2020 SUMMARY OF CITY OF AUSTIN SPRING MANAGEMENT ACTIVITIES ON THE BALCONES CANYONLANDS PRESERVE

Crystal Datri searching a spring run

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1 October 2019 – 30 September 2020
Submitted 11 December 2020

Abstract

This report details the Balcones Canyonlands Conservation Plan (BCCP) springs management activities performed during the 2020 fiscal year. On-going management activities for FY 2020 include mapping and characterizing newly documented springs, monitoring previously documented springs, survey for stygofauna, prioritizing sites for protection from feral hogs, and maintaining a database of springs. Biologists documented 143 new spring locations in FY2020. Invertebrates were sampled at 12 springs, resulting in the first known collection of groundwater fauna on the Cortaña, Steiner Ranch, Bohls, and JJ&T tracts. Multiple new records of groundwater invertebrates were obtained including two for *Caecidotea reddelli,* a BCCP species of concern, and four for the critically imperiled *Stygobromus russelli,* identified as an additional species of concern by the BCCP. Multiple specimens await further taxonomic scrutiny.

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Introduction

The Balcones Canyonlands Preserve (BCP) is a regional system of preserve tracts created for the protection of federally listed species and species of concern as specified by the Balcones Canyonlands Conservation Plan (BCCP). The BCCP is a regional 10(a)(1)(B) permit jointly issued to the City of Austin and Travis County by the U.S. Fish and Wildlife Service (USFWS) under the endangered species act. The regional permit addresses the stewardship of habitat for the permanent protection of eight federally listed endangered species (two songbirds and six invertebrates) and twenty-seven species of concern (two plants and twenty-five invertebrates). Should the species of concern become federally listed, no additional mitigation would be required by the permittees with the full implementation of all BCCP protections (BCP 2007a, USFWS 1996).

The permit area, or Balcones Canyonlands Preserve, is located in Western Travis County on the eastern edge of the Edwards Plateau ecoregion. This area comprises part of the Balcones Canyonlands, characterized by steep streams and canyons deeply dissecting the Balcones Escarpment. The karstic limestone found here is highly fractured and pocked with numerous solution cavities and springs. These subterranean features and spring-fed drainages support unique ecological niches and a high degree of endemism (BCP 2007a).

Balcones Canyonland Conservation Plan (BCCP) spring management obligations include: identifying spring locations (BCP 2007e, 2007g, 2007j), monitoring springs for water quality and seasonal discharge (BCP 2007b, 2007g, 2007h, 2007j), protecting springs (BCP 2007b, 2007d, 2007h, 2007i, 2007j), controlling invasive species (BCP 2007g, 2007h, 2007i, 2007j), and monitoring for populations of aquatic target species (BCP 2007b, 2007c, 2007h, 2007j). These management obligations include research goals that specify improving understanding of the ecology of preserve species and aquatic and subterranean environments (BCP 2007b). Those topics that contribute to management practices and permanent protection for listed species and species of concern are emphasized. The BCCP cites a lack of information regarding karst species and karst habitat management and specifically encourages research regarding aquatic life within the aquifer (BCP 2007c).

The animals that occur in subsurface water are referred to as stygofauna. This report addresses the two categories of stygofauna found on the Balcones Canyonlands Preserve: the stygophiles that exploit aquatic subsurface environments for some portion of their life cycle, and the stygobites that complete their entire life cycle in subsurface waters (Malard *et al.* 2002).

Among the twenty-seven species of concern protected under the BCCP, three are stygobitic: the flatworm *Sphalloplana mohri*, the ostracod *Candona sp. nr. stagnalis*, and the isopod *Caecidotea reddelli*. Further, the BCCP identifies additional species of concern (BCP 2007a). Of these are two stygobitic invertebrates: the amphipods *Stygobromus russelli* and *Stygobromus bifurcatus*. Both amphipods have a conservation status of vulnerable (Hutchins 2017), and *S. russelli* is a critically imperiled state species of greatest conservation need (TPWD 2012). The stygophilic Jollyville Plateau salamander (*Eurycea tonkawae*) and the undescribed "Pedernales Springs" salamander are not listed as a species of concern by the 1996-issued BCCP permit; however, the BCCP does list these species as additional species of concern and indicates that *Eurycea* salamanders may deserve further scrutiny throughout the term of the permit (BCP 2007a). The "Pedernales Springs" salamander is an undescribed neotenic *Eurycea* species (*Eurycea* sp. 1) occurring in springs along the lower Pedernales River in Blanco, Travis, and Hays Counties (Devitt *et al*. 2019). NatureServe rankings indicate this salamander will be listed as critically imperiled once described (NatureServe 2020). The Jollyville Plateau salamander has since been federally listed as threatened and is a vulnerable-imperiled state species of greatest conservation need (USFWS 2013, TPWD 2012). Numerous populations are found on the BCP and monitoring Jollyville Plateau salamanders is specifically prescribed in the management objectives (BCP 2007f, 2007h). Table 1 and Table 2 summarize the conservation status of the stygofauna of the BCCP.

Table 1. The stygofauna protected under the BCCP along with their most recently assessed conservation status[1]. These species may merit federal listing if the BCP does not adequately protect their habitat[2].

Common name	Scientific Name	Conservation Status	Federal Status	State Species of Greatest Conservation Need
Flatworm	*Sphalloplana mohri*	Vulnerable		
Ostracod	*Candona sp. nr. stagnalis*			
Isopod	*Caecidotea reddelli*	Apparently secure		

[1] Hutchins 2017
[2] BCP 2007a.

Table 2. The stygofauna the BCCP names as additional species of concern along with their most recently assessed conservation status[1,2].

Common name	Scientific Name	Conservation Status	Federal Status	State Species of Greatest Conservation Need
Jollyville Plateau salamander	*Eurycea tonkawae*		threatened	Imperiled/Vulnerable
"Pedernales springs" salamander	*Eurycea sp. 1*			
Bifurcated cave amphipod	*Stygobromus bifurcatus*	Vulnerable		
amphipod	*Stygobromus russelli*	Vulnerable		Critically Imperiled

[1] Hutchins 2017.
[2] Texas Parks and Wildlife Department 2012.

There is insufficient data on the taxonomy, distribution, and ecology of stygofauna. Spring outflows provide access points or "windows" into aquatic subterranean ecosystems (Malard 2002). The City of Austin (COA) wishes to establish baseline physical condition data for all COA BCP springs and assess these springs for aquatic target species, with the long-term goal of monitoring sites for changes that could be in response to the surrounding growing urban population, climate change, or invasive species.

BCP staff initiated mapping and characterizing springs in FY 2017. In FY 2018, BCP staff continued to map and characterize spring locations, began monitoring springs, and established a geospatial springs database. These activities were expanded to include increased survey for stygofauna with the initiation of a contract agreement with permitted biologist, Crystal Datri, owner, Wren Daytree LLC. Management activities in FY 2019 included mapping and characterizing newly documented springs, monitoring previously documented springs, survey for stygofauna, prioritizing sites for protection from feral hogs, updating the springs database, refining methods, establishing a system of curation for collections, and preparation of the 2019 Summary of Spring Management Activities annual report. This annual report details ongoing activities for FY 2020 including mapping and characterizing newly documented springs (expanded to include the Pedernales and South Lake Austin macrosites), monitoring previously documented springs, survey for stygofauna, site protection from feral hogs, updating the springs database, and refining methods. Please see the concurrent "Spring, Cave, and Stygofauna Investigations at Westcave Preserve, Travis County, Texas" for spring management activities specific to Westcave Preserve, Pedernales macrosite.

Methods

Here we define springs following Springer and Lawrence (2009): ecosystems where groundwater reaches the Earth's surface either at or near the land-atmosphere interface or the land-water interface. Seeps are small springs where discharge is immeasurably diffuse (Stevens *et al.* 2016). The source of the spring or its point of emergence is referred to as the orifice (Springer and Lawrence 2009).

Identifying Undocumented Springs

Biologists selected locations to search for springs by identifying canyons and ravines within City of Austin (COA)-owned tracts of the Balcones Canyonlands Preserve (BCP) using topographic maps. FY 2020 included spring survey on Travis County-owned BCP tracts. Previously documented spring locations were considered to identify gaps in COA springs data. Biologists traversed streams, canyons, ravines, and their tributaries, searching for signs of springs (e.g. spring-associated vegetation, sounds of water flowing, temperature gradients). Spring locations were documented when water issuing from an orifice was observed. Seeps were documented where there was not an obvious orifice of flowing water, but indications of diffuse seepage. Positions of all features were documented with a commercial handheld Global Positioning System (GPS) receiver and checked with field maps based on digital imagery. The locations of all features were mapped using ArcGIS software.

Characterizing Springs

Location accessibility and spring morphology on the Balcones Canyonland Preserve System limit the types of data that can be collected for characterization. FY2020 field survey consisted of a single researcher searching for spring locations and collecting data based on the equipment they could hike with and the nature of the unique conditions encountered at each site. Researchers focused on documenting those characteristics in the immediate vicinity of the spring orifice; however, in many cases, descriptions of spring-run habitat deemed suitable for stygofauna was additionally described. The following were collected in FY2020 as possible: size and description of orifice morphology, photographs, water depth, substrate composition, rock cover, calcium carbonate cementation, water temperature, ambient temperature, some measure of water quantity, and notable flora and fauna. Discharge was measured by capturing spring outflow for time. Spring outflow could be directly captured at a rock-face pour-off in a graduated cylinder or diverted for capture using laminated paper or plastic sheeting. A visual estimate of percentage of flow captured was recorded. When outflow could not be captured, a description of the wetted perimeter and flow

characteristics was described. Substrate in the immediate vicinity of the spring outlet was assessed as a visual estimate of the particles that fall within each category of the modified Wentworth scale. Rock cover and calcium carbonate cementation was measured by modifying established methods for Jollyville Plateau salamander occupancy surveys (Bendik et al. 2016). Researchers measured as a visual estimate of the percentage of rocks available (i.e. unembedded) for salamander cover (>8 mm) at the substrate surface in the immediate vicinity of the spring orifice. Calcium carbonate cementation was visually estimated as being in one of four categories: (1) no carbonate build-up; (2) low to moderate build up (but <50% area); (3) moderate to high build up (>50% area); and (4) complete covering of area with carbonate and tufa, in the immediate vicinity of the spring orifice. Water depth was measured at the thalweg of the spring orifice. Ambient temperature was measured within 0.5 meters of the spring orifice. Water temperature was measured as far into the spring orifice as a handheld probe thermometer (Reotemp K79-7) could reach. Weather conditions were noted at the beginning and the end of the survey day. Local temperature and humidity was recorded from the nearest reported Wunderground weather station. Researchers visually estimated cloud cover. Wind speed was estimated using the Bufort scale. Geologic formation was noted according to elevation *a posteriori*.

Stygofauna

Researchers searched for salamanders and macroscopic invertebrate stygofauna by removing and replacing all cover objects such as rocks and leaf litter within the wetted perimeter in the immediate vicinity of the spring orifice where water accumulated enough to provide useable habitat as pools, streams, or within surveyable portions of karst features. Search surface area and time were recorded. Submerged spring orifices can be difficult to discern. Further, Jollyville Plateau salamanders are known to range widely (500m+) in spring-influenced stream habitats (Bendik 2016). While traversing stream runs in search of spring locations, researchers frequently stopped to informally search what they evaluated as suitable habitat using their best judgement. Because locations were not known *a priori* in these cases, survey sites were not delimited, and searching times were not noted.

Drift nets and cotton mop-head material (mops) were used to sample for fauna as appropriate according to spring morphology and location accessibility. On retrieval, mops were carefully removed and visually searched for both salamanders and macro invertebrates. Drift nets consisted of 150 to 200 micron, mesh filter bags. Drift nets were checked at least once per week. On retrieval, nets were rinsed into a 250 micron sieve and then visually searched for any remaining macroinvertebrates. Sieve material was sorted and visually searched, both with the naked eye and in combination with a 2x lens.

Specimen Collection and Curation

Macroscopic invertebrate stygofauna were collected and fixated in 95% ethyl alcohol. Samples were sorted and assigned specimen numbers at the Reicher Ranch Wildlands Conservation Division office. Samples were then sent to the University of Texas Rio Grande Valley at Edinburg (gastropods), USFWS San Marcos Aquatic Resources Center (*Stygobromus*), Edwards Aquifer Research and Data Center at San Marcos (*Assellidae*), and the Texas Natural History Collection at the University of Texas at Austin (troglofauna) where they await further taxonomic scrutiny and curation. Epigean fauna is curated at Reicher Ranch.

Testudo Tube cave

Bi-annual monitoring events at Testudo Tube cave for Jollyville Plateau salamanders were conducted on January 23, 2020 and August 5, 2020. Two biologists exhaustively searched a previously delineated monitoring zone of stream passage (Figure 1). Animals were captured with pool nets and held in mesh boxes in the water until they were photographed. Animals were photographed in an acrylic tray filled with spring water, set on top of 1 cm grid background (Figure 2). These images can later be used to identify individuals and measure body length. Animals were released within the immediate vicinity of their capture. At the beginning of each survey, water temperature, specific conductivity, pH, and dissolved oxygen were measured with a Hydrolab Compact MS5.

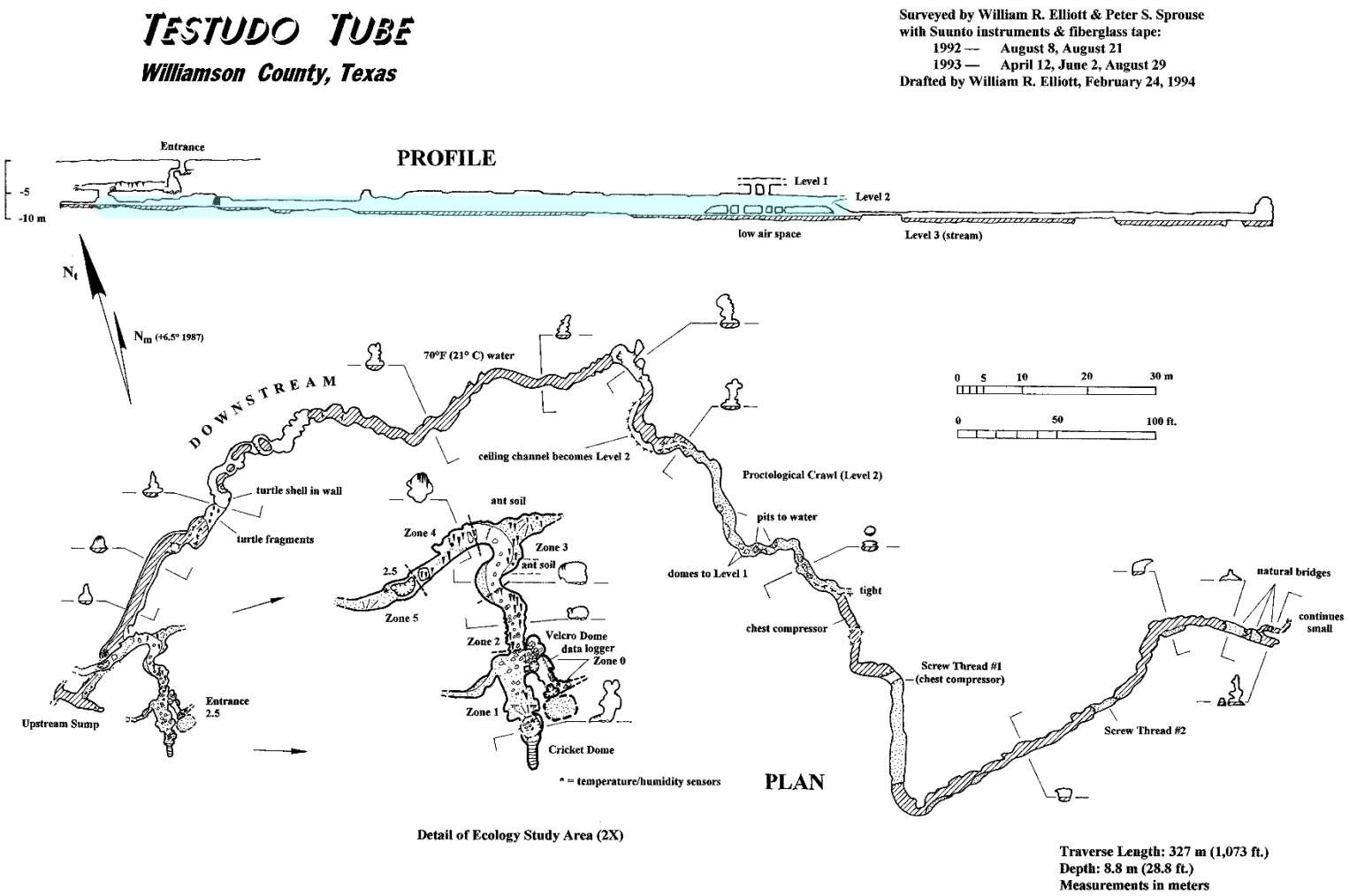

Figure 1. Map of Testudo Tube cave. The monitoring zone is highlighted in blue in the profile view.

Figure 2. Salamanders to be photographed in Testudo Tube Cave. Photo by Colin Strickland.

Springs Database

The Wildlands Conservation Division Springs Database was established by city staff biologist Colin Strickland in 2018. Colin compiled all known COA BCP springs data into a single format in ArcGIS and continues to add BCP springs data as collected through FY2020.

Priority for Feral Hog Protection

Certain spring sites are more easily protected from rooting and wallowing action by feral hogs due to their morphology and accessibility. Sites that can be feasibly be fenced-off for protection from feral hogs are identified and prioritized for protection.

Results

Identifying Undocumented Springs

143 new spring and seep locations were documented in FY2020 on City of Austin Balcones Canyonland Preserve tracts Kent Butler, Cortaña, JJ&T, and Bohls, Travis

County tract Steiner Ranch, and Lower Colorado River Authority tract Westcave Preserve. These locations are depicted on maps shown in Figures 3 through 8. For more detailed information on the springs specific to Westcave Preserve, please see the concurrent “Spring, Cave, and Stygofauna Investigations at Westcave Preserve” report. Two existing wells were documented. Location and characterization data are housed with the City of Austin Wildlands Conservation Division office.

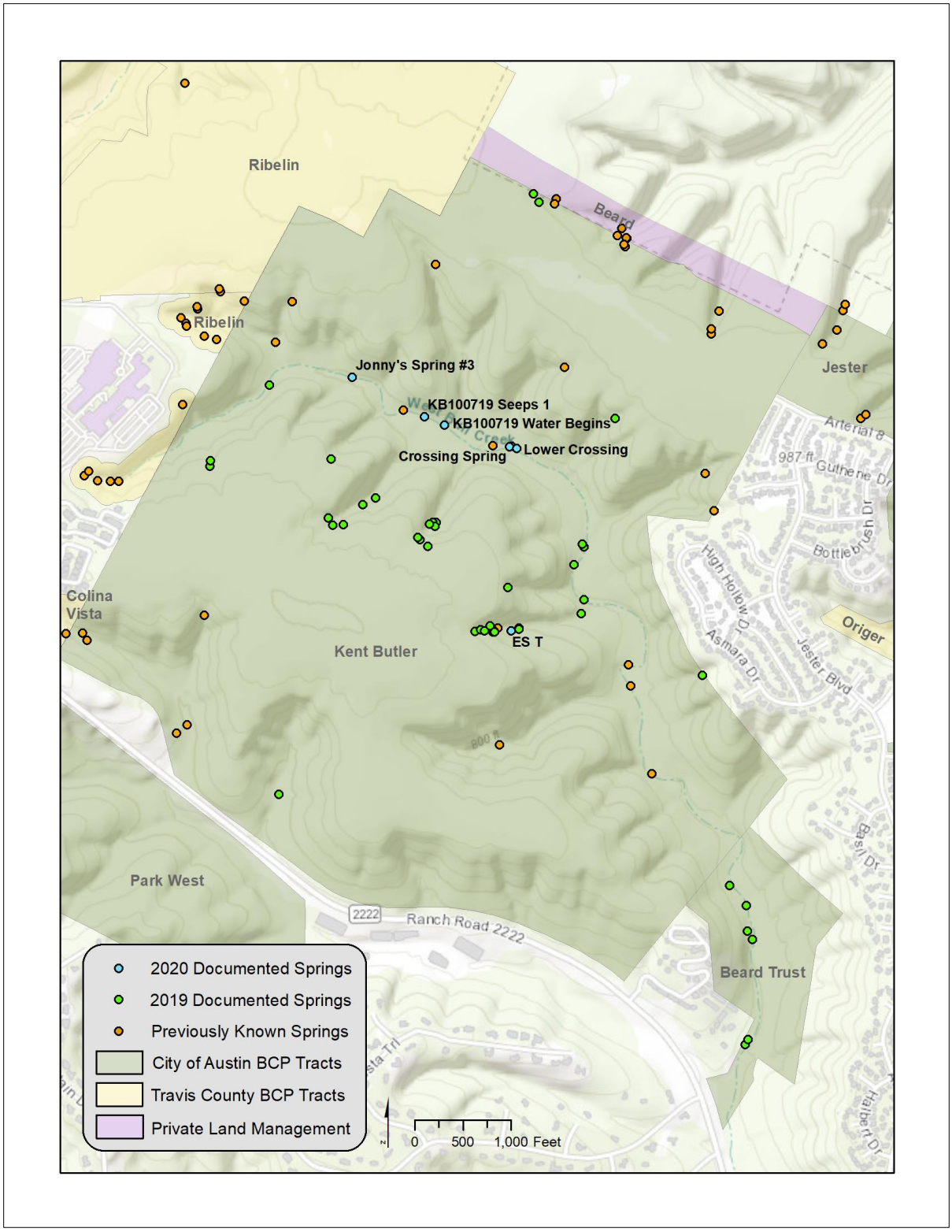

Figure 3. Springs documented on the Kent Butler tract. Map by Colin Strickland.

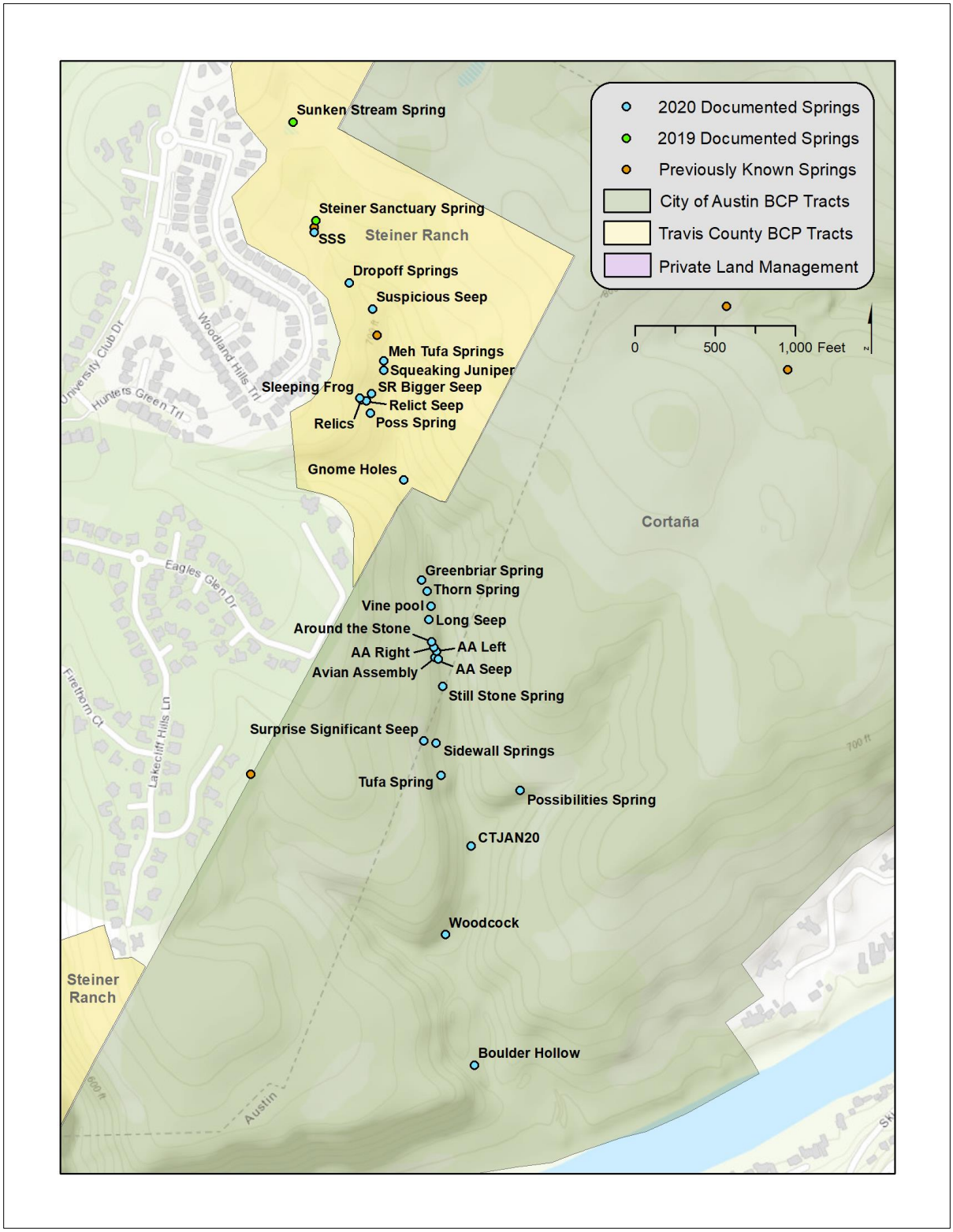

Figure 4. Springs documented on the Steiner Ranch tract and southern portions of the Cortaña tract. Map by Colin Strickland.

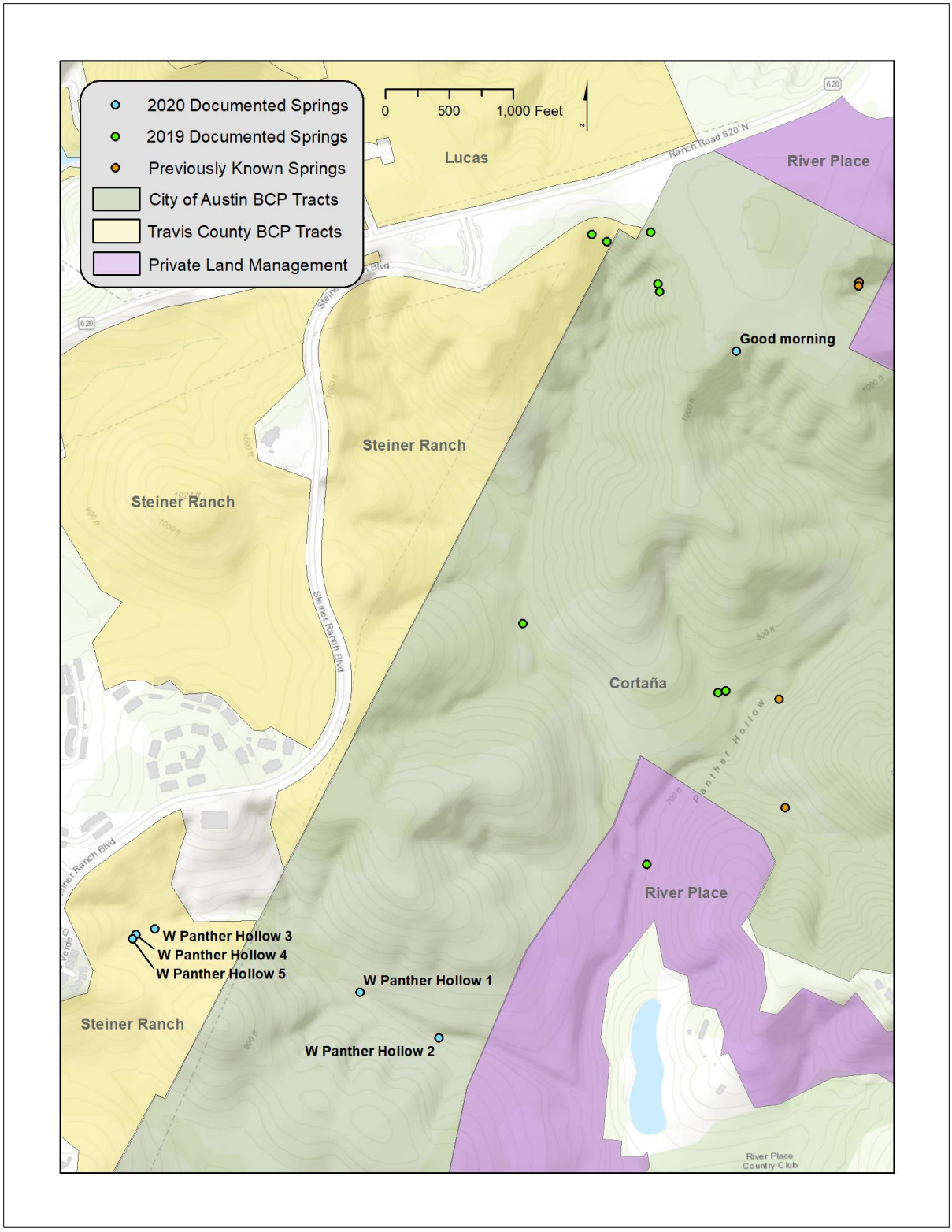

Figure 5. Springs documented on the Steiner Ranch Tract and northern portions of the Cortaña tract. Map by Colin Strickland.

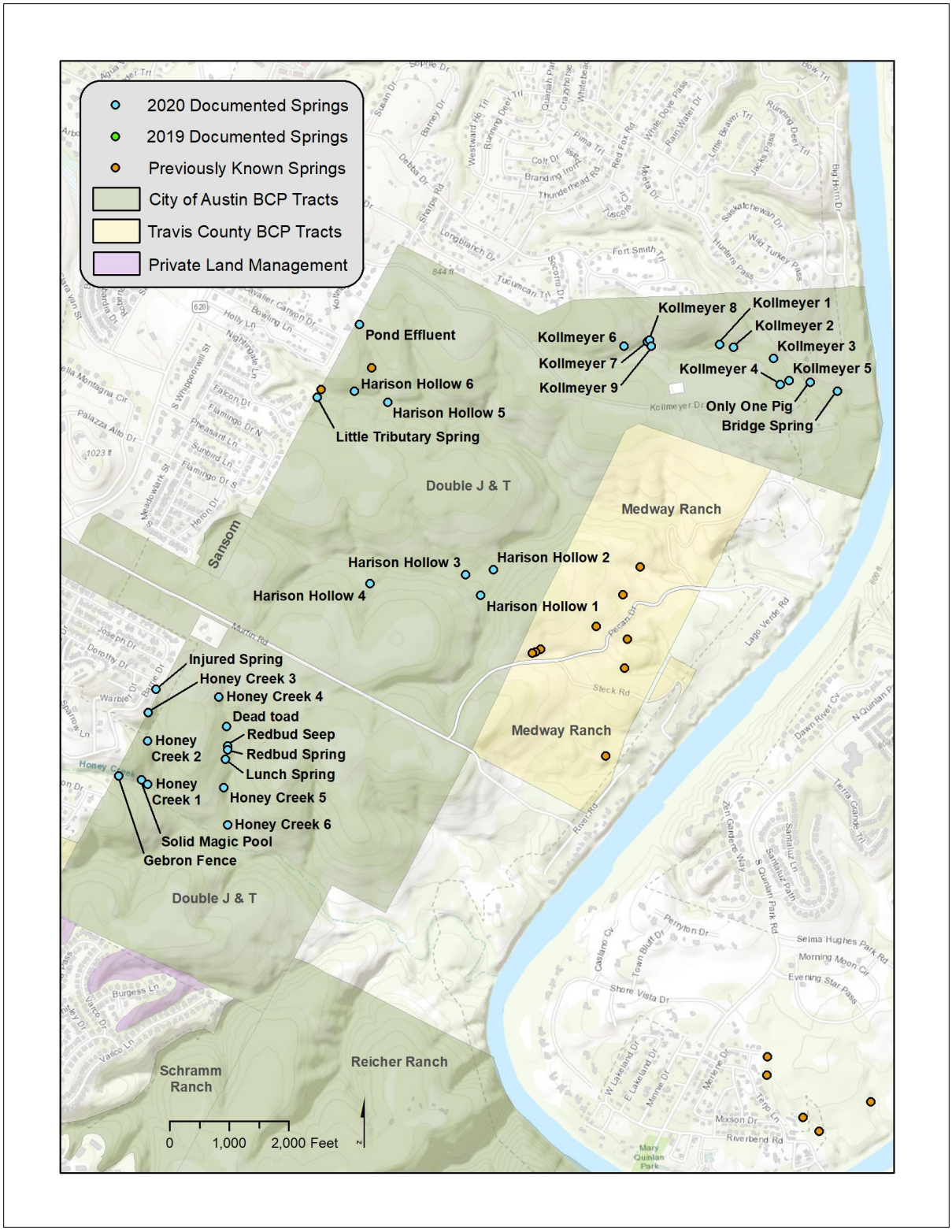

Figure 6. Springs documented on the JJ&T tract. Map by Colin Strickland.

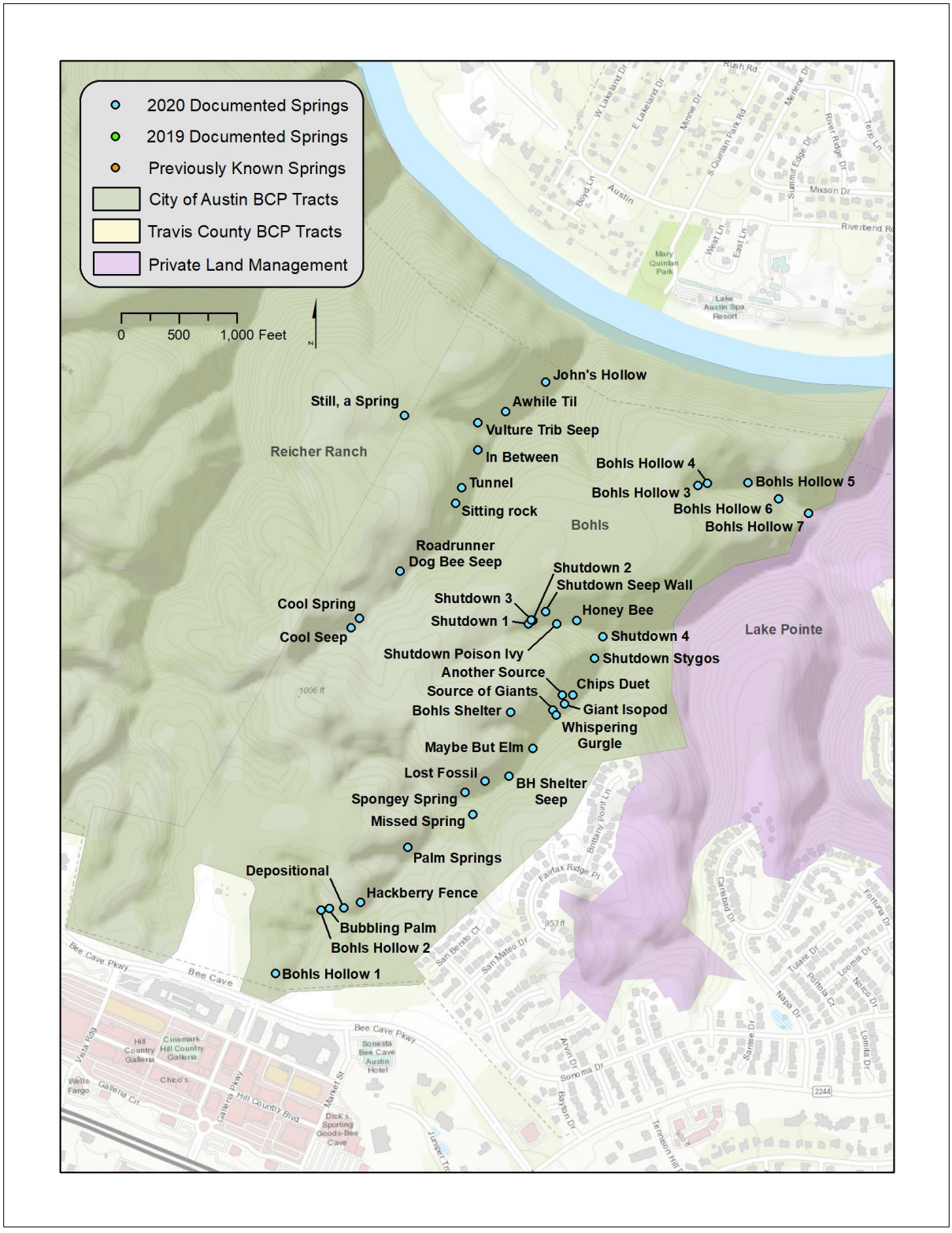

Figure 7. Springs documented on the Bohls tract. Map by Colin Strickland.

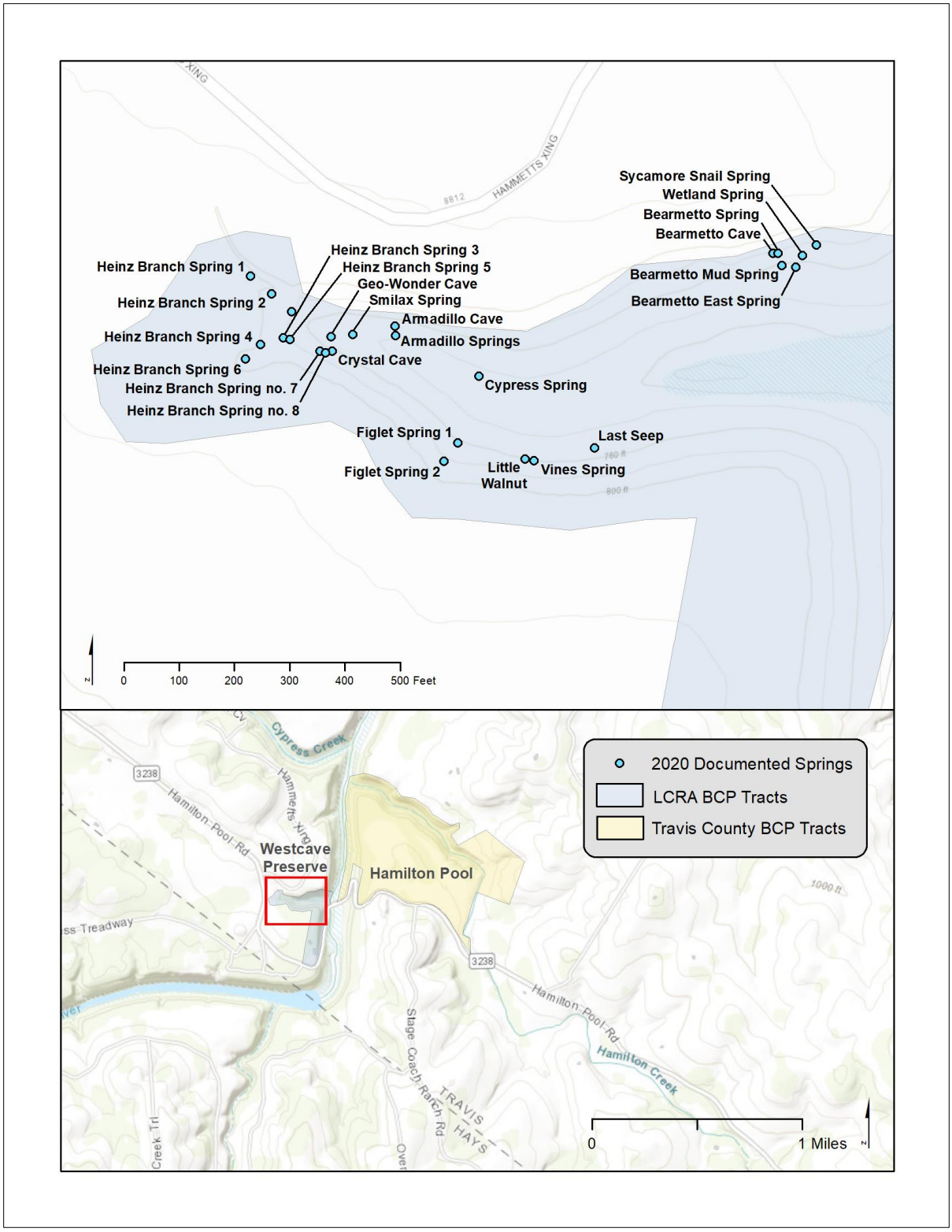

Figure 8. Springs documented at Westcave Preserve. Map by Colin Strickland.

Stygofauna

Invertebrates were collected from 12 springs in FY2020. Gastropods and *Stygobromuss* have undergone taxonomic scrutiny by species experts. Assellidae and troglofauna await further taxonomic scrutiny. A summary of all invertebrate fauna collected in FY2020 with their current lowest level of taxonomic identification is shown in Table 3. All are new occurrence records. Accession information for all invertebrates collected as part of this project are housed with the City of Austin Wildlands Conservation Division. No new locations for *Eurycea* neotenic salamanders on COA BCP were found in FY2020.

Table 3. Summary of invertebrates collected at springs on the Balcones Canyonlands Preserve for FY 2020.

Spring	BCP Tract	Date of Collection	Current Identification	Sampling Method
Avian Assembly Right	Cortana	Jan 14, 2020	*Hyalella*	Free-living at orifice (no trap)
Chip's Duet	Bohls	Mar 31, 2020	*Stygobromus balconis*	Free-living at orifice (no trap)
Giant Isopod	Bohls	Mar 31, 2020	Asellidae stet. *Stygobromus* stet. Entomobryomorpha stet. Tricladida stet.	Free-living at orifice (no trap)
Greenbriar	Cortaña	Feb 18, 2020	Asellidae stet. *Stygobromus russelli* *Hyalella azteca* Acariformes stet.	Drift net: 150 micron
Greenbriar	Cortaña	Feb 24, 2020	Hemiptera stet. Asellidae stet. Entomobryidae stet. *Gastrocopta* sp. Tricladida stet.	Drift net: 150 micron
Greenbriar	Cortaña	Mar 2, 2020	*Stygobromus russelli* Asellidae stet. Trichoptera stet. Platyhelminthes stet.	Drift net: 150 micron
Greenbriar	Cortaña	Mar 5, 2020	Asellidae stet. *Stygobromus russelli* Entomobryidae stet. Dytiscidae stet. Trichoptera stet.	Drift net: 150 micron
Greenbriar	Cortaña	Feb 10, 2020	Asellidae stet. *Phreatodrobia nugax* *Hawaiia minuscula*	Drift net: 150 micron
Injured Spring	JJ&T	Mar 5, 2020	*Stygobromus balconis* Stratiomyidae stet. Odonata stet.	Drift net: 150 micron
John's Hollow	Bohls	May 13, 2020	*Stygobromus balconis* Asellidae stet. *Gastrocopta* sp.	Drift net: 150 micron

			Dytiscidae stet. Coleoptera stet.	
John's Hollow	Bohls	May 19, 2020	*Stygobromus balconis* Asellidae stet. Entomobryidae stet. Dytiscidae stet. Trichoptera stet. Odonata stet. Entomobryomorpha stet. *Lucidella* sp. *Glyphyalinia* sp. *Gastrocopta* sp. *Fossaria* sp.	Drift net: 150 micron
John's Hollow	Bohls	May 26, 2020	*Stygobromus balconis* Asellidae stet. Entomobryomorpha stet. Trichoptera stet. *Gastrocopta* sp. *Phys* sp. *Glyphyalinia* sp. *Helicodiscus* sp. *Lucidella* sp. *Phreatodrobia nugax*	Drift net: 150 micron
John's hollow	Bohls	Jun 4, 2020	Asellidae stet. *Stygobromus balconis* Philopotamidae stet. Coleoptera stet. Rebuviidae stet. Dytiscidae stet. Curculionoidea stet. *Glyphyalinia* sp. *Helicodiscus* sp. *Phreatodrobia nugax* *Phys* sp.	Drift net: 150 micron
Only 1 Pig	JJ&T	Jul 21, 2020	*Strobilops* sp. *Gastrocopta* spp. *Carychium* sp. *Hawaiia minuscula*	Drift net: 250 micron
Shutdown Stygos	Bohls	Mar 27, 2020	*Stygobromus russelli* Gastropoda sp. indet.	Free-living at orifice (no trap)
Source of Giants	Bohls	Apr 6, 2020	Asellidae stet. *Stygobromus russelli*	Free-living at orifice (no trap)
Squeaking Juniper	Steiner Ranch	Feb 13, 2020	*Stygobromus* stet. *Caecidotea reddelli*	Cotton mop material
Squeaking Juniper	Steiner Ranch	Feb 18, 2020	Amphipoda stet. Asellidae stet. *Phreatodrobia nugax* *Euglandina* sp. Philapotamidae stet.	Drift net: 250 micron
Squeaking Juniper	Steiner Ranch	Feb 24, 2020	*Stygobromus russelli* Trichoptera stet.	Drift net: 250 micron
Squeaking Juniper	Steiner Ranch	Mar 2, 2020	*Stygobromus russelli* Trichoptera stet.	PVC pipe trap with 250 micron net
Squeaking Juniper	Steiner Ranch	Mar 5, 2020	Asellidae stet. *Stygobromus tenuis* group	PVC pipe with 250 micron net

			Entomobryibae stet. Symphypleona stet. Diplopoda stet.	
Steiner Sanctuary	Steiner Ranch	Feb 18, 2020	*Stygobromus* stet. *Phreatodrobia nugax* *Caecidotea reddelli* Collembolan stet. Diplopoda stet. Diptera stet.	Drift net: 250 micron
Steiner Sanctuary	Steiner Ranch	Feb 24, 2020	Siphonophoridae stet. Diplopoda stet. Asellidae stet. *Stygobromus tenuis* group Hempitera stet. Diptera stet. Odonata stet.	Drift net: 150 micron
Steiner Sanctuary	Steiner Ranch	Mar 2, 2020	Diplopoda stet. Asellidae stet. *Stygobromus tenuis* group Acariformes stet. Planarian stet. Dytiscidae stet. Diptera stet. Planarian stet.	Drift net: 150 micron
Steiner Sanctuary	Steiner Ranch	Mar 5, 2020	Asellidae stet. *Stygobromus tenuis* group Diplopoda stet. Diptera stet. Hemiptera stet.	Drift net: 150 micron
Tunnel	Bohls	May 19, 2020	Gastropoda stet. Polycentropodidae Trichoptera stet. Tabanidae stet. Tricladida stet. Culicidae stet. Diptera stet.	Drift net: 150 micron

A video of *Caecidotea reddelli* observed in Chip's Duet spring can be found at this link: https://www.youtube.com/watch?v=YM5SRJVS9ng. Photos of this species at that location are shown in Figure 9.

Figure 9. *Caecidotea reddelli*, a species of concern protected by the Balcones Canyonlands Conservation Plan, observed in Chip's Duet spring. Photos by Colin Strickland.

Testudo Tube cave

On the 23 Jan 2020 survey, 17 Jollyville Plateau salamanders were captured and photographed. One individual observed to have only one eye is shown in Figure 10, and an exceptionally large individual observed is shown in Figure 11. A decaying salamander was observed in a previously wet portion of the cave. On the 5 August 2020 survey, 17 salamanders were observed, 15 of which were captured and photographed. A summary of water chemistry data collected on these two survey dates is in Appendix A.

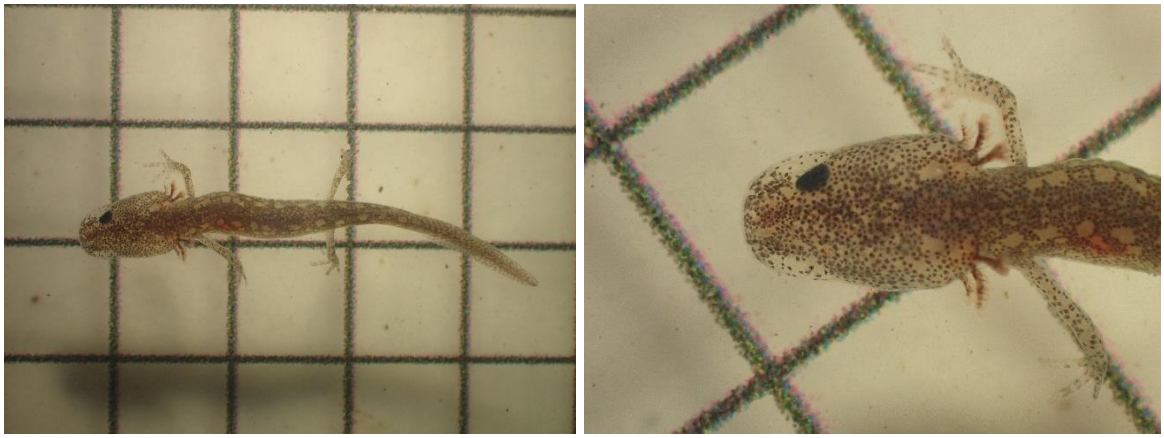

Figure 10. A salamander with one eye observed in Testudo Tube cave on 23 Jan 2020. Photos by Colin Strickland.

Figure 11. A large salamander observed in Testudo Tube cave on 23 Jan 2020. Photo by Colin Strickland.

Feral Hog Protection

Lanier Spring was fenced in 2005 by City of Austin biologist Mark Sanders due to wallowing activity by feral hogs. In FY2020, rooting activity was observed in the area immediately to the west of the fenced area, exposing more of the spring. Jollyville Plateau salamanders were observed in this new wallowed area. During the spring of 2020, Mark expanded the fencing to include the newly exposed spring area (Figure 12 left). In late August, a period of low spring flow, Mark searched the newly fenced area to ensure no salamanders were present and then added cobble in an effort to enhance habitat for Jollyville Plateau salamanders (Figure 12 right).

Figure 12. Fencing was expanded at Lanier Spring to include this area newly wallowed by feral hogs. Biologist Mark Sanders then added cobble in a habitat enhancement effort. Photos by Mark Sanders.

Discussion

One hundred and forty-three spring locations were documented on the Balcones Canyonlands Preserve in FY2020. Research goals were met with the expanded assessment of aquatic target species. Invertebrates were sampled at 12 springs, resulting in the first known collection of groundwater fauna on the Cortaña, Steiner Ranch, Bohls, and JJ&T tracts. We await further identification of 34% of specimens collected in FY2020, the majority of which are from the family Asellidae. At this reporting we present new occurrence records for the following stygofauna: *Caecidotea reddelli*, *Stygobromus russelli*, *S. balconis*, *S. tenuis* group, and *Phreatodrobia nugax*.

Caecidotea reddelli, collected from Squeaking Juniper and Steiner Sanctuary springs, is a species of concern protected by the Balcones Canyonlands Conservation Plan (BCP 2007a). *Stygobromus russelli,* collected from Greenbriar, Shutdown Stygos, Source of Giants, and Squeaking Juniper springs, is identified as an additional species of concern by the BCCP and is a critically imperiled state species of greatest conservation need (BCP 2007a, TPWD 2012). *Stygobromus balconis*, collected from Chips Duet, Injured, and John's Hollow Springs, has a conservation status of imperiled (Hutchins 2017). The individuals identified to the *Stygobromus tenuis* group were juveniles and too small to distinguish to species. This group includes *S. balconis*, *S. bifurfactus*, and *S. russelli*. *Phreatodrobia nugax*, collected from John's Hollow, Greenbriar, Squeaking Juniper, and Steiner Sanctuary springs, has a conservation status of vulnerable (Hutchins 2017).

Spring Management Activities Planned for FY2021

Biologists will continue to search COA BCP for undocumented spring locations and continue to refine methods of spring characterization. Sites will be prioritized for further characterization. Biologists will revisit a portion of previously documented locations to observe known springs and potentially find more springs under varying seasonal conditions. The collection of samples at some springs for water quality analysis is anticipated as are additional measures of water quantity. Faunal survey may include an expansion of methods for more representative sampling (e.g. identify microscopic fauna) and developing methods for trapping on existing wells. Researchers will continue prioritizing spring sites that could feasibly be protected from rooting by feral hogs.

The on-going management activities for FY2020 are in accordance with the Balcones Canyonland Conservation Plan spring management obligations and research goals

that contribute to the knowledge, recovery, and protection of BCP species; however, much of the BCP awaits survey for springs and groundwater fauna.

Literature Cited

Balcones Canyonlands Preserve 2007. Balcones Canyonlands Preserve Land Management Plan, Austin, Texas.

(BCP 2007a) Tier I, Balcones Canyonlands Preserve Overview.
(BCP 2007b) Tier II A, Chapter I Land Management Plans and Guidelines
(BCP 2007c) Tier II A, Chapter IX Karst Species Management
(BCP 2007d) Tier II A, Chapter X Animal Management
(BCP 2007e) Tier II A, Chapter XI Water Quality Management
(BCP 2007f) Tier II C, Bull Creek Macrosite
(BCP 2007g) Tier III, City of Austin Cortana Tract, North Lake Austin Macrosite
(BCP 2007h) Tier III, City of Austin Lower Bull Creek, Bull Creek Macrosite
(BCP 2007i) Tier III, City of Austin Cowfork/Coldwater Tracts (Park West, Long Canyon, Coldwater) North Lake Austin, Macrosite
(BCP 2007j) Tier III, City of Austin South Lake Austin Tracts (Reicher Ranch, Double J&T, Bohls) South Lake Austin Macrosite

Bendik, Nathan, McEntire, Kira, Sissel, Blake 2016. Movement, demographics, and occupancy dynamics of a federally-threatened salamander: evaluating the adequacy of critical habitat. PeerJ 4:e1817; DOI 10.7717/peerj.1817

Devitt, Thomas J., Wright, April M., Cannatella, David C., Hillis, David M. 2019. Species delimitation in endangered groundwater salamanders: Implications for aquifer management and biodiversity conservation Proceedings of the National Academy of Sciences Feb 2019, 116 (7) 2624 - 2633; DOI: 10.1073/pnas. 1815014116

Hutchins, Benjamin 2017. The conservation status of Texas groundwater invertebrates. Biodiversity and Conservation. 10.1007/s10531-017-1447-0.

Malard, Florian & Dole-Olivier, Marie-José & Mathieu, J & Stoch, Fabio 2002. Sampling Manual for the Assessment of Regional Groundwater Biodiversity. European Project PASCALIS. 1-74.

Texas Parks and Wildlife Department 2012. Texas Conservation Action Plan 2012 - 2016: Overview. Editor, Wendy Connally, Texas Conservation Action Plan Coordinator. Austin, Texas.

Springer, Abraham & Stevens, Lawrence 2009. Spheres of discharge of springs. Hydrogeology Journal. 17. 83-93. 10.1007/s10040-008-0341-y.

Stevens, L.E., A.E. Springer, and J.D. Ledbetter 2016. Springs Ecosystem Inventory Protocols. Springs Stewardship Institute, Museum of Northern Arizona, Flagstaff, Arizona.

U. S. Fish and Wildlife Service (USFWS) 1996. Final Environmental Impact Statement/Habitat Conservation Plan for Proposed Issuance of a Permit to Allow Incidental Take of the Golden-cheeked Warbler, Black-capped Vireo, and Six Karst Invertebrates in Travis County, Texas. Albuquerque, N. M.

_____2013. 50 CFR Part 17 Endangered and Threatened Wildlife and Plants; Determination of Endangered Species Status for the Austin Blind Salamander and Threatened Species Status for the Jollyville Plateau Salamander Throughout Their Ranges; Final Rule Federal Register Vol. 78 No. 151, 20 August, 2013.

_____2014. Section 10(a)(1)(A) Scientific Permit Requirements For Conducting Georgetown, Jollyville Plateau, and Salado Salamander Surveys, revised June 26, 2014. USFWS Ecological Services Field Office, Austin, Texas. 18 pp. Available at: https://www.fws.gov/southwest/es/Documents/R2ES/Northern_Edwards_sals_Survey_protocols_20140626.pdf. Accessed 12 November 2019.

Appendix A. Water Chemistry Data

Water chemistry data collected in Testudo Tube Cave for FY 2020.

Parameter	23 Jan 2020	5 Aug 2020
Temp (°C)	19.48	20.29
Spc (µS/cm)	751.6	738.9
pH	6.91	7.21
DO (mg/L)	7.01	7.92