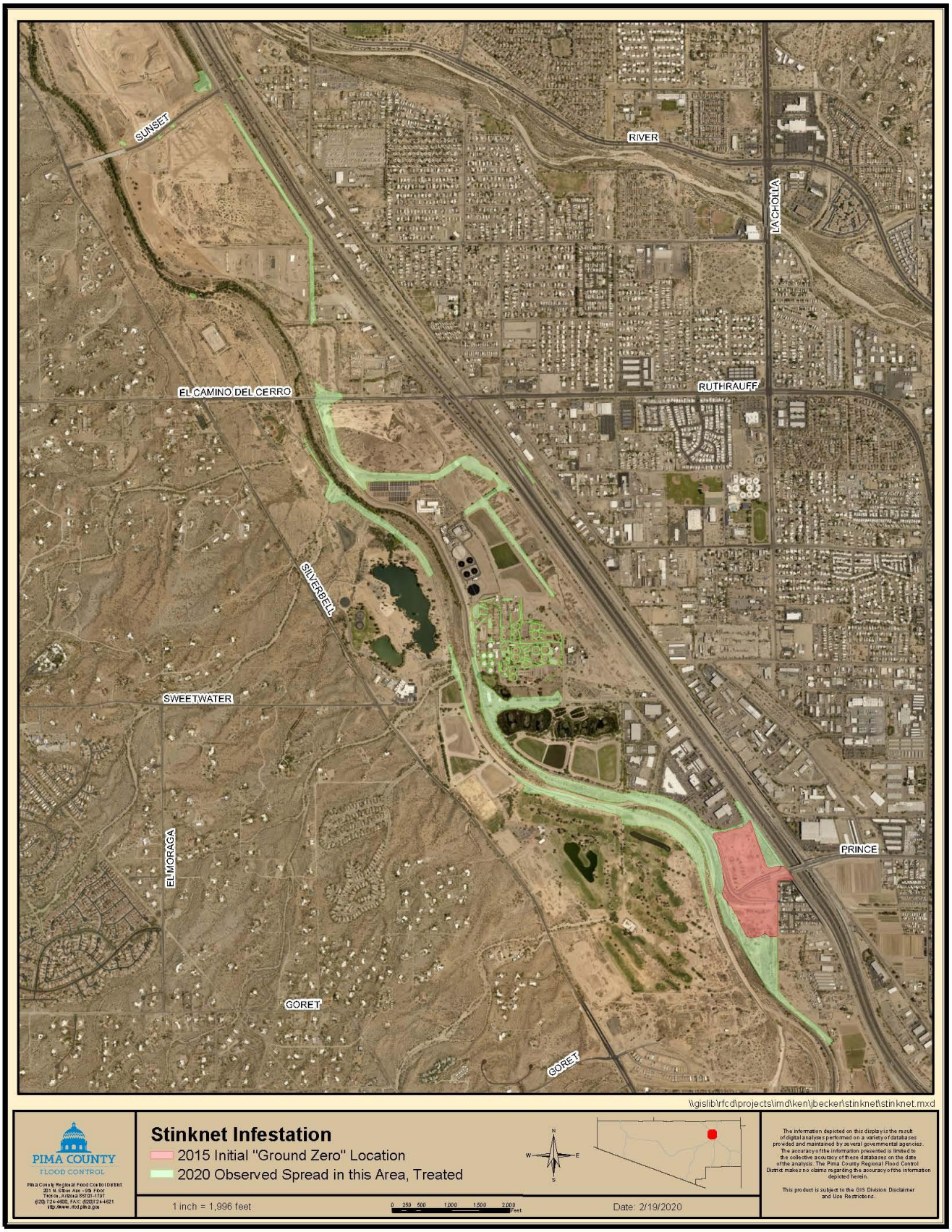
Arizona Wildlands Invasive Plant Working Group: Invasive Species Plant List (continued)

Scientific Name	Common Name
Cortaderia selloana	Pampas grass
Cynodon dactylon	Bermudagrass
Erodium cicutarium	Redstem filaree
Hordeum murinum	Mouse barley
Linaria dalmatica	Dalmatian toadflax
Linaria vulgaris	Yellow toadflax
Lolium perenne	Perennial ryegrass
Melilotus alba	White sweetclover
Melilotus officinalis	Yellow sweetclover
Mesembryanthemum nodiflorum	Slenderleaf iceplant
Rhus lancea	African sumac
Rubus armeniacus	Himalayan blackberry
Rubus discolor	Himalayan blackberry
Saccharum ravennae	Ravennagrass
Salsola collina	Slender Russian thistle
Salsola paulsenii	Barbwire Russian thistle
Salsola tragus	Prickly Russian thistle
Schismus arabicus	Arabian schismus
Schismus barbatus	Common Mediterranean grass
Sonchus asper	Spiny sowthistle
Sonchus oleraceus	Annual sowthistle
Sorghum halepense	Johnsongrass
Ulmus pumila	Siberian elm
Vinca major	Bigleaf periwinkle
Low	
Aegilops cylindrica	Jointed goatgrass
Asphodelus fistulosus	Onionweed
Cirsium vulgare	Bull thistle
Cynoglossum officinale	Houndstongue
Echinochloa crus-galli	Barnyardgrass
Elymus repens	Quackgrass
Eragrostis curvula	Weeping lovegrass
Leucanthemum vulgare	Oxeye daisy
Mesembryanthemum crystallinum	Common iceplant
Onoprodum acanthium	Scotch thistle
Panicum antidotale	Blue panicum
Tamarix aphylla	Athel tamarisk

Excerpted from the Regulated Riparian Habitat Mitigation Standards and Implementation Guidelines

Appendix E: Map of Initial Stinknet Infestation and Spread in Pima County

This map from Pima County Regional Flood Control District shows the initial infestation and spread of stinknet along the Chuck Huckleberry Loop and surrounding areas in northwestern Tucson.


SUNSET
RIVER
LA CHOLLA
EL CAMINO DEL CERRO
RUTHRAUFF
SILVERBELL
SWEETWATER
EL MORAGA
PRINCE
GORET
GORET
\\gislib\rfcd\projects\imd\ken\jbecker\stinknet\stinknet.mxd
PIMA COUNTY
FLOOD CONTROL
Pima County Regional Flood Control District
201 N. Stone Ave - 9th Floor
Tucson, Arizona 85701-1797
(520) 724-4600, FAX: (520) 724-4621
http://www.rfcd.pima.gov
Stinknet Infestation
2015 Initial "Ground Zero" Location
2020 Observed Spread in this Area, Treated
N
W
E
S
1 inch = 1,996 feet
0 250 500 1,000 1,500 2,000
Feet
Date: 2/19/2020
The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Regional Flood Control District makes no claims regarding the accuracy of the information depicted herein.
This product is subject to the GIS Division Disclaimer and Use Restrictions.

Pima County
Multi-species Conservation Plan:
2019 Annual Report

Appendix 12

Pima County Aquatic Invasive Species Monitoring Protocol

42 pages

Pima County Ecological Monitoring Program
Aquatic Invasive Species Monitoring Protocol

July 2020

PIMA COUNTY
SUSTAINABILITY & CONSERVATION

Prepared by Pima County Office of Sustainability and Conservation Staff:
Ian W. Murray
Jeff M. Gicklhorn

Cover photo: American bullfrog (*Lithobates catesbeianus*) at a pond on County preserve lands.

Recommended citation:
Murray, I.W., & J.M. Gicklhorn. 2020. Aquatic Invasive Species Monitoring Protocol. Ecological Monitoring Program, Pima County Multi-species Conservation Plan. Report to the U.S. Fish and Wildlife Service, Tucson, AZ.

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Table 1. List of aquatic invasive species in Arizona, as defined by State law and outlined in Director's Order 1 – R09/18. 9

Table 2. Prioritization framework indicating the relative importance of aquatic sites on Pima County lands informing management decisions concerning aquatic invasive species. 1 = most important. 26

Table 3. Prioritization framework indicating the relative threat posed by a particular aquatic invasive species, which in some cases varies by site. 1 = highest threat level. 28

Executive Summary

In arid ecosystems, riparian vegetation communities and their associated perennial or near-perennial waters play an outsized role in their contribution to plant and animal species richness. Many species that could not otherwise occur in arid regions depend on these riparian systems, and many more species that are more widespread in their habitat preferences still make important use of these 'ribbons' or 'patches' of green in an otherwise dry and challenging landscape. One well recognized threat to aquatic plant and animal species in the desert southwest is the invasion and establishment of nonnative aquatic plants and animals. These invasions often results in negative impacts to native species, in many cases resulting in chronic site-level extirpations and population reductions. This protocol outlines potentially damaging invasive species that could impact key sites and native species on Pima County conservation lands, as well as how Pima County will monitor the occurrence of these invasives.

A key part of Pima County's Multi-species Conservation Plan (MSCP) includes the County's stewardship of its extensive network of open space, or conservation lands. The streams, springs, and other riparian sites that occur on these lands are especially important to many of the species that the County covers under its MSCP. Additionally, many of these conservation lands are potential or allocated mitigation lands under the MSCP, and they therefore represent the primary focus of Pima County's Ecological Monitoring Program (EMP).

Pima County will use a variety of methods to monitor for the presence of invasive aquatic species, including:

- **Assessments made during wet-dry mapping of perennial surface water, fish, and leopard frog monitoring;**
- **Regular tracking of observations recorded from a variety of species databases, such as imapinvasives.org;**
- **Regular communication and collaboration with conservation partners operating within the same general area.**

Riparian sites within the scope of this protocol are highly variable in their species composition, relative importance towards maintenance of aquatic species diversity, relevant stressors or impacts, and proximity to urban areas. Further, some aquatic sites are located on lands that Pima County owns, versus those located on lands for which the County holds a grazing lease from the Bureau of Land Management (BLM) or Arizona State Land Department (ASLD). The status of land ownership dictates the scope of feasible management actions, including any addressing of invasive species. Subsequently, Pima County's natural resource managers will be required to prioritize and weigh the relative costs and benefits of any potential responses to the presence of aquatic invasive species. One key element of this protocol are guidelines meant to inform County managers in evaluating the relative threat that a particular invasive species may pose at a particular site and consequently to strategize use of limited resources in management responses.

The realities imposed by the finite resources available for management and monitoring, as well as the complexities of land ownership and regulations also highlights the critical role that prompt communication, relationship development, and coordination concerning invasive species play among the County's local, state, and federal conservation partners. Pima County will strive to maintain strong working relationships with these partners, with the goal of leveraging the strongest possible aquatic invasive species management and monitoring capabilities. For example, regardless of management decisions on the part of the County, all observations of nonnative aquatic species will be reported to the Arizona Game and Fish Department (AZGFD) and the U.S. Fish and Wildlife Service (USFWS) through annual reporting. Additionally, for those invasive species that are not already known to occupy the area and for which surveillance and early responses may be especially valuable, County staff will promptly communicate these observations through the respective State and federal invasive species programs.

Acknowledgements

We thank our colleagues in Pima County for their past, current, and future due diligence in their reporting of species of interest on Pima County open space lands. We also thank Pima County IT GIS, especially Mike List and Pankaj Jamwal for their continual efforts to build and improve the ecological monitoring program's geodatabase, as well as for assisting the monitoring program with other GIS-related needs like producing map products and providing assistance with digital data collection best practices and hardware. We are grateful to Julia Fonseca, OSC, and Don Swann, Saguaro National Park, for critical review of the material herein.

Background and Objectives

In arid regions, riparian and aquatic habitats make up a relatively small part of the landscape, yet they hold disproportionately high species diversity. These systems and are important not only for aquatic species, but also for terrestrial species that may depend on riparian systems as important habitats for foraging, movement, and shelter. Throughout the development of its flagship Sonoran Desert Conservation Plan (SDCP) Pima County has long recognized the critical role that aquatic habitats play in maintaining healthy ecosystems containing the full spectrum of native plants and animals present in our region and where these habitats occur across the > 250,000 acres of conservation lands that Pima County provides stewardship over. The County has, and continues to invest considerably in the acquisition and stewardship of these aquatic and riparian resources where they occur.

Pima County's Multi-species Conservation Plan (MSCP) is the vehicle by which the County remains in compliance with its Section 10 Incidental Take Permit issued by the U.S. Fish and Wildlife Service (USFWS) in 2016 (Pima County 2016). The MSCP covers 44 species of plants and animals (Covered Species), including nine species considered to be obligate riparian species (fishes, frogs, one snake species, and one plant species), as well as another eight species of birds and mammals which are also dependent on riparian habitats, particularly where these species occur in more arid regions.

Across Pima County, as well as more broadly throughout the southwestern United States, aquatic and riparian-dependent species are under a variety of threats and in many cases have experienced substantial declines and regional or local population extirpations. Indeed, federal and state lists of endangered and threatened species are widely populated by fishes, amphibians, reptiles, birds, and invertebrates that are dependent on riparian systems. Notable threats impacting aquatic and riparian systems and the species that depend on them include habitat loss, de-watering due to climate trends and human management and use, as well as the introduction of nonnative plant and animal species that may rapidly reduce or eliminate populations of native species. The introduction of nonnative and invasive aquatic species (especially bullfrogs, crayfish, mosquitofish, as well as nonnative sportfish) have been especially instrumental in causing range-wide declines and in some cases extirpations of native frogs, fishes, invertebrates, and gartersnakes throughout Arizona.

Pima County's ecological monitoring program (EMP) is a crucial part of the MSCP and it allows the County to track the condition and effectiveness of its stewardship as well as the status of Covered Species across County conservation lands. Specifically, most of the EMP's efforts are targeted towards existing and potential mitigation lands that Pima County has allocated or may allocate as mitigation under its MSCP. One required element of the EMP is a protocol that addresses surveillance for and potential responses to the presence of invasive aquatic species across County lands. Additionally, Pima County's MSCP identifies a set of changed circumstances that could potentially arise and that would impact Covered Species or their habitats (Table 7.1, MSCP). Several of these changed circumstances are related to potential

impacts caused by invasive aquatic species which will be discussed in further detail below, along with the County's potential response to these problems.

The objective of this protocol is to create a roadmap by which invasive species presence in aquatic habitats on potential or existing Pima County MSCP mitigation lands may be identified as soon as possible after invasion (i.e. especially for those invasive species that have not yet breached a particular habitat), to quickly and efficiently share this information with local, state, and federal partners, and where feasible, to manage or eliminate the threat.

Furthermore, where feasible and compatible with other management-related goals, the County will seek to maintain occupancy of perennial waters on County lands by the full range of native aquatic species, including the target aquatic species, through protecting those species that already occur there, as well as supporting the re-establishment of target aquatic species as laid out in the Aquatic Species Management Plan (Powell and Fonseca 2019). Those sites and species that are of particular importance to protect are highlighted below:

- **Ensure that native aquatic species persist at Cienega Creek Natural Preserve (CCNP) and prevent CCNP from serving as a conduit for invasive aquatic species to reach the headwaters of Cienega Creek within the Las Cienegas National Conservation Area**
- **Ensure that native aquatic species persist and prevent the establishment of invasive aquatic species (nonnative fish, crayfish) in Buehman and Bullock Canyons**
- **Ensure the persistence of naturally colonizing[1] Chiricahua leopard frog populations on County lands**

Aquatic features by area

Pima County's conservation lands system is made up of > 250,000 acres of fee and leased lands (for which the County holds a grazing lease) surrounding the City of Tucson (Figure 1). Aquatic and riparian habitats on these lands that have permanent or almost-permanent surface water include both supplemented and non-supplemented dirt stock tanks, springs, and stream stretches. The Aquatic Species Management Plan provides an in depth inventory of these features, as well as some of the native aquatic species that they harbor (Powell and Fonseca 2019). These sites broadly occur in both the Santa Cruz and the San Pedro River watersheds. Here we follow Powell and Fonseca (2019) in organizing County conservation lands and the aquatic features that they contain into four general areas based on similarities such as hydrology, elevation, human presence, baseline and historical populations of target species (Fonseca and Powell 2019)(Figure 1). Within these areas, key sites are highlighted and context is provided for how they fit into the County's Ecological Monitoring Program (EMP) and their importance to native aquatic species.

[1]Pima County may establish new populations of MSCP-covered species, including Chiricahua leopard frogs, through translocations, but the County cannot guarantee these translocations will persist in perpetuity. These translocations are a covered activity under the County's MSCP.

Map #	Name
1	Davidson Canyon Wash
2	Espiritu Canyon Wash
3	Buehman Canyon Wash
4	Edgar Canyon Wash
5	Bullock Canyon Wash
6	Sparkplug Tank Wash
7	Cienega Creek
8	Youtcy Canyon Wash
9	Santa Cruz River
10	Cerro Colorado Tank
11	Hopkins Tank
12	Hospital Tank
13	Big Tank
14	Buckelew Farms Pond
15	Goat Well Wildlife Pond
16	Bingham Pond
17	Canoa Historic Pond
18	Agua Caliente Ponds
19	South Pond
20	KERP Ponds
21	Roger Road Pond
22	Turney Spring
23	Robles Spring
24	Peck Spring
25	Central Pond
26	Waterfall

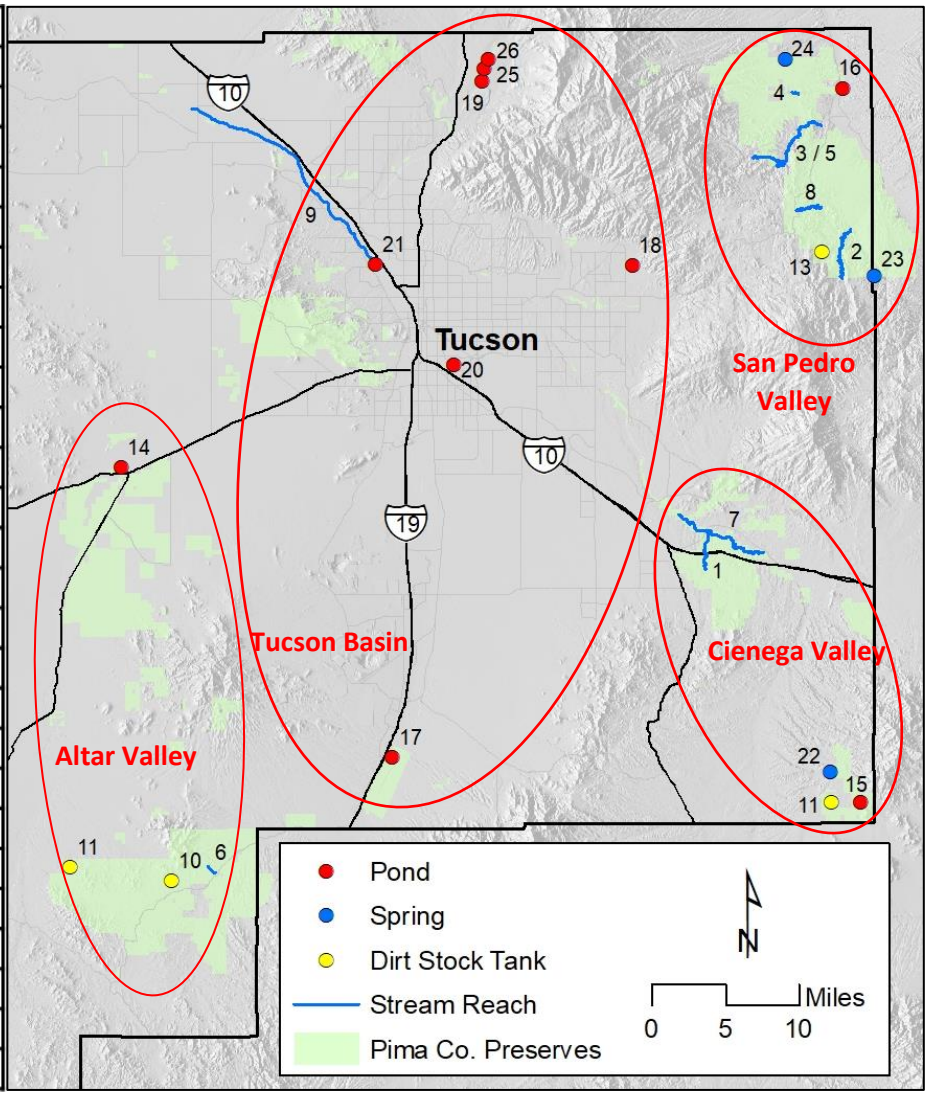

Figure 1. Perennial aquatic features on Pima County preserve lands. Modified from Powell and Fonseca (2019).

Cienega Valley

Aquatic sites on Pima County lands in this area are particularly important because they have a high biodiversity and are currently occupied by, or contain potential habitat for, a number of species covered by the County's MSCP. Additionally, these aquatic sites are both occupied by federally listed species (i.e., Gila topminnow, Gila chub, Chiricahua leopard frog) and connect metapopulations in adjacent riparian habitats managed by other agencies. The EMP regularly monitors conditions and status of riparian habitats on County lands here, including for the presence of invasive aquatic species and for leopard frog monitoring.

Cienega Creek Natural Preserve

Pima County's Cienega Creek Natural Preserve is centered on an approximately 9 mile stretch of lower Cienega Creek that contains intermittent stretches of permanent surface water as well as robust broadleaf deciduous riparian forest and mesquite bosque vegetation communities. CCNP stands out among the County's preserves for the extent of riparian habitat it contains, as well as the number of MSCP covered species that occur within its bounds. Indeed, for several species, this is the only property within the County's preserve network where they currently occur (e.g. Gila chub, Northern Mexican gartersnake), and for some species it is one of the most important preserve properties in terms of anchoring large populations (e.g., western yellow-billed cuckoo, Gila topminnow, longfin dace, and lowland leopard frog). From the perspective of invasive species management, CCNP is also important because it is one avenue by which nonnative and invasive species could enter Cienega Creek from the Tucson metro area. From here, there is potentially access to the upper reaches of Cienega Creek which currently has a fully intact aquatic fish, amphibian, and reptile fauna and which has few to no known established populations of invasive animals such as bullfrogs or crayfish.

There is a long history of monitoring that has taken place in Cienega Creek Natural Preserve, extending back to the original acquisition of the property in 1984. Currently Pima Association of Governments organizes a quarterly census of the extent of aquatic habitat in this preserve (surveyors walk almost the entire extent of the preserve, downstream of Interstate 10), which also includes observations of important aquatic species. EMP staff also assist in these quarterly 'walk throughs.'

Dirt tanks and ponds – Sands and Clyne Ranch

Sands and Clyne Ranches have several dirt stock tanks that may regularly hold water during parts of the year, but only Hospital Tank, on Clyne Ranch, is known to have held water continuously for many years. Hospital Tank is also a historic site where both lowland and Chiricahua leopard frogs have been noted, at different times. More recently, Chiricahua leopard frogs have colonized and reproduced in this tank, from nearby populations on BLM lands. This tank has been the target of a variety of management efforts targeted towards removing nonnative bullfrogs, mosquitofish, and green sunfish. Most recently, the tank was pumped dry in summer of 2019 to remove mosquitofish and bullfrogs. The many Chiricahua leopard frog tadpoles present at this time were relocated to other nearby sites, whereas the

juvenile and adult leopard frogs were either eaten by bullfrogs and other predators or emigrated from the drying pond. Following heavy monsoon rains in 2019, Hospital Tank is again full, and Chiricahua leopard frogs have already been reported to have re-colonized the site (observed in September 2019).

Goat Well Pond is a lined and supplemented pond fed by a well that Pima County specifically built for Chiricahua leopard frogs and other wildlife. Chiricahua leopard frogs colonized and reproduced in this site in 2018. In 2019, many Chiricahua leopard frog tadpoles from Hospital Tank were relocated into this site when that tank was drained for invasive species management. Monitoring both of these sites for invasive species presence will be a perpetual necessity.

Turney Spring – Clyne Ranch

Turney spring is a complex of four small features with some associated herbaceous riparian vegetation within a single drainage. One of these features is a spring-fed pool that is large enough to potentially be used by breeding amphibians. During June 2019 County staff observed unidentified leopard frog tadpoles (probably Chiricahua leopard frog tadpoles) within this pool. This site is not far from known Chiricahua leopard frog populations on BLM and County land, and illustrates the importance that springs and other aquatic features have for maintaining meta-populations of aquatic species on a landscape level scale. County staff regularly monitor the status of this spring, including any observations of invasive species, during regularly scheduled spring and seep monitoring.

Tucson Basin

Middle Santa Cruz River

Most of the native aquatic organisms that were historically present in the portion of the Santa Cruz River in Tucson have been extirpated for a variety of reasons including habitat modifications/loss and invasive species presence. Importantly, what used to be a perennially flowing river is no longer perennial in its lower reaches. However, highly treated effluent released from two County wastewater treatment plants allows for sections of the middle Santa Cruz River to flow year-round, though only some of this effluent-derived aquatic habitat passes through land that is owned by the County. Much of this aquatic habitat passes through land owned by the City of Tucson, which is out of the purview of this monitoring program. The City of Tucson and Tucson Water have recently begun releasing treated effluent in the Santa Cruz River in downtown Tucson (between Silverlake Road and Congress Street) which may also create suitable aquatic habitat for some species.

The Sonoran Institute (with funding from Pima County Regional Flood Control District and Regional Wastewater Reclamation Department) coordinates a variety of partners to monitor fish presence and diversity at four sites in the middle Santa Cruz River, on an annual basis. In most years, EMP staff assist in this monitoring, otherwise this site is not included in annual

mapping of aquatic habitats (this is considered a supplemented site) or in leopard frog monitoring (which are not known to occur in the river channel).

Due to its proximity to a large urban center with a variety of ponds that are actively maintained for sportfish as well as water features on private land, the Santa Cruz River is highly vulnerable to being invaded by additional invasive species. Nonnative aquatic species such as bullfrogs, common carp, green sunfish, black bullhead, and mosquitofish are already well established here and unlikely to be eradicated. Sightings of additional, yet unestablished invasive species such as quagga mussels or apple snails, would be a significant observation, however. Unlike for many already established invasive aquatic species for which eradication is not likely to be feasible or successful, an early and targeted response could potentially limit or eradicate newly detected aquatic invasive species before they become established, pending a rapid and coordinated response. Unique among sites, Gila topminnow, following natural recolonization of the effluent-supported reach of the middle Santa Cruz River in 2017, have occurred with the much more abundant mosquitofish over the last two years.

Managed ponds

Pima County manages several permanent ponds (supplemented) within the Tucson Basin, and most of these features are located in or near urban areas and frequently visited by the public. These urban areas include several lakes and ponds that Arizona Game and Fish Department's collaborative Santa Cruz Watershed Management Plan highlights as being managed as urban fisheries. Consequently, these features are intensively stocked with a variety of sportfish species, particularly channel catfish, largemouth bass, sunfish, crappie, and during the winter, rainbow trout. Because these waters are managed as sport fisheries, they will be a permanent avenue for potential invasion by invasive aquatics. However, most of the urban waters are relatively isolated from water bodies currently containing native aquatic species. Most of these pond sites on County lands are not regularly monitored by EMP staff (KERP ponds, Canoa Historic Pond), though most are visited sporadically by other County staff in the course of their duties. Further, in most cases, these sites are not considered to be important sites for the maintenance of native aquatic species, with the exception of Agua Caliente Park and Catalina Regional Park ponds (see below). Novel observations of nonnative aquatic species not known to be present elsewhere in Pima County are most likely to come from sites such as this, through communication with partners, the public, or other County staff.

Managed ponds – Agua Caliente Park, Catalina Regional Park, Roger Road, Mission Garden

Permanent ponds in Agua Caliente Park, Roger Road nodal park, and Catalina Regional Park are either currently occupied by native aquatic species covered by the County's MSCP (lowland leopard frog; Catalina Regional Park) or are targeted for native aquatic species restoration pending pond rehabilitation and nonnative species removal efforts (Gila topminnow, longfin dace; Agua Caliente Park and Roger Road Pond). Catalina Regional Park ponds are included in the sites that EMP staff monitor leopard frogs in, and pending any native fish restoration at Agua Caliente Park and the Roger Road Pond, County and AZGFD staff will regularly monitor fish

population status at Agua Caliente Park. Mission Garden features a historic representation of an irrigation canal that Gila topminnow were introduced to in 2019. Pima County owns the Mission Garden property, but the non-profit Friends of Tucson's Historic Birthplace manages the property, resulting in the County having a minimal role in invasive species management at this particular feature.

San Pedro Valley

San Pedro River tributaries

There are several intermittent and perennial stretches of stream flow on Pima County conservation lands (including both fee and leased lands) on the east side of the Santa Catalina and Rincon Mountains within the San Pedro River basin. Edgar, Buehman, and Bullock Canyons all have some degree of intermittent and perennial flow during the hottest and driest part of the year (June), whereas upper and lower Espiritu Canyon have an annually variable set of tinajas and pools, some of which come and go as they are alternately scoured out or sedimented in by heavy flow events. However, during June there are always at least some areas with permanent tinajas in this canyon, particularly in the lower reaches. Youtcy Canyon wash has some perennial stretches fed by spring flow, as well as several tinajas that reliably hold water.

All of these stream stretches represent regionally important riparian habitat for many plant and animal species (Buehman Canyon in particular, is one of the most important remaining riparian habitats in the lower San Pedro River drainage), as well as anchoring important populations of one or more MSCP-covered aquatic species. The AZGFD has recently stocked the endangered Gila topminnow into Edgar Canyon, and Buehman and Bullock Canyons have resident populations of native longfin dace. Lowland leopard frogs occur in all of these streams, which serve as an important metapopulation network. EMP staff visit all of these locations annually during a June census of perennial aquatic habitats on County lands (wet-dry mapping), as well as during triennial leopard frog monitoring efforts. All of these streams experience frequent scouring flows subsequent to heavy rains, which are not conducive to establishment of some invasive species such as bullfrogs, crayfish, and some species of aquatic plants. As of 2019 there are no known invasive aquatic animals that have established in these systems. In 2000, green sunfish were observed in several pools in Espiritu Canyon, but monitoring efforts have not documented this species since then (Fonseca, personal communication). Though no longer extant, past monitoring shows that green sunfish, goldfish, and mosquitofish were both present at one time in parts of Buehman Canyon, showing that some invasive animals could become established again, and highlighting the importance of continued monitoring (Malusa and Porter 1990).

Dirt tanks and ponds

Many dirt stock tanks occur across County lands in this area of active ranch lands. However, the majority of these dirt tanks do not hold permanent water and are not considered to be important features for the maintenance of native aquatic species. These dirt tanks are only

opportunistically monitored by EMP staff, but many do receive episodic visitation in the course of other work priorities which is one venue for reporting incidental observations on aquatic species presence. Additionally, the Bingham Pond is a large well-fed pond currently part of a life estate that is stocked with sportfish and not managed for native species, nor monitored by EMP staff.

Altar Valley

There are many dirt stock tanks and one series of perennial tinajas (Sparkplug Tank Canyon Wash) that occur on County lands in this area. Only a few stock tanks maintain permanent or near-permanent water, including Cerro Colorado Tank, Hopkins Tank, Buckelew Farms Pond, and Verdugo Pond. Though used by a wide variety of species, including desert-dwelling toads, none of these sites are currently occupied by native aquatic fishes, frogs, or reptiles. However, dirt tanks on Buenos Aires National Wildlife Refuge are currently occupied by Chiricahua leopard frogs, and the potential exists for these frogs to naturally colonize other tanks, such as the nearby Hopkins Tank on the County's Rancho Seco. No known aquatic invasive species are known to occupy these features, with the exception of bullfrogs that have been observed in Sparkplug Tank Canyon wash. County staff periodically visit many of these features and any incidentally observed native or nonnative aquatic species will be reported through these means.

MSCP changed circumstances

All USFWS habitat conservation plans, including the MSCP, need to include an accounting of and assessment of potential responses to what are called 'changed circumstances.' Changed circumstances are any changes in a situation that may impact a species or its habitat covered by a habitat conservation plan. These are changes that are realistic and that may be planned for (these are not the same as unforeseen circumstances, like civil unrest) and a complete list is included in Table 7.1 of the MSCP (Pima County 2016). Several of the changed circumstances are directly tied to the introduction of nonnative aquatic species and their potential to have negative impacts to species covered by the County's MSCP through degradation of habitat or direct impacts through competition, predation, or disease. These include both invasion of nonnative aquatic species into Cienega Creek or other aquatic sites through the use of Central Arizona Project (CAP) canal water as well as from sources other than CAP-derived water. The potential responses of the County in these cases are varied (see Table 7.1, MSCP for a complete list) and include working with partners to implement a contingency plan, assessing any potential negative impacts to covered species in Pima County, managing stock tanks with invasive species on County lands, attempting to eradicate invasives at certain sites, and engaging in public outreach and education on the issue. Pima County reports all changed circumstances to the USFWS as they are identified, and will work with the USFWS as well as State and local partners on the best response strategy as the situation may dictate.

Arizona regulations concerning aquatic invasives

Arizona law defines aquatic invasive species as "any species that is not native to the ecosystem under consideration and whose introduction or presence in this state may cause economic or environmental harm or harm to human health." This definition does not include any nonnative species lawfully or historically introduced for sport fishing or any species introduced by AZGFD or other entities that is pursuant to this title (A.R.S. 17-255). The most recent list of aquatic invasive species as classified by Arizona includes species that have been confirmed in the State and those species which have not been confirmed but which pose an imminent threat (Table 1). In addition to regulating the use and movement of watercraft, vehicles, conveyances, or other equipment that has been in contact with a list of waters infested with invasive species, state law prohibits possession, transport, release, or any commerce any of the species listed in Table 1 within Arizona. More generally, AZGFD regulations also include an extensive list of Restricted Live Wildlife (Article 4. Section R12-4-406; https://s3.amazonaws.com/azgfd-portal-wordpress/PortalImages/files/rules/Laws%20and%20Rules%20Book.pdf) whose possession or release is prohibited save for under permission from the Department. Included on this list are various aquatic species, including many nonnative fishes, turtles, and invertebrates.

Table 1. List of aquatic invasive species in Arizona, as defined by State law and outlined in Director's Order 1 – R09/18.

Common Name	Scientific Name	Status in Arizona	Status in Pima County
Bighead carp	*Aristichthys nobilis*	No occurrence	Not known
Black carp	*Mylopharyngodon piceus*	No occurrence	Not known
Silver carp	*Hypophthalmichtys molotrix*	No occurrence	Not known
Apple snail	*Pomacea spp.*	Present	Not known
Golden mussel	*Limnoperna fortunei*	No occurrence	Not known
New Zealand mudsnail	*Potamopyrgus antipodarum*	Present	Not known
Quagga mussel	*Dreissena bugensis*	Present	Present
Zebra mussel	*Dreissena polymorpha*	No occurrence	Not known
Red claw crayfish	*Cherax quadricarinatus*	No occurrence	Not known
Rusty crayfish	*Orconectes rusticus*	No occurrence	Not known
Snakehead fish species	*Channa spp./Parachanna spp.*	No occurrence	Not known
Spiny waterflea	*Byothrephes longimanus*	No occurrence	Not known
Fishhook waterflea	*Cercopagis pengoi*	No occurrence	Not known
Didymo or rock snot	*Didymosphenia geminate*	Present	Not known
Giant Salvinia	*Salvinia molesta*	Present	Not known
Golden algae	*Prymnesium parvum*	Present	Present
Hydrilla	*Hydrilla verticillata*	Present	Not known
Water hyacinth	*Eichhornia crassipes*	Present	Present

Crayfish are considered restricted live wildlife and some species are considered aquatic invasive species. The most common crayfish species in Pima County, however, the Northern crayfish, is not considered an aquatic invasive species under Arizona law. With some exceptions, crayfish are only allowed to be trapped and used as bait within the water body from which they came from, and may not be moved to a different water body. In some parts of the state there are exceptions to this rule, but that does not include Pima County. Bullfrogs are also restricted live wildlife species, but those held in private ponds and tanks (as well as fish) are not considered to be State property, unlike other wildlife species. Under State law, mosquitofish are neither considered an aquatic invasive species or included on the Restricted Live Wildlife list. Their possession and movement for use as bait is a permitted action.

Additional information on aquatic invasive species and their management in Arizona may be found on the Arizona Game and Fish Department's webpage at https://www.azgfd.com/fishing/invasivespecies/. Information on the Department's Santa Cruz Watershed Management Plan may be found at https://azgfd.maps.arcgis.com/apps/Cascade/index.html?appid=452a79fb9e2a438aa0bda7184de0225a. A major goal of this plan includes the recovery and protection of native aquatic species in this area. The area addressed by this plan includes many of Pima County's lands, and where appropriate Pima County will work with AZGFD to monitor and manage invasive aquatic species.

USFWS Aquatic Invasive Species Program

The USFWS has created an Aquatic Invasive Species (AIS) Program housed in the Service's Fisheries Program office (https://www.fws.gov/fisheries/ANS/ANS.html). This program supports aquatic invasive species coordinators who work with private, local, and state partners on a regional scale to implement and respond to aquatic invasives. On a more local scale, the Service staffs aquatic invasive species coordinators at regional USFWS offices. Arizona's aquatic invasive species coordinator is housed in the Region 2 office in Albuquerque, New Mexico. The USFWS also has an Arizona Fish and Wildlife Conservation Office (AZFWCO) in Pinetop, Arizona, that is responsible for aquatic species monitoring in Arizona.

As part of the program, an extensive set of risk assessments for various aquatic species are provided in an online library, as well as supporting an online platform to report invasive species sightings through the USGS Nonindigenous Aquatic Species (NAS) database and alert system (https://nas.er.usgs.gov/SightingReport.aspx). Additional activities include devoting resources towards public education and outreach, monitoring, rapid response actions, and contributing to an intergovernmental organization dedicated to the prevention and control of invasive aquatic species, the Aquatic Nuisance Species (ANS) Task Force (https://www.anstaskforce.gov/default.php). The ANS Task Force itself provides many resources concerning managing invasive aquatic species.

U.S. Bureau of Reclamation aquatic species monitoring

As part of mitigation efforts related to impacts to native fishes by the Central Arizona Project (CAP) water delivery system, the Bureau of Reclamation (BOR) is responsible for monitoring the CAP canal and primary connected waters every five years, primarily for aquatic invasive species surveillance. Included in this monitoring effort would be portions of the CAP and associated pumping stations within and near Pima County. There are also monitoring requirements targeting native fish species in select streams within the Gila River Basin. Currently, BOR monitors for native fish occupancy and invasive species presence in Cienega Creek on Pima County's Cienega Creek Natural Preserve every five years.

Invasive species of interest

There are many invasive aquatic species that have already become established or have the potential to become established in the waters that are covered by this plan, and both USGS NAS aquatic species database and information portal and the USFWS AIS program provide information on a wide variety of these species. Some species are known or suspected to be a threat even if they have not been documented in Arizona waters. There may be additional species that are not known to be a threat currently, that in the future could prove to be detrimental, and County monitoring staff will keep abreast of the current state of knowledge concerning these threats. Species of plants and animals listed below are known or suspected to be particularly likely to impact the aquatic habitats on County lands. Many of these species are included in Arizona's Aquatic Invasive Species Management Plan (AZGFD 2011). See Appendix B for a more detailed status of these aquatic invasives across County open space lands. Observations of invasive aquatic species that are not outlined below will also be reported to USFWS and AZGFD Aquatic Invasive Species coordinators, and evaluated on an individual basis for what if any action is required. A variety of other nonnative plant species have a high potential to, or are already impacting riparian systems in Pima County, many of which are plants that also grow in upland areas (i.e., not only restricted to riparian/aquatic systems). Examples include onion weed (*Asphodelus fistulosus*), fountain grass (*Pennisetum setaceum*), and tamarisk (*Tamarix ramosissima*), among others. These are covered in Pima County's invasive plant species protocol (Webb 2020).

Vertebrates

American bullfrog (*Lithobates catesbianus*)

Worldwide, bullfrogs are considered to be one of the most ecologically problematic invasive species. This species is native to the United States and eastern Canada east of the Mississippi River, but has been deliberately, as well as unintentionally, introduced throughout the world. Native aquatic species in Arizona have been particularly hard hit by the presence of this species and its rapacious appetite for anything that can fit into its mouth.

Bullfrogs are currently not known to be established and reproducing in many of Pima County's most important aquatic habitats, partially because many of these systems experience heavy scouring events subsequent to winter and summer rainfall, something which bullfrogs are not

well equipped to deal with. For example, bullfrogs are sporadically, but regularly observed in the Cienega Creek Natural Preserve (CCNP), but these individuals seem to be originating in neighboring ponds on private property, they are not known to be reproducing within CCNP. However, bullfrogs are widely established in many permanent waters on private and public lands in eastern Pima County, and are known to occur and be reproducing in some sites on County land, only some of which are regularly monitored.

Rio Grande leopard frog (*Lithobates berlandieri*)

This large species of leopard frog, native to southeastern New Mexico, Texas, and parts of Mexico is widespread and well-established in the Lower Colorado River and lower Gila River drainages in Arizona (extending south and west of Phoenix) and southern California, and has occurred there since at least the 1970s. It was likely accidentally introduced as tadpoles mixed in with stocked fishes from Texas (Rorabaugh et al. 2002). There are no confirmed cases where this species' distribution overlaps that of native leopard frogs, though Rio Grande leopard frogs are known to occur near extant lowland leopard frog populations near Lake Pleasant (Rorabaugh 2013). There is currently not an active monitoring program for this species, though its population is thought to be expanding. It could have a detrimental impact on native leopard frogs through predation, competition, and/or hybridization. This species is also better able to coexist with nonnative fishes, crayfish, and bullfrogs (all species that it is sympatric with in its native distribution). It is not likely that a casual observer would be able to differentiate between native and nonnative leopard frogs. This species has not been documented in Pima County.

Southern leopard frog (*Lithobates sphenocephalus*)

The southern leopard frog is native to broad swaths of the eastern United States and is not known to be established in Arizona, though there are established nonnative populations in California. In 2015, this species was successfully eradicated from two ponds in the Huachuca Mountains, in native Chiricahua leopard frog habitat. This species could be easily introduced into an area through tadpoles contaminating aquatic plants in backyard ponds, or through intentional introductions as an addition to garden ponds. It is not likely that a casual observer would be able to differentiate between native and nonnative leopard frogs. This species has not been documented in Pima County.

African clawed frog (*Xenopus laevis*)

This obligatory aquatic species of frog occurs in Africa, but has been introduced and successfully established populations in isolated parts of Arizona and southern California. This frog was imported from Africa in large numbers during the 1940s and 1950s for laboratory studies, including for use in human pregnancy testing. This frog is also thought to be a natural host for the devastating amphibian pathogen *Batrachochytrium dendrobatidis* (Bd or chytrid), and is hypothesized to be involved with the spread of this fungus worldwide (USFWS 2015). The species remains an important and widely used animal in the laboratory, though its possession in Arizona is prohibited except under special license. There has been a reproducing population of this frog in the golf course ponds at Arthur Pack Regional Park since the 1960s, with observations as recent as 2015 (Dawson 2015). Additionally, older reports (1997) exist of specimens in the Reid Park golf course ponds, but the current status of this other population is

not known. There are no other known, established populations of this frog in Arizona. This species is likely not well equipped to disperse across large expanses of desert, but the danger of the established frogs at Arthur Pack is their potential to be captured and moved to other sites by unknowing or curious persons.

Barred tiger salamander (*Ambystoma mavortium mavortium*)

The barred tiger salamander, particularly in its larval form (often called waterdogs), is commonly used as live fish bait and subsequently has become established outside of its native range, including in parts of Arizona. The Sonoran tiger salamander subspecies (*Ambystoma mavortium stebbinsii*) is federally listed and occurs in only a small part of southern Arizona, centered on the San Raphael Valley. There is also an additional native subspecies of tiger salamander on the Mogollon Rim (*Ambystoma mavortium nebulosum*). Introductions of nonnative forms of tiger salamander are a threat to the rare Sonoran subspecies due to hybridization and disease transfer. With a valid Arizona fishing license anyone can import, move, or possess live waterdogs or metamorphosed adults (i.e., for use as fish bait), except for that portion of Santa Cruz and Cochise County where Sonoran tiger salamanders may occur. This does not include any of Pima County's conservation lands. Nonnative barred tiger salamanders have been observed and removed from various stock tanks on the north side of the Tortolita Mountains, Buenos Aires National Wildlife Refuge, as well as from stock tanks along Redington Road in the Santa Catalina Mountains. The current status of these populations are unknown. During a 2002 herpetofauna inventory biologists observed more than 100 tiger salamanders during nocturnal road surveys near Pima County's Avra Valley Waste Water Treatment Facility (Harris Environmental Group, Inc. 2003). Construction at this site in 2007 removed the two deep ponds that salamanders reproduced in, replacing them with multiple shallow ponds and eliminating salamander breeding habitat (Higgins 2011). Though the current status of this population is unknown, salamanders are likely no longer reproducing at this site; however, there may still be deep and permanent waters in the form of stock tanks on private lands and the City of Tucson's Southern Avra Valley Storage and Recovery Project ponds that is also nearby. They have also been observed on the Loop trail adjacent to the lower Santa Cruz River in Tucson.

Watersnakes (*Nerodia fasciata/Nerodia sipedon*)

The southern watersnake and the common watersnake are both species of snake native to the eastern United States that have become established in parts of California. These snakes occur in riparian and aquatic habitats and feed on a variety of prey, most commonly including amphibians and fishes, and they are a threat to native fishes, amphibians, and reptiles. The southern watersnake was recently (2015) found to have become established in the Mittry Lake area near Yuma, Arizona, and poses a direct threat to a variety of native species should it spread further into the Colorado River system. This species is not known to occur in Pima County, but it represents a potentially invasive species that could impact native aquatic species on County preserves given how common it is in the pet trade. Snakes in the genus *Nerodia* are not included on the AZGFD list of Restricted Live Wildlife.

Mosquitofish (*Gambusia affinis*)

Mosquitofish have been widely moved around into water bodies beyond their native southeastern United States range, and are a common cause of decline and/or extirpation of small native fish such as Gila topminnow. They may also have negative impacts on some species of frogs via direct predation on eggs or small larvae. Nonnative mosquitofish and the endangered native Gila topminnow are very difficult to differentiate in the field, and may require specimens to be captured and closely examined by someone who is aware of the small morphological differences between the two species. Their invasion and establishment in Cienega Creek Natural Preserve would be an ecological catastrophe and would open the door for the specie's continued upstream movement into the upper portions of Cienega Creek. Mosquitofish are widely used in private ponds, occur widely in urban and other waters in eastern Pima County, and are established in several aquatic habitats on County preserve lands.

Green sunfish (*Lepomis cyanellus*)

Green sunfish are native to the Mississippi River drainage in the Midwest, naturally occurring as far west as parts of eastern New Mexico and Colorado. Through accidental introductions through the stocking of similar bluegill, or intentional releases, this species has spread widely in aquatic habitats large and small, throughout the western United States. This fish is a voracious predator on smaller fishes and larval amphibians, as well as being an efficient competitor for larger native fishes, and has been responsible for local extirpations or declines of native aquatic species in parts of Arizona. Similar to mosquitofish, the establishment or movement through Cienega Creek Natural Preserve would prove disastrous not only for native aquatic fauna in lower Cienega Creek, but could allow this invader to gain entry into upper portions of Cienega Creek as well. While the natural streams that are routinely surveyed by staff during wet-dry mapping have not yielded any observations of green sunfish, this species is established or has been recently observed in several aquatic habitats on County preserve lands (as well as widely across other urban waters).

Nonnative game fish

Other species of traditional 'warm water' game fish are commonly transported and released intentionally or unintentionally, and are widespread in Arizona's water bodies. Permanent lakes and ponds, particularly those well-visited by the public, are those that are most likely to have various game fishes, often stocked intentionally for sportfishing. Arizona Game and Fish Department maintains three put-and-take lakes in its Urban Fishing Program that are located within Tucson. These are Silverbell Lake (Christopher Columbus Park), Kennedy Lake (Kennedy Park), and Lakeside Lake (Chuck Ford-Lakeside Park). Several other waters outside of Tucson are stocked for public fishing as well, including Sahuarita Lake and Rose Canyon Lake. Additionally, many waters in other parks, golf courses, and private property may be stocked with a variety of fishes. In most cases, nonnative game fish are not compatible with the continued existence of robust populations of native frogs and fishes. Many aquatic sites on County lands are not optimal for long-term occupancy of these sportfish for reasons such as small size and tendency to have scouring floods. Many of the features that have potential to harbor established populations of game fish are not regularly monitored by EMP staff (i.e., KERP ponds and Canoa Pond). Of note are extensive pond restoration and nonnative species removal efforts that are pending completion at Agua Caliente Park ponds, previously a site with

significant numbers of nonnative fish species. Largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), black bullhead (*Ameiurus melas*), and carp (*Cyprinus carpio*) are some of the more commonly encountered species.

Invertebrates

Northern crayfish (*Orconectes virilis*)

The northern crayfish is currently established in many locations in Arizona, including some parts of Pima County, such as Rose Canyon Lake in the Santa Catalina Mountains. Observations of crayfish in ponds located in public parks in Tucson (Kennedy Park and Christopher Columbus Park) are also likely this species. Arizona does not have any native crayfish species, and the northern crayfish has spread due to the frequency with which it is moved around different water bodies as fishing bait, as well as under its own power of dispersal once reaching a site. This species has proven to be extremely detrimental to native fish, amphibians, and reptiles due to direct predation and its ability to alter the habitat through its burrowing and herbivory of aquatic vegetation. Northern crayfish are mostly likely to become established in larger, more lentic waters; they do not often become established long-term, in streams that regularly experience scouring floods. Nonetheless, the presence of any crayfish in Cienega Creek Natural Preserve must be taken seriously as the species, should it become established, would have negative impacts on native fishes, frogs, and reptiles both in lower and upper Cienega Creek. Other species of crayfish like the western plains crayfish (*Faxonius causeyi*) and the red swamp crayfish (*Procambarus clarkii*) have been documented at individual sites upstream of County lands, Parker Canyon Lake and the San Pedro River National Conservation Area, respectively (Moody and Taylor 2012; Smithsonian Institution 2014). The rusty (*Faxonius rusticus*) and the red claw (*Cherax quadricarinatus*) crayfish are additional species with a high potential for invasion in Arizona, but which have not been confirmed in the state. Arizona Game and Fish maintains the latter two species on a 'watch list' of potentially invasive species that could become established in Arizona. The casual observer is not likely to be able to differentiate among crayfish species. An unconfirmed observation of a crayfish in CCNP during 2015 was investigated during a follow up survey, but was not confirmed.

Apple snail (*Pomacea* sp.)

Several species of apple snail, native to South America, are invasive and have spread in aquatic systems throughout several states. These are large aquatic snails, that can reach over 3 inches. The channeled or golden apple snail has become established in parts of the Salt River and parts of the lower Colorado River. This tropical species can survive in a variety of aquatic habitats, and can withstand long periods of desiccation. These snails are spread through accidental or intentional introductions from the aquarium trade, as well as through introductions for human consumption. Apple snails can carry parasites harmful to humans, and are not a recommended food source. They feed on aquatic vegetation and pose a threat to native snails and other invertebrates. There are currently no known populations on County lands. A bleached shell belonging to this species was found on County land on the east side of the Tucson Mountains, and could have originated from Kennedy Park Lake, which was not far away (J. Sorensen, AZGFD Invertebrate Program Manager, personal communication to I. Murray). Due to its large size as well as its unique habit of laying large clusters of bright pink eggs above the water line on reeds

and cattails, infestations of this species are likely to be noticed. Any observations of live individuals on County lands should be followed up on and early elimination accomplished through partnership with AZGFD.

Chinese mystery snails (*Cipangopaludina chinensis malleata*)
These golf ball-sized snails have long been a popular addition to aquariums and garden ponds and have consequently become established in many locations outside of their native range. The impacts that this detritivore may have on native aquatic mollusks are not clear, but it may have negative impacts on native species through competition and its superior ability to resist crayfish predation, relative to native snails. The Chinese mystery snail broods its eggs internally, and gives 'live birth' to fully developed snails. It is established in Salt River Project (SRP) canals in Tempe, AZ, as well as the Bubbling Ponds Fish Hatchery in Cornville, AZ. One individual was also collected from a pond on the University of Arizona campus in 1965, but additional information on the pond's location is not provided. Young and Boyarski (2012) report on northern Mexican gartersnakes attempting to feed on this species at Bubbling Ponds, and document snakes getting their mandibles stuck between the snail's shell and operculum, potentially leading to death. This snail species is on the AZGFD list of Restricted Live Wildlife. There are no known occurrences on Pima County lands, but a large aquatic snail observed by a citizen in 2019 at Tucson's Silverbell Lake (Christopher Columbus Park), may be of this species. This observation is awaiting confirmation.

Red-rim melania (*Melanoides tuberculata*)
These African and Asian snails are established in multiple sites in Arizona, including SRP canals, the lower part of the Salt River, Lake Havasu, and in the lower Colorado River near Yuma. The red-rim melania, or Malaysian trumpet snail, is a common in the aquarium hobby, and likely became established through direct release or indirectly through aquarium plants. This species reproduces mainly via parathenogenesis (i.e., clonal reproduction). Fully developed snails hatch from internally brooded eggs. The red-rim melania can competitively displace native snails in some cases, a fact leveraged during its use as a bio-control method to reduce snail species hosts for schistosomiasis. It is also an intermediate host for a nonnative fish trematode that has the potential to harm some native fishes (USFWS 2012). This conical, mid-sized aquatic snail species is likely to be noticed, especially if it has built up to high population densities at a site. Casual observations indicate that this species may be present in some aquaculture tanks at the Arizona Sonora Desert Museum, but there are no other reports of this species from Pima County.

New Zealand Mudsnail (*Potamopyrgus antipodarum*)
This small aquatic snail species poses a threat to Arizona's native aquatic snails through competition. It is easily spread through both natural means, as well as through fishing and boating equipment. This small species (4-6 mm) reproduces asexually, and is not as likely to be casually observed and flagged as a potentially nonnative/unusual observation, as compared to larger and flashier aquatic snails such as the apple snail. This species can build up to large population densities that make up the majority of local macroinvertebrate biomass, and can consume the majority of the epiphytic diatoms in a system, thus directly competing with native macroinvertebrates that may feed on the same things (Shannon et al. 2002). Importantly, this

species is largely passed through the digestive tracts of fishes completely undigested, and thus makes a relatively small contribution to local food webs. In Arizona, the mudsnail has been established in the Colorado River and its tributaries below the Glenn Canyon dam, as well as recent observations from AZGFD's Page Springs Fish Hatchery and adjacent Oak Creek. There are no known observations on County lands, but should it gain a foothold in our area, it could not only negatively impact aquatic habitats where found, but also be a source population for infestation of other aquatic habitats, on and off County lands where it could be detrimental to native snails such as springsnails.

Quagga/Zebra mussels (*Dreissena bugensis/Dreissena polymorpha*)
These two closely related mussel species are native to Eurasia, and via discharge of ballast water from ships became established in the Great Lakes during mid-1980s. From there, both species have spread widely given their propensity to survive periods of dessication while attached to boats or boating equipment as well as by spreading the free-living larvae in transported water (e.g., bilge water, bait buckets). Not only are the dense colonies of this species often a maintenance nightmare for any sort of pumping station or equipment requiring unimpeded flow of water through intake pipes, but the filter feeding nature of these mussels, combined with their high densities, represents a significant alteration of aquatic food webs through their consumption of substantial amounts of phyto- and zoo-plankton. The quagga mussel is established in several Arizona lakes, including Lakes Mead, Pleasant, and Havasu. The Central Arizona Project (CAP) canal system and pumping stations also have quagga mussel infestations, and the species has been observed in the CAP canal as far south as the Brawley pumping plant (west of the Tucson Mountains) in 2017. The zebra mussel is not known from Arizona yet. Neither species has been confirmed from the Santa Cruz River.

Asian Clams (*Corbicula fluminea*)
This small, invasive bivalve has long occurred throughout the United States, and it too may cause significant economic damage through clogging water intake pipes, as well as potentially disrupting aquatic food webs through rampant filter feeding of plankton. In Arizona the species is well established in the Agua Fria, Colorado, Gila, Salt, and Verde River systems, as well as many canals in Maricopa County. It undoubtedly also occurs in other water bodies as well. In eastern Pima County, they have been observed in Kennedy Park Lake, as well as Tucson's Central Avra Valley Storage and Recovery Project recharge basins. This species may also occur in other urban lakes in Tucson, and may yet appear in the lower Santa Cruz River.

Plants

Potential – not yet established

Purple loosestrife (*Lythrum salicaria*)
Purple loosestrife is an invasive European perennial plant that has established itself in most states. This marsh plant can form thick, monotypic stands in marshes and on shorelines, crowding out native species and negatively impacting various wildlife species. Arizona has eliminated purple loosestrife, and is the only state without an established population (AZGFD 2011). A targeted and rapid response must be mustered following any observation of this species on County preserve lands, particularly in Cienega Creek Natural Preserve or the lower

Santa Cruz River. We note that the native California loosestrife, *Lythrum californicum*, occurs at Cienega Creek Natural Preserve as well as in other riparian habitats in this area, and care must be taken to not mistakenly remove the native.

Established in Arizona

Giant salvinia (*Salvinia molesta*)

This South American fern grows floating on the water's surface, and can quickly form dense mats, blocking sunlight from penetrating the surface, and compromising oxygen levels. Giant salvinia has invaded some areas on and near the lower Colorado River in Arizona (i.e., Imperial National Wildlife Refuge) as early as 1999, and is actively being managed. In 2003 a biological control agent, the salvinia weevil was released, which has contributed towards the control of the plant. Additionally, cold winter temperatures knock back infestations of this plant. Though there are no known occurrences in Pima County, continued vigilance is important.

Hydrilla (*Hydrilla verticillata*)

Hydrilla, a common water garden and aquarium plant, grows underwater, rooted into the substrate. Additionally, broken off pieces of stem can move with the flow of water and grow into a new plant. This species is prohibited in Arizona, but has been detected in multiple parts of the state, most commonly in the metro Phoenix area, but is not widespread. There are isolated observations that have been reported on Natureserv's imapinvasive program in the urban Tucson area, and it likely occurs in some of the urban ponds and lakes. There are no known infestations of it in natural systems on County preserve lands.

Brazilian elodea (*Egeria densa*)

Elodea is a South American species that also grows submerged in the water and is a popular aquarium plant. It is present in Arizona, though not widespread, particularly in Pima County, where the few observations are decades old. There are no known occurrences on County open space lands.

Parrotfeather (*Myriophyllum aquaticum*)

Parrotfeather, or parrotfeather watermilfoil is an invasive South American plant that grows leaves that occur submerged in the water, as well as leaves that are above the water (emergent). It is widely used as a water garden or aquarium plant. It has been observed in Arizona, but is not known to occur on County preserve lands.

Eurasian watermilfoil (*Myriophyllum spicatum*)

This Eurasian species is an invasive in lakes and ponds throughout much of the United States, and grows submerged in the water column. It has been documented in Arizona, including in Pima County, but these isolated observations are not recent. However, it has been flagged as being potentially an issue by the AZGFD invasives plan. There are no known populations on County preserve lands.

Curly leaf pondweed (*Potamogeton crispus*)

Curly leaf pondweed is widely invasive outside of its native Eurasia. This plant can form thick mats underwater, and has noticeably wavy leaf margins, serving as a convenient field marker. It

has proven to be a problem in some parts of Arizona, but no known populations occur in Pima County, or on County preserve lands.

Water hyacinth (*Eichhornia crassipes*)
This is a floating flowering plant originally from Brazil, but long established in the southeastern United States. This plant can clog waterways by forming expansive carpets across the water's surface, and millions of dollars are spent on its control every year. In 2016 it was reported from Ferguson Lake on the California side of the lower Colorado River, north of Yuma. A prompt and concerted control response has prevented this infestation from spreading. In September 2018 AZGFD provided an update of locations where listed (on list of designated aquatic invasive species) aquatic invasive species were known or suspected (https://s3-us-west-2.amazonaws.com/azgfd-portal-wordpress-pantheon/wp-content/uploads/archive/2018-DO-2.pdf). In Pima County, water hyacinth has been reported in lower Tanque Verde Creek, Arroyo Chico (tributary of the Santa Cruz River), and King Canyon, Saguaro National Park - West (Thomas and Guertin 2007). None of these locations contain permanent water, and these observations likely do not represent populations that are currently extant (the original observations were made in 2002). These locations do, however, potentially represent connections to the lower Santa Cruz River which does have permanent water, as well as representing sources for members of the public to collect and transport the plants elsewhere. While the possession, transport, and propagation of this plant is illegal in Arizona, it is a common water garden plant and any potential infestations are likely to appear in ponds and lakes that are visited by the public.

Golden algae (*Prymnesium parvum*)
This single-celled aquatic organism occurs worldwide now due to multiple invasions, but is considered nonnative in the United States. It is thought that the now established populations in the United States established through several different invasions from Europe. This species naturally occurs in brackish situations of estuaries and lagoons, but also occur in inland waters. It frequently occurs at low levels among many algal species and causes no harm. However, certain environmental conditions (such as elevated salinities) may trigger massive blooms of golden algae, which release a toxin that is lethal to fish, bivalves, tadpoles, and other gilled organisms, but harmless to livestock and humans. In some, but not all blooms, the water can take on a golden appearance. This species is unlikely to be casually detected, unless a bloom causes a fish die-off (if fish are present). AZGFD has documented this species in a municipal park lake in Tucson (Lakeside Park), and more widely in ponds and reservoirs elsewhere in Arizona, especially in Maricopa County. Any County preserves with fishes could be potentially impacted by this species.

Didymo (*Didymosphenia geminata*)
Didymo is a benthic diatom that can form expansive growths on rocks and other underwater surfaces. This species is native to Europe and Asia, as well as the Great Lakes region, but has been widely spread elsewhere within and outside of the United States, by those who recreate in streams and rivers. Didymo grows best in cool, flowing water with low nutrient loads. These growths are unsightly (growths may be confused with the presence of sewage) and lead to its

vernacular, 'rock snot.' This species can have negative impacts to aquatic macroinvertebrates and aquatic food web structure, as well causing economic damage through biofouling. Conditions that are conducive to this species are not likely to be found widely, or at all, on County preserves. In Arizona, it has been documented below Davis Dam in Lake Havasu.

Giant reed (*Arundo donax*)

Giant reed is an invasive grass from Asia that grows in dense thickets along perennial and ephemeral washes and other bodies of water. It can reach heights well over 20 feet tall. This plant can form monocultures that crowd out native species, creates fire-prone fuels, and alters riparian vegetation communities. It is already widespread throughout the United States, including Pima County. Two species of insects (a gall wasp and a scale insect) have been recently released in south Texas to aid in the control of giant reed. Eradication is likely not practical, rather control of this species must be evaluated on a site by site basis. Controlling isolated clumps of giant reed in Cienega Creek Natural Preserve has remained a continuous management need to prevent it from becoming widespread. Previous control efforts have succeeded in removing it from the upper portions of Sabino Canyon (U.S. Forest Service) and from a County-owned property in Bear Canyon, both in the Santa Catalina Mountains. Giant reed is widespread along the lower Santa Cruz River as well as the Tanque Verde Wash.

Floating primrose willow (*Ludwigia peploides montevidensis*)

This perennial, yellow-flowered plant grows rooted in the soil and grows both in shallow waters as well as moist soils. It can form thick and extensive mats, choking out aquatic habitat and other plant species and has become an invasive pest in many parts of the world. This subspecies is native to South America, though there are two subspecies native to parts of the southwestern U.S., *L. p. peploides* and *L. p. glabrescens*. All forms have the potential to form thick, waterway-choking stands. The native subspecies have been documented from the lower Santa Cruz River. Differentiating the various forms of this plant is likely difficult should this plant be documented on County lands. Collection of samples, with flowers, as well as photographs would be valuable in ascertaining what subspecies it is.

Methods

We will use visual encounter surveys to monitor for the presence of aquatic invasive species. Surveillance for these invasives will primarily occur during monitoring of scheduled perennial spring and stream systems (wet-dry mapping) and leopard frog and fish monitoring. County staff monitor the status of most of the perennial streams and springs on County lands annually during the hottest and driest part of the year (June) immediately prior to the monsoons. This allows staff to evaluate the status of these aquatic habitats in the state at which they contain the most limited amount of surface water or flow. Monitoring for leopard frogs and for longfin dace and Gila topminnow in Buehman and Edgar Canyons, respectively, are also done at this time of year. Because perennial water is at its minimal extent during June, any invasive aquatic species would likely be at their highest detectability. Additionally, the Sonoran Institute coordinates annual fish monitoring along parts of the effluent-derived lower Santa Cruz River during fall, an effort that County staff also assist with. Pending credible observations of aquatic

invasive species on County lands from conservation partners or regional databases, County staff may conduct follow up monitoring visits to assess the observation on a case-by-case basis.

Field survey methodology

We will assess presence and relative abundance of aquatic invasive species concurrently during annual wet-dry mapping of perennial surface water, as well as during fish and leopard frog monitoring efforts in some of these same waters. All of these monitoring efforts rely on passive visual encounter-style surveys. One to several surveyors walk along or around the extent of the aquatic feature to be surveyed during data collection on species present and condition and extent of aquatic habitat. Primary surveyors are biologists who have extensive experience in the desert southwest and who are familiar with and able to confidently identify native species of amphibians, reptiles, and most fishes and many plants of interest. These surveyors are capable of identifying what would likely be the most important aquatic invasive species present, including bullfrogs, crayfish, and green sunfish. In some cases, secondary surveyors also assist with monitoring (especially wet-dry mapping) either alone or accompanying a primary surveyor. Secondary surveyors may or may not have biological expertise such that they could confidently identify aquatic invasives of interest (particularly bullfrogs and nonnative fish). Observations of aquatic invasives made by secondary surveyors would potentially warrant a follow-up verification by a primary surveyor, depending on the site and the species observed.

In many cases surveyors will record an individual observation (preferably a GPS waypoint with documenting photograph) when a particular aquatic invasive is located during a survey or incidentally to other work. For some invasive plant infestations, a point-based observation may be qualified by extent, estimated number of individuals, severity of infested patch, etc. Furthermore, in some cases surveyors may encounter a rampant infestation of a species such as American bullfrog, crayfish, or nonnative fish where enumerating/taking point observations of each individual is not practical or possible. In these cases, a point(s) will be taken to capture the linear stretch or place where the species are, followed by an estimate of abundance and area occupied.

Other data collection methods

External databases

County staff will periodically (at least annually) assess any observations of aquatic invasive species that may be gleaned from a variety of species databases, which may not overlap in their data content. As part of its Heritage Data Management System (HDMS) the Arizona Game and Fish Department maintains a database of observation and survey data for invasive species called the Arizona iMapInvasives project. This database is populated by submissions from both citizen scientists and natural resource professionals, and is vetted before being accessioned. Additionally, iNaturalist contains species observation data, largely submitted by citizen scientists, and this database will also be used to look for potential aquatic invasive species observations on County lands and flag potential follow up surveys or requests for further

locality information from the project managers at iNaturalist. Herpmapper is also a widely used platform for citizens to submit observations on reptiles and amphibians, and County staff will also query this database for any relevant observations of bullfrogs, as well as other potential invasive species such as African clawed frogs or southern watersnakes.

Partner communications

Informal communication and networking with local, state, and federal agency partners is also a valuable means to keep abreast of notable observations of aquatic invasives potentially impacting County lands. Pima County EMP staff regularly communicate with County staff from other departments that spend substantial amounts of time on County lands during normal work responsibilities, various other partners agencies (AZGFD, USFWS and BLM) and non-profit organizations (i.e., Sonoran Institute and The Nature Conservancy), and researchers from the University of Arizona. Regular communications with all of these entities are another means for which EMP staff may become aware of, and follow up on if needed, observations of aquatic invasives on County lands. Through partner communications, database searches, and on the ground field surveys, Pima County will regularly assess the composition of the list of highest priority invasive species across County lands for potential monitoring and management considerations.

Support of external invasive species study and monitoring

Where feasible Pima County will support studies targeting the distribution, management, early detection, and ecology of aquatic invasive species and/or the native aquatic species that they potentially impact. Not only will supporting work like this improve the County's ability to respond and manage to invasive species, but it will likely also result in improved understanding of how and where aquatic invasives may be distributed on County lands.

Invasive Species and Monitoring Site Prioritization Framework

The perennial waters on County preserve lands within the scope of this protocol are diverse and span a wide spectrum in the degree to which they are managed, where they are located (and how isolated they are), what stressors/impacts they receive, their species composition, and their relative importance to those species that do occur there. Some of these perennial waters are in or near urban areas, while some are more remote. Additionally, some sites are on County fee-owned land, whereas some sites are on land for which the County holds the associated grazing lease from BLM or the ASLD. Land ownership largely determines the discretion the County has when addressing invasive species.

All aquatic invasive species have the potential to negatively impact aquatic habitats on and off of Pima County lands. Some species may have more of a known or potential negative impact than others, and or be particularly detrimental to particular sites, but not others. Further, a prompt and targeted eradication effort may be especially valuable where an invasive species has not yet become established at a site or area, versus efforts spent to control or manage an invasive species that is already known to be well-established and has little potential to be

eradicated. Additionally, there may be nonnative aquatic species that are not yet known to have a threat potential or are not otherwise mentioned here, and where possible EMP staff will be poised to become familiar with additional hazardous species as the current state of knowledge regarding these threats evolves.

The following framework outlines a rubric for how to respond to observations or reports of invasive aquatic species, and informs a strategy to prioritize allocation of resources for monitoring and management of invasive species on County preserve lands. Some sites are more important than other sites as related to maintaining landscape level conservation of covered species. Further, from a species-centric view, some sites may be especially important for Pima County to demonstrate its continued commitment to the MSCP and the goals therein. These are recommendations only and are contingent upon the discretion of those County departments tasked with managing the resources.

The AZGFD aquatic invasive species plan (AZGFD 2011) contains three priority levels ranking the relative importance and ability to cause damage for a variety of species, which we follow here. However, when ranking aquatic sites, we introduce a 4th priority level describing permanent ponds on County lands that are near other urban waters managed by AZGFD for sportfish and that are not located on potential or existing MSCP mitigation lands. In some cases aquatic invasive species ranked highly in the AZGFD plan are considered to be less of a threat in Pima County due to a lack of appropriate habitat on County lands (i.e., the absence of large lakes).

Factors considered during protocol development

In most situations, management actions necessary to accomplish conservation-related goals involve a diversity of partners from the local, state, and federal levels. Whereas the USFWS is tasked with administering the list of threatened and endangered species and regulating and directing actions associated with their recovery at a high level, AZGFD is more closely involved with managing on the ground monitoring, executing studies, and implementation of actions directly tied to recovery. Pima County works closely with both USFWS and AZGFD biologists in its stewardship of the species occurring on its conservation lands. A large part of this monitoring protocol entails outlining how to facilitate expedient communication, information sharing, and coordination among our conservation partners in response to invasive aquatic species observations. This is a necessity not only due to the legal structure of how wild plants and animals are regulated and the complexities of land ownership, but also due to the realities of the finite resources that are available to use in the course of potential management and monitoring actions.

We considered the factors below when structuring recommendations for possible actions, if any, in response to an invasive species observation at a particular site. Regardless of the response chosen, Pima County would report all observations of nonnative species to AZGFD and the USFWS via annual reporting and via prompt communications in the case of invasives

that are not already known to occur in an area via the respective aquatic invasive species programs (USFWS and AZGFD). Elements to consider include:

1. What is the land ownership of the site in question?

   County preserve lands include fee-owned lands, leased lands, and conservation easements. In general, the County retains the greatest degree of discretion for managing its fee-owned lands, which should be prioritized.

2. Is the invasive species in question already known to be established?

   Priority should be given when deciding on an appropriate management response for those observations that represent novel invasive species that are not yet established in Arizona, or are otherwise not yet established at or near a particular site.

3. Does the invasive species pose an immediate threat to the known occurrence of a federally listed aquatic species or a population of aquatic species covered by the MSCP?

   High priority should be given to protecting known populations of listed frogs, fish, and gartersnakes on Pima County lands. Emphasis should also be placed on ensuring the survival of established populations of non-listed, but MSCP-covered aquatic species on County lands.

4. Is the invasive species detected at a site that could be a conduit through which it invades other sites across a landscape – on or off of County lands?

   Emphasis should be given towards responding to an invasive species that is observed where it could move up- or downstream to impact other sites or other native species (i.e., Cienega Creek Natural Preserve).

Priority sites and species

We present a prioritization framework below with a tiered evaluation (priorities 1-4) of aquatic sites based on sites included in the Aquatic Species Management Plan (Powell and Fonseca 2019) and nonnative species (priorities 1-3) following AZGFD. Rankings here are meant to incorporate a site's relative ecological value as well as the relative damage potential of an invading aquatic species. Site and species priority rankings are shown in Tables 2 and 3.

Priority 1 sites

Highest priority sites (Priority 1) are sites for which an invasive species poses an especially damaging risk to continued occupancy of native aquatic species or for which invasion of the site may result in continued movement of a nonnative species into a larger watershed. These sites are those for which either known populations of federally listed target species occur and/or represent especially important riparian and aquatic habitats for which the impacts from an

invasion would have especially several impacts on a landscape scale (i.e., species moving into the Cienega Creek headwaters from the Cienega Creek Natural Preserve). These sites are all County fee-owned lands, and with the exception of Goat Well Pond, they are not supplemented. The highest consideration will be given to these sites when assessing a risk analysis and resource availability for a management response.

Priority 2 sites

Priority 2 aquatic sites also make substantial contributions to regional biodiversity and may host important populations of native aquatic species, including species covered by the MSCP. These sites may be smaller and/or not represent as great of a threat for invasive aquatic species to use them as a 'gateway' to additional susceptible aquatic habitats up or downstream. Several Priority 2 sites are artificially supplemented sites that are managed, or will be managed, for native aquatic species, but that do not represent naturally occurring populations, having resulted from relocations or restorations. Some of these sites are also located on County leased-lands where Pima County may be limited in its options to monitor or manage invasive species. Pima County will assess invasive aquatic species occurrences at these sites, and if feasible and/or possible may carry out a management response. The County may also seek assistance or guidance through partners such as the Arizona Game and Fish Department to appropriately respond to an invasive species at these sites. Importantly, while the County will make reasonable efforts to ensure the persistence of a population of translocated native aquatic species, the County cannot guarantee that those translocated populations will be occupied by those species indefinitely.

Priority 3 sites

Priority 3 sites are sites that are not known to be occupied by native aquatic species of interest (i.e., MSCP covered species) and most are relatively small and not well connected to other aquatic features. Included here would be dirt stock tanks, as well as small seeps and springs that are not occupied by aquatic species of interest. These sites are less important towards the maintenance of regional biodiversity and represent a very minor proportion of riparian and aquatic habitat on County preserve lands. An important exception the above are parts of the middle Santa Cruz River in the Tucson area. This stretch is effluent dependent and already has a variety of nonnative aquatic species established in its waters. However, the listed Gila topminnow continues to occupy portions of this reach since it was discovered in 2017. In this case, the County participates in annual multi-agency fish monitoring efforts led by the Sonoran Institute where data on nonnative aquatic species are collected. For most other Priority 3 sites, there are no regular monitoring efforts. Though Pima County may assess each occurrence of an invasive species individually, in most cases these sites are of a lower priority and less likely to receive a management response. Detected invasive species would be reported to conservation partners such as AZGFD. In some cases, however, the appearance of particular, as yet unestablished aquatic invasives at Priority 3 sites may still warrant a management response, particularly when coordinated with AZGFD (see Priority species below). Pima County is working with AZGFD on several pond restorations and subsequent native fish species translocations

within urban County parks. Though these ponds are within the Tucson area and are not considered 'natural' sites, County managers will have discretion to evaluate any specific invasive species management needs for these sites while balancing their educational and conservation value with the resources available for such endeavors.

Priority 4 sites

Priority 4 sites are ponds on County lands that are within or near lakes and ponds that are intensively stocked by AZGFD for urban sportfish management. These ponds are not managed for, nor known to be occupied by, MSCP covered aquatic species, and do not contribute towards the maintenance or enhancement of the native aquatic species addressed here. Priority 4 sites are the lowest priority for consideration of resources invested in management of nonnative aquatic species, as it relates to the maintenance of native aquatic species populations. As with Priority 3 sites, any observations of locally novel aquatic invasives will be assessed, and may merit a management response, particularly in coordination with AZGFD.

Table 2. Prioritization framework indicating the relative importance of aquatic sites on Pima County lands informing management decisions concerning aquatic invasive species. 1 = most important.

Area	Site	Priority
Altar Valley	Buckelew Farms Pond	3
	Cerro Colorado Tank	3
	Hopkins Tank	3
	Sparkplug Tank Wash	3
	Verdugo Pond	3
Cienega Valley	Davidson Canyon	1
	Cienega Creek	1
	Hospital Tank	1
	Turney Spring	2
	Goat Well Pond	1
San Pedro Valley	Big Tank	3
	Espiritu Canyon	2
	Robles Spring	3
	Youtcy Canyon	2
	Bingham Pond	3
	Bullock Canyon	1
	Buehman Canyon	1
	Edgar Canyon	1
Tucson Basin	Canoa Historic Pond	4
	Agua Caliente Park Ponds*	3
	Catalina Regional Park Ponds	3
	KERP ponds	4
	Santa Cruz River	3
	Roger Road Pond*	3
	Mission Garden Pond**	3

*Planned restoration efforts include establishing Gila topminnow at these sites.

**A multi-partner effort led to establishment of a Gila topminnow population here in 2019.

Priority 1 species not known to be established

Early detection and eradication of a pioneering invasive species is important because it is at this step in an invasion that elimination of the threat is most likely and the most cost-effective. Observations of the following species are especially important to document and bring to the attention of local, state, and federal partners (e.g., USFWS and AZGFD aquatic invasive species coordinators) in order to avoid or quash an early invasion. For some invasives, species identification may be difficult or may require further examination by an expert. Such observations made by Pima County staff will be evaluated and may be brought to species experts for confirmation if necessary. See Table 3 for species for which an early detection and elimination campaign may be useful and for which an observation anywhere on County lands is important.

Priority 1 species known to be established in or near Pima County

High priority aquatic invasive species are those that are the most likely to cause ecological damage and a rapid management and/or eradication response is of the utmost importance. In many cases, the threat they represent is a function of site because in general these species are widely established over large areas where landscape eradication is not possible. Rather, efforts would focus on control or eradication on a site by site basis. See Table 3 for a complete list.

Priority 2 species

Aquatic invasive species considered to be Priority 2 are known or suspected to be able to cause significant ecological harm, but that are already established at locations near sites on County lands (Table 3). Priority 2 species may also be species that have not established populations in Arizona, but that would be unlikely to spread or be able to flourish in most aquatic sites on County lands due to ecological requirements that may be difficult to meet on County lands. Though they may not be likely to impact particular sites on County lands, many of these species represent a greater risk to other aquatic sites elsewhere in Arizona, and the County would promptly communicate with relevant managers at the state and federal level regarding these observations.

Priority 3 species

Priority 3 aquatic invasive species are those species that are either established in areas on or near County lands (red-eared slider) or that have a very low likelihood of reaching and becoming established in aquatic sites on County lands (round goby). In general, these species present a very low risk to the continued occupancy of native species in perennial waters on County lands (Table 3).

Table 3. Prioritization framework indicating the relative threat posed by a particular aquatic invasive species, which in some cases varies by site. 1 = highest threat level.

Species	Priority Ranking	Site Prioritization
Surveillance and early detection important (at all sites)		
Apple snail	1	Not known
New Zealand mudsnail	1	Not known
Quagga/Zebra mussel	1	Confirmed, CAP waters
Golden mussel	1	Not known
Asian clam	1	Confirmed, limited distribution
Watersnake species (Nerodia)	1	Not known
Southern/Rio Grande leopard frogs	1	Not known
African clawed frog	1	Confirmed, limited distribution
Rusty/redclaw crayfish	1	Not known
Purple loosestrife	1	Not known
Giant salvinia	1	Not known
Parrotfeather	1	Not known
Curly-leaf pondweed	1	Not known
Hydrilla	1	Confirmed, urban waters?
Water hyacinth	1	Confirmed, not established in wild
Eurasian watermilfoil	1	Confirmed, not recent obs
Brazilian elodea	1	Confirmed, not recent obs
Didymo	1	Not known
Northern snakehead	2	Not known
Nutria	2	Not known
Chinese mystery snail	2	Not known
Red-rim melania	2	Not known, obs in aquaculture facility
Asian carp (Bighead, Black, Silver)	2	Not known
Round goby	3	Not known
Established in Pima County – threat is site specific		
American bullfrog Green sunfish Mosquitofish Northern Crayfish	1	Cienega Creek Natural Preserve Buehman/Bullock/Edgar Canyons Goat Well Pond Hospital Tank
American bullfrog Green sunfish Mosquitofish Northern Crayfish	2	All other sites
Giant reed	1	Cienega Creek Natural Preserve Buehman/Bullock/Edgar Canyons
Giant reed	3	All other sites
Black bullhead	2	All sites (difficult to differentiate bullhead species)
Chinese mystery snail	2	All sites
Red-rim melania	2	All sites
Golden algae	2	All sites

Species	Priority Ranking	Site Prioritization
Ludwigia peploides	2	All sites (difficult to differentiate native vs. nonnative subspecies)
Red-eared slider	3	All sites
Tilapia species	3	All sites
Common carp	3	All sites
Barred tiger salamander	3	All sites
tamarisk	3	All sites

Management response decision matrix

Management responses concerning reported occurrences of nonnative, aquatic species on County preserves will vary depending on the site and the species in question. Threats posed by invasive species often extend across the landscape scale, and should and do concern partners across land management jurisdictions (i.e., local, state, federal). The following actions are recommendations that are weighted by the relative risk, or priority level of a particular species or site. Pending an assessment of the situation, Pima County or its external partners may elect to respond in any manner that is evaluated to be the most prudent course of action.

Priority 1 species or site

1. If an unconfirmed observation, evaluate the need for having County staff/partners confirm the observation
2. Report occurrence to AZGFD and USFWS aquatic invasive species coordinators if the observation is of a new, not yet established invasive species
3. Communicate observation to conservation partners (AZGFD, USFWS, University of Arizona)
4. Evaluate feasibility and the need for treatment or eradication efforts at the site. Consider:
    a. What is the land ownership of the site?
    b. What are the chances of successful eradication and at what cost?
    c. Are there listed species or other MSCP covered species in immediate risk?
    d. What is the potential for species to spread from the site?
5. Coordinate site access if partners undertake eradication or management effort
    a. On a case-by-case basis, County may provide staff/equipment support to effort
6. Include observation and what if any action taken in annual MSCP report
7. Include observation in annual AZGFD Scientific Collecting License report
8. Evaluate the need for follow-up monitoring post-management response or otherwise

Priority 2 species or site

1. If an unconfirmed observation, evaluate the need for having County staff/partners confirm the observation

2. Communicate observation to conservation partners (AZGFD, USFWS, University of Arizona)
3. Evaluate feasibility and the need for treatment or eradication efforts at the site. Consider:
    a. What is the land ownership of the site?
    b. What are the chances of successful eradication and at what cost?
    c. Are there listed species or other MSCP covered species in immediate risk?
    d. What is the potential for it to spread from the site?
4. Coordinate site access if partners undertake eradication or management effort
    a. On a case-by-case basis, County may provide staff/equipment support to effort
5. Include observation and what if any action taken in annual MSCP report
6. Include observation in annual AZGFD Scientific Collecting License report
7. Evaluate the need for follow-up monitoring post-management response or otherwise

Priority 3 species or site

1. Communicate observation to conservation partners, if relevant (AZGFD, USFWS, University of Arizona)
2. Include observation and what if any action taken in annual MSCP report
3. Include observation in annual AZGFD Scientific Collecting License report

Priority 4 site

1. Communicate observation to conservation partners, if relevant (AZGFD, USFWS, University of Arizona)
2. Include observation and what if any action taken in annual MSCP report
3. Include observation in annual AZGFD Scientific Collecting License report

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Appendix A: Aquatic Invasive Species Program Contact Information

Arizona Game and Fish Department
Aquatic Invasive Species
Alex Martinez, AIS Program Specialist
623.236.7271
https://www.azgfd.com/fishing/invasivespecies/

Arizona Department of Environmental Quality
Monitoring and Assessment Unit
Jason Jones, Supervisor
1110 W. Washington Street
Phoenix, AZ 85007

Colorado River Aquatic Invasive Species Task Force
Dr. David Walker, University of Arizona
dwalker@ag.arizona.edu
https://cals.arizona.edu/craistf/what-are-aquatic-invasive-species-ais

Frog Conservation Project
Dr. Phil Rosen; 520.621.3187; pcrosen@u.arizona.edu
http://frog.cienega.org/home/contact-info

U.S. Fish and Wildlife Service
Aquatic Invasive Species Program
Region 2 – Southwest Region contact
Barak Shemai, Regional AIS Coordinator
505.248.6593
barak_shemai@fws.gov
P.O. Box 1306
Albuquerque, NM 87103
https://www.fws.gov/fisheries/ANS/ANS.html

U.S. Geological Survey
NAS – Nonindigenous Aquatic Species
https://nas.er.usgs.gov/
7920 NW 71st Street
Gainesville, FL 32653
352.378.4956 (fax)
Sighting Report Form:
https://nas.er.usgs.gov/SightingReport.aspx

U.S. Bureau of Reclamation
Aquatic Invasive Species
Jolene Trujillo, Invasive Species Coordinator
303.445.2903
jtrujillo@usbr.gov
https://www.usbr.gov/mussels/detection/index.html

Appendix B: Invasive aquatic species known on or near Pima County open space lands

Common Name	Scientific Name	Known from County fee land	Known from County leased land (BLM, ASLD)	Known from drainage area (Altar Valley, San Pedro, Cienega Valley, Tucson Basin)	Known from adjacent lands to County preserves
Amphibians					
American bullfrog	*Lithobates catesbianus*	Yes	ASLD	All	Yes
African clawed frog	*Xenopus laevis*	Yes	No	Tucson	No
Barred tiger salamander	*Ambystoma mavortium mavortium*	Yes	No	Tucson	Yes
Fish					
Mosquitofish	*Gambusia affinis*	Yes	No	Tucson, Cienega	Yes
Green sunfish	*Lepomis cyanellus*	Yes	No	Tucson	Yes
Common carp	*Cyprinus carpio*	Yes	No	Tucson	Yes
Bluegill	*Lepomis macrochirus*	Yes	No	Tucson	Yes
Largemouth bass	*Micropterus salmoides*	Yes	No	Tucson	Yes
Black bullhead	*Ameiurus melas*	Yes	No	Tucson	Yes
Goldfish	*Carassius auratus*	No	No	Tucson	Yes
Channel catfish	*Ictalurus punctatus*	Yes	No	Tucson	Yes
Grass carp	*Ctenopharyngodon idella*	Yes	No	Tucson	Yes
Invertebrates					
Northern crayfish	*Orconectes virilis*	Yes	No	Tucson	Yes
Apple snail	*Pomacea asp.*	No	No	Tucson	Yes
Red-rim melania	*Melanoides tuberculate*	No	No	Tucson	No
Quagga mussel	*Dreissena bugensis*	No	No	Tucson	Yes
Asian clam	*Corbicula fluminea*	Yes	No	Tucson	Yes
Plants					
Giant reed	*Arundo donax*	Yes	No	Tucson	Yes
Floating primrose willow	*Ludwigia peploides*	Yes	No	Tucson	?
Golden algae	*Prymnesium parvum*	No	No	Tucson	No

Pima County
Multi-species Conservation Plan:
2019 Annual Report

Appendix 13

Pima County Off-highway Vehicle (OHV) Monitoring Protocol

21 pages

Pima County Off-highway Vehicle (OHV) Monitoring Protocol

March 2020

PIMA COUNTY
SUSTAINABILITY & CONSERVATION

Prepared by Pima County Office of Sustainability and Conservation Staff:
Ian W. Murray
Amanda D. Webb

Cover photo: Pima County Regional Flood Control District's Diablo Estates property. Pima pineapple cactus (within circle) adjacent to an OHV track

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Abstract

In Pima County, the iconic and variable landscapes that sustain many native species are often the same that attract people seeking opportunities for outdoor recreation. Off-highway vehicle (OHV) use is a common mode of recreation in Pima County, as it is nation-wide. Like other kinds of recreation, OHV use is not always compatible with conservation goals, including sustainable management of threatened and endangered species. Where operators leave established roads and trails that are authorized for OHV use, the result can be significant destruction of vegetation, increased soil erosion, impaired water quality, noise that disturbs wildlife movements, and even the directly mortality of organisms. The Pima County Multi-Species Conservation Plan (MSCP) outlines conservation measures that the County is undertaking to preserve and enhance 44 species and the habitats that support them. Under the MSCP, the County is committed to avoiding and minimizing impacts of its disturbances. This protocol describes the geographic and regulatory environment of Pima County's fee lands and grazing leases, the processes by which data on unauthorized OHV use and impacts will be collected, and the channels of communication that will be used to report violations and needs for a management or enforcement response.

Acknowledgements

We thank our colleagues in Pima County, particularly staff within Natural Resources, Parks and Recreation and the Regional Flood Control District for their ongoing passion and diligence in working towards the best conservation and stewardship of Pima County conservation lands. We thank Brian Powell, NRPR, and Marisa Rice, RFCD, for providing helpful comments and review. We thank Pima County IT staff, particularly Pankaj Jamwal for his continued efforts to support staff's digital data collection and database needs.

Background and Objectives

Recreation involving off-road or off-highway vehicles (OHV) continues to grow throughout lands open to the public, especially in the western United States. The wide interest and demand for areas to recreate in this manner means that many land managers need to include OHV recreation management in land management plans. The Arizona Motor Vehicle Division (Department of Transportation) governs the use of OHVs, including requiring a registration and licensing system (except on private lands), and various state laws regulate the operation of OHVs in Arizona. Funding from this licensing system goes to support the three State departments that manage, enforce, and liaise with the OHV community in Arizona: Arizona State Parks, Arizona Game and Fish Department, and the Arizona State Land Department. Only the latter two departments perform law enforcement as it pertains to OHV use.

The State of Arizona defines an OHV as being a motorized vehicle that is used primarily on a natural terrain and including any "two-wheel, three-wheel, four-wheel vehicle, motorcycle (greater than 49cc), dune buggy, amphibious vehicle, ground effects or aircushion vehicle and any other means of land transportation deriving motive power from a source other than muscle or wind." However, for the purposes of this protocol the County includes potential impacts from off-road use of ANY motorized vehicle, including jeeps, trucks, cars, or any other otherwise street-legal vehicle that may be used on Pima County open space lands.

Pima County's Multi-species Conservation Plan (MSCP) is the County's way to remain in compliance with its Section 10 Incidental Take Permit issued by the U.S. Fish and Wildlife Service (USFWS) in 2016 (Pima County 2016). The MSCP covers 44 species of plants and animals (Covered Species), including eight federally listed species. A key part of the MSCP is Pima County's ecological monitoring program (EMP), which is tasked with tracking the effectiveness of the County's conservation and stewardship of the MSCP-covered species and their habitats across Pima County lands. Though the scope of the EMP includes most County lands, the majority of the EMP is focused towards existing and potential mitigation lands that Pima County has allocated or may allocate as mitigation under its MSCP. An important part of the EMP highlights the commitment to track various types of threats that may directly or indirectly impact Covered Species or their habitats. Impacts stemming from OHV use (primarily unregulated use) on County lands may be an especially detrimental threat.

The objective of this protocol is to address how Pima County will assess the threat that OHV traffic poses to potential or existing Pima County MSCP mitigation lands and the natural resources that they contain. Where appropriate and feasible, Pima County will work to identify and address OHV activity that is damaging these lands or the natural resources therein, through outreach, education, deterrence, and by working with law enforcement.

Geographic scope and context

Pima County's open space lands are made up of > 250,000 acres of fee (County-owned) and leased lands (for which the County holds a grazing lease) surrounding the City of Tucson (Figure 1). The County's Range program oversees eleven active ranches. In most cases, these ranches are made up of a combination of land that Pima County owns and land that the County leases either from the Arizona State Land Department (ASLD), or the Bureau of Land Management (BLM). The County has the greatest latitude for management of its fee lands. In contrast, on the County's leased lands, most management (outside of those actions directly tied with the County's grazing program) lies with either BLM or ASLD. This is an important distinction because on leased lands, any OHV violations and related management or enforcement needs would be reported to the appropriate contact at the state (ASLD or Arizona Game and Fish Department) or federal (BLM) level. However, on fee lands, reports would go directly to the Pima County Sheriff's Department.

This protocol makes a distinction between otherwise legal operation of motorized vehicles on trails and roads versus illegal operation of motorized vehicles. See Appendix A for a summary of OHV regulations by land manager. It is the impacts associated with the latter, illegal use and operation of OHVs that are the focus of this document. Important to note is that US Border Patrol operations and other types of law enforcement and rescue operations may, and often do, involve traveling off-road, including extensively in desert washes. While there may be negative impacts associated with these actions, they are done during legal duty operations.

Illegal operation of motorized vehicles includes:

- Traveling on trails or roads that are closed to motorized traffic
- Driving across open lands not demarcated with a road or trail
- Creating new roads
- Traveling through desert washes and streams

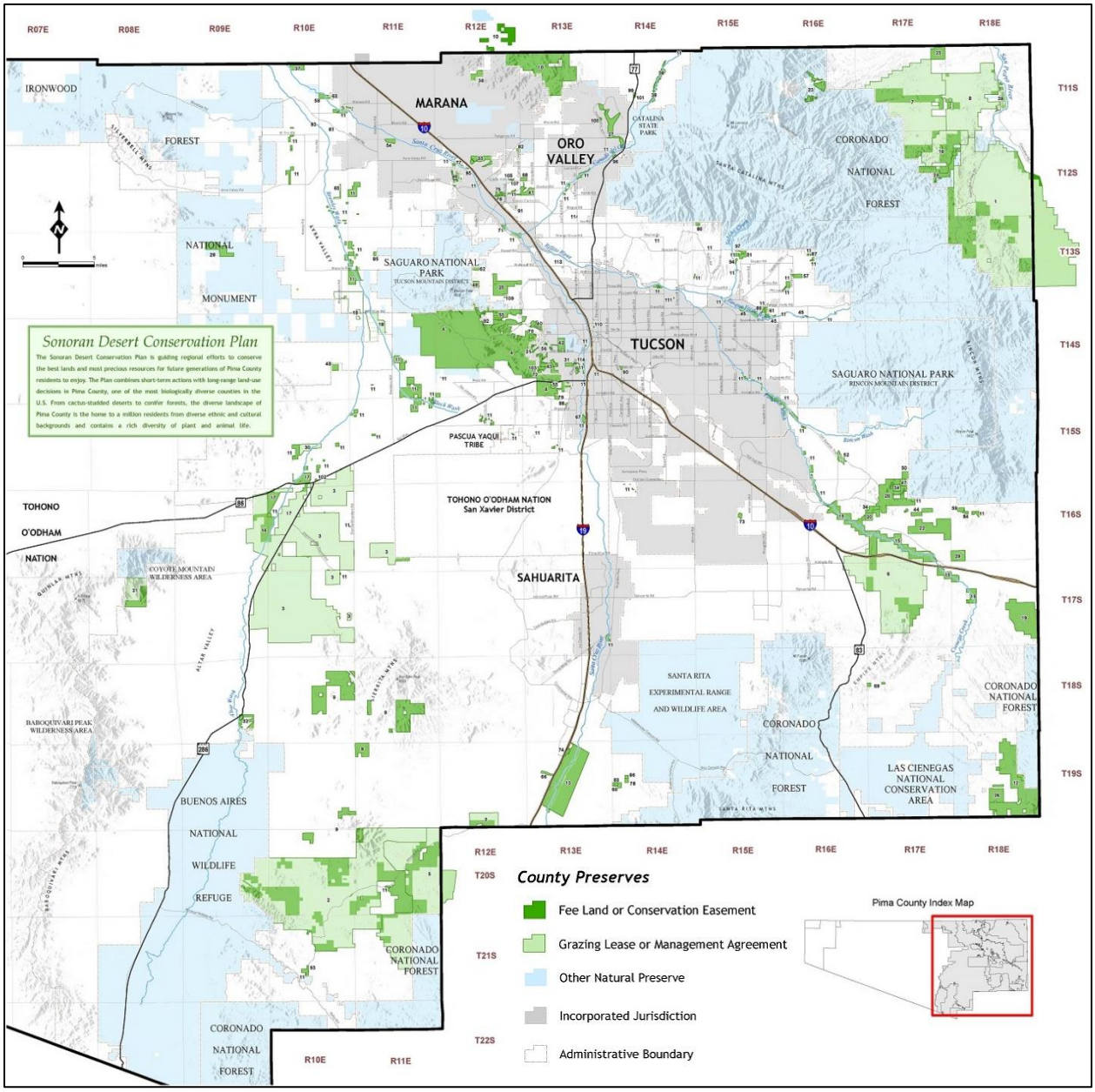

Figure 1. Map of Pima County's conservation lands in eastern Pima County, including fee lands (dark green) and lands held under grazing leases or some other management agreement (light green).

Summary of OHV regulations by agency

Pima County

For some of its ranches, Pima County has cooperative stewardship agreements with the Arizona Game and Fish Commission to maintain recreational access on existing roads that have been historically used by the public, are indicated in the relevant agreement, and that traverse County-owned ranch lands. Under these agreements, Pima County has the ability to close roads due to public health and safety concerns, as well as for protection of ecological values. Pima County does not allow OHVs, or any use of motorized vehicles, within its extensive trail system

in Tortolita and Tucson Mountain Parks or within Cienega Creek Natural Preserve. Pima County ordinance 9.12.020 stipulates that OHVs may not be used in any publicly owned washes (except for cases where an otherwise legal road or trail crosses a wash) as well as prohibiting any OHV operation that contributes visible dust pollution that extends across property lines into areas including recreational, residential, or business areas, among others. Furthermore, Pima County does not permit use of motorized vehicles on trails, cross-country, or on unsurfaced roadways where restrictions have been posted or signed at Pima County parks and recreation areas (see Pima County Parks Rules, Ch. 4, Sec. 040; https://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Natural%20Resources%20Parks%20and%20Recreation/Rules/Park_Rules.pdf). Where OHV use is allowed on the County's leased lands and where ownership lies with either the Arizona State Land Department or Bureau of Land Management (additional details are provided below), operators may not drive off-road, through washes, or through otherwise closed areas as indicated by signage. To report any OHV violations within unincorporated Pima County call the Pima County Sheriff's non-emergency number at 520.351.4900.

One area on Pima County lands where OHV use is encouraged (on trails) is on Pima County's Southeast Regional Park (https://webcms.pima.gov/cms/One.aspx?pageId=77130), located near the Pima County Fairgrounds. The Southeast Regional Park offers recreation ranging from shooting sports (i.e., shooting and archery ranges) to a variety of motorsports. At this park there are a variety of trails where OHV riders of all skill levels can enjoy the sport in a safe and regulated environment.

City of Tucson

The City of Tucson does not permit any operation of an OHV off of the roadway that is within ¼ mile of a structure (occupied or not)(Tucson, AZ Code of Ordinances, Section 11-70.1). In this case a 'roadway' is any dedicated street, alley, road, or parking lot that is generally open for vehicular use. Here, a 'roadway' also covers any private property or driveway that is used for any purpose (with permission from the private property owner) except for access or entry into a wash.

Town of Marana

The Town of Marana's code prohibits the use of any motorized vehicle on any property owned or leased by the town other than a public roadway. Similar to Pima County ordinances, motorized vehicles may not be operated in any publicly owned wash with the exception of instances where an otherwise legal and open roadway crosses such a wash. Also, operation of a motorized vehicle that contributes visible dust pollution that then crosses into other residential, recreational, or business areas is prohibited (Marana Town Code Chapter 12-4-2).

Town of Oro Valley

The Town of Oro Valley does not permit the use of off-road motorized vehicles on any undeveloped public or private property, including washes, desert areas, and non-paved empty lots (Oro Valley Town Code Section 11-3-17). Some exceptions are permitted for the use of

OHVs off of the roadway on private property, including with written permission of the land owner, use for farming or ranching purposes, and others. However, these exceptions for use on private property do not include allowing the operation of an OHV within a wash closer than ¼ mile to any structure.

State of Arizona

Arizona Department of Transportation and Arizona Game and Fish Department

By law, all OHV operators need to have a valid OHV decal (issued by the Arizona Motor Vehicle Division) when on any public or State trust lands within Arizona (https://www.azgfd.com/OHV/). This decal applies to any vehicle weighing ≤ 1,800 pounds and/or with an engine > 49 cubic centimeters. It is the operator's responsibility to have the appropriate registration and license plate which in turn indicates where the OHV may be operated (i.e., is it 'street-legal' to allow operation on roads and trails where this registration is required). The Arizona Game and Fish Department supports an OHV recreation program and provides OHV-related law enforcement. See their website for additional information (https://www.azgfd.com/OHV/Rules/).

Arizona State Land Department

ASLD allows OHV operators with a valid OHV decal to cross State lands on existing roads, designated routes, and trails (unless otherwise indicated as closed). Importantly, in most cases washes are not considered to be open and existing roads or trails and subsequently are not areas where OHV users may operate. Beyond this travel, having the OHV decal does not permit users to engage in any other activities on State lands, such as picnicking, parking, staging, camping, or operating support vehicles. Separate recreation permits are required for these activities (https://land.az.gov/faqs).

US Forest Service, Coronado National Forest

A number of Pima County open space lands are adjacent to large expanses of US Forest Service lands spread across three ranger districts (Sierra Vista, Nogales, and Santa Catalina Ranger Districts) of the Coronado National Forest. The Travel Management Rule mandates that all national forests need to have a sustainable roads management plan that includes the minimum roads network required to serve the needs of constituents and maintain the ecological integrity of the national forest. To that end, the Coronado National Forest has created a Motor Vehicle Use Maps, by district, that indicate which routes are open to motorized traffic, during which seasons, and to which types of motorized traffic (https://www.fs.usda.gov/detailfull/coronado/maps-pubs/?width=full&cid=FSEPRD585913). It is the responsibility of the motorized vehicle user to understand what is allowed, based on where they are. An interactive map published by the US Forest Service includes information detailing where and what types of motorized travel are allowed across all Forest lands (https://www.fs.fed.us/ivm/index.html).

In many cases, roads that are considered to be "motorized roads" for otherwise legally operated OHVs on the Coronado National Forest continue onto lands that Pima County either

manages directly (fee lands) or lands for which Pima County holds the grazing lease from the BLM or ASLD (leased lands) for which the respective agency land holders would manage. In some cases, there is not an evident gate or signage signaling a change in land ownership. None of Pima County's grazing leases include any leased US National Forest lands.

US Bureau of Land Management

OHV operators on BLM lands must comply with all relevant state rules and regulations (i.e., in Arizona users must follow State rules and maintain a valid OHV decal, motorcycles must be outfitted with an approved spark arrester and muffler). The BLM designates its lands as either open, limited, or closed. Open areas are those for which any legally operated vehicle is allowed at all times at any location, while a limited area means that there are restricted times, areas, or particular kinds of vehicular use. Closed areas are those places for which off-road vehicles are not permitted. BLM does not allow any off-trail OHV use, even for hunters retrieving big game. These designations and other information regarding OHV use on BLM lands are addressed in a particular area's Resource Management Plan. Users are advised to consult with the appropriate state or local BLM field office for additional information. More information is available online (https://www.blm.gov/programs/recreation/recreation-activities/arizona).

Impacts from OHV use on natural resources

Impacts of OHV use on natural resources are wide-ranging and well-documented (e.g., Ouren et al. 2007). They include impacts to soils, vegetation, wildlife, water quality, and air quality that is affected by dust and exhaust (Ouren et al. 2007; Howard et al. 2014; Switalski 2018). Particularly where OHVs deviate from roads and trails, soils are compacted and water infiltration is reduced, leading to reduced primary productivity and increases in erosion in affected areas. In many cases the impacts of cross-country ORV use on soils and vegetation are visible and measurable after a single pass of an OHV; repeated use leads to cumulative impacts that can persist on the landscape for decades. OHVs can serve as vectors for spreading invasive plants (Ouren et al. 2007; Switalski 2018). In addition to the widely-recognized negative impacts on vegetation and wildlife, OHV use can damage cultural resources and interfere with other forms of recreation (Switalski 2018). Noise pollution can disrupt the activities of both people and wildlife (Ouren et al. 2007; Switalski 2018).

In the Southwest especially, washes and streambeds are often used for unauthorized OHV travel because they traverse the landscape and, combined with roads, provide a network of pathways. Where washes are incised, they also provide opportunities to travel unseen as steep banks can obscure the line of sight from a distance, making it much more difficult to detect intrusions while they are happening. The popularity of washes and streambeds as travel corridors for OHVs puts a number of MSCP Covered Species at risk, including birds nesting in riparian/xeric-riparian vegetation that may be disturbed by noise as well as physical damage to vegetation. Desert washes and their associated vegetation communities, which are often more structurally complex with higher primary productivity, are used by a variety of animal species, and OHV activity may negatively impact the use of these areas by some of these species, as well

as degrade the natural vegetation structure. Additionally, during hot summers, OHV use may prevent some wildlife species from utilizing shaded and cooler microhabitats that are often primarily available in these washes. On top of these concerns, OHV traffic has the potential to impact wildlife through the mortality of individuals that are run over. For example, the giant spotted whiptail is one of many species that inhabit riparian washes and may be crushed by OHVs. Also of concern are native fish, amphibians, and other riparian species (many of which are also MSCP covered species), which may suffer mortality directly or have their habitat damaged via changes in stream and pool morphology caused by tires, which may also degrade water quality and potentially be a means for the dispersal of some invasive species.

Individual plant species may also be negatively affected by OHV traffic through a variety of mechanisms. For example, the MSCP covered species Pima pineapple cactus grows in the same open and largely level areas that may be used by OHV operators. The locations of many known Pima pineapple cacti populations (*Coryphantha sheeri* var. *robustispina*; PPC) are in areas where Pima County staff has observed OHV use in the past (see cover photo), and where there is easy access for OHVs via washes and roads, irrespective of whether use of these access routes is authorized for the general public. PPC is particularly vulnerable to off-road and off-trail travel; its small stature makes it difficult to see and subsequently avoid. If seen, it may still be crushed by travel because, unlike large cacti, it poses very little threat to vehicles and operators that may run over it. Furthermore, off-road travel may cause harm to ground-nesting bees, such as *Diadasia rinconis*, that pollinate PPC (McDonald 2005). OHV-related impacts may also enhance surface erosion, alter the natural hydrological function of an area, negatively impact potential nurse plants for germinating cacti, and generally degrade the habitat for this and other species.

MSCP Changed Circumstances

All USFWS Habitat Conservation Plans (HCP), of which the MSCP is one, are required to identify 'changed circumstances' that could be anticipated to come about during the duration of the conservation plan. These changed circumstances are any processes or developments that could be reasonably anticipated to impact a covered species, covered species habitat, or the geographic area included in the conservation plan. In addition to identifying potential changed circumstances, the conservation plan's proponent, here Pima County, must indicate the potential response or reaction to the changed circumstance. A complete list is included in Table 7.1 of the MSCP (Pima County 2016). One of the MSCP's changed circumstances is any loss or degradation of habitat that off-road vehicle use may have on potential or allocated mitigation lands, as well as any negative and direct impacts that off-road vehicle use may have on covered species (i.e., direct mortality).

Importantly, not every observation or instance of OHV use rises to the level of a changed circumstance. Indications that OHV use on allocated or potential Pima County mitigation lands has resulted in impacts to MSCP covered species or their habitats would trigger subsequent assessment and discussion with the Service about whether a changed circumstance has occurred. The following situations could constitute an MSCP changed circumstance as it relates to OHV activity:

- Evidence that OHV activity has resulted in direct 'take' or mortality (i.e., individuals run over) of covered species
- Evidence to suggest that OHV activity has significantly and negatively impacted a covered species or a local population of a covered species or its habitat

In some cases, such as in discretely bound aquatic habitats, or other areas containing sensitive or small populations of covered species, observations of illegal OHV activity and the resulting assessment of whether a changed circumstance has been met may be relatively straightforward. This assessment should include evaluating whether the OHV impacts have resulted in a negative impact to the continued persistence or status of one or more covered species or populations. For example, if OHVs were found to be impacting nesting success or territory occupancy of cactus ferruginous pygmy owls (an uncommon species that does not occur widely across all County lands) on lands that the County manages, then there could be a clear case of a changed circumstance being triggered. This observation would then subsequently trigger an assessment of whether it was a 'significant' impact. In this or a similar case, prudence calls for being conservative when evaluating if a changed circumstance has occurred (i.e., a relatively lower bar for making the determination that there may be significant impacts to a species or its habitat). Less straightforward would be observations of OHV impacts that occur in areas with widespread or relatively 'common' covered species. In many of these cases, it is unlikely that an evaluation of the impact would meet the threshold determining that a changed circumstance has been triggered (i.e., a relatively higher bar for making the determination that there may be a significant impact). Scattered cases of OHV tracks in Pima pineapple cactus habitat would be an example where the threshold necessary to attain a changed circumstance may not be met for this relatively widespread MSCP covered species on County lands. See Appendix B for a summary of the relative threat that OHV-related impacts may have on covered species and their habitats across County lands.

County staff collect data on instances of unlawful OHV use (particularly cases where OHV users are driving off of pre-existing roads or trails) on Pima County fee lands and report these to relevant land managers within the County. The County would only then report these observations to the USFWS only if observed OHV use is determined to be potentially triggering a changed circumstance. For these cases, Pima County will work with the USFWS on the best response strategy as the situation may dictate, ranging from pursuing enhanced enforcement to implementing road and habitat restoration efforts. The status of land ownership (i.e., County-leased versus County-owned) of the potential or allocated mitigation land will also have bearing on the available scope of management responses. Additionally, whether the OHV impacts are occurring on otherwise legal and open roads and trails, or are occurring in areas closed to OHVs and/or off of any established roads or trails, will influence how or what Pima County's response may be. Ongoing efforts in Pima County include identifying all existing unimproved roads on County lands, especially on ranch lands, and creating a data layer within a GIS to manage those data. This information could then be used in property or area specific

management plans and to monitor change over time for this type of land use and its associated impacts.

Methods

County staff will rely largely on incidental collection of data on occurrences of unlawful OHV incursions and associated impacts. Some MSCP-covered species and their habitats may have a relatively high potential to be impacted by OHV activity based on patterns of recreational use and locations of particular County conservation lands relative to the Tucson metro area and major travel routes. Staff will record data on OHV activity during routine property assessments and inventories, as well as ancillary to several species-specific monitoring protocols, such as Pima pineapple cactus monitoring and cactus ferruginous pygmy owl monitoring.

Property assessments

County staff regularly conduct property assessments and inventories on County lands. These visits occur on both new acquisitions and on established County conservation lands, and so include a combination of first-time visits and repeated visits to the same general area. Property assessments have a variety of objectives including gaining a better understanding of the distributions of Covered Species and other species of conservation concern; documenting the occurrence and status of sensitive habitat elements such as springs, riparian vegetation, and key plant communities; and generally enhancing knowledge of the biodiversity and natural resources contained on County lands. Further, staff document the status of infrastructure on County lands and a host of threats (e.g., presence of invasive species, vandalism, hazards such as open mine shafts, broken fences on range lands, and any illegal use of the land or its resources). Observations of this sort are shared with the appropriate land managers within the County and/or law enforcement.

Though this protocol primarily addresses the work of EMP staff, staffs from multiple County departments collect information on and respond to illegal OHV incursions. Pima County Regional Flood Control District, and Pima County Natural Resources, Parks and Recreation both have staff who regularly spend time in the field; they monitor the condition of various resources, assess management needs, and implement management on mitigation lands (allocated and potential), as well as throughout the County's preserve system. For example, these departments have already implemented measures to keep unlawful OHV traffic out of County lands, such as Tortolita Mountain Park, Cienega Creek Natural Preserve, and Bar V Ranch.

Other field monitoring protocols

EMP will leverage time spent implementing other monitoring protocols to collect data on OHV intrusions. When they conduct field monitoring for a number of monitoring elements, EMP staff are already required to be in parts of the County's conservation lands where monitoring OHV incursions is a continual need. Some of these endeavors are species-specific monitoring efforts where observations of OHV activity can be easily incorporated into overall data collection. For

these species in particular, OHV impacts have been identified as potentially harmful to their habitats; for some species, OHV activity may even result in direct take.

For example, EMP will leverage time spent monitoring Pima pineapple cactus (PPC) to concurrently monitor OHV use and impacts. County staff will record observed indicators of OHV use and impacts while implementing distance sampling at PPC monitoring plots. During regularly scheduled monitoring, surveyors will look for the signs and impacts of OHV use, including OHV tracks, damaged vegetation, and cut fences. Using a field tablet and digital datasheet, surveyors will collect data on the extent and geographic location of OHV incursions, and ensure that the appropriate land manager receives these observations.

Pima Association of Governments staff and Pima County staff map surface water quarterly along Cienega Creek and Davidson Canyon in the Cienega Creek Natural Preserve. Additionally, EMP staff regularly monitors other stream reaches on a more infrequent schedule. During these 'wet-dry' mapping surveys, surveyors walk the stream corridor, collecting data on pools, flowing water, and dry areas. In addition, staff collect data on other observations of significance, such as MSCP-covered species detections and invasive species. These efforts will also include opportunistic data collection on OHV use and impacts, including OHV tracks and vegetation damage. Observations made by EMP staff will be collected via a digital database on a field tablet and routed in a timely manner to the appropriate land manager.

Lastly, EMP staff completes monitoring for cactus ferruginous pygmy-owls (CFPO) every three years. This monitoring occurs largely in the Altar Valley (i.e., southwestern portion of Pima County's conservation lands in an area that is already known have illegal OHV use). Woody vegetation, large trees, and scattered large saguaros are important components of CFPO habitat, and therefore monitoring transects are often located along desert washes where mesquite woodlands occur. Staff will opportunistically record observations on OHV use while implementing this protocol. As indicated above, observations will be collected via a digital datasheet and sent to the relevant land manager.

Data management and analysis

In most cases, data on incidental observations, including observations of OHV impact, extent, and location, are entered directly into a digital datasheet on a field tablet and 'synced' with the geodatabase once the tablet has viable wireless connectivity. However, in some cases, field data are recorded using a handheld GPS and paper datasheets, or are reported to EMP staff by others via other means. These data are downloaded and manually entered into a geodatabase (maintained by Pima County IT GIS) once the surveyor returns to the office, using the ArcGIS Collector app. After data are in the geodatabase, surveyors check the data for any inaccuracies or errors before the data are finalized. Proofed data in the geodatabase are available for County staff and external partners (as relevant) via several mechanisms, including visualization in an Enterprise geodatabase in ArcGIS Portal or sharing of exported shapefiles. County IT GIS staff are working to create a workflow such that time-sensitive data requiring a land manager's attention (i.e., damaged infrastructure, certain invasive species, some OHV incursions), and that

are collected by field staff using digital datasheets, are routed automatically to the appropriate County land manager on a daily basis through an automated script.

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Appendix A: A summary of OHV prohibitions by jurisdiction relevant to Pima County lands

Table A-1. Summary of relevant OHV prohibitions for land managers managing land among and near Pima County lands.

Jurisdiction	Prohibited use of OHVs	Enforcement	Code/Ordinance/Rule*
Pima County	• Publicly owned washes (except in legal road crossings) • Trails, cross-country, or on unsurfaced roadways where restrictions have been posted or signed in Pima County parks and recreation areas • Operation that contributes visible dust pollution that extends across property lines into other areas	Pima County Sheriff	• Pima County Ordinance 9.12.020 • Pima County Parks Rules Ch. 4, Sec. 040
Town of Oro Valley	• No use on any undeveloped public or private property, including washes and desert areas ○ See exceptions – including farming, ranching, with written property owner permission, etc. • Within a wash and closer than ¼ mile to any structure (for private property exception)	Oro Valley Police Department	• Oro Valley Town Code Section 11-3-17
Town of Marana	• No use on any property owned or leased by the Town other than a public roadway • Publicly owned washes (except in legal road crossings) • Operation that contributes visible dust pollution that extends across property lines into other areas	Marana Police Department	• Marana Town Code Chapter 12-4-2
City of Tucson	• Within ¼ mile of a structure while driving off of the roadway	Tucson Police Department	• Tucson Code Section 11-70.1

Jurisdiction	Prohibited use of OHVs	Enforcement	Code/Ordinance/Rule*
	• A roadway includes any private driveway or property used by the owner or one with permission of the owner for any purpose other than entry into a wash		
Arizona	• No use off of existing roads, designated routes, and trails	Arizona State Land Department Arizona Game and Fish Department	• Arizona Revised Statutes, Title 28, Article 20 Off-Highway Vehicles
U.S. Forest Service	• See relevant Motor Vehicle Use Maps by Forest District • No use in wilderness or other special designated areas	Coronado National Forest, U.S. Forest Service	• Title 36, Chapter II, Part 261 & Part 212 (Code of Federal Regulations)

Bureau of Land Management	• See relevant area's Resource Management Plan
	  ○ Consult with local BLM field office
	  ○ Areas are designated as open, limited, or closed
	• No use in wilderness or other special designated areas
		Tucson Field Office, U.S. Bureau of Land Management	• Title 43, Subtitle B, Chapter II, Subchapter H, Part 8340 (Code of Federal Regulations)

*All OHV users must follow AZ state laws and display a valid OHV decal to operate on public and state trust lands in Arizona.

Appendix B: Potential risk to Covered species or their habitats due to OHV activity as it relates to a MSCP changed circumstance

Table B-1. Summary of potential risk to MSCP-covered species or their habitats that OHV activity represents across Pima County lands. Low, medium, or high vulnerability bins are based on how widespread or common covered species may be and/or the sensitivity of covered species habitat elements. Bins are approximations only, and are meant to provide context for any assessments of whether a changed circumstance may have occurred, due to OHV-related impacts only.

Covered species	Habitat elements potentially impacted by OHV activity	Hypothetical vulnerability to changed circumstance trigger by OHV activity
Talussnails species • Widespread, but some species have restricted distribution	Talus slopes and rocky outcrops	low
Sonoran desert tortoise • Widespread in suitable habitat • Potential for localized impacts from OHV disturbance	Rocky slopes and washes	low
Pima pineapple cactus • Widespread across multiple County ranches and properties	Areas of known occurrences in desert-grassland and desert-scrub	medium
Needle-spine pineapple cactus • Widespread on County ranches and properties on E. side of Catalinas and near Vail	Areas of known occurrences in desert-scrub and desert-grassland	low
Tumamoc globeberry • Likely more widespread than currently known on County lands in and near Tucson Mountain Park, Avra and Altar Valleys	Areas of known occurrences in lower elevation desert-scrub	low-medium
Huachuca water umbel • No known wild populations on County lands	Any confirmed natural or translocated occurrence in riparian habitat	medium
Cactus ferruginous pygmy owl • Limited distribution on County lands; vulnerable to nesting disturbance	Large saguaros and mature xeric riparian vegetation in desert washes (Altar Valley)	medium-high

Covered species	Habitat elements potentially impacted by OHV activity	Hypothetical vulnerability to changed circumstance trigger by OHV activity
Swainson's hawk • No known nesting sites on County lands • Any nest sites would be vulnerable to OHV disturbance	Any confirmed nest sites/territories in desert grassland or desert-scrub	medium
Western burrowing owl • Nesting or roosting burrows vulnerable to OHV disturbance • No recently observed nest burrows on County lands	Any confirmed nesting or roosting burrows in open, desert grassland or desert-scrub, especially in Altar/Avra Valleys	medium
Rufous-winged sparrow, AZ Bell's vireo, Abert's towhee • Widespread across many County ranches and properties	Riparian vegetation (xeric- to meso-riparian) or desert-scrub (rufous-winged sparrow)	low
Aquatic and riparian species (frogs, fish, birds, reptiles)* • Key species may inhabit small, limited, or otherwise vulnerable sites	Streams, springs, ponds, mesic riparian vegetation	medium-high
Bats • Key roosts for some species vulnerable to disturbance • Agave and saguaro nectar resources may be vulnerable to disturbance • Riparian woodland integrity and structure potentially vulnerable to disturbance	Roosts, agave and saguaro nectar sources, riparian woodland vegetation	low-medium
Mesquite mouse • Widespread in suitable habitat on County lands • Species determination may be challenging	Xeric riparian woodlands, especially mesquite bosques	low

Covered species	Habitat elements potentially impacted by OHV activity	Hypothetical vulnerability to changed circumstance trigger by OHV activity
Groundsnake and Tucson shovel-nosed snake • Likely more widespread than currently known in upland properties (groundsnake) • Populations in lower elevation areas in the Avra Valley likely more vulnerable (groundsnake) • No known occurrences on County lands (Tucson shovel-nosed snake)	Any confirmed populations of Tucson shovel-nosed snake (Avra Valley) Groundsnake populations in the Avra Valley Groundsnake populations in upland properties like Tortolita MP, A7 Ranch, etc.)	high high low

*Here birds include southwestern willow flycatcher and western yellow-billed cuckoo; reptiles include desert box turtle, giant-spotted whiptail, and northern Mexican gartersnake.

Pima County
Multi-species Conservation Plan:
2019 Annual Report

Appendix 14

Pima County Climate Monitoring Protocol

40 pages

Pima County Ecological Monitoring Program
Climate Monitoring Protocol

March 2020

PIMA COUNTY
SUSTAINABILITY & CONSERVATION

Prepared by Pima County Office of Sustainability and Conservation Staff:
Jeff M. Gicklhorn

Cover photo: Monsoon storm over the Santa Catalina Mountains on Six Bar Ranch

Recommended citation: Gicklhorn, J.M. 2020. Climate Monitoring Protocol. Ecological Monitoring Program, Pima County Multi-species Conservation Plan. Report to the U.S. Fish and Wildlife Service, Tucson, AZ.

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Abstract

In arid systems, water is often the limiting resource for plants and animals to survive and thrive. Annual weather patterns are often quite variable, tending to provide a feast one year and famine the next. However, changes in long-term climate can lead to large-scale structural change in plant and animal species abundance, distribution, and community composition and structure. Pima County's Ecological Monitoring Program (PCEMP) focuses on monitoring long-term trends for a suite of covered species, their habitats, and other landscape-change elements. Therefore, monitoring changes in local and regional climate over time is critical to properly interpreting results from other monitoring elements over the 30-year lifespan of the EMP. This protocol discusses the proposed monitoring methods as well as several data quality considerations for monitoring long-term climate on County conservation lands. We propose to track precipitation on a five-year cycle at multiple spatial scales from an individual vegetation and soils monitoring plot all the way up to climate regions roughly aligned with major watersheds. Summer monsoonal precipitation in highly spatially variable in southern Arizona, therefore we will expend the majority of effort quantifying seasonal precipitation. We will also summarize short and long-term drought effects at larger spatial scales. Precipitation and drought data will be used to interpret results from other PCEMP monitoring elements. Lastly, we propose a method to establish a pre-permit (2016) climate baseline in order compare contemporary climate values against for future trend analysis.

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Background and Objectives

In arid regions, access to water is crucial for survival. Both variable annual weather and long-term local climate dictate where and when that critical water is available to plant and animal species. Temperature, combined with water availability, dictates evaporative demand and drought stress for species; where lack of suitable access to water or extended temperatures outside the normal range of variability can lead to mortality. Therefore, monitoring local climate, and subsequently how climate change over time, is essential to understanding monitoring data associated with plant and wildlife species and their habitats.

Southeastern Arizona has a bimodal rainfall distribution, with two defined wet periods during the winter (Nov-Mar) and summer monsoon (Jun-Sept) (McPhee et al. 2004). Interannual variability in precipitation combined with the highly localized nature of monsoonal rainfall patterns means that water availability can vary both spatially, across relative small geographical areas, and temporally, within and across seasons and years. This variability can lead to one localized area being inundated with flash flooding, where an area nearby may see little to no rainfall. Additionally, upstream rainfall may be accessible to riparian plant or wildlife species downstream far from where the precipitation event actually occurred.

Pima County's Multi-species Conservation Plan (MSCP) is the vehicle by which the County remains in compliance with its Section 10 Incidental Take Permit issued by the U.S. Fish and Wildlife Service (USFWS) in 2016. The MSCP covers 44 species of plants and animals (Covered Species) and their habitats, which occur across a wide range of landscapes and elevations. In addition to climate, the Ecological Monitoring Program (PCEMP) is tasked with monitoring Covered Species and their habitats, landscape pattern change, and threats such as invasive species. Annual weather variability directly and indirectly affects both covered and invasive species populations and their habitats; therefore, monitoring how local and regional climate is changing over time is essential to interpreting changes in those populations and habitats over the 30-year lifetime of the Section 10 permit.

A key element of the PCEMP is monitoring uplands vegetation and soils composition and structure across the full suite of County conservation lands. The protocol for this element was developed by the National Park Service's Sonoran and Chihuahuan Desert Inventory and Monitoring Networks (Hubbard et al. 2012), and the County will establish a minimum of 100 monitoring plots across multiple elevation and soil type strata that span the full suite of conservation lands (Gicklhorn 2020). Understanding the climactic conditions that these plots experience over time will allow for better interpretation of detected changes and trends in vegetation and soils composition and structure over time. Additionally, understanding trends in local climate will be useful in interpreting species-specific monitoring results, such as for Sonoran desert tortoise (*Gopherus morafkai*) occupancy monitoring and Pima pineapple cactus (*Coryphantha scheeri* var. *robustispina*) distance sampling.

Climate change models forecast changes in the timing and intensity of temperature and precipitation patterns for the desert southwest. These changes include a shift towards fewer but larger magnitude monsoon precipitation events, as well as decreased winter precipitation (Garfin et al. 2014, Lower Santa Cruz River Basin Study preliminary analysis). Warmer temperatures, especially winter nighttime low temperatures, along with the increase in frequency and duration of high-temperature events. Native plants and animals are expected to face longer, hotter, and more frequent drought events, potentially leading to changes in species abundance and overall community composition. Tracking long-term trends in local and regional climate will allow County staff to characterize actual climate conditions for monitored resources, rather than modelled conditions. Observations collected by Pima County may be useful to others in calibrating new regional climate models.

Lastly, understanding local climate trends can benefit other County programs, such as the Range Management program. This program requires data about annual precipitation in specific locations (County ranch properties), however changing climate trends may determine how management is implemented going forward. For example, Sustainability program staff work with the Facilities and Transportation departments to help them understand climate model projections for our area. Forecasted increases in localized rainfall intensity have considerable implications for County-managed infrastructure projects. Our dataset may help to determine to what degree those models are accurate, as well as to define the longer-term range of variability for our region. Additionally, the Range Management program currently utilizes data from a network of passive rain gauges across County ranch properties to make within-year range management decisions. Informed decision making requires access to current data and due to the remote nature of the gauges, data gaps can occur due to lack of staff resources. The proposed climate monitoring protocol and dataset may support work to identify the most accurate local or regional climate model correlated with County conservation properties and provide a long-term record of the range of variability in precipitation across County ranch lands that may assist in future range management decision making.

This protocol will 1) define methods by which long-term climate metrics (precipitation and drought) will be monitored and summarized across County conservation lands at multiple spatial scales, 2) discuss climate data storage and management for future interpretation of long-term trends observed at soil-vegetation plots and other monitoring sites, and 3) propose the methodology for establishing a pre-permit climate baseline for future trend analyses.

We expect climate trend data to potentially useful for numerous other County initiatives, including the County's Sustainability and Range Management programs and participation in the Pima County Local Drought Impact Group. Where possible, the data may contribute to the greater understanding of long-term climate monitoring through collaborations and partnerships.

Geographic and Temporal Scope

The climate monitoring protocol covers the full suite of Pima County conservation lands and spans the 30-year duration of the County's Section 10 incidental take permit, from 2016 to 2046. A historic climate baseline (pre-2016 permit) will also be quantified for future trend analyses (discussed below).

Pima County's conservation lands are made up of > 250,000 acres of fee and leased lands (for which the County holds a grazing lease) surrounding the City of Tucson (Figure 1). These lands are located across five major watersheds, which include the Altar-Brawley Wash, San Pedro River, Cienega Creek, and upper and lower Santa Cruz River, and range in elevation from 425 to 1870 m (1400 to 6130 ft). These conservation properties range in size from 0.1 to 16,500 hectares (0.25 to 41,000 acres) and individual properties can vary in elevation by as much as 750 m (2460 ft). County conservation lands do not include higher elevations of the mountain ranges within eastern Pima County and thus snow makes up a relatively minor portion of the annual precipitation across County lands.

Assessing climate at multiple spatial scales requires first defining those categories and scales. Pima County's Uplands Vegetation and Soils monitoring protocol divides County conservation lands into elevational strata roughly correlated with biome-level plant communities (Table and Figure 1). County conservation lands contain primarily strata 200-400, and the final 100 vegetation and soils monitoring plots are distributed within three rock fragment classes across these three strata respectively (Figure 2). Classes 402 and 403 were combined as they represented a smaller area than the 401 rock fragment class. County conservation lands and subsequently vegetation and soils monitoring plots are also grouped into geographic regions, which experience distinct climates, roughly correlating to major watersheds identified above (Table and Figure 2). However, several properties were grouped due to their geographic proximity rather than watershed. For example, Rancho Seco is split between the Brawley Wash and Upper Santa Cruz watersheds, however due to its proximity to Sopori Ranch, we have grouped it into the Southwest region.

This protocol proposes to summarize precipitation at multiple spatial scales, including the individual level for each of the 100 final vegetation and soils sample plots, the larger climate region (roughly correlated with watershed), and the elevational strata levels associated with the County's uplands vegetation and soils monitoring protocol (200, 300, 400). We propose to summarize drought effects at the climate region (watershed) and elevational strata level.

Assessing climate at these specific scales will allow PCEMP staff to directly apply climate monitoring data to the interpretation of Uplands Vegetation and Soils monitoring data and other PCEMP monitoring elements. Vegetation and soils data will be collected every five years throughout the duration of the MSCP; therefore, summarizing the seasonal and annual climate patterns and trends for each monitoring plot may help to explain any detected changes in vegetation composition or structure on that particular plot. Additionally, summarizing

precipitation and drought at the region and elevational strata levels will allow for higher-level interpretation and comparison of monitoring data across the suite of County conservation lands. For example, local research efforts have already detected climate change driven changes in flowering plant phenology in eastern Pima County, where plant communities at different elevations are responding differently to novel climate regimes (Rafferty et al. 2020). A preliminary study examining pre-permit climate between regions and elevational strata has already indicated differences in precipitation, temperature, and seasonality across scales (Preliminary Studies section below). Our climate monitoring efforts may facilitate regional and elevational comparisons of trends in vegetation composition and structure over time.

Table 1. Elevational and soil/rock type strata definitions (from Hubbard et al. 2012).

Biome(s)	Elevation		Score
	Feet	Meters	
Desert	<2,500′	<762	100
Thornscrub	2,501–3,700′	762.1–1,127.76	200
Semi-desert Grassland	3,701–4,500′	1,127.77–1,371.6	300
Madrean Woodland & Interior Chaparral	4,501–6,000′	1,371.61–1,828.8	400
Temperate Forest	>6,000′	>1,828.8	500

Rock fragment modifier	Fragment content % by volume	Score
None or adjective (e.g., loam or gravelly loam)	<35	1
"very" or "extremely"	35–90	2
Bedrock or rock outcrop	--	3

Table 2. Pima County preserves by geographic climate region. Not all County properties are listed.

Region	Preserve Name	
Northwest	Tucson Mountain Park	Tortolita Mountain Park
	Sweetwater Preserve *	
Northeast	A7 Ranch	Oracle Ridge
	Buehman Canyon / Tesoro Nueve	Six Bar Ranch
	M Diamond Ranch	
Southeast	Bar V Ranch	Clyne Ranch
	Cienega Creek Natural Preserve	Empirita Ranch
	Colossal Cave Mountain Park	Sands Ranch
Southwest	Canoa Ranch	Sopori Ranch
	Rancho Seco	Marley Ranch (Cerro Colorado parcels) *
West	Diamond Bell Ranch	Madera Highlands
	Kings 98 Ranch	Marley Ranch (Serrita parcels)
	Buckelew Properties	Old Hayhook Ranch

* Indicates that no vegetation and soils monitoring plots have been or will be established on these properties.

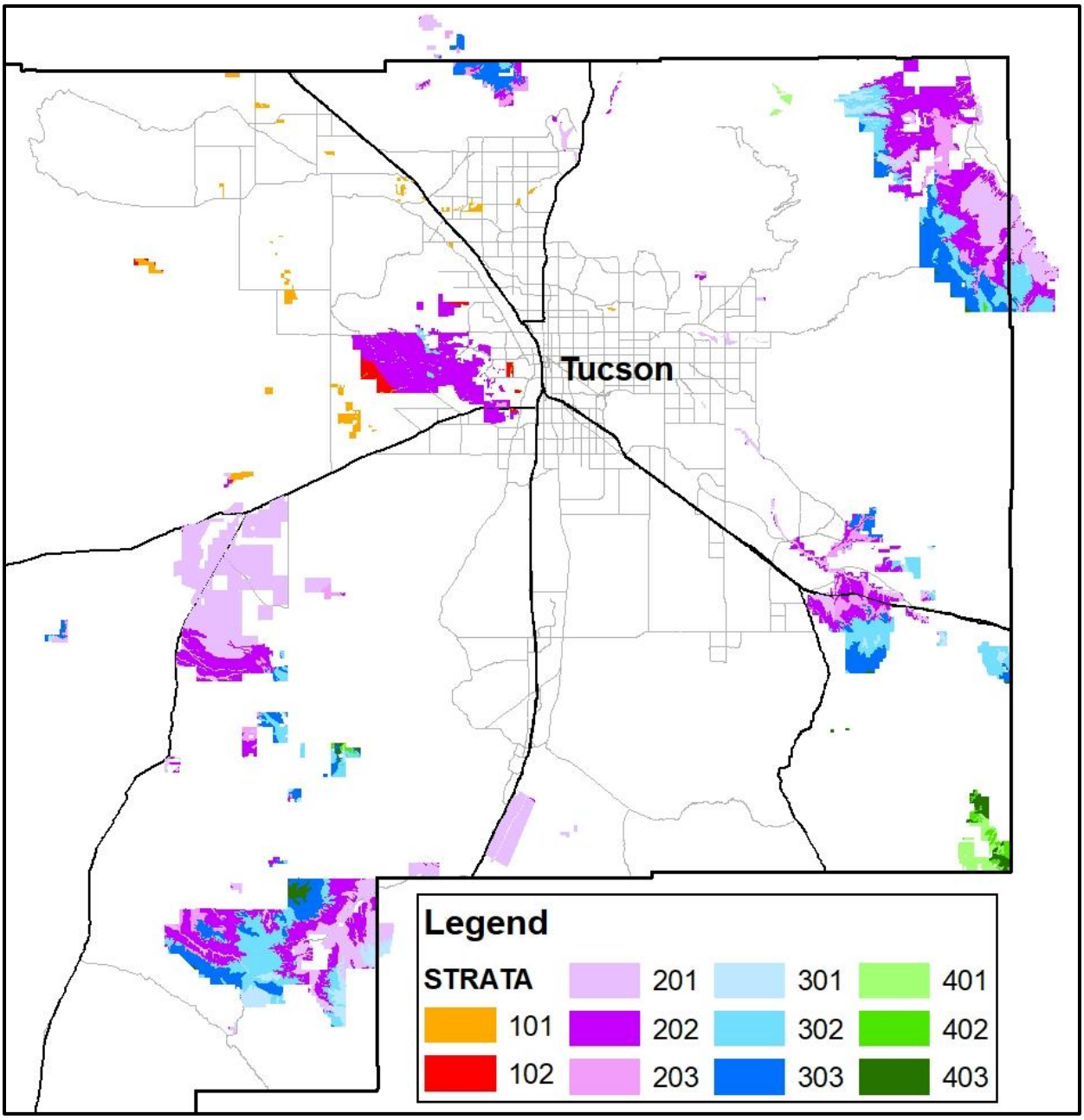

Figure 1. Distribution of Pima County conservation lands with elevation and soils strata shown.

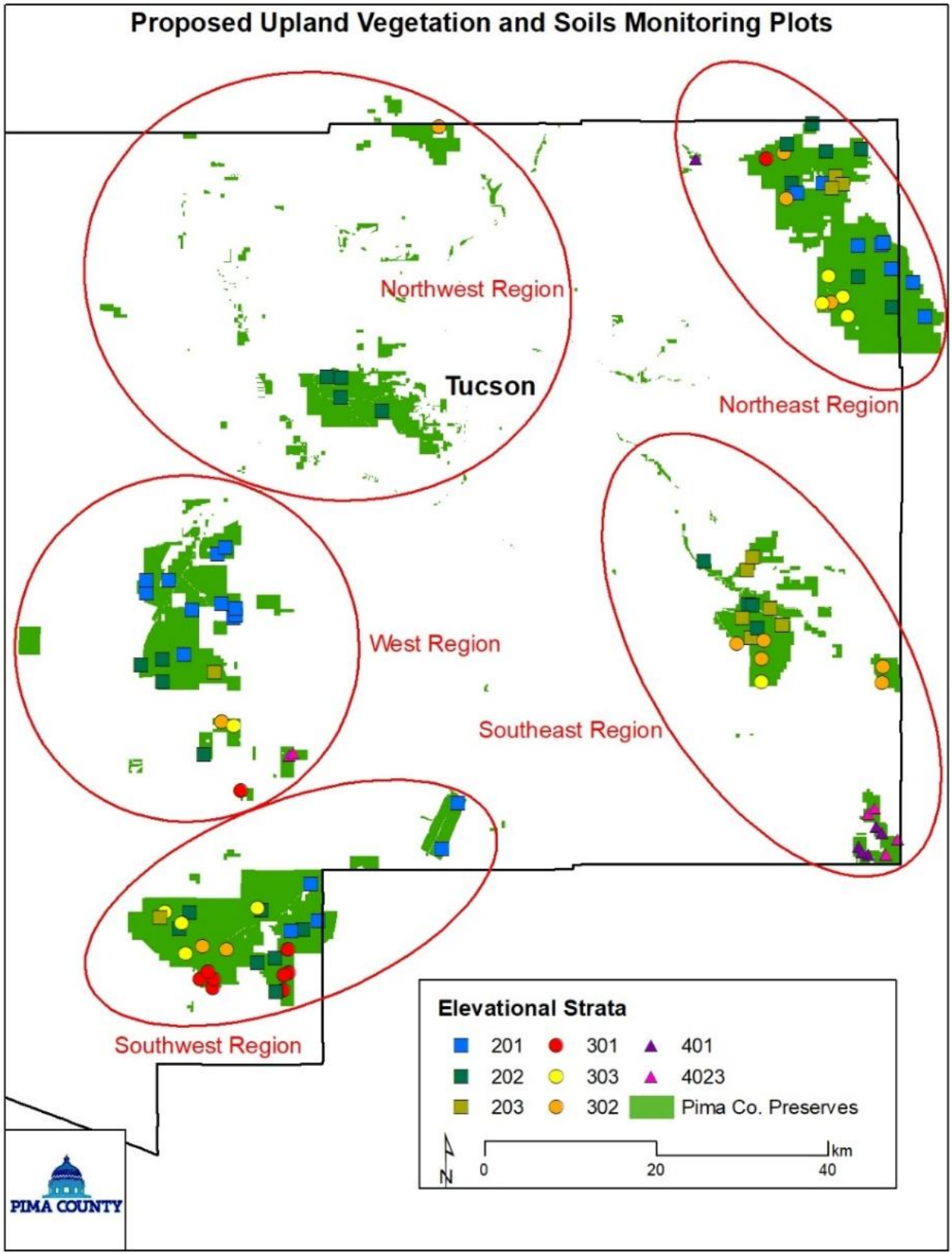

Figure 2. Proposed uplands vegetation and soils monitoring plots displayed by elevational strata with geographic climate regions shown.

Methods

Here we discuss proposed climate metrics to be monitored, monitoring schedule, freely available climate products, and proposed data storage and analysis methods.

Climate Metrics

This protocol focuses primarily on quantifying local precipitation, due to its highly variable spatial and temporal nature in southeastern Arizona, and secondarily drought, which integrates precipitation and temperature. National-level gridded climate products have considerable difficulty accurately estimating monsoon precipitation in southern Arizona, whereas winter precipitation is more accurately estimated (Weiss and Crimmins 2016). Additionally, precipitation and temperature will be integrated by reporting a metric of drought intensity or severity, such as the Standardized Precipitation Index (SPI) or Standardized Precipitation Evapotranspiration Index (SPEI).

Monitoring Schedule

The climate monitoring cycle will align with the 100-plot panel for the County's vegetation and soils monitoring protocol (Hubbard et al. 2002) which repeats on a five-year interval (i.e., 20 plots read per year). Climate data at each uplands vegetation and soils monitoring plot location will be summarized by season (summer = June – September, winter = October – May) for precipitation and by month for temperature, with each unit (month or season) averaged across the specified five-year monitoring period. The climate-monitoring schedule is offset earlier than the upland vegetation and soils monitoring schedule due to the time lag associated with seasonal precipitation and vegetation growth (Ogle and Reynolds 2004). The first panel of monitoring plots were established beginning in summer of 2017 and will finish in winter of 2021; therefore, the first five-year climate monitoring period will begin winter 2016 (Oct 2016 – May 2017) and end summer 2021 (June 2021 – September 2021), and will be submitted concurrently with the 2021 annual report in March 2022. The future climate monitoring periods are defined in Table 2 below. Monitoring periods for the pre-permit baseline are discussed in the relevant section below.

Table 3. Climate monitoring periods.

Monitoring Period	Season / Year
Sec. 10 Permit Issued	July 2016
1	Winter 2016 – Summer 2021
2	Winter 2021 – Summer 2026
3	Winter 2026 – Summer 2031
4	Winter 2031 – Summer 2036
5	Winter 2036 – Summer 2041
6	Winter 2041 – Summer 2046

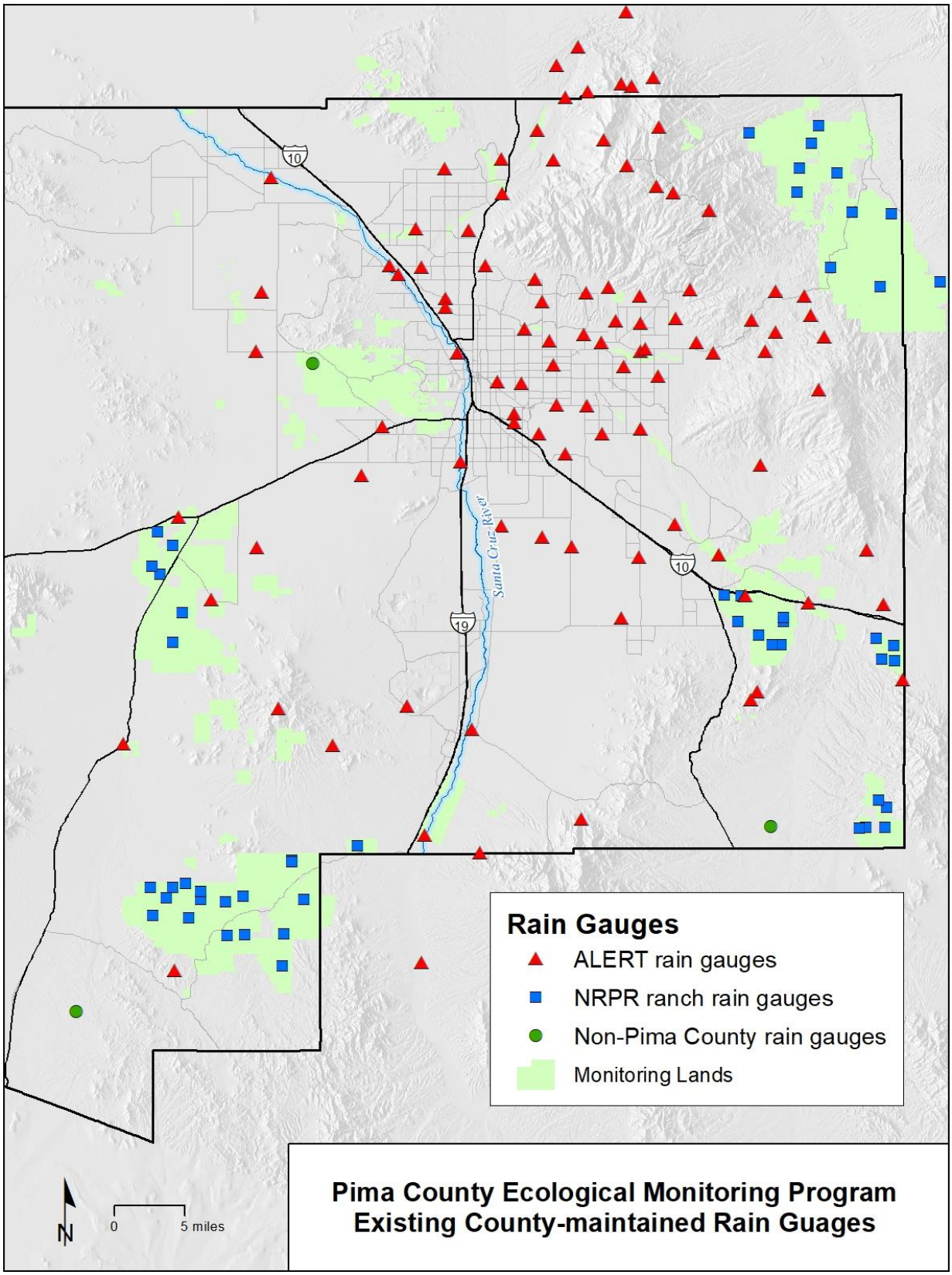

Figure 3. Rain gauges maintained by Pima County, plus several additional maintained by partners.

County-Maintained Weather Stations

Pima County maintains a large suite of both active and passive weather stations throughout eastern Pima County (Figure 3). The Regional Flood Control District's (District) Automated Local Evaluation in Real Time (ALERT) network utilizes real-time, active precipitation and stream flow gauges to aid in forecasting possible flood risk. Many of these stations were installed in the 1980s, however some have been installed as recently as the early 2000s. Ninety-six stations are located along major waterways and mountain canyons to provide instantaneous data when either precipitation or stream flow are detected. Additionally, 12 of those 96 ALERT stations record temperature. The Natural Resources, Parks and Recreation Department (NRPR) manages a suite of passive rain gauges associated with the Range Management program (Figure 2). These gauges are located on remote county conservation lands with active grazing leases, are checked twice a year to determine seasonal precipitation totals. These data are primarily used to make within-year livestock management decisions. The gauges consist of simple clear 1" PVC pipes with a screened cap mounted to a stationary post, and are located in select grazing allotments. The data from both types of gauges can potentially be leveraged to compliment the proposed methods in the protocol, by correlating modeled precipitation values to empirical values collected from weather stations. This effort will not initially be included in the proposed protocol, however PCEMP staff will reserve the ability to add this analysis if warranted.

Available Climate Products

There are a number of freely available model-based, national-level, gridded climate products available. These products involve either interpolating or extrapolating known weather observations from a limited number of weather stations across the landscape, while accounting for changes in local topography using a digital elevation model (DEM). These products are national in scale and therefore the spatial resolution associated with each may be quite large (1-4 km). This spatial variation suggests that one product may be better correlated with empirical rain gauge data, especially during the notoriously unpredictable summer monsoon season (June 15 – Sept 30). These products are known to be relatively accurate at larger scales (watersheds, counties, states, etc), but have challenges modeling climate at very small spatial scales. This consideration should be taken into account when determining which gridded data product to use (Daly 2006). We also discuss a potential new radar-based product under development by the University of Arizona Climate Assessment for the Southwest (CLIMAS) group that utilizes a different approach to generating precipitation estimates. We compare PRISM and DAYMET for application on Pima County Conservation Lands in the "Gridded Climate Product Comparison" in the Preliminary Studies section below.

Precipitation

Modeled precipitation data are commonly available through gridded data products available at various spatial and temporal scales. Below we discuss two commonly used national-level, gridded precipitation products and a local radar-based product currently in development. County staff initiated a comparison of historic precipitation gauge data to determine the ability

to use either PRISM or Daymet data as a proxy for both active District ALERT and passive NRPR ranch rain gauge data (Preliminary Studies below).

PRISM

One of the most extensively used products is the Parameter-elevation Regressions on Independent Slopes Model (PRISM) developed and produced by the Northwest Alliance for Computational Science & Engineering (NACSE), based at Oregon State University (http://www.prism.oregonstate.edu/). PRISM utilizes a variety of data inputs, including National Weather Service and BLM Remote Activated Weather Stations (RAWS), and produces daily, monthly, and annual precipitation and temperature estimates at 4 km resolution across the conterminous United States (Daly et al. 1994). This process also accounts for the physiographic position (aspect, elevation, etc.) for each grid cell, thereby increasing accuracy and accounting for issues such as rain shadows in precipitation estimates (Weiss and Crimmins 2016). These precipitation estimates are updated daily (with time lag) and monthly. PRISM also produces a higher-resolution product downscaled to 800 m resolution, however only data on 30-year climate normals are freely available at this resolution, daily and monthly data are not free.

DAYMET

Another highly used gridded national climate product is Daymet produced by the US Department of Energy's Oak Ridge National Laboratory (Thorton et al. 1997, https://daymet.ornl.gov/). This product was initially developed as an input into Daymet is similar to PRISM in design, however uses a different set of input stations and different model to produce precipitation and temperature estimates. This process also incorporates a higher resolution DEM into the modeling process, resulting in higher resolution estimates as compared to PRISM. Daymet offers daily, monthly, and annual precipitation and temperature estimates at a 1 km resolution. As compared to PRISM, Daymet purports to better incorporate topographical variation, which should contribute to the accuracy of its temperature and precipitation estimates. Daymet is only updated on an annual basis, rather than daily or monthly like PRISM.

CLIMAS Radar-Based Precipitation Estimate

The University of Arizona's Institute for the Environment - Climate Assessment for the Southwest (CLIMAS) is currently working to develop a radar-derived, gauge-corrected precipitation product, focused on the Tucson basin but encompassing much of eastern Pima County, based on the Multi-Radar/Multi-Sensor System (MRMS, https://www.nssl.noaa.gov/projects/mrms/) developed and produced by the National Oceanographic and Atmospheric Administration's (NOAA) National Severe Storms Laboratory (NSSL). The MRMS Quantitative Precipitation Estimation (QPE) product provides high-resolution (1 km) precipitation type and amount estimates based on regional radar data. These estimates are then corrected with empirical rain gauge data (ALERT, University of Utah Meso West stations, and Rainlog.org public observer stations) using a CoKriging approach. This approach allows for the relatively low coverage (poorly sampled) radar product to be corrected with the

high-density rain gauge data, centered on the Tucson basin. No change is made when the two values agree, however scenarios exist where the RMRS estimates precipitation at a particular point but a rain gauge at that location received none. Conversely, there are also situations when RMRS did not predict precipitation at a point, but a rain gauge at that location received some accumulation. In those scenarios the resulting precipitation estimate is more accurate than either the estimate from the radar-based product or the estimate using an interpolated point based on a model using point-based rain gauge records. The CLIMAS model utilizes County ALERT gauge as inputs, which are distributed throughout eastern Pima County, therefore the modeled product could provide near full coverage of the County's suite of conservation lands. We may assess the accuracy of the radar-based product against PRISM precipitation estimates across Pima County conservation lands when it becomes available.

Drought

Drought is commonly reported through modeled indices, which incorporate some combination of precipitation and temperature. These indices can be calculated for varying lengths of time and at various spatial resolutions.

Standardized Precipitation Index

The Standardized Precipitation Index (SPI) compares observed total precipitation amounts for an accumulation period of interest (e.g. 1, 3, 12, 48 months) with the long-term historic rainfall record for that same period at a given location (McKee et al. 1993; Edwards and McKee 1997). The SPI improves on the PDSI by incorporating a multi-scalar temporal approach (able to be calculated at different time scales) and performing similarly across different vegetative communities, thereby allowing for direct comparisons across time and space. The SPI has become a widely accepted drought index. SPI data products are widely available down to a ~4km resolution.

Standardized Precipitation-Evapotranspiration Index

The Standardized Precipitation-Evapotranspiration Index (SPEI) improves on the SPI by incorporating temperature via modeled potential evapotranspiration (PET) into the multi-scalar approach (Vicente-Serrano et al. 2010). Global temperatures are already warming, and drought stress will differ based on environmental conditions. The SPEI can account for future climate scenarios by modeling different PET rates associated with different environmental conditions. The Hargreaves PET estimate works well in southeastern Arizona and is user-friendly. The SPEI has not yet become as widely accepted as the SPI and higher resolution data products are not as readily available; however, SPEI products area available at the county-scale.

Climate Summary Output Products

Pima County proposes to summarize mean seasonal precipitation (monsoon = June – September, winter = October – May) for the specific five-year monitoring period at each established uplands vegetation and soils monitoring plot location using monthly PRISM precipitation estimates. These values will then be averaged within each geographic climate

region and elevational strata, for each five-year monitoring period to determine larger-scale climate trends. We will report not only mean values but also error associated with those means in order to quantify whether monthly or seasonal variation is changing over time.

We propose to summarize drought using freely available gridded SPI or SPEI index data at the climate region and elevational strata scales for both short- (<1 year) and longer-term drought (1-5 years). Preliminary research suggests that for both SPI and SPEI track modeled soil moisture dynamics in southeastern Arizona, with 2-month values tracking 10 cm soil moisture values and 9-month tracking 30 cm values (Mike Crimmins personal communication), suggesting their utility in summarizing drought effects and trends in the region. Results from this research will help to determine which drought index is most appropriate for assessing drought impacts on vegetation community composition and structure in southeastern Arizona. We acknowledge the current availability and resolution of different drought index data products and will utilize the best available data for each monitoring period. If indices are changed, drought summaries for all prior monitoring periods will be recalculated with the new index. Drought summary data will then be compared to prior monitoring periods and the historic baseline using a trend analysis (discussed below) to determine changes in temperature and precipitation patterns over time. If appropriate, these trend analyses may be compared to larger-scale climate anomaly data from the National Oceanic and Atmospheric Administration's National Centers for Environmental Information (NOAA NCEI). Climate summary products and trend analyses can then be used to aid in interpreting data and trends from other PCEMP monitoring elements.

Pre-Permit Climate Baseline

The County's Section 10 Incidental Take permit was acquired from the U.S. Fish and Wildlife Service in July, 2016; subsequently, the County's MSCP and EMP satisfy the regulatory and monitoring requirements associated with the Section 10 permit. We propose to summarize climate data (temperature and precipitation) across the suite of County conservation lands (scales identified above) for the 35 years prior to this baseline (1981-2016). We selected this period because the PRISM gridded climate product provides estimates beginning in 1980. Baseline data will be used to compare pre- to post-2016 climate data to determine if and how temperature and precipitation are changing across County conservation lands after acquiring the Section 10 permit. Baseline climate will be summarized in five-year baseline monitoring periods going backward from the summer 2016 permit acquisition. We may also incorporate precipitation and temperature anomaly data from NOAA NCEI for the areas and time periods of interest.The proposed climate baseline analysis methodology and preliminary example is discussed further in the *Preliminary Studies* section below. The final baseline summary will be produced after all 100 uplands monitoring plots have been established.

Climate Trend Analysis

We will use the non-parametric Mann-Kendall (M-K) test to analyze trends in precipitation and temperature over time (Mann 1945, Kendall 1975, Gilbert 1987, NCAR 2014). This test can

determine if a monotonic upward or downward trend exists within a time-series dataset, even if input data are not normally distributed. The M-K test will allow us to examine the trend in precipitation at all spatial scales of interest in the climate monitoring protocol.

Statistical Assumptions

1. Observations obtained over time are independent and identically distributed when no trend is present, therefore observations are not serially correlated over time.
2. The observations obtained over time are representative of the true conditions at sampling times.
3. The sample collection, handling, and measurement methods provide unbiased and representative observations of the underlying populations over time.

Model Outputs

tau - Kendall's tau statistic: direction and magnitude of trend. Positive values indicate a positive trend, negative values indicate a negative trend over sampled period.

sl - Two-sided p-value, we consider $p \leq 0.05$ to be statistically significant, while $p \leq 0.1$ suggests a possible trend.

The *Kendall* package in the R Programing Software allows for streamlined analysis of time series data using the Mann-Kendall test. The *MannKendall* function calculates *tau and sl* a for a time series across all months (annual trend), while the *SeasonalMannKendall* function calculates the same variables for but for each month separately to determine if the monotypic trend is occurring by month, rather than across the entire year. This comparison will allow County staff to determine if there is a statically significant trend in precipitation values over time at any spatial scale.

Preliminary Studies

PCEMP staff implemented two preliminary studies to 1) compare the performance of available gridded precipitation products to local weather station data, and 2) to test methodology for summarizing pre-permit precipitation baseline against which to determine future trends. These studies helped to determine the appropriate approach for monitoring climate on County conservation lands.

Gridded Precipitation Product Comparison

County staff initiated a comparison of historic precipitation gauge data to determine the ability to use either PRISM or Daymet data as a proxy for both active District ALERT and passive NRPR ranch rain gauge data. We selected ten ALERT stations distributed across eastern Pima County and located on or near conservation land properties (Figure 4, Table 4) and acquired all daily historic data available for each station (varied by station). We compared seasonal precipitation totals (summer = June – Sept, winter = Oct – May) from select ALERT stations to monthly summaries from both PRISM and Daymet (collocated with ALERT stations) for the same time periods using Spearman's rank correlation (R_s values in Table 4). We also calculated mean percent difference by season for the PRISM/ALERT comparison ([PRISM – ALERT] / ALERT) to determine if and the percent to which PRISM was over- or under-estimating relative to measured ALERT values. For interpreting mean percent difference, positive values represent an overestimation and negative values an underestimation of PRISM estimates relative to the original ALERT values.

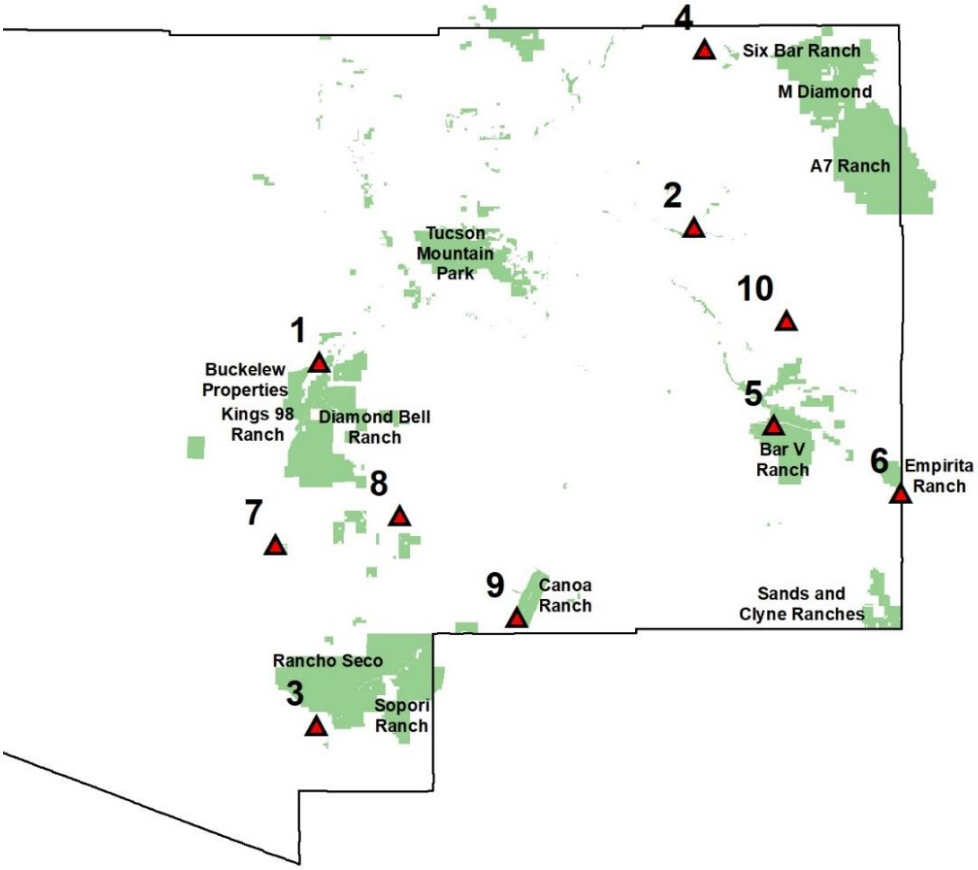

Figure 4. ALERT stations and County ranch properties used in data quality comparison. Station numbers and ranch properties correspond to Tables 1 and 2.

Seasonal ALERT data correlated higher with winter precipitation (R_s = 0.886) than summer precipitation (R_s = 0.589) across both gridded products, which supports recent climate research in southern Arizona (McGowan 2019). PRISM performed considerably better than Daymet for summer precipitation estimates (PRISM R_s = 0.680 to Daymet R_s = 0.498) with similar performance in winter (R_s = 0.891 to 8.880). PRISM on average over-estimated precipitation values across both seasons at all stations (42.3 ± 12.8 %) with winter (45.3 ± 10.2 %) having higher over-estimates but slightly lower standard errors as compared to summer precipitation (39.3 ± 15.5 %). We acknowledge several ALERT stations with severe over-estimates are likely due to station location and instrumentation, with the Dan Saddle station located at high-elevation but sensors not designed to accurately measure winter snowfall (winter = 74.9 ± 1.55 % over-estimation). Additionally, the Keystone Peak ALERT gauge in the Empire Mountains is known to collect less precipitation than actually occurs in the area due to exposure to high winds, thereby likely leading to the large overestimation across both seasons (summer = 148.0 ± 14.7 %, winter = 156.3 ± 18.4 %). By censoring these two stations, percent over-estimation drops across both seasons (30.4 ± 12.3 %) with winter (27.7 ± 7.8. %) and summer (33.1 ± 16.8 %). This result suggests that censoring outliers that are known to have instrumentation or location issues may be appropriate. It would be a useful effort to repeat this exercise with all 96 ALERT gauges to determine if significant data issues exist at regional or elevational scales.

Table 4. Spearman's rank correlations (R_s) for seasonal precipitation between ALERT gauges in Figure 4 and gridded climate products (A-P = ALERT/PRISM and A-D = ALERT/DAYMET comparisons). Mean seasonal percent difference and standard errors (se) for PRISM estimates vs. ALERT gauge values for each ALERT gauge measured.

Number	Station	Comparison	Monsoon	Winter	Season	Mean%dif	se
1	Brawley Wash @ 286	A-P	0.588	0.940	Monsoon	0.060	0.081
		A-D	0.528	0.942	Winter	0.183	0.072
2	Tanque Verde Creek	A-P	0.810	0.979	Monsoon	0.307	0.082
		A-D	0.787	0.981	Winter	0.177	0.027
3	Arivaca	A-P	0.782	0.876	Monsoon	0.181	0.051
		A-D	0.650	0.956	Winter	0.335	0.060
4	Dan Saddle	A-P	0.819	0.685	Monsoon	-0.202	0.054
		A-D	0.448	0.781	Winter	0.749	0.216
5	Davidson Canyon	A-P	0.840	0.897	Monsoon	0.194	0.167
		A-D	0.775	0.837	Winter	0.114	0.058
6	Haystack-Whetstones	A-P	0.672	0.947	Monsoon	0.238	0.050
		A-D	0.451	0.908	Winter	0.314	0.071
7	Madera Highlands	A-P	0.654	0.890	Monsoon	-0.044	0.070
		A-D	0.240	0.795	Winter	0.087	0.058
8	Keystone Peak	A-P	0.612	0.902	Monsoon	1.480	0.147
		A-D	0.235	0.918	Winter	1.563	0.184
9	Canoa Ranch	A-P	0.773	0.925	Monsoon	0.948	0.456
		A-D	0.763	0.865	Winter	0.362	0.069
10	Rincon Creek	A-P	0.250	0.871	Monsoon	0.768	0.387
		A-D	0.106	0.815	Winter	0.646	0.209
-	Mean All Stations	A-P	0.680	0.891	Monsoon	0.393	0.155
		A-D	0.498	0.880	Winter	0.453	0.102
		Both	0.589	0.886	All Seasons	0.423	0.128

We also compared passive NRPR ranch gauge data (collected twice annually) to summed daily PRISM precipitation estimates for those locations to determine the ability to use PRISM as a proxy for these data (Table 5). We used all available NRPR range gauge data, ranging back to 2011. Data quality issues included missing collection dates and precipitation readings, which varied by gauge. Gauges were established in differing years and all entries with potential quality issues were censored for this analysis, resulting in a different number of entries per gauge. No gauge had more than four values per season censored; however, the number of seasonal readings per gauge ranged from two to seven. NRPR gauge data were collected on different dates every season, therefore daily PRISM estimates for the exact date range corresponding to the NRPR read dates were downloaded and summed to calculate seasonal estimates. Seasonal

PRISM estimates and NRPR data were compared using Spearman's rank correlation. Correlation values for all gauges within a specific ranch property (2-5 gauges per property) and all properties within regions (northeast, southeast, and southwest) were averaged. We also assessed the mean percent difference (± standard error) by season for the PRISM/ALERT comparison across each property and region to determine if PRISM was consistently over- or underestimating relative to empirical values.

Winter PRISM estimates (0.649) were more correlated with NRPR data than summer estimates (0.490) across all regions. Northeast (summer = 0.643; winter = 0.71) and southeast regions (0.603 / 0.681) were comparable, while the southwest watershed (0.224; 0.557) showed significantly lower correlations across both seasons. Diamond Bell (0.042; 0.721) and Sopori Ranch (0.091 / 0.312) showed extremely low correlation values, especially during summer, within the west and southwest regions, respectively (Table 4). PRISM estimates neither over- or underestimated when comparing across all seasons, properties, or regions (0.6 ± 12.5 %). However, when compared to NRPR ranch gauges, PRISM slightly over-estimated summer precipitation (3.3 ± 11.9 %) and under-estimated winter precipitation (-2.0 ± 13.1 %) across all regions despite having large seasonal variation between regions. Interestingly, PRISM generally over-estimated precipitation in the northeast region (17.6 ± 14.9 %) while underestimating the southwest (-11.4 ± 11.5 %) region. The southeast region (-4.3 ± 11.2 %) showed mixed results.

Table 5. First column: Spearman's rank correlations (R_s) for seasonal precipitation between seasonal NRPR ranch gauge data and PRISM precipitation estimates averaged by ranch property and by region. Second column: Mean seasonal percent difference and standard errors (se) for PRISM estimates vs. NRPR gauge values for each NRPR gauge measured also averaged by ranch property from 2011-2018.

	Ranch Property	Monsoon R_s	Winter R_s	Season	Mean%dif	se
Northeast	A7 Ranch	0.6	0.583	Monsoon	0.148	0.103
				Winter	0.321	0.29
	M Diamond	0.826	0.675	Monsoon	0.249	0.164
				Winter	0.185	0.194
	Six Bar Ranch	0.504	0.872	Monsoon	0.209	0.097
				Winter	-0.054	0.044
	Mean Region	0.643	0.71	Mean Monsoon	0.202	0.121
				Mean Winter	0.151	0.176
				Mean Region	0.176	0.149
Southeast	Bar V Ranch	0.604	0.713	Monsoon	-0.01	0.101
				Winter	-0.211	0.064
	Clyne Ranch	0.691	0.474	Monsoon	-0.064	0.112
				Winter	0.158	0.211
	Sands Ranch	0.758	0.629	Monsoon	-0.227	0.082
				Winter	-0.29	0.044
	Empirita Ranch	0.358	0.909	Monsoon	0.133	0.156
				Winter	0.164	0.123
	Mean Region	0.603	0.681	Mean Monsoon	-0.042	0.113
				Mean Winter	-0.045	0.111
				Mean Region	-0.043	0.112
Southwest	Diamond Bell	0.042	0.721	Monsoon	-0.155	0.091
				Winter	-0.191	0.087
	Kings 98	0.267	0.7	Monsoon	0.234	0.176
				Winter	0.061	0.214
	Buckelew	0.368	0.705	Monsoon	0.015	0.162
				Winter	-0.187	0.112
	Rancho Seco	0.295	0.626	Monsoon	-0.256	0.05
				Winter	-0.219	0.059
	Carrow	0.281	0.275	Monsoon	-0.004	0.153
				Winter	-0.203	0.065
	Sopori Ranch	0.091	0.312	Monsoon	-0.203	0.113
				Winter	-0.263	0.099
	Mean Region	0.224	0.557	Mean Monsoon	-0.062	0.124
				Mean Winter	-0.167	0.106
				Mean Region	-0.114	0.115
All Region				Mean Monsoon	0.033	0.119
	All Regions	0.490	0.649	Mean Winter	-0.020	0.131
				All Seasons	0.006	0.125

Results from this initial data comparison resulted in a few key findings. First, that seasonal ALERT data (for gauges sampled) is more highly correlated with seasonal PRISM estimates than with Daymet data, suggesting that we should employ PRISM data when estimating precipitation across areas with low gauge coverage. In general, PRISM tends to overestimate precipitation relative to the actual ALERT data. Regional differences in performance were not evident in the ALERT/PRISM comparison, however we observed them in the NRPR/PRISM comparison. PRISM performed substantially better in the northeast and southeast regions than the southeast region, though we note that the southeast region had the fewest ranch gauge inputs (5 gauges). We were originally concerned that the precipitation seasonal NRPR ranch gauge totals in the southwest region were skewed for some reason due to extremely high values; however, double-checking with external passive gauge data (Rainlog.org observers in Arivaca, AZ, <10 km to the south) led us to believe these observations to be valid. PRISM consistently overestimated the northeast region, while it consistently underestimated the southwest region. The southeast region varied by property but in general was quite accurate with a slight overall underestimation. Understanding regional variability in PRISM performance will be important when interpreting precipitation estimates at specific spatial scales (property, region), therefore we suggest defining more spatially explicit geographic regions (e.g. Northwest, Northeast, Southeast, Southwest, West), rather than the three included in this preliminary study.

Pre-Permit Climate Baseline

Pima County acquired its Section 10 permit from the USFWS in July 2016, which allows the County to implement the MSCP. This date marks the initialization of monitoring for the EMP and the baseline for many monitoring elements are determined from data sourced at that time. Annual and seasonal precipitation can be highly variable in southeastern Arizona, and monitoring potential changes in climate inherently requires a longer-term view. Therefore, we propose to analyze a 20-year period to quantify the pre-permit climate baseline, which was determined to be the length required for spatial variability of cumulative precipitation patterns within a single instrumented watershed within southeastern Arizona to become uniform (Goodrich et al. 2008). This baseline will allow for comparisons of pre-permit to post-permit 5-year climate monitoring periods.

Here we propose the methodology for summarizing historic climate across the suite of County conservation lands up to the 2016 issuance of Pima County's Section 10 Incidental Take Permit. This summary defines the baseline against which all future climate-monitoring periods will be compared. To establish the historic baseline we will summarize seasonal precipitation and mean monthly temperature at each established uplands vegetation and soils monitoring plot (minimum 100 total) using the five-year panel design (Table 5). Summarizing climate data and trends at the plot level is essential, as we are monitoring vegetation composition and structure data at each plot every five years. Plot-level data will allow for more informed interpretation of regular vegetation monitoring data. Plot-level climate data will then be summarized at the two

larger spatial scales (region, elevational strata) associated with vegetation and soils monitoring plot distribution.

The example below assesses the historic baseline for 15 monitoring plots established in either 2017 or 2018 (Table 6) as a proof of concept for what the final analysis of all 100 monitoring plots would resemble once established (Figure 2). Here we analyze a 35-year baseline; however we will only analyze a 20-year period when we develop the baseline for all 100 final plots.

Table 6. Date ranges composing each historic baseline climate-monitoring period.

Monitoring Period	Season / Year
-7 (baseline)	Winter 1981 - Summer 1986
-6 (baseline)	Winter 1986 - Summer 1991
-5 (baseline)	Winter 1991 - Summer 1996
-4 (baseline)	Winter 1996 - Summer 2001
-3 (baseline)	Winter 2001 - Summer 2006
-2 (baseline)	Winter 2006 - Summer 2011
-1 (baseline)	Winter 2011 - Summer 2016

Table 7. Specific uplands vegetation and soils monitoring plots established in either 2017 or 2018 used in the example below. Summary of number of plots by group and region are also included

Strata Group	Strata	Plot #	Region	Year Est.
200	201	4	West	2017
200	201	5	Northeast	2017
200	202	59	Northwest	2017
200	202	61	West	2017
200	202	65	Southwest	2017
200	202	68	Northwest	2018
200	203	121	Southeast	2017
300	301	134	Southwest	2018
300	302	149	Southeast	2018
300	303	174	Southwest	2017
300	303	177	Northeast	208
400	401	195	Northeast	2017
400	401	196	Southeast	2018
400	4023	206	West	2017
400	4023	207	Southeast	2018

Strata Group	Number of Plots
200	7
300	4
400	4

Region	Number of Plots
Northwest	2
Northeast	3
Southeast	3
Southwest	3
West	3

We summarized PRISM seasonal precipitation (monsoon = June – September, winter = October – May) and monthly temperature estimates for each of these 15 sample plots within each historic baseline climate-monitoring period (Figures 5-8). In this example, I do not include enough plots per property to draw inference at the property level, so historic climate values were only summarized at the elevational strata and geographic region levels. This exercise will be rerun in winter 2021 once all 100 (minimum) monitoring plots have been established.

Precipitation estimates generally increased and temperature estimates generally decreased with elevational strata (Figures 5 and 6). Temperature estimates also generally increased across elevational strata historic monitoring periods, while precipitation estimates showed high variability between periods and did not demonstrate a consistent trend; monsoonal precipitation error remained consistent across periods while winter precipitation error was highly variable both within and across elevational strata (Figures and 9).

Precipitation estimates varied highly across regions, with the general order of increasing total precipitation across all periods being Northwest < West < Southeast < Southwest < Northeast, and general order of increasing monsoonality (summer precipitation / total precipitation) being Northeast < Northwest < West < Southeast < Southwest (Table 7). Monsoonal precipitation error remained relatively consistent both within regions among periods and across regions, while winter precipitation error was considerably more variable both within regions among periods and across regions. Temperature estimates varied across region, with the increasing average annual temperatures generally inverse to the total precipitation values by region, Northwest < Southeast < Southwest < West < Northwest (Table 10). All regions showed consistent, slight increases in mean annual temperatures from periods -7 to -3, with a leveling off or even slight cooling trend during the last two monitoring periods.

The Southeast and Southwest regions displayed the highest level of monsoonality, while the Northeast displayed the lowest. Both regions are dominated by 200 and 300 level strata and the comparison within strata but across regions over time will shed some interesting light on trajectory of uplands vegetation communities based on the current climate forecasts. Plot density in the Northwest region will be considerably lower than any of the other regions, therefore we will consider adding simulated 100-level strata plots on conservation properties in this region if warranted. 100-level monitoring point locations were originally generated using the same process as the proposed plots; however, the decision was made to drop the 100-level strata due to very low representation on the suite of conservation lands. Adding several of these back in to the climate monitoring protocol may provide insight into what may be happening at lower elevations within the suite of conservation lands as well as bolster the sample size for drawing inference within the Northwest region.

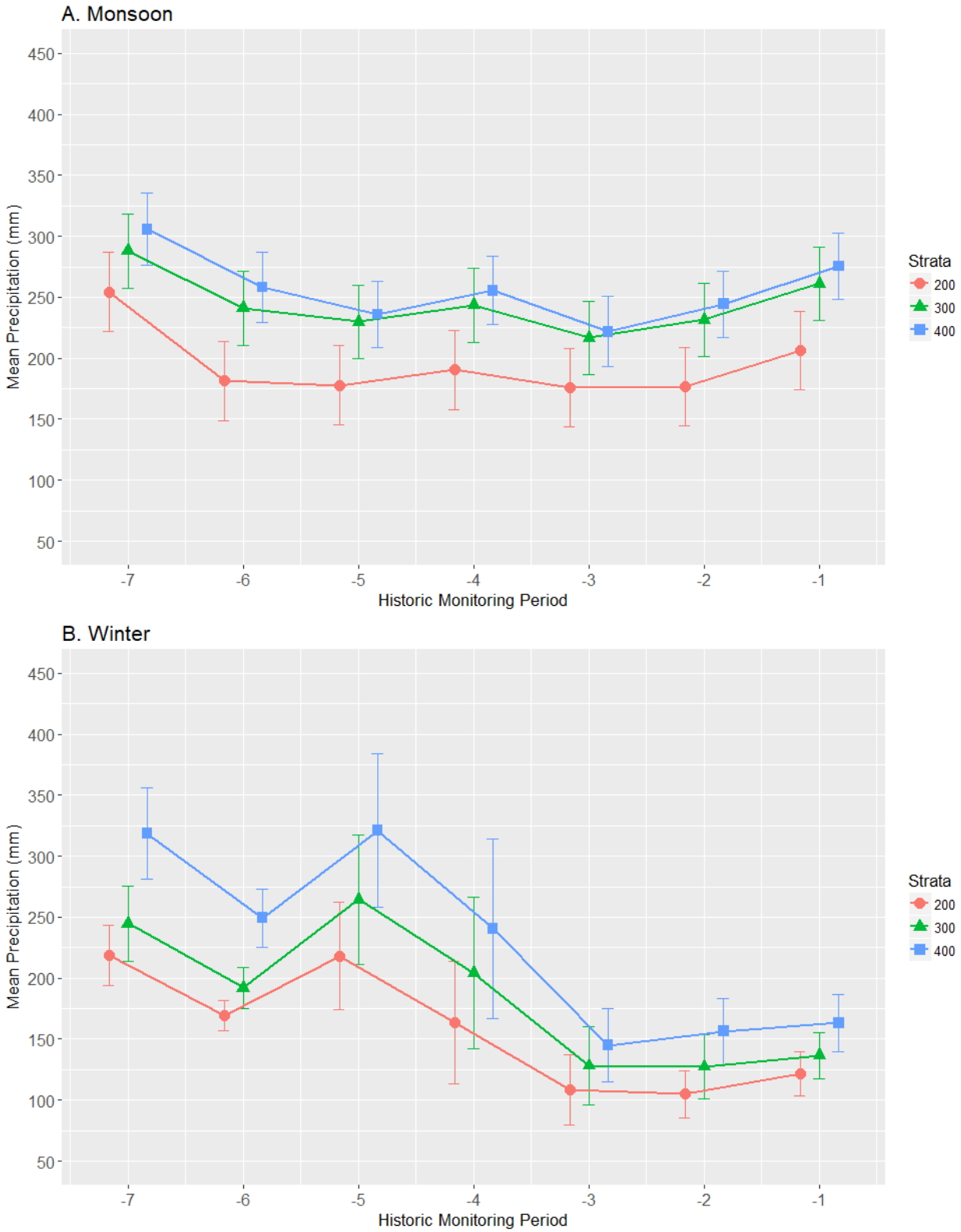

Figure 5. Mean seasonal PRISM precipitation estimates for 15 soil-veg plots in millimeters (± standard error) by elevational strata for the seven historic climate monitoring periods.

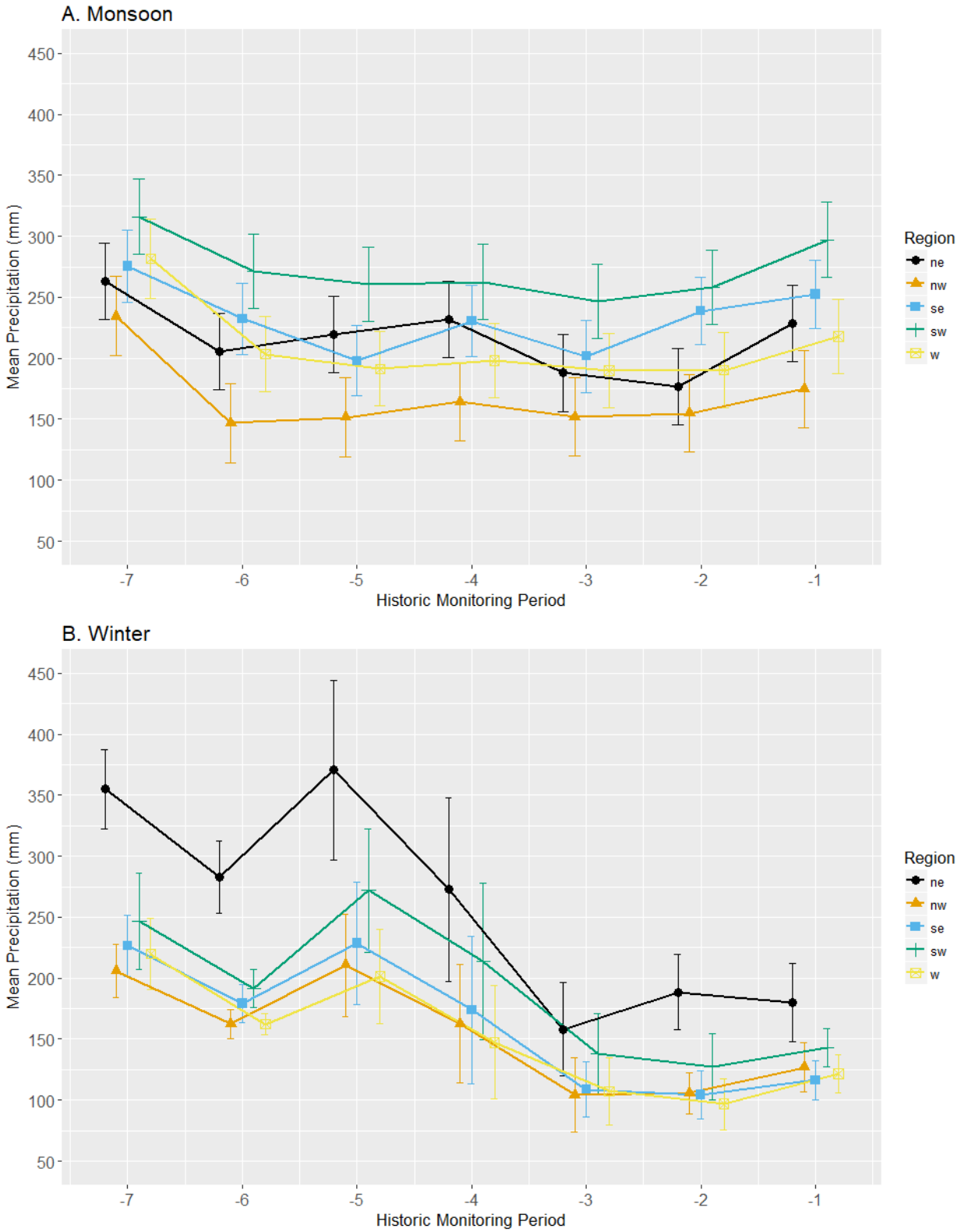

Figure 6. Mean seasonal PRISM precipitation estimates for 15 soil-veg plots in millimeters (± standard error) by geographic region for the seven historic climate-monitoring periods.

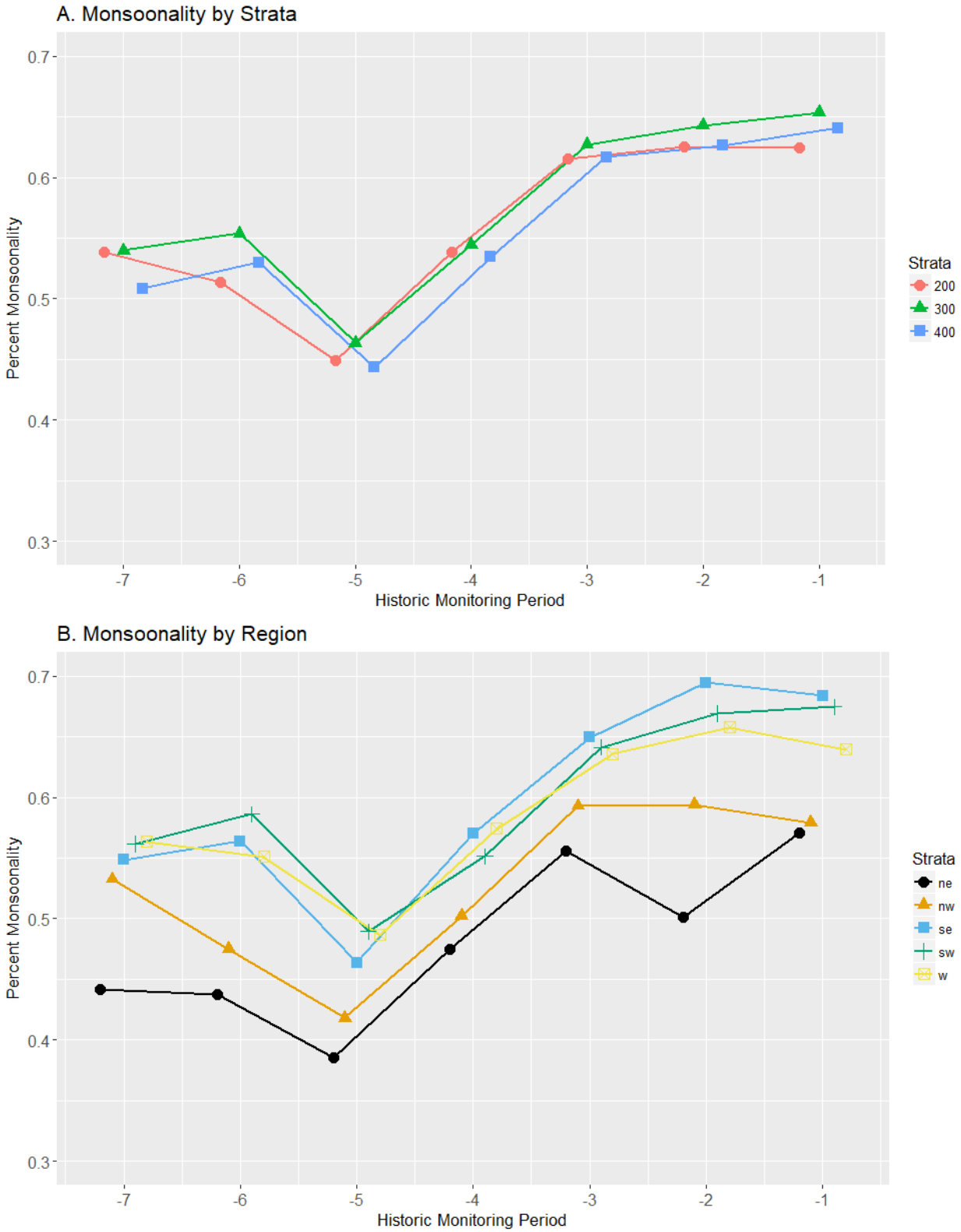

Figure 7. Percent monsoonality of 15 soil-veg plots by elevational strata and geographic region for the seven historic climate-monitoring periods

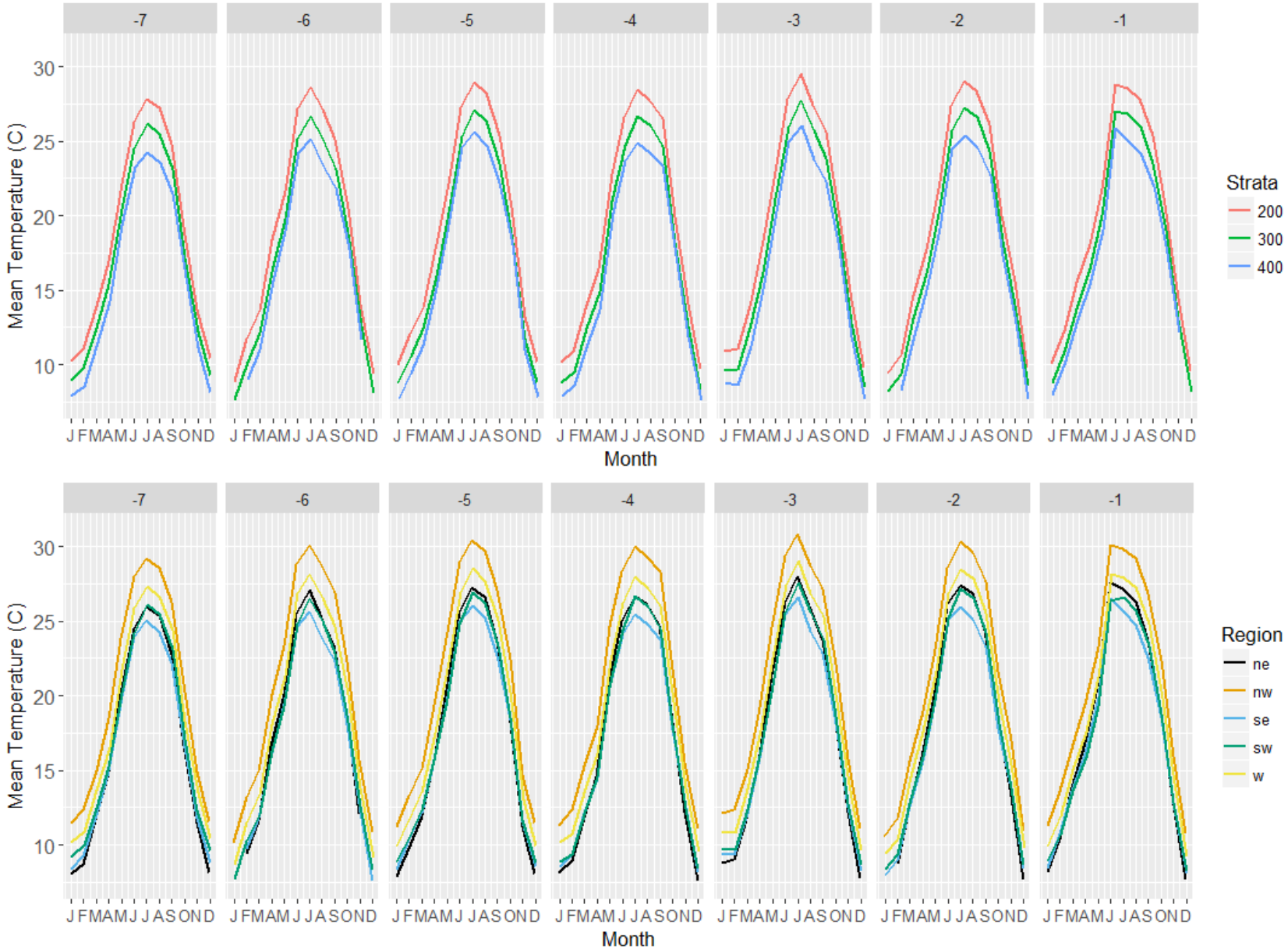

Figure 8. Mean monthly PRISM temperature estimates in degrees C for 15 soil-veg plots grouped by elevational strata and geographic region for the seven historic climate monitoring periods. Monitoring periods are denoted by the bars at the top of each figure. Standard error values are not shown.

We used the Kendall-Mann test to analyze trend in the precipitation and temperature estimates across all monitoring periods (Table 8). *Tau* denotes direction and magnitude of the monotonic trend, while *sl* denotes the statistical significance if that trend. We consider values of $sl \leq 0.05$ to be statistically significant and $sl \leq 0.1$ to suggest significance. Annual temperature did not change significantly, however monthly temperature showed a consistent positive trend across both strata and region. Monsoonal precipitation was highly variable between periods and did not show a significant trend, while winter precipitation in the 200 and 400 strata and West region showed significant negative trends. Winter precipitation in the Northeast and Southeast regions also suggest a negative trend ($sl \leq 0.1$).

This trend analysis will be repeated in after all 100 monitoring plots are established. We acknowledge the potential accuracy issues with using PRISM precipitation estimates (Weiss and Crimmins 2016); however, it is the most accurate gridded data product currently available for our area. We may also test the RMRS radar-based precipitation estimate (described above) against PRISM when recalculating the historic baselines in 2021.

Table 8. Kendall-Mann trend analysis for temperature and precipitation by elevational strata and geographic region. Temperature is divided into annual and monthly trends and precipitation is divided into monsoon and winter trends.

Temperature

	Strata	*tau*	*sl*
Annual	200	0.059	0.426
	300	0.059	0.431
	400	0.059	0.426
Monthly	200	0.295	0.001
	300	0.298	0.001
	400	0.295	0.001

	Region	*tau*	*sl*
Annual	nw	0.050	0.501
	ne	0.078	0.293
	sw	0.053	0.482
	se	0.062	0.404
	w	0.055	0.463
Monthly	nw	0.198	0.030
	ne	0.425	0.001
	sw	0.251	0.006
	se	0.302	0.001
	w	0.251	0.006

Precipitation

	Strata	*tau*	*sl*
Monsoon	200	-0.238	0.548
	300	-0.143	0.764
	400	-0.238	0.548
Winter	200	-0.714	0.035
	300	-0.524	0.133
	400	-0.714	0.035

	Region	*tau*	*sl*
Monsoon	nw	0.238	0.548
	ne	-0.333	0.368
	sw	-0.333	0.368
	se	0.048	1.000
	w	-0.333	0.368
Winter	nw	-0.429	0.230
	ne	-0.619	0.072
	sw	-0.524	0.133
	se	-0.619	0.072
	w	-0.714	0.035

Lastly, this preliminary analysis does not integrate precipitation and temperature into a metric of drought stress as discussed in the Methods section above. The final pre-permit climate baseline will identify historic periods of drought within the identified pre-permit period.

Conclusion

Regional climate models forecast long-term changes to the climate in Pima County, which could lead to large-scale change in vegetation composition and structure over time. The County's uplands vegetation and soils monitoring protocol is designed to detect structural change in habitat characteristics over time; however, without also tracking trends in climate, staff will not be able to properly interpret those monitoring data. The interpretation of other EMP elements may also directly benefit from integration with a discussion of local climate trends.

To that effect, we propose to monitor precipitation and drought at multiple spatial scales across the suite of County conservation lands, focusing effort primarily on precipitation due to the high spatial variability of rainfall patterns in southern Arizona. Climate will be assessed on five-year cycles, which roughly align with the five-year panels for the uplands vegetation and soils monitoring protocol. We will compare climate summary values for the current monitoring period to both prior monitoring periods and the pre-permit baseline to determine whether trends are occurring, and if so what direction and magnitude.

The preliminary gauge comparison completed while developing this protocol have provided useful insight into how to move forward with monitoring climate. We determined that PRISM precipitation estimates were more accurate as compared to those from Daymet despite the smaller spatial scale (4 km vs 1 km). We assessed regional variation in PRISM's estimates relative to passive NRPR rain gauge data, which possibly suggested that the higher a region's monsoonality the poorer PRISM estimates correlate with empirical values. That finding led to splitting properties into five smaller geographic climate regions, rather than the initial three.

The proof-of-concept pre-permit climate baseline analysis indicated that regional differences may exist in precipitation and temperature estimates across geographic regions and elevational strata. Downward trends in annual precipitation, with decreasing number but increasing intensity of summer monsoonal events, has already been recorded in southeastern Arizona to the acquisition of the Section 10 permit in 2016 (Nichols et al. 2002, Demaria et al. 2019). Relative monsoonality in the region has shifted over time, which if continued may lead to changes in relative plant composition for those species that favor the new climate regime. Our pilot project showed that monsoonality has increased over time within all climate regions and strata, suggesting that warm-season plants may show increased fitness as compared to cool-season plants if this trend continues. Summarizing climate experienced at each vegetation and soils monitoring plot may allow us to better interpret any potential changes in vegetation composition and structure that are observed on those plots. We will rerun the pre-permit baseline analysis once all 100 final vegetation and soils monitoring plots have been established.

Finally, Pima County looks forward to working with agency and university partners to further developing and implement this climate monitoring protocol.

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Appendix A: Climate Baseline Supplementary Materials

Table A1. Mean (and standard error) seasonal PRISM precipitation estimates (in mm) by elevational strata for 15 soil-veg plots during all five-year historic monitoring periods.

	Period															
Strata	**-7**		**-6**		**-5**		**-4**		**-3**		**-2**		**-1**		**All Periods**	
Monsoon	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**
200	254.14	32.46	181.37	32.36	177.92	32.23	190.33	32.17	175.83	32.18	176.58	32.09	206.15	32.04	194.62	32.22
300	288.03	30.36	240.94	30.23	229.84	30.02	243.47	30.14	216.71	30.23	231.46	30.20	261.22	30.22	244.52	30.20
400	305.73	29.62	258.15	28.65	235.98	27.46	255.61	28.07	221.73	28.75	244.36	27.18	275.46	27.46	256.72	28.17
All Strata	*282.63*	*30.81*	*226.82*	*30.41*	*214.58*	*29.90*	*229.80*	*30.13*	*204.76*	*30.39*	*217.47*	*29.82*	*247.61*	*29.91*	*231.95*	*30.20*
Winter	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**
200	218.37	24.64	169.61	12.30	218.07	43.92	163.33	50.33	108.67	28.82	104.92	19.38	121.72	17.83	157.81	28.17
300	244.74	30.94	192.08	16.87	264.41	53.03	204.16	62.12	128.14	32.18	127.29	26.42	136.70	18.98	185.36	34.36
400	318.57	37.67	249.23	23.62	321.01	63.15	240.53	73.83	144.96	29.91	156.19	27.14	163.38	23.53	227.70	39.84
All Strata	*260.56*	*31.09*	*203.64*	*17.60*	*267.83*	*53.37*	*202.67*	*62.09*	*127.26*	*30.30*	*129.47*	*24.32*	*140.60*	*20.11*	*190.29*	*34.12*

Table A2. Mean (and standard error) seasonal PRISM precipitation estimates (in mm) by geographic region for all five-year historic monitoring periods.

	Period															
Region	**-7**		**-6**		**-5**		**-4**		**-3**		**-2**		**-1**		**All Periods**	
Monsoon	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**
Northwest	234.44	32.56	147.08	32.51	151.42	32.33	164.27	32.15	151.88	32.07	154.85	31.89	174.75	31.75	168.38	32.18
Northeast	263.32	31.28	205.76	31.29	219.82	31.29	231.81	31.46	188.18	31.70	176.66	31.52	228.80	31.33	216.34	31.41
Southeast	275.34	29.43	232.45	29.38	197.87	28.65	230.41	29.10	201.67	29.62	238.75	27.87	252.42	28.35	232.70	28.91
Southwest	316.10	31.11	271.44	30.68	260.33	30.36	262.69	30.49	246.80	30.50	258.09	30.64	297.01	30.75	273.21	30.64
West	281.84	32.37	203.46	31.20	191.30	30.44	198.31	30.49	189.74	30.68	190.13	30.81	217.73	30.64	210.36	30.95
All Regions	*274.21*	*31.35*	*212.04*	*31.01*	*204.15*	*30.61*	*217.50*	*30.74*	*195.65*	*30.91*	*203.70*	*30.55*	*234.14*	*30.56*	*220.20*	*30.82*
Winter	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**	**mean**	**se**
Northwest	205.80	21.88	162.43	11.69	210.71	41.88	162.65	48.36	104.11	30.40	105.81	16.99	126.86	19.92	154.05	27.30
Northeast	354.92	32.69	282.95	29.41	370.55	73.50	272.75	75.48	158.08	38.37	188.64	31.02	180.27	31.95	258.31	44.63
Southeast	226.50	24.84	179.28	15.82	228.73	50.08	173.89	60.32	108.79	22.75	104.42	19.55	116.38	16.18	162.57	29.93
Southwest	246.70	39.57	191.60	15.50	271.85	50.43	213.80	64.07	137.81	33.29	127.62	27.21	142.65	15.67	190.29	35.11
West	219.77	29.01	162.30	8.90	201.54	38.78	147.19	46.47	107.35	27.77	96.77	21.04	121.44	15.82	150.91	26.83
All Regions	*250.74*	*29.60*	*195.71*	*16.26*	*256.68*	*50.93*	*194.06*	*58.94*	*123.23*	*30.52*	*124.65*	*23.16*	*137.52*	*19.91*	*183.23*	*32.76*

Table A3. Mean monthly PRISM temperature estimates (in ˚ C) by strata for 15 soil-veg plots during all five-year historic monitoring periods.

		Period							
Strata	**Month**	**-7**	**-6**	**-5**	**-4**	**-3**	**-2**	**-1**	***All Periods***
200	Jan	10.23	8.90	10.03	10.16	10.91	9.46	10.11	9.97
	Feb	11.09	11.75	12.04	10.94	11.08	10.64	12.29	11.41
	Mar	13.89	13.70	13.86	13.96	13.95	14.63	15.50	14.21
	Apr	16.89	18.37	17.71	16.45	17.90	17.71	18.09	17.59
	May	22.11	21.66	22.11	22.80	22.90	21.84	21.82	22.18
	June	26.31	27.13	27.23	26.61	27.81	27.32	28.77	27.31
	July	27.85	28.64	28.93	28.50	29.51	29.00	28.58	28.72
	Aug	27.21	27.07	28.21	27.77	27.41	28.38	27.84	27.70
	Sept	24.81	25.14	25.40	26.49	25.62	26.08	25.35	25.56
	Oct	18.69	20.46	20.55	19.94	20.43	20.01	20.75	20.12
	Nov	13.67	14.11	13.22	14.09	14.29	15.58	14.52	14.21
	Dec	10.42	9.36	10.16	9.68	9.76	9.80	9.50	9.81
	All Months	*18.60*	*18.86*	*19.12*	*18.95*	*19.30*	*19.20*	*19.43*	*19.06*
300	Jan	8.92	7.65	8.76	8.83	9.63	8.19	8.78	8.68
	Feb	9.76	10.19	10.59	9.52	9.69	9.35	10.87	9.99
	Mar	12.42	12.12	12.43	12.41	12.42	13.12	13.99	12.70
	Apr	15.35	16.57	15.97	14.87	16.22	16.10	16.45	15.93
	May	20.39	19.79	20.20	20.95	21.11	20.10	20.04	20.37
	June	24.50	25.15	25.29	24.72	25.91	25.70	27.01	25.47
	July	26.16	26.72	27.05	26.69	27.75	27.26	26.81	26.92
	Aug	25.48	25.11	26.37	26.04	25.72	26.60	25.93	25.89
	Sept	23.10	23.13	23.49	24.65	23.81	24.32	23.51	23.72
	Oct	17.16	18.77	18.82	18.23	18.72	18.29	19.04	18.43
	Nov	12.21	12.59	11.72	12.64	12.78	14.00	13.00	12.70
	Dec	9.26	8.04	8.77	8.30	8.49	8.51	8.16	8.50
	All Months	*17.06*	*17.15*	*17.45*	*17.32*	*17.69*	*17.63*	*17.80*	17.44
400	Jan	7.87	6.73	7.70	7.92	8.81	7.32	7.95	7.75
	Feb	8.58	9.02	9.44	8.64	8.61	8.31	9.98	8.94
	Mar	11.19	10.99	11.31	11.40	11.24	11.95	13.03	11.59
	Apr	14.26	15.66	15.13	13.68	15.06	14.94	15.34	14.87
	May	19.33	18.96	19.35	20.18	20.24	19.08	19.05	19.45
	June	23.26	24.25	24.53	23.69	24.99	24.50	25.83	24.43
	July	24.21	25.15	25.59	24.92	26.05	25.39	25.00	25.18
	Aug	23.49	23.29	24.61	24.19	23.76	24.54	24.13	24.00
	Sept	21.48	21.84	22.22	23.33	22.31	22.70	21.96	22.26
	Oct	15.87	17.70	18.09	17.35	17.77	17.33	18.01	17.44
	Nov	11.14	11.66	10.96	11.86	11.91	13.27	12.13	11.85
	Dec	8.16	7.00	7.80	7.57	7.65	7.69	7.42	7.61
	All Months	*15.73*	*16.02*	*16.39*	*16.22*	*16.53*	*16.42*	*16.65*	*16.28*
All Strata	Jan	9.25	7.99	9.07	9.21	10.01	8.55	9.18	9.04
	Feb	10.06	10.61	10.96	9.95	10.05	9.67	11.29	10.37
	Mar	12.78	12.56	12.79	12.86	12.82	13.51	14.44	13.11
	Apr	15.78	17.17	16.56	15.29	16.69	16.54	16.92	16.42
	May	20.91	20.44	20.86	21.60	21.71	20.64	20.61	20.97
	June	25.01	25.83	25.99	25.32	26.55	26.13	27.51	26.05
	July	26.43	27.20	27.54	27.06	28.11	27.57	27.15	27.29
	Aug	25.75	25.54	26.76	26.35	25.99	26.88	26.34	26.23
	Sept	23.47	23.72	24.04	25.16	24.25	24.71	23.96	24.19
	Oct	17.53	19.27	19.43	18.79	19.26	18.83	19.56	18.95
	Nov	12.60	13.05	12.22	13.11	13.25	14.54	13.48	13.18
	Dec	9.51	8.38	9.16	8.75	8.86	8.89	8.58	8.88
	All Months	*17.42*	*17.65*	*17.95*	*17.79*	*18.13*	*18.04*	*18.25*	*17.89*

Table A4. Mean monthly PRISM temperature estimates (in ˚ C) by region for 15 soil-veg plots during all five-year historic monitoring periods.

		Period							
Region	**Month**	**-7**	**-6**	**-5**	**-4**	**-3**	**-2**	**-1**	***All Periods***
Northwest	Jan	11.48	10.19	11.21	11.31	12.10	10.58	11.32	11.17
	Feb	12.35	13.18	13.30	12.34	12.37	11.81	13.57	12.70
	Mar	15.01	14.98	15.13	15.28	15.06	15.64	16.75	15.41
	Apr	18.45	20.10	19.36	17.94	19.23	18.92	19.42	19.06
	May	23.83	23.38	23.85	24.61	24.54	23.14	23.26	23.80
	June	27.99	28.81	28.93	28.29	29.38	28.56	30.12	28.87
	July	29.22	30.13	30.46	30.02	30.82	30.30	29.88	30.12
	Aug	28.59	28.72	29.67	29.25	28.75	29.61	29.24	29.12
	Sept	26.28	26.95	27.07	28.29	27.13	27.63	26.88	27.18
	Oct	20.23	22.30	22.44	21.80	22.14	21.67	22.33	21.84
	Nov	14.91	15.72	14.65	15.55	15.76	17.02	15.96	15.65
	Dec	11.55	10.81	11.45	11.05	11.09	10.89	10.76	11.09
	All Months	*19.99*	*20.44*	*20.63*	*20.48*	*20.70*	*20.48*	*20.79*	*20.50*
Northeast	Jan	8.08	7.02	7.93	8.12	8.82	7.29	8.22	7.93
	Feb	8.73	9.43	9.79	8.99	9.05	8.73	10.38	9.30
	Mar	11.72	11.62	11.75	11.87	11.73	12.63	13.87	12.17
	Apr	14.87	16.58	15.74	14.53	16.05	15.85	16.81	15.77
	May	20.20	20.12	20.31	21.21	21.36	20.32	20.55	20.58
	June	24.46	25.46	25.64	24.94	26.27	26.15	27.61	25.79
	July	25.91	27.05	27.27	26.71	27.98	27.45	27.18	27.08
	Aug	25.38	25.21	26.56	26.07	25.81	26.83	26.29	26.02
	Sept	22.75	23.39	23.55	24.75	23.73	24.37	23.70	23.75
	Oct	16.69	18.55	18.87	18.19	18.69	18.21	19.16	18.34
	Nov	11.49	12.01	11.25	12.17	12.21	13.75	12.73	12.23
	Dec	8.13	7.13	8.07	7.57	7.75	7.65	7.62	7.70
	All Months	*16.53*	*16.97*	*17.23*	*17.09*	*17.45*	*17.43*	*17.84*	*17.22*
Southeast	Jan	8.35	7.26	8.41	8.54	9.42	7.97	8.46	8.34
	Feb	9.29	9.78	10.35	9.35	9.32	9.06	10.76	9.70
	Mar	12.04	11.78	12.19	12.16	12.14	12.63	13.81	12.39
	Apr	14.97	16.20	15.73	14.48	15.75	15.59	16.08	15.54
	May	19.91	19.46	19.90	20.59	20.74	19.64	19.86	20.01
	June	23.94	24.68	24.98	24.14	25.46	25.10	26.51	24.97
	July	25.03	25.62	26.04	25.46	26.57	25.95	25.60	25.75
	Aug	24.24	23.88	25.18	24.77	24.36	25.15	24.75	24.62
	Sept	22.19	22.29	22.69	23.76	22.83	23.26	22.55	22.79
	Oct	16.54	18.09	18.36	17.70	18.13	17.81	18.51	17.87
	Nov	11.83	12.23	11.57	12.53	12.49	13.84	12.79	12.47
	Dec	8.77	7.57	8.51	8.18	8.21	8.36	8.04	8.23
	All Months	*16.42*	*16.57*	*16.99*	*16.80*	*17.12*	*17.03*	*17.31*	*16.89*
Southwest	Jan	9.23	7.72	8.85	8.85	9.72	8.38	8.97	8.82
	Feb	10.04	10.27	10.54	9.34	9.69	9.33	10.78	10.00
	Mar	12.47	12.03	12.34	12.25	12.36	13.13	13.67	12.61
	Apr	15.24	16.24	15.68	14.58	15.93	15.89	15.83	15.63
	May	20.18	19.26	19.78	20.57	20.68	19.65	19.27	19.91
	June	24.19	24.77	24.83	24.44	25.51	25.21	26.38	25.05
	July	26.08	26.53	26.89	26.65	27.60	27.20	26.62	26.80
	Aug	25.43	25.01	26.21	25.96	25.65	26.50	25.69	25.78
	Sept	23.08	22.88	23.32	24.49	23.75	24.21	23.31	23.58

	Oct	17.07	18.72	18.58	18.05	18.61	18.15	18.76	18.28
	Nov	12.29	12.59	11.63	12.45	12.81	13.82	12.85	12.63
	Dec	9.64	8.33	8.82	8.35	8.63	8.66	8.21	8.66
	All Months	*17.08*	*17.03*	*17.29*	*17.17*	*17.58*	*17.51*	*17.53*	*17.31*
West	Jan	10.16	8.73	9.89	10.14	10.86	9.41	9.89	9.87
	Feb	10.94	11.50	11.81	10.72	10.83	10.35	11.93	11.15
	Mar	13.65	13.43	13.55	13.79	13.78	14.55	15.07	13.98
	Apr	16.52	18.03	17.49	16.08	17.67	17.55	17.57	17.27
	May	21.73	21.30	21.80	22.39	22.51	21.61	21.23	21.80
	June	25.83	26.83	26.90	26.19	27.44	26.81	28.17	26.88
	July	27.32	28.16	28.51	27.97	29.01	28.43	27.91	28.19
	Aug	26.59	26.49	27.67	27.20	26.84	27.81	27.21	27.12
	Sept	24.40	24.67	25.04	26.00	25.27	25.54	24.79	25.10
	Oct	18.34	20.11	20.27	19.59	20.09	19.62	20.31	19.76
	Nov	13.53	13.86	13.02	13.85	14.07	15.35	14.12	13.97
	Dec	10.39	9.13	9.93	9.54	9.57	9.75	9.20	9.65
	All Months	*18.28*	*18.52*	*18.82*	*18.62*	*19.00*	*18.90*	*18.95*	*18.73*
All Regions	Jan	9.25	7.99	9.07	9.21	10.01	8.55	9.18	9.04
	Feb	10.06	10.61	10.96	9.95	10.05	9.67	11.29	10.37
	Mar	12.78	12.56	12.79	12.86	12.82	13.51	14.44	13.11
	Apr	15.78	17.17	16.56	15.29	16.69	16.54	16.92	16.42
	May	20.91	20.44	20.86	21.60	21.71	20.64	20.61	20.97
	June	25.01	25.83	25.99	25.32	26.55	26.13	27.51	26.05
	July	26.43	27.20	27.54	27.06	28.11	27.57	27.15	27.29
	Aug	25.75	25.54	26.76	26.35	25.99	26.88	26.34	26.23
	Sept	23.47	23.72	24.04	25.16	24.25	24.71	23.96	24.19
	Oct	17.53	19.27	19.43	18.79	19.26	18.83	19.56	18.95
	Nov	12.60	13.05	12.22	13.11	13.25	14.54	13.48	13.18
	Dec	9.51	8.38	9.16	8.75	8.86	8.89	8.58	8.88
	All Months	*17.42*	*17.65*	*17.95*	*17.79*	*18.13*	*18.04*	*18.25*	*17.89*

Pima County
Multi-species Conservation Plan:
2019 Annual Report

Appendix 15

MSCP potential mitigation land acquisitions and releases during 2019

10 pages

Appendix MSCP potential mitigation land acquisitions and releases during 2019

EXHIBIT A

MSCP Restrictive Covenant Amendment Properties: Pima County Owner & Grantor; FCD Grantee

Property to Add	Map ID	APN	Acres
PRF3 - Cochie Area	1	218-10-005V	26.75
Trail's End	2	212-04-003J	60.99
Robles Pass	3	119-35-1870	42.3
			130.04

Property to Release	Map ID	APN	Acres
Henderson	4	116-09-011A	3.31
			3.31

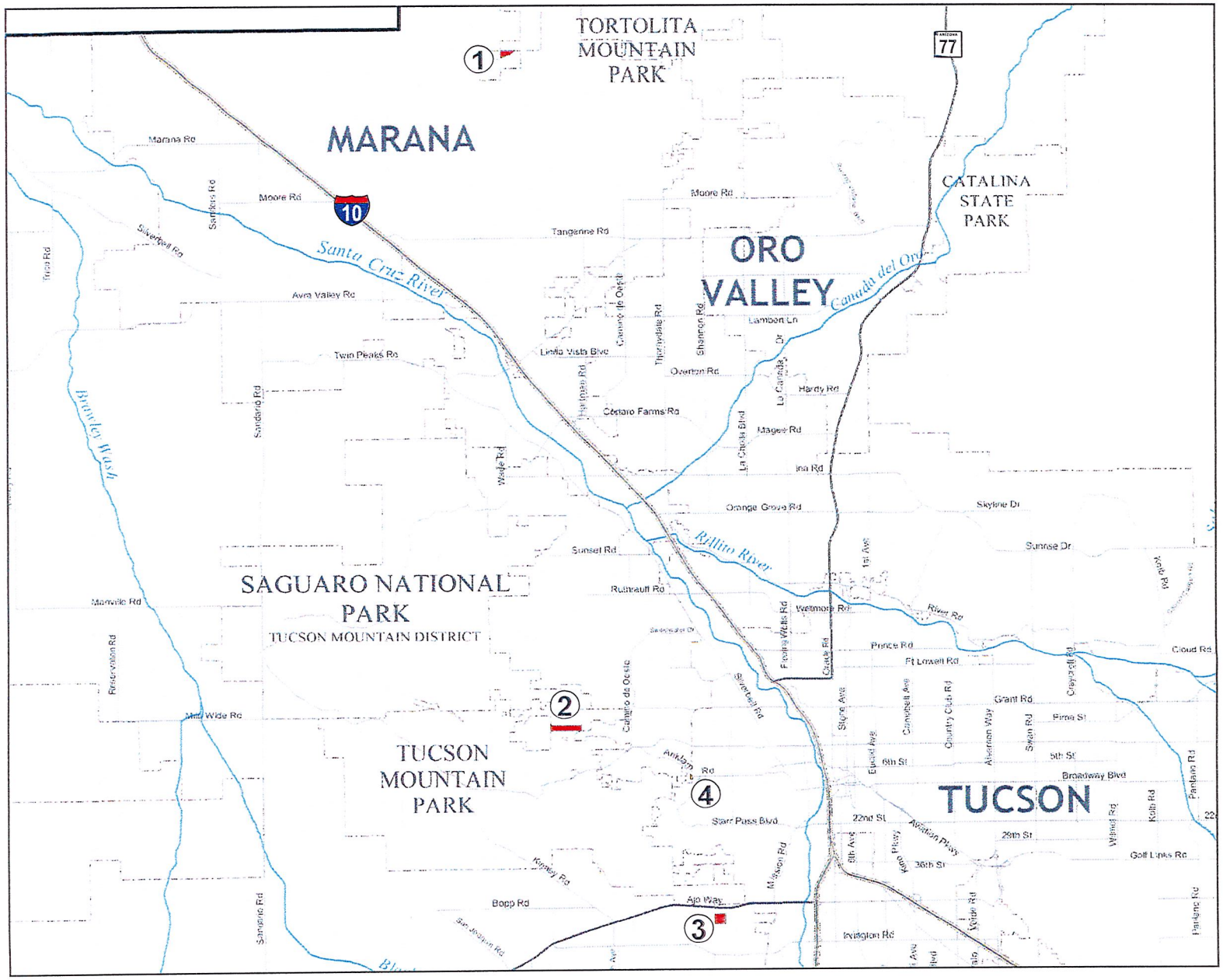

EXHIBIT B

MSCP Restrictive Covenant Amendment Properties: Pima County Owner & Grantor; FCD Grantee

Property to Add	Map ID	Acres
PRF3 - Cochie Area	1	26.75
Trail's End	2	60.99
Robles Pass	3	42.30
		130.04

Property to Release	Map ID	Acres
Henderson	4	3.31
		3.31

N

0 2 miles

PIMA COUNTY

12/12/2018

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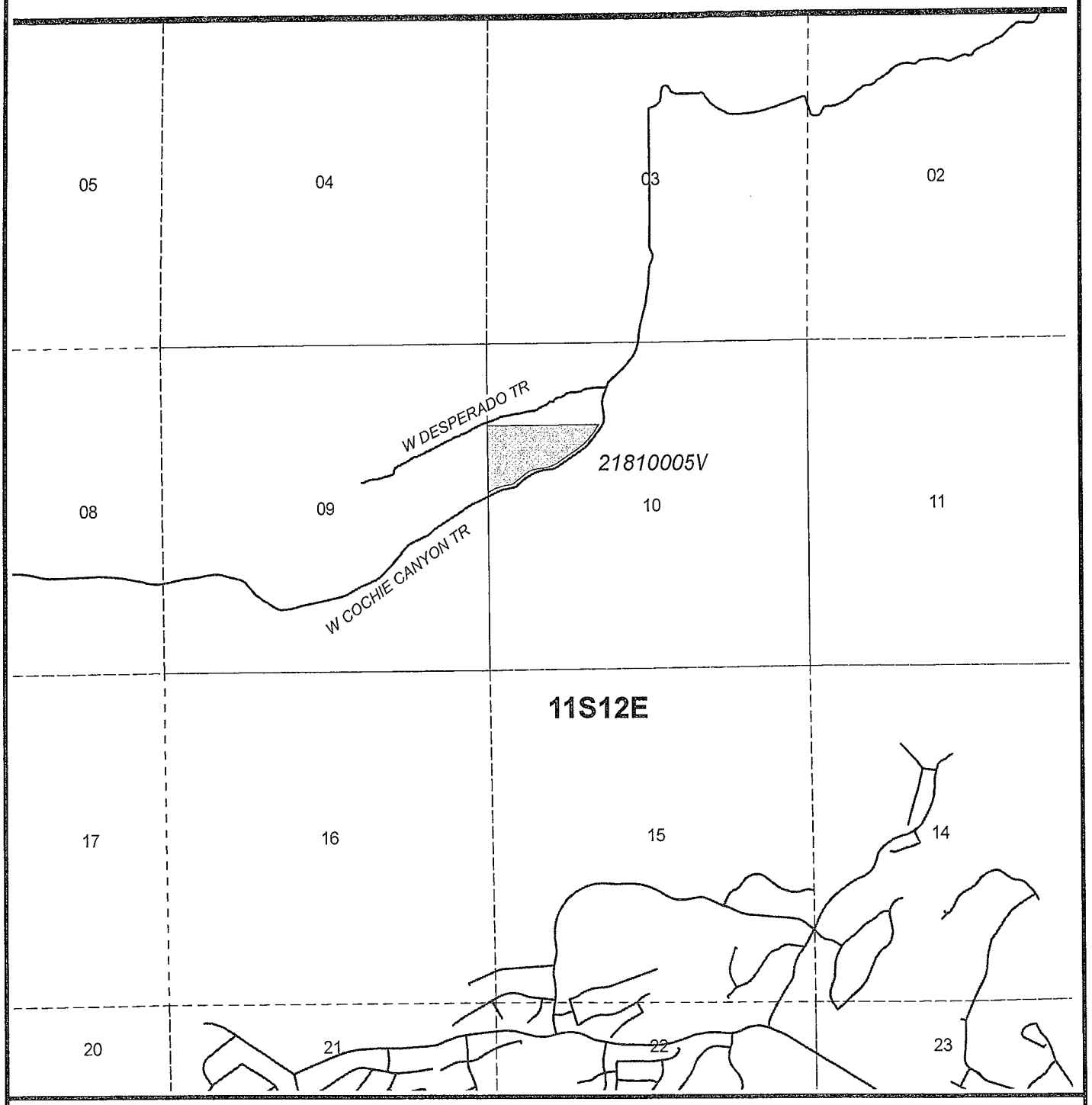

Proposed MSCP Restrictive Covenant: Pima County Owner & Grantor; FCD Receives Covenant

EXHIBIT C

0 1,000 ft

PRF3 - Cochie (1)

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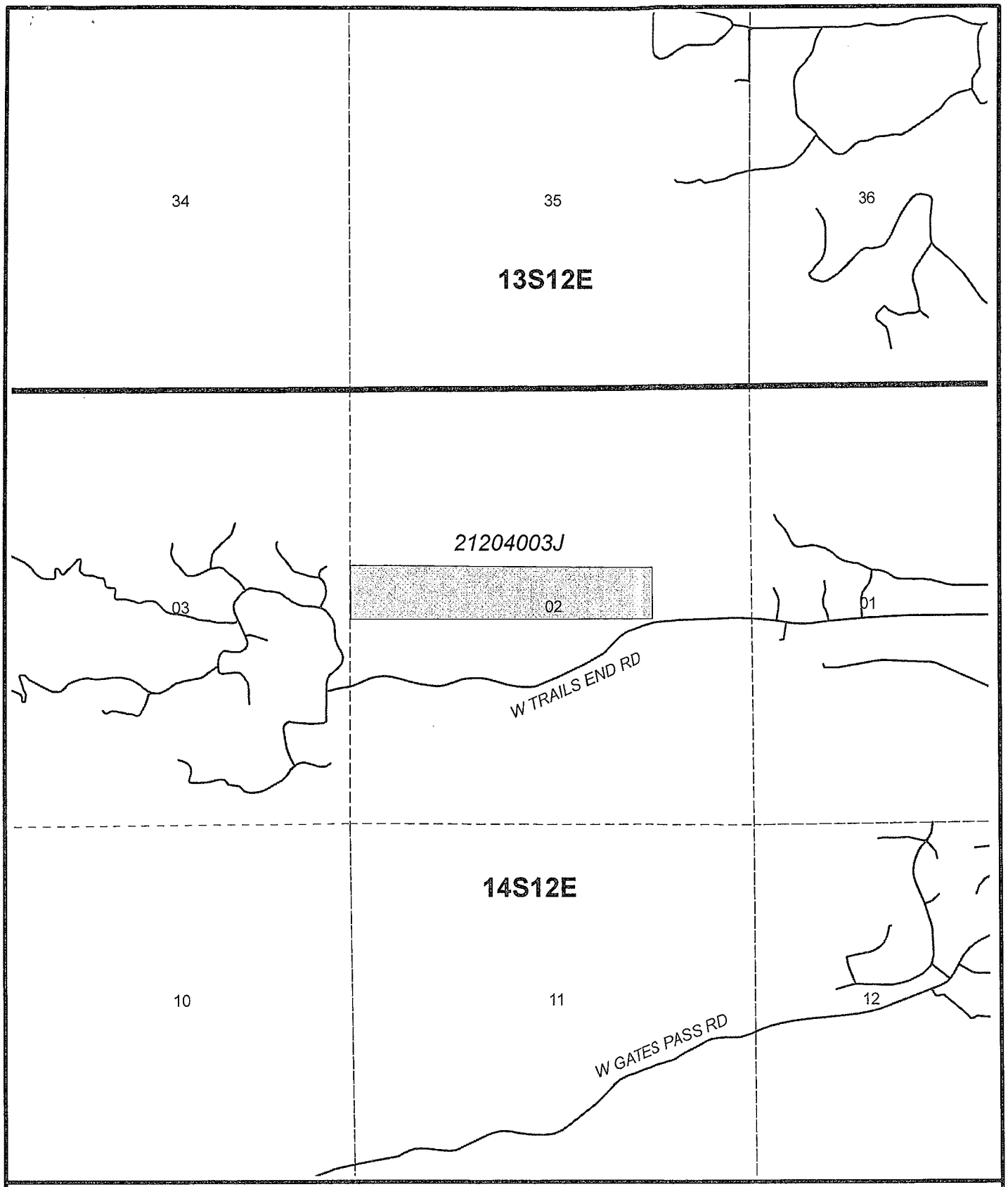

Proposed MSCP Restrictive Covenant: Pima County Owner & Grantor; FCD Receives Covenant

EXHIBIT C

0 1,000 ft

Trail's End (2)

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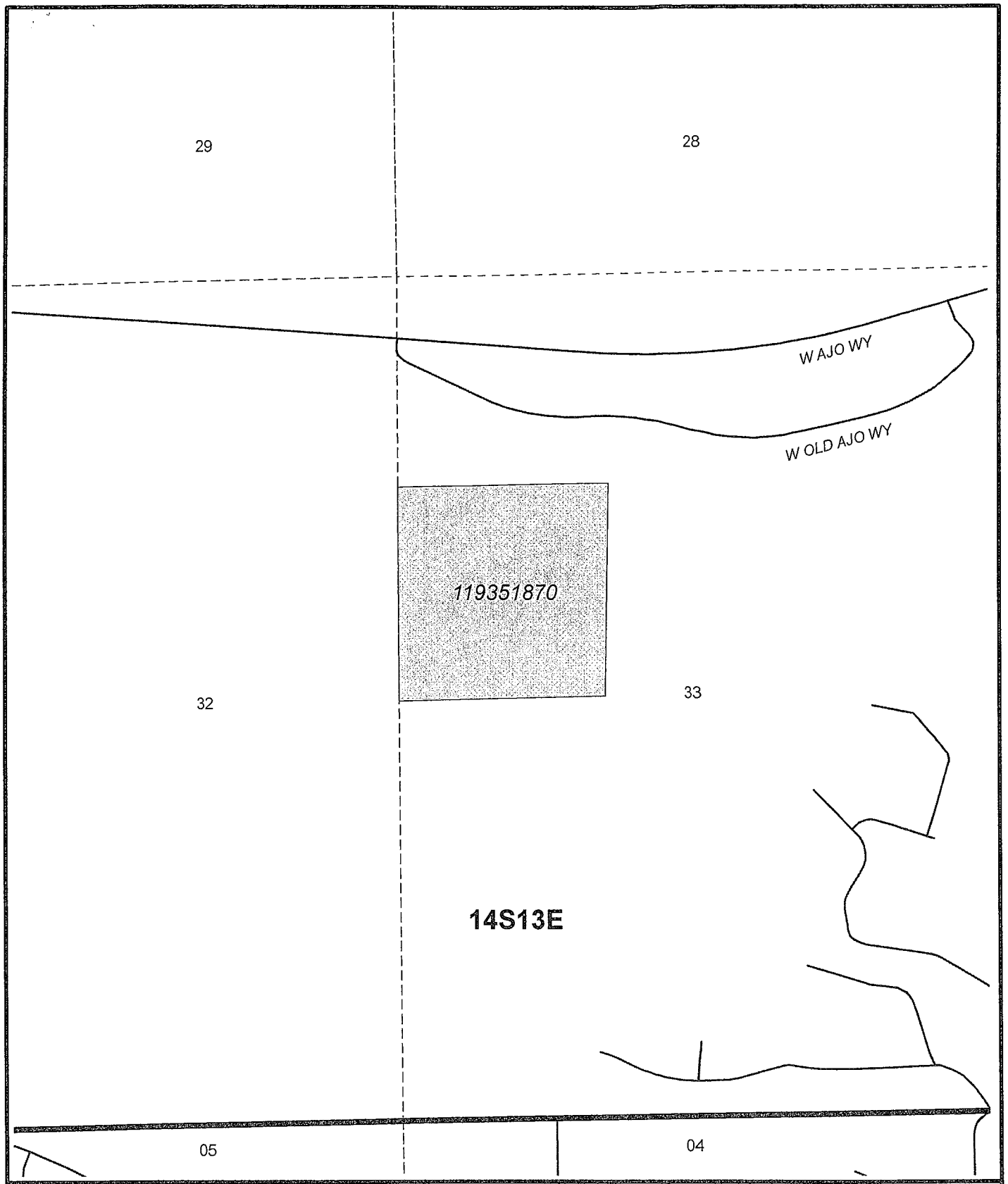

Proposed MSCP Restrictive Covenant: Pima County Owner & Grantor; FCD Receives Covenant

EXHIBIT C

N

0 500 ft

Robles Pass (3)

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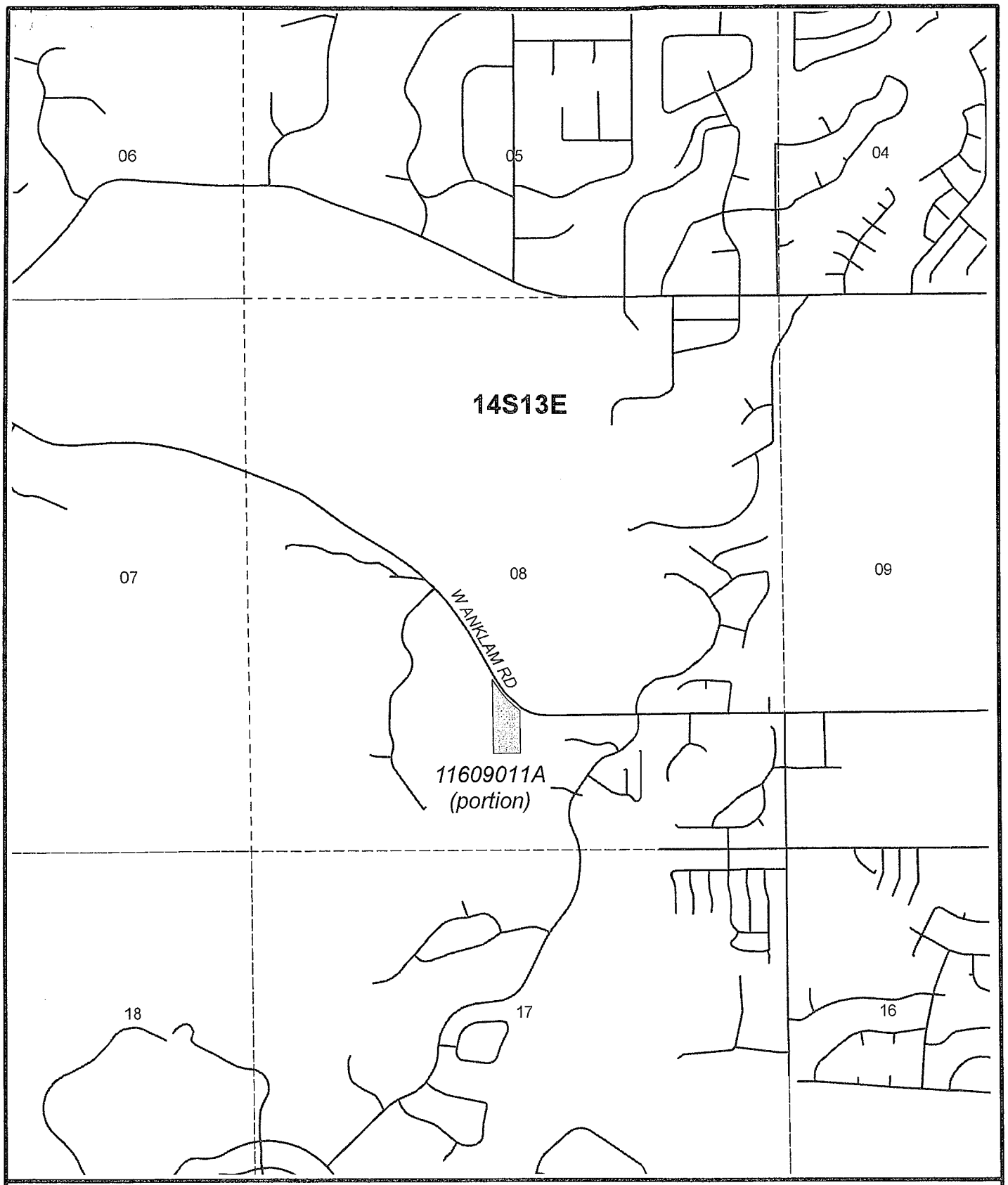

EXHIBIT C

Release from MSCP:
Pima County Owner

0 750 ft

Henderson (4)

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EXHIBIT A

MSCP Restrictive Covenant Amendment Properties: FCD Owner & Grantor; Pima County Grantee

Property to Add	Map ID	APN	Acres
Agua Verde Ranch	1	306-11-006L	78
Agua Verde Ranch	1	306-11-006M	41.58
LRON Houghton	2	133-03-281D	4
			123.58

EXHIBIT B

MSCP Restrictive Covenant Amendment Properties: FCD Owner & Grantor; Pima County Grantee

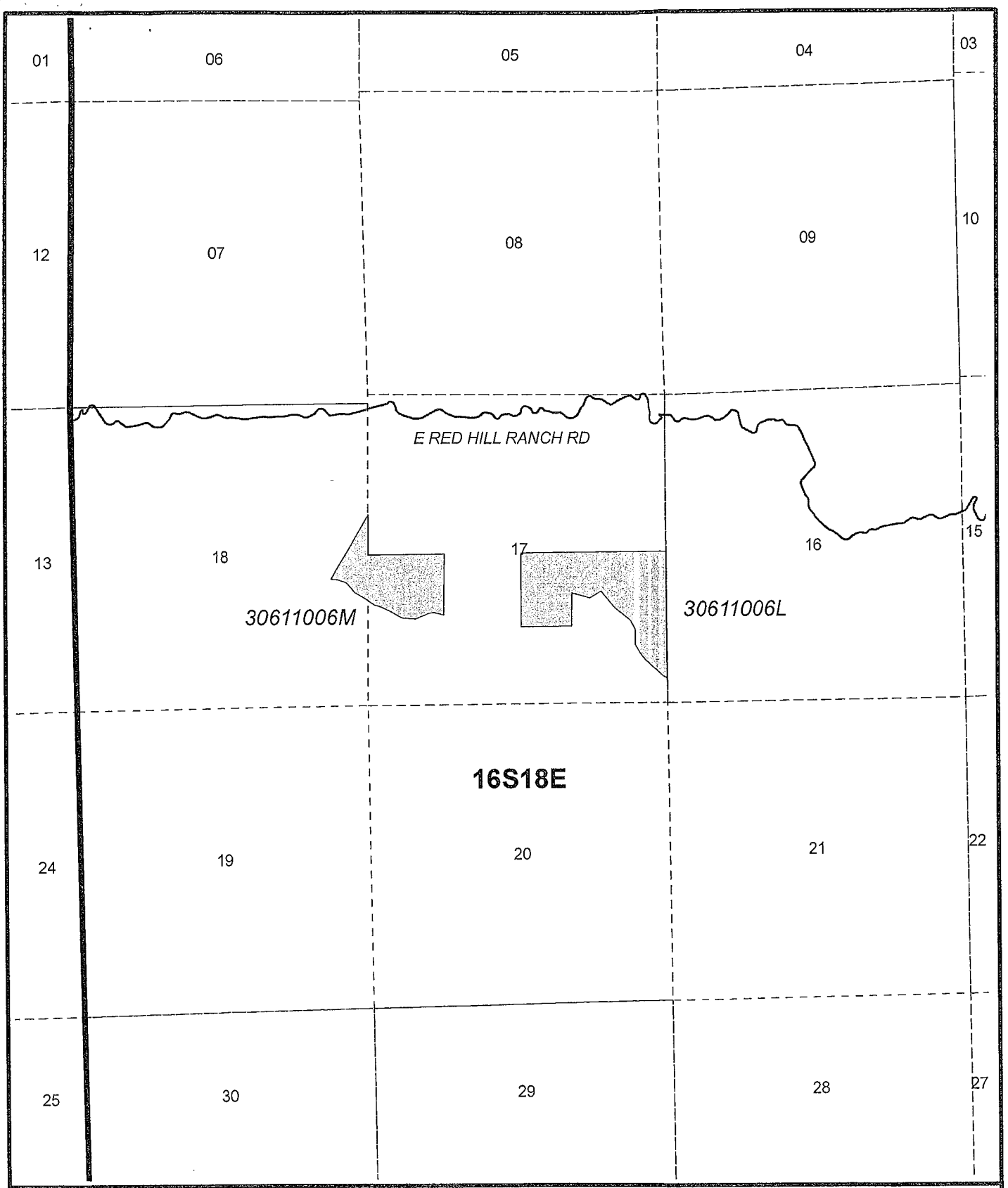
Property to Add	Map ID	Acres
Agua Verde Ranch	1	78
Agua Verde Ranch	1	41.58
LRON Houghton	2	4
		123.58

N

0 1 mile

PIMA COUNTY

12/12/2018



Proposed MSCP Restrictive Covenants: FCD Owner & Grantor; Pima County Receives Covenants

EXHIBIT C

N

0 1,000 ft

Agua Verde Ranch (1)

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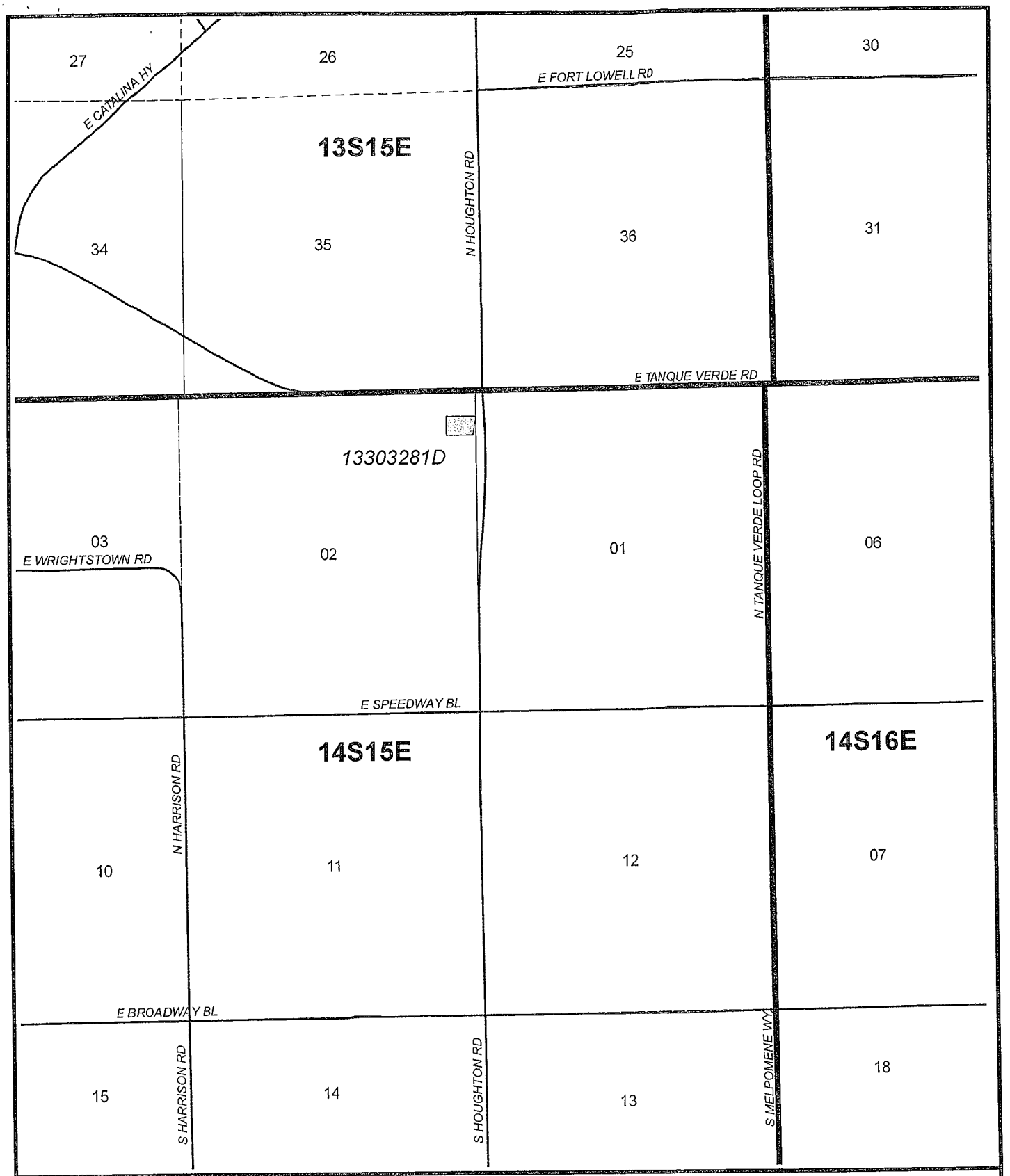

Proposed MSCP Restrictive Covenant: FCD Owner & Grantor; Pima County Receives Covenant

EXHIBIT C

N

0 1,000 ft

LRON Houghton (2)

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