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TECHNICAL REPORT FOR KARST MANAGEMENT SERVICES AT THE BALCONES CANYONLANDS PRESERVE – KOTRLA UNIT, TRAVIS COUNTY, TEXAS



Excavation gear at the entrance of Karst Feature SW-13.

Prepared for
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Abstract

Twenty-two previously recorded karst features and one previously undiscovered cave were evaluated for potential karst invertebrate habitat during this investigation on the Kotrla Unit located in northwest Travis County, Texas. All 22 features met the initial criteria for potential karst invertebrate habitat. Six features were further evaluated for habitat during excavation activities. Several features are recommended for further excavation and karst fauna surveys. Two previously undiscovered features were not addressed during this investigation but should be evaluated for potential karst invertebrate habitat in the future.

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Appendix. Personnel

Introduction

This technical report has been prepared in support of karst management activities at the Balcones Canyonlands Preserve (BCP) Kotrla Unit, located in northwest Travis County, Texas. The Kotrla Unit consists of two preserve tracts (Scott and White Tract and Kotrla Tract) owned and managed by Travis County (County), who contracted Zara Environmental LLC (Zara) to provide karst management services including karst invertebrate habitat assessments, excavation of karst features, and collection of karst invertebrates during excavation activities. The karst management services were conducted at features previously identified by the County on the Kotrla Unit.

Federally Listed Karst Invertebrates

Five invertebrate species known only from caves and karst areas in Travis and Williamson Counties were federally listed as endangered species under the Endangered Species Act (ESA) by the US Fish and Wildlife Service (USFWS) on 16 September 1988 (USFWS 1988). These species include the Bee Creek Cave harvestman (*Texella reddelli*), Tooth Cave pseudoscorpion (*Tartarocreagris texana*, formerly *Microcreagris texana*), Tooth Cave spider (*Tayshaneta myopica*, formerly *Neoleptoneta myopica*), Tooth Cave ground beetle (*Rhadine persephone*), and the Kretschmarr Cave mold beetle (*Texamaurops reddelli*). Two additional karst invertebrate species, the Bone Cave harvestman (*Texella reyesi*), and the Coffin Cave mold beetle (*Batrisodes texanus*) from Travis and Williamson counties were federally listed as endangered species due to taxonomic revisions on 18 August 1993 (USFWS 1993).

Balcones Canyonlands Conservation Plan – Species of Concern

A regional habitat conservation plan and incidental take permit, known as the Balcones Canyonlands Conservation Plan (BCCP), was issued in 1996 by the USFWS to the City of Austin and Travis County for the protection of two endangered bird species (including the Golden-cheeked Warbler [*Setophaga chrysoparia*]), six endangered karst invertebrate species (described above, with the exception of the Coffin Cave mold beetle), 25 karst Species of Concern (SOCs), and two plant SOCs (Regional Environmental Consultants [RECON] and USFWS 1996). For the purposes of this report, only the karst SOCs are presented below (Table 1). Since the BCCP was issued in 1996, some of the SOCs have been synonymized with other species based on recent genetic and taxonomic studies. As such, the protected status of these reclassified species may have changed. Additional details are included as footnotes in Table 1.

Table 1. Species of Concern addressed in the Balcones Canyonlands Conservation Plan (RECON and USFWS 1996).

Group	Species
Flatworms	*Sphalloplana mohri*
Ostracods	*Candona* sp. nr. *stagnalis*
Spiders	*Cicurina bandida*[1] *Cicurina cueva*[1] *Cicurina ellioti*[2] *Cicurina reddelli*[3] *Cicurina reyesi*[1] *Cicurina travisae*[3] *Cicurina wartoni*[3] *Tayshaneta concinna*[4] *Tayshaneta devia*[4] *Eidmannella reclusa*
Millipedes	*Speodesmus* N. S.
Pseudoscorpions	*Aphrastochthonius* N. S. *Tartarocreagris comanche* *Tartarocreagris reddelli*[5] *Tartarocreagris intermedia* *Tartarocreagris* N. S. 3
Harvestmen	*Texella spinoperca*
Ground Beetles	*Rhadine s. subterranea* *Rhadine s. mitchelli* *Rhadine austinica*
Isopods	*Caecidotea reddelli* *Miktoniscus* N. S. *Trichoniscidae* N. S.

[1] *Cicurina cueva* and *C. reyesi* have been synonymized under *C. bandida* (Paquin et al. 2008; Paquin and Dupérré 2009; BCP 2016).
[2] *Cicurina ellioti* was originally listed as an SOC (RECON and USFWS 1996); however, this species has been synonymized with *C. buwata* (Cokendolpher 2004), which currently is not listed as an SOC (BCP 2016).
[3] *Cicurina reddelli* and *C. wartoni* have been synonymized under *C. travisae* (Hedin 2015; BCP 2016)
[4] *Tayshaneta concinna* and *T. devia* were originally listed in the BCCP (RECON and USFWS 1996) under the genus *Neoleptoneta*; however, recent studies revised *Neoleptoneta*, thus placing these species in the genus *Tayshaneta* (Campbell et al. 2012; BCP 2016).
[5] *Tartarocreagris reddelli* was originally listed as an SOC (RECON and USFWS 1996); however, this species has been synonymized with *T. infernalis* (Muchmore 2001), which currently is not listed as an SOC (BCP 2016).

Methods

Prioritization of Karst Features

The County provided Zara with a list of 24 previously identified features to evaluate during this investigation. The list included 18 higher priority and six secondary priority karst features. Given the time and personnel allocated for this investigation, the established goal was to evaluate as many karst features as possible by first focusing on those designated as high priority followed by the secondary priority features. Any previously undiscovered features encountered during fieldwork were recorded and presented to the County to determine whether additional assessments were warranted during the investigation. A list of these features is provided in the results section below.

Once an evaluation of these County-prioritized features was completed, features recommended for further excavation were re-prioritized based on ease of access, estimated time of excavation effort, probability of reaching potential habitat, and further input from the County. For example, large features that likely provided karst invertebrate habitat but were estimated to require considerable excavation effort were deprioritized compared to those that could be easily excavated and evaluated for the presence of habitat.

Karst Invertebrate Habitat Guidelines

Previously identified karst features were evaluated by scientists holding a valid USFWS 10(a)(1)(A) permit (TE85077A-1) covering endangered karst invertebrate species to determine the features' potential to contain suitable habitat for karst invertebrate species. Where necessary, scientists performed reconnaissance excavation to remove loose fill from each evaluated feature and subsequently characterized the feature based on recommendations contained in USFWS (2015) and paraphrased below. If any of the following criteria were met, then the feature was considered potential habitat, subjected to reconnaissance excavation (where applicable), and evaluated for potential to lead to a void:

- Feature contains leaf litter, loose modern soils, and a few rocks;
- Feature exhibits airflow;
- Feature displays channelized recharge of water;
- Feature exhibits collapse development;
- Feature contains loose fill to a depth of at least 30 cm (1 ft);
- Feature contains clean-washed rocks at its base; or
- Feature contains *Ceuthophilus cunicularis* cave crickets, *Cicurina varians* spiders, or other cave-adapted species.

The USFWS (2015) provides additional criteria for features that do not meet the above characteristics. If the evaluated karst features did not meet any of the above criteria but met at least two of the following, then the feature was considered potential habitat:

- Feature developed along a fracture;
- Feature extends at least 1 m (3.3 ft) beyond the original surface expression;
- Feature similar in appearance to nearby caves in similar geologic setting; or
- A potentially humanly enterable void is visible.

Additional factors indicating potential habitat include: proximity to known endangered species caves; formation in Karst Zone 1 or 2; physical characteristics indicative of a cave; presence of artificial fill material; presence of roots/soil in the feature; proximity to fault, photolineament or an area with high fracture density; or vegetation known to preferentially grow in cave entrances or karst features.

In cases where excavation was not recommended based on the criteria for potential habitat listed above, the consideration of additional factors indicating the potential for habitat, five characteristics of features not likely to contain suitable habitat were considered. These characteristics provided by USFWS (2015) are paraphrased here:

- All or nearly all of the interior surfaces covered with calcite speleothems;
- Absence of cave-adapted species;
- Features are dry or do not have evidence of modern water flow;
- Absence of airflow, and;
- Feature not formed by a collapse or related to a collapse.

In some cases, evaluation of potential habitat via excavation is recommended. All excavations were performed by or under the direct supervision of a scientist holding a valid USFWS 10(a)(1)(A) permit. Features were excavated until one of the following was encountered:

- Suitable habitat (i.e., cave passage) was reached for sampling karst invertebrate species;
- A distinct terminus (i.e., bedrock) with no conduits;
- Packed clay with no airflow present;
- Potential archaeological or paleontological materials, or;
- Continued excavation would be dangerous (due to large overhanging rocks, high levels of carbon dioxide, etc.)

Karst Invertebrate Specimen Collection

Scientists holding a valid 10(a)(1)(A) permit for karst invertebrates collected karst invertebrate specimens during excavations. Visible surfaces and the undersides of rocks were examined for the presence of karst invertebrates. Observed fauna encountered was noted on field sheets, and notable specimens were collected for accessioning, further identification, and/or to create a museum record of notable fauna from each site. Collected specimens were retained by the County for further taxonomic studies.

Results

Initial karst invertebrate habitat assessments were conducted on 30 March and 7, 4, and 23 May 2017. Subsequent excavation activities occurred on 8, 13, 16, 20, 21, 22, 29 June and 12, 20, and 26 September 2017. Habitat assessments, excavations, and specimen collections were conducted by a crew of two of the following scientists under USFWS 10(a)(1)(A) permit TE85077A-1: Jeanette Joost, David McBee, Jimmy MacMillan, Jean Krejca, and/or Brian Cowan.

All of the high priority karst features were evaluated during this investigation. Four secondary priority karst features also were evaluated. Secondary priority features SW-9 and SW-10 were not evaluated. In addition, one previously undiscovered cave was recorded and evaluated during this investigation (SW Cave 4; McMac Cave). These features are summarized in Table 2 and described below. Potential habitat parameters indicating the need for additional assessment via excavation and/or karst fauna surveys are described in Table 3. Provided below is a detailed description of the evaluated features, activities performed, and recommendations for future work for each feature. A summary of these recommendations is provided in the following section.

Table 2. Summary table of evaluated features.

Feature Name	Feature Type	Potential Habitat	Cave Adapted Species [Specimen ID, if collected]
KO-1[1]	Solution-formed sinkholes	Y	None
KO-2[2]	Solution-formed sinkhole	Y	None
SW Cave 1[1]	Cave	Y	*Ceuthophilus* sp.
SW Cave 2[1]	Cave	Y	*Ceuthophilus cunicularis,* *C. secretus*
SW Cave 3[1]	Cave	Y	*Cicurina* sp. (eyeless) [Zara-9884], Collembola, *Texoreddellia* sp., *Ceuthophilus secretus,* *Batrisodes* sp. (eyeless) [Zara-9882]
SW Cave 4 (McMac Cave)[3]	Cave	Y	*Ceuthophilus cunicularis,* *C. secretus,* *Texoreddellia* sp.
SW-1[1]	Enlarged fracture	Y	None
SW-2[1]	Enlarged fracture	Y	None
SW-3[2]	Enlarged fracture	Y	None
SW-4[2]	Solution-formed sinkhole (Cluster)	Y	None
SW-5[2]	Enlarged fracture	Y	None
SW-6[1]	Enlarged fracture	Y	None
SW-7[1]	Enlarged fracture	Y	None
SW-8[1]	Cave	Y	Collembola, *Ceuthophilus secretus* [Zara-9733]
SW-9[2]	--	--	--
SW-10[2]	--	--	--
SW-11[1]	Enlarged fracture	Y	None
SW-12[1]	Enlarged fracture	Y	None
SW-13[1]	Cave	Y	Araneae (reduced pigment/eyes?) [Zara-10099, Zara-10017] *Speodesmus* sp. [Zara-10097], *Ceuthophilus secretus* *Ceuthophilus* sp. nymphs [Zara-10098]
SW-14[1]	Enlarged fracture	Y	None
SW-15[1]	Enlarged fracture	Y	None
SW-16[1]	Cave	Y	Collembola [Zara-10102], *Ceuthophilus cunicularis,* *Ceuthophilus secretus,* *Ceuthophilus* sp. nymphs [Zara-10100]
SW-17[1]	Solution-formed sinkhole	Y	Collembola, *Ceuthophilus secretus*
SW-18[1]	Sinkhole	Y	None
SW-19[1]	Solution-formed sinkhole	Y	*Ceuthophilus* sp.

[1] High priority karst feature
[2] Secondary priority karst feature
[3] Previously undiscovered karst feature
-- Feature not evaluated

Table 3. Summary table of USFWS (2015) conditions indicating potential habitat for features discovered during karst surveys at this project.

Feature Name	Potential habitat if feature meets any one criterion							Potential habitat if feature meets at least two criteria				Not Habitat if all conditions are met				
	Leaf litter, modern soil, rocks	Airflow	Channelized recharge	Collapse development	Loose fill ≥30 cm	Clean washed rocks	Cave fauna	Developed along fracture	Extends ≥ 1 m	Similar to nearby caves	Enterable void	All surfaces calcite	No cave fauna	No evidence of water flow	No airflow	Not related to collapse
KO-1	X												X		X	X
KO-2	X												X		X	X
SW Cave 1	X						X		X	X	X				X	
SW Cave 2	X						X		X		X				X	
SW Cave 3	X						X		X	X	X				X	
SW Cave 4 (McMac Cave)	X					X	X		X	X	X				X	
SW-1	X							X					X		X	X
SW-2	X					X		X	X				X		X	X
SW-3	X							X	X				X		X	X
SW-4	X												X		X	X
SW-5	X								X				X		X	X
SW-6	X							X	X				X		X	X
SW-7	X							X	X				X		X	X
SW-8	X										X				X	
SW-9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SW-10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SW-11	X	X						X					X			X
SW-12	X					X		X	X				X		X	X
SW-13	X	X		X		X			X	X	X					
SW-14	X							X					X		X	X
SW-15	X							X					X		X	X
SW-16	X			X		X	X		X		X				X	X
SW-17	X						X	X	X		X					
SW-18	X		X	X	X	X			X		X		X		X	
SW-19	X												X		X	X

-- Feature not evaluated

Feature Descriptions

Feature KO-1; Solution-formed Sinkholes

Feature KO-1 consists of two solution-formed sinkholes located south western portion of the Kotrla tract on the edge of an exposed limestone ridge (Table 4; Figure 1 and Figure 2). Infill consists of leaf litter and modern soil. No cave-adapted fauna was observed during the evaluation (Table 4). Minor hand excavation indicated soils becoming compact a depth of 15 cm. There is also a potential connection of the two sinkholes at depth.

This feature meets the initial criteria for potential habitat due to the presence of loose, modern soil (Table 3), although further excavation is needed to fully evaluate it. Feature KO-1 was not evaluated further during this investigation, as the required effort for additional excavation surpassed the allotted time. It is anticipated that a minimum of 1 to 2 days of excavation would be required to further determine whether this feature truly provides suitable karst invertebrate habitat. Karst fauna surveys are not recommended at this time.

Table 4. Feature KO-1 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
23 May 2017	0.5 (1.6)	0.5 (1.6)	0.6 (2)	N	coarse-grained soil	*Leiobunum townsendii* (harvestman)



Figure 1. Feature KO-1, two solutional sinkholes in exposed limestone.

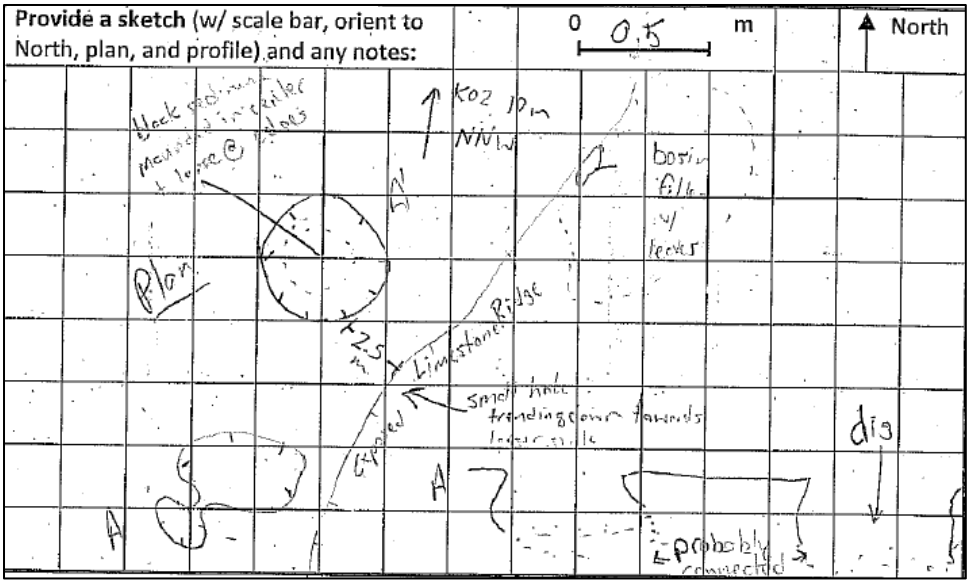


Figure 2. Field sketch of feature KO-1.

Feature KO-2; Solution-formed Sinkhole

Feature KO-2 is a solution-formed sinkhole located southwestern portion of the Kotrla tract (Table 5; Figure 3 – Figure 5). This feature was relatively small and shallow, with the entrance dimensions measuring 0.25 m wide by 0.1 m long by 0.3 m deep. Infill consists of leaf litter and modern soil. No fauna was observed during the evaluation (Table 5).

This feature meets the initial criteria for potential habitat due to the presence of loose, modern soil (Table 3), although further excavation is needed to fully evaluate it. Minor hand excavation indicated soils becoming compact a depth of 5 cm. While KO-2 is considered potential habitat, this feature was not prioritized for further excavation due to the extensive time required to excavate in solid limestone bedrock with a jackhammer (2 to 3 weeks) and a low potential of reaching karst habitat. Therefore, further excavation at this feature is not recommended. Karst fauna surveys are not recommended at this time.

Table 5. Feature KO-2 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
23 May 2017	0.25 (0.82)	0.1 (0.3)	0.3 (1)	N	Modern, dark, fine-grained soil	None observed



Figure 3. Exterior view of feature KO-2.



Figure 4. Leaf litter and modern soil infill at the bottom of feature KO-2.

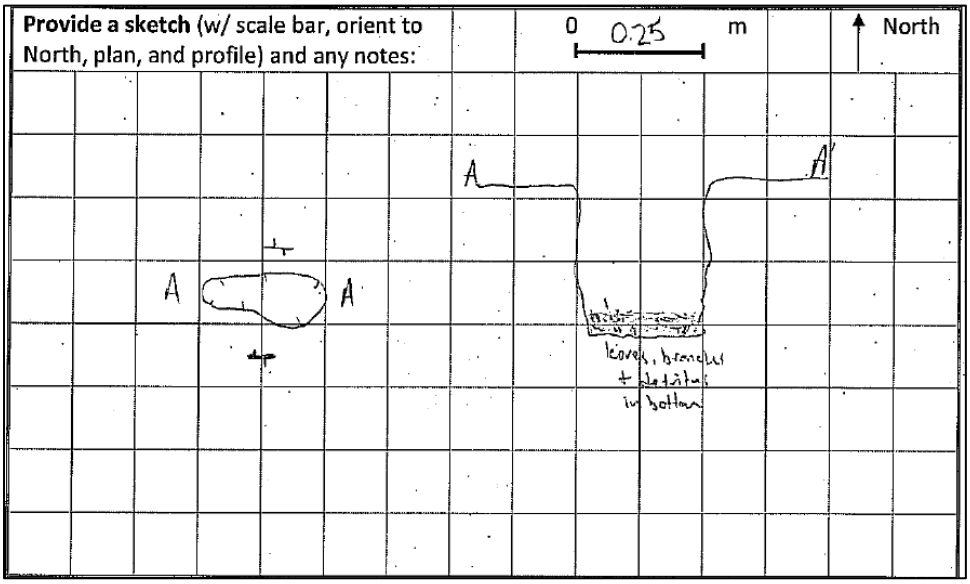


Figure 5. Field sketch of feature KO-2.

SW Cave 1; Cave

Feature SW Cave 1 is a small cave located at the northwest side of the Kotrla Unit (Table 6; Figure 6 - Figure 9). The entrance pit dimensions were 1.3 m long, 0.6 m wide, and 3 m deep (Figure 9). Approximately 2 m past the bottom of the pit, the passage narrowed to a physical restriction. It appeared that the passage ended approximately 1 m past the narrow restriction. The floor of the cave consisted of black soil and rocks (Figure 7). No drains were observed at the floor. No cave-adapted fauna was observed during the assessment; however, *Ceuthophilus* sp. crickets were observed (Table 6).

SW Cave 1 meets the initial criteria for potential habitat due presence of cave-adapted species, evidence of nutrient flow into the feature, its depth of greater than 1 m, similarity to other nearby caves (SW Cave 4/McMac Cave and SW Cave 3), and its enterable size (Table 3). While this feature is considered potential habitat, SW Cave 1 was not prioritized for further excavation during this investigation due to difficulty in accessing its location with excavation equipment and the amount of time required for excavation (estimated 5 to 6 days). SW Cave 1 does not appear to have obvious drains, mesocavernous voids, or visible extensions that would warrant excavation. While additional excavation is not recommended, karst fauna surveys are recommended to continue the evaluation of this feature for protected species. Black plastic should be placed over the entrance to stabilize the temperature and humidity in the room prior to future fauna surveys.

Table 6. Feature SW Cave 1 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
4 May 2017	0.75 (1.6)	3 (9.8)	3 (9.8)	N	Modern, dark, fine-grained soil and leaf litter	*Ceuthophilus* sp. (cave crickets)



Figure 6. View of the entrance of SW Cave 1. The cave is obscured by heavy brush.



Figure 7. Dark soil floor at the back of SW Cave 1.



Figure 8. Lower room in SW Cave 1.

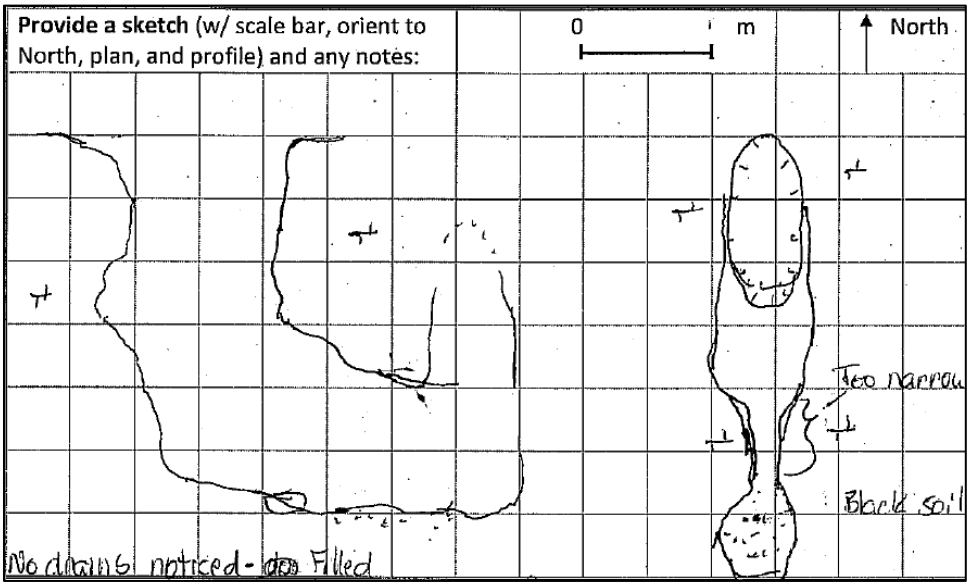


Figure 9. Field sketch of SW Cave 1.

SW Cave 2; Cave

Feature SW Cave 2 is a small cave located at the northeast corner of the Kotrla tract (Table 7; Figure 10 - Figure 13). The cave entrance measured 1.5 m long and 1 m wide, while the interior dimensions of the cave measured 12 m long, 3.5 m wide, and 1.5 m high (Figure 13). The substrate mostly consisted of rock breakdown with some modern soil and leaf litter (Figure 11). Along the back wall was a small drain that may provide a lead for future excavation (Figure 12). No cave-adapted fauna was observed during the assessment; however, *Ceuthophilus* sp. crickets were observed Table 6(Table 7).

SW Cave 2 meets the initial criteria for potential habitat due to the presence of cave-adapted species, evidence of nutrient and water flow into the feature, its depth of greater than 1 m, and its enterable size (Table 3). Karst fauna surveys are recommended to continue the evaluation of this feature for protected species. Black plastic should be placed over the entrance to stabilize the temperature and humidity in the room prior to future fauna surveys. SW Cave 2 currently provides potential habitat for karst invertebrates and adequate access throughout. Additional excavation at this feature is not recommended.

Table 7. Feature SW Cave 2 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
4 May 2017	3.5 (11)	12 (39)	1.5 (4.9)	N	Modern, dark, fine-grained soil and leaf litter and breakdown	*Leiobunum townsendii* (harvestman); *Ceuthophilus secretus* and *C. cunicularis* (cave crickets); *Erethizon dorsatum* (North American porcupine)



Figure 10. Entrance to SW Cave 2.



Figure 11. Main room of SW Cave 2. Note the scientist in the back of the room.



Figure 12. Small drain in SW Cave 2.

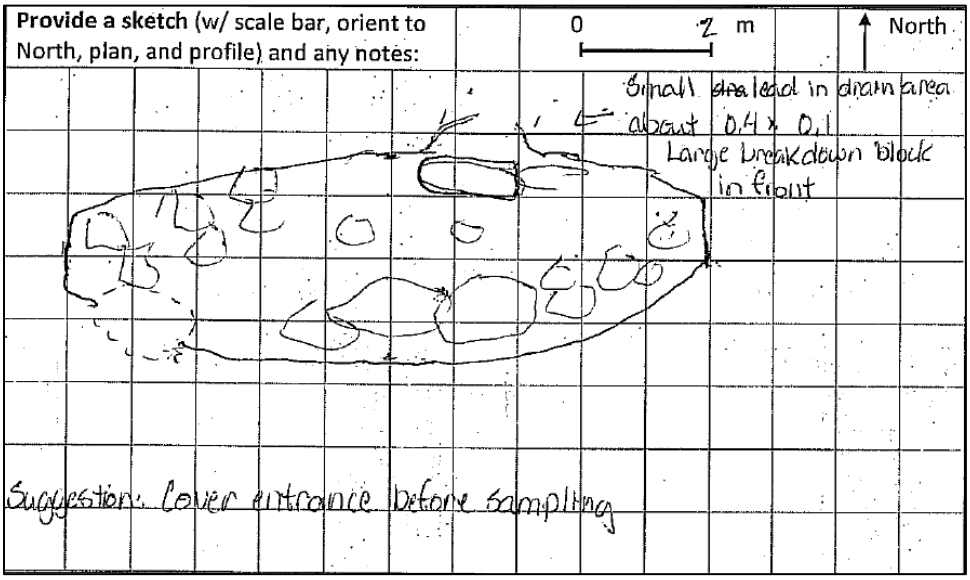


Figure 13. Field sketch of SW Cave 2.

SW Cave 3; Cave

Feature SW Cave 3 is located in the north-central area of the Kotrla Tract (Table 8; Figure 14 - Figure 19). The cave entrance measured approximately 0.75 m wide, and a constriction in the limestone walls was recorded at approximately 4 m deep (Figure 18). The constriction was widened for further access on 12 September 2017. A drill and jackhammer were used to remove approximately 0.1 m^3 rock from the wall, allowing access to the next 2 m of cave passage. Bad air was detected deeper in the cave after opening the constriction, and a drain covered with breakdown was recorded at the bottom of the passage (Figure 17). Cave adapted fauna was observed in SW Cave 3 (Table 8).

SW Cave 3 meets the initial criteria for potential habitat due to the presence of cave-adapted species, evidence of nutrient and water flow into the feature, its depth of greater than 1 m, similarity to other nearby caves (SW Cave 4 [McMac Cave] and SW Cave 1) and its enterable size (Table 3). Karst fauna surveys are recommended to continue the evaluation of this feature for protected species. Black plastic should be placed over the entrance to stabilize the temperature and humidity in the room prior to future fauna surveys. Additional excavation (3 to 4 days) is recommended to remove breakdown at the bottom of the cave and determine whether the drain continues or terminates. Due to the poor quality of air in SW Cave 3, future work in this feature should be performed with adequate ventilation using a blower and/or during the winter.

Table 8. Feature SW Cave 3 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
4 May 2017 12 September 2017	0.75 (2.5)	0.75 (2.5)	6 (20)	N	Modern, dark, fine-grained soil and leaf litter and breakdown	*Cicurina* sp. (eyeless spider) Specimen ID Zara-9983*;* *Leiobunum townsendii* (harvestman) Specimen ID Zara-9984; Collembola (springtails), *Texoreddellia* sp. (subterranean silverfish)*;* *Ceuthophilus secretus* (cave crickets)*;* Coleoptera (*Tachys* sp.?) Specimen ID Zara-9985; Staphylinidae (rove beetle); *Batrisodes* sp. (eyeless mold beetle) Specimen ID Zara-9982; *Eleutherodactylus marnockii* (cliff chirping frog)*;* *Crotalus atrox* (western diamondback rattlesnake)



Figure 14. Entrance to SW Cave 3 before excavation.



Figure 15. Entrance of SW Cave 3 after excavation at the surface.



Figure 16. View looking upward from 4 meters into SW Cave 3.



Figure 17. Drain at the bottom of the lower room in SW Cave 3.

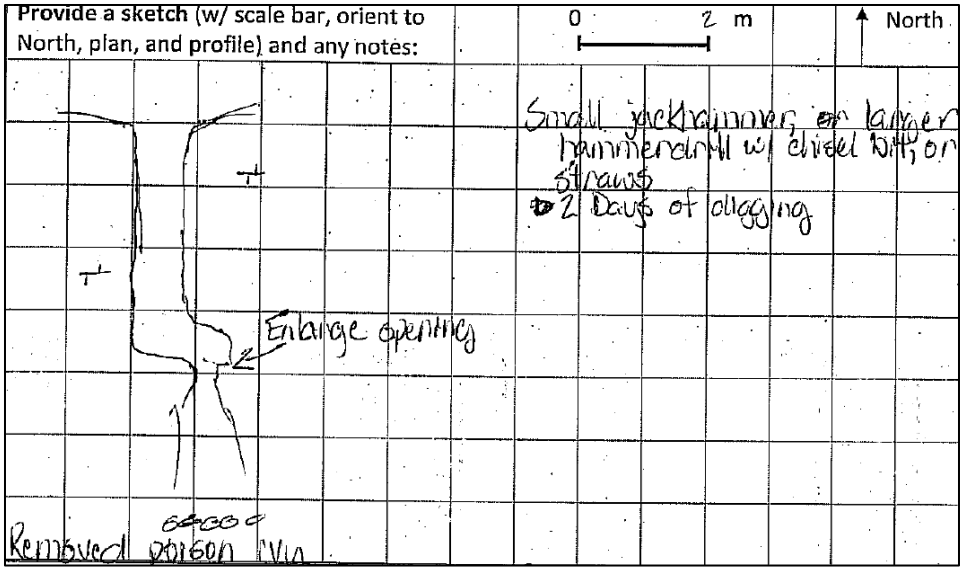


Figure 18. Field sketch of SW Cave 3.

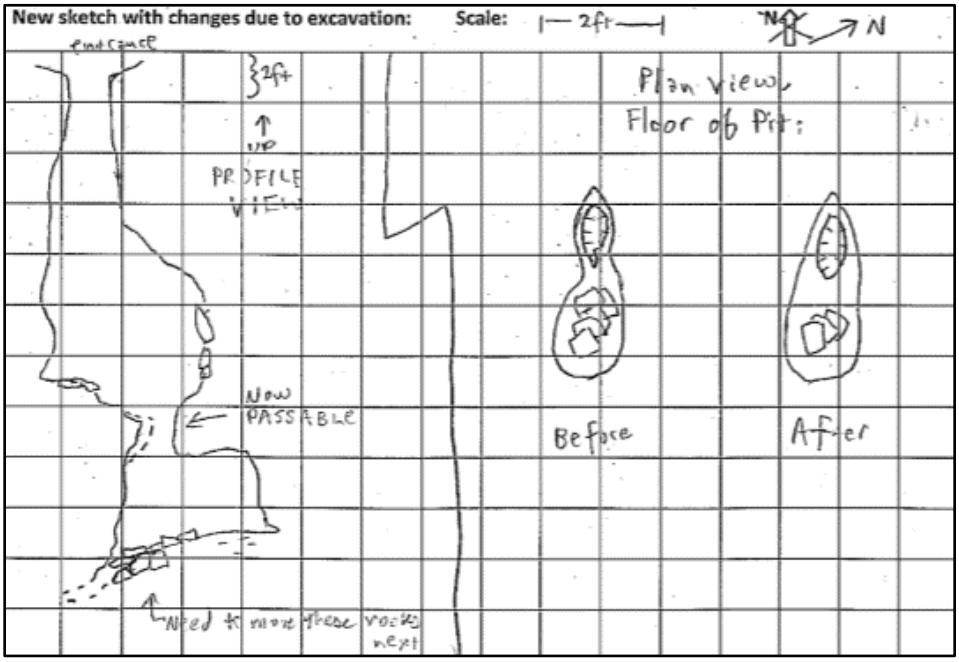


Figure 19. Sketch of SW Cave 3 after excavation.

SW Cave 4; McMac Cave

McMac Cave (SW Cave 4), a previously unrecorded feature, was discovered when investigating features SW-12 and SW-13 in the southeast central area of the Kotrla Tract (Table 9; Figure 20 - Figure 22). The entrance dimensions were approximately 1 m wide by 2 m long, and the entrance drop measured approximately 10 m deep. The cave trended east and west along a low crawl, terminating approximately 3.2 m to the east and extending west roughly 10 m before trending slightly upwards and branching into a low crawl that requires excavation for further access (Figure 22). Flowstone was observed at the bottom of McMac Cave (Figure 21). Cave adapted fauna was observed in McMac Cave (Table 9).

McMac Cave meets the initial criteria for potential habitat due to the presence of cave-adapted species, evidence of nutrient and water flow into the feature, its depth of greater than 1 m, and its enterable size (Table 3). Karst fauna surveys are recommended to continue the evaluation for protected species at this feature. Black plastic should be placed over the entrance to stabilize the temperature and humidity in the room prior to future fauna surveys. While the McMac Cave currently is accessible for sampling, additional excavation is recommended (1 to 2 days) to further evaluate whether the low crawl space continues or terminates.

Table 9. SW Cave 4 (McMac Cave) assessment.

Assessment date	**Dimensions meters (feet)**			**Airflow**	**Sediment**	**Fauna Observed/ Comments**
	X	**Y**	**Z**			
23 May 2017	14 (46)	2 (6.6)	10 (32.8)	N	Modern, dark, fine-grained soil and breakdown	*Leiobunum townsendii* (harvestman); Collembola (springtails); *Texoreddellia* sp. (silverfish); *Ceuthophilus cunicularis* and *C. secretus* (cave crickets)



Figure 20. Scientist at the entrance of McMac Cave, a previously undiscovered karst feature.



Figure 21. Flowstone was observed in McMac Cave.

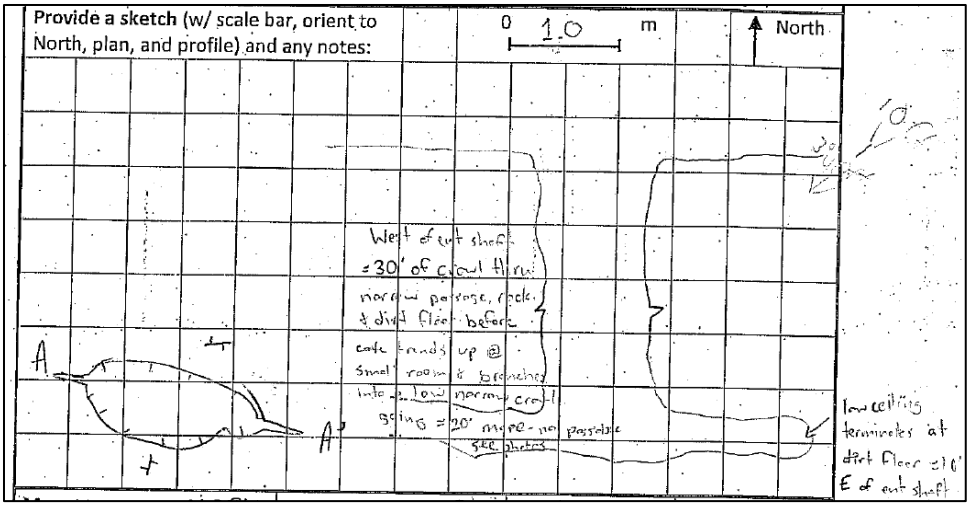


Figure 22. Field sketch of McMac Cave.

Feature SW-1; Enlarged Fracture

Feature SW-1 is an enlarged fracture located on the northwest side of the Kotrla Tract panhandle (Table 10; Figure 23 - Figure 25). The feature opening was guided by a fracture with a trend of 277° (Figure 25). The substrate consisted of modern soil and leaf litter (Figure 24). While a small mesocavernous void was observed, there were no obvious drains in this feature. No cave-adapted species were observed during the evaluation (Table 10).

Feature SW-1 meets the initial criteria for potential habitat due to loose, modern soil and development along a fracture (Table 3). However, this feature was not prioritized for further excavation during this investigation. Due to its small aperture in limestone bedrock, excavation of SW-1 would require a jackhammer and extensive time (estimated 1 to 2 weeks) to determine whether this feature truly provides suitable karst invertebrate habitat. Given the level of estimated excavation effort along with a low potential of reaching karst invertebrate habitat, additional excavation at this feature is not recommended. Karst fauna surveys are not recommended at this time.

Table 10. Feature SW 1 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
4 May 2017	0.3 (1)	0.6 (2)	0.5 (1.6)	N	Modern, dark, fine-grained soil and leaf litter	*Leiobunum townsendii* (harvestman)



Figure 23. Entrance to feature SW-1.



Figure 24. Bottom of feature SW-1, with a floor covered in leaf litter.

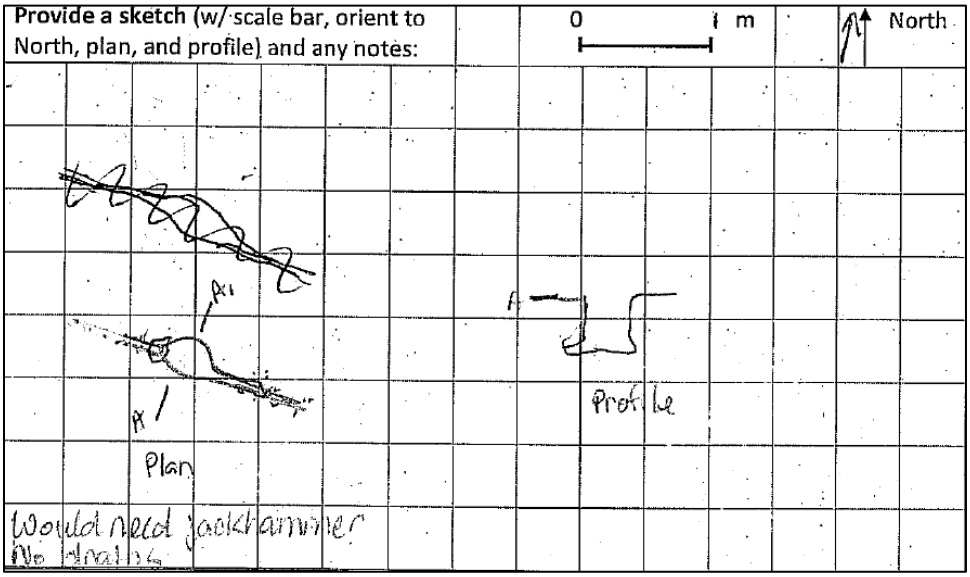


Figure 25. Field sketch of feature SW-1.

Feature SW-2; Enlarged Fracture

Feature SW-2 is an enlarged fracture located just west of the two-track access road at the western side of the Kotrla Tract panhandle (Table 11; Figure 26 – Figure 28). The feature entrance was guided by a fracture with a trend of 310°; however, the feature was not enterable (Figure 28). Mesocavernous voids were observed within the modern black soil substrate. No fauna was observed during the evaluation (Table 11).

Feature SW-2 meets the initial criteria for potential habitat due to modern soil, evidence of nutrient and water flow into and out of the feature, depth of greater than 1 m, and development along a fracture (Table 3); however, this feature was not prioritized for further excavation. Due to its small aperture in limestone bedrock, excavation of SW-2 would require a jackhammer and extensive time (estimated 5 to 7 days) to determine whether this feature truly provides suitable karst invertebrate habitat. Given the level of estimated excavation effort along with a low potential of reaching karst invertebrate habitat, additional excavation at this feature is not recommended. Karst fauna surveys are not recommended at this time.

Table 11. Feature SW 2 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
4 May 2017	1 (3.3)	0.25 (0.82)	2 (6.6)	N	Modern, dark, fine-grained soil and rocks	None observed



Figure 26. Opening of feature SW-2.



Figure 27. Bottom of feature SW-2, with a floor covered in leaf litter.

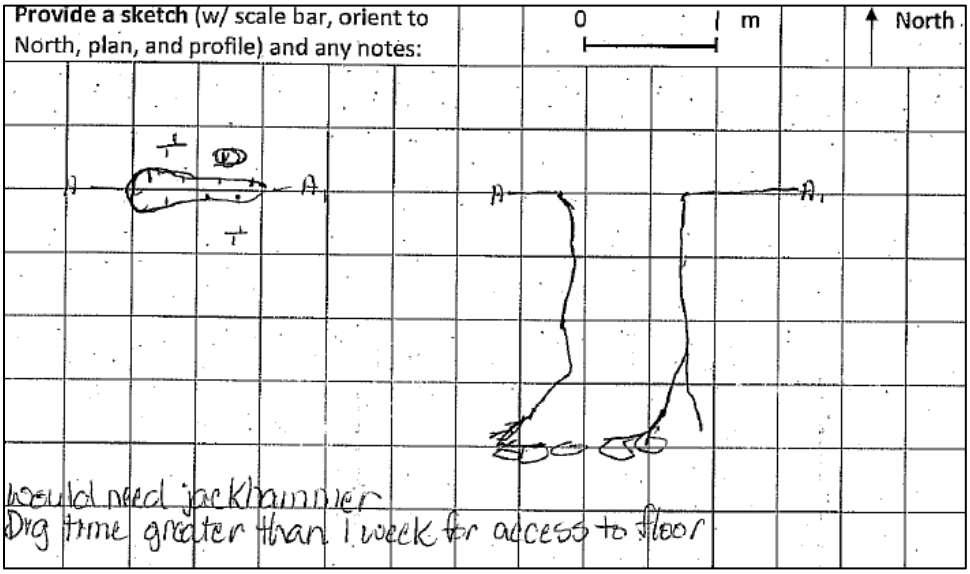


Figure 28. Field sketch of feature SW-2.

Feature SW-3; Enlarged Fracture

Feature SW-3 is an enlarged fracture located just west of the two-track access road on the western side of the Kotrla Tract panhandle (Table 12; Figure 29 – Figure 31). The fracture was enlarged along a bearing of 10° (Figure 31). Modern black soils, leaf litter, rocks, and a mesocavernous void are on the floor beneath the entrance (Figure 30). No cave-adapted species were observed during the evaluation, but claw marks at the entrance indicate the feature is being used as a shelter by small mammals (Table 12).

Feature SW-3 meets the initial criteria for potential habitat due to modern soil, evidence of nutrient and water flow into the feature, depth of greater than 1 m, and development along a fracture (Table 3); however, this feature was not prioritized for further excavation. Due to its small aperture in limestone bedrock, excavation of SW-3 would require a jackhammer and extensive time (estimated 5 to 7 days) to determine whether this feature truly provides suitable karst invertebrate habitat. Given the level of estimated excavation effort along with a low potential of reaching karst invertebrate habitat, additional excavation at this feature is not recommended. Karst fauna surveys are not recommended at this time.

Table 12. Feature SW-3 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
4 May 2017	0.3 (1)	0. 1 (0.3)	1.4 (4.6)	N	Modern, dark, fine-grained soil and rocks	*Leiobunum townsendii* (harvestman)



Figure 29. Opening of feature SW-3.



Figure 30. Interior of feature SW-3.

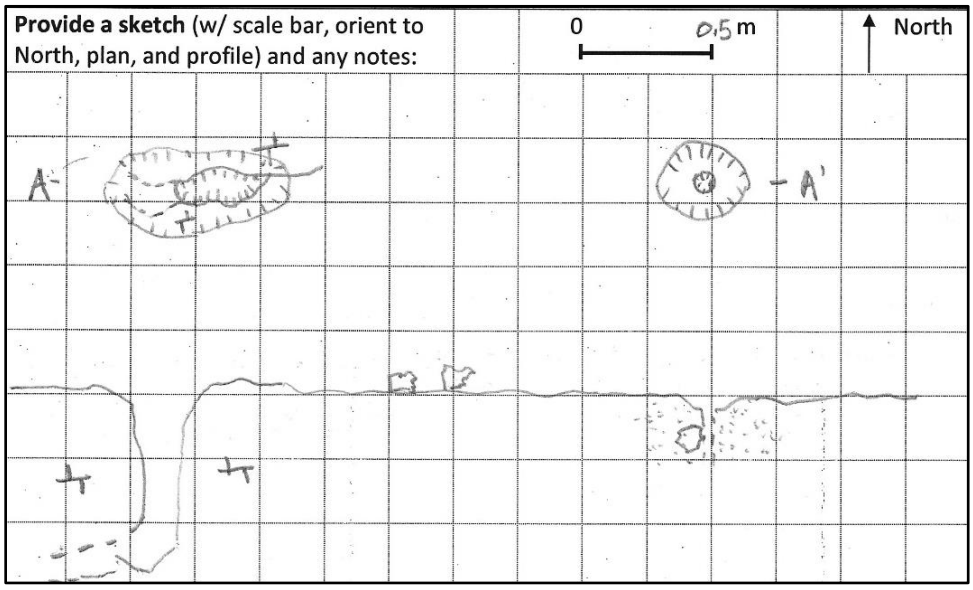


Figure 31. Field sketch of feature SW-3.

Feature SW-4; Solution-formed Sinkhole (Cluster)

Feature SW-4 represents a cluster of solution-formed sinkholes located just west of the two-track access road on the western side of the Kotrla Tract panhandle (Table 13; Figure 32 – Figure 34). Infill consisted of modern soil and vegetation (Figure 33). Mesocavernous voids were not observed. No fauna was observed during the evaluation (Table 13).

While SW-4 meets the initial criteria for potential habitat due to modern soil (Table 3), this feature was not prioritized for further excavation. It has a low potential of reaching karst habitat. The small size and shallow depth indicate that these features could be epikarst. Due to its small aperture in limestone bedrock, excavation of SW-4 would require a jackhammer and extensive time (estimated 1 to 2 weeks) to determine whether this feature truly provides suitable karst invertebrate habitat. Given the level of estimated excavation effort along with a low potential of reaching karst invertebrate habitat, additional excavation at this likely epikarstic feature is not recommended. Karst fauna surveys are not recommended at this time.

Table 13. Feature SW-4 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
4 May 2017	0.1 (0.3)	0.2 (0.6)	0.3 (1)	N	Vegetation, modern, dark, fine-grained soil	None observed



Figure 32. Overview of feature SW-4 with shrubs growing from holes in the rock.



Figure 33. Small trees and brush growing out of feature SW-4.

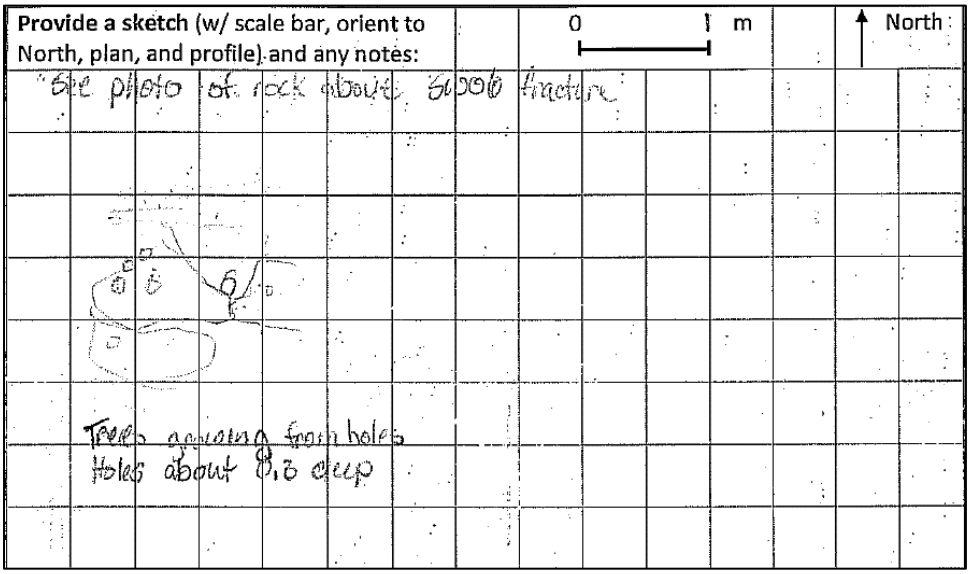


Figure 34. Field sketch of feature SW-4.

Feature SW-5; Solution-formed sinkhole

Feature SW-5 is a solution-formed sinkhole located on the northwest side of the Kotrla Tract panhandle (Table 14; Figure 35 – Figure 37). This very narrow sinkhole measured 0.15 m wide by 1 m long by 1.75 m deep. The substrate of this feature consisted of modern soil. No mesocavernous voids were observed. No cave-adapted species were observed during the evaluation (Table 14).

While SW-5 meets the initial criteria for potential habitat due to modern soil and leaf litter and it extends greater than 1 m in depth (Table 3), this feature was not prioritized for further excavation. Due to its small aperture in limestone bedrock, excavation of this feature would require a jackhammer and extensive time (estimated 1 week) to determine whether SW-5 truly provides suitable karst invertebrate habitat. Given the level of estimated excavation effort along with a low potential of reaching karst invertebrate habitat, additional excavation at this feature is not recommended. Karst fauna surveys are not recommended at this time.

Table 14. Feature SW-5 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
4 May 2017	0.15 (0.49)	1 (3.3)	1.75 (5.74)	N	modern, dark, fine-grained soil and leaf litter	*Leiobunum townsendii* (harvestman)



Figure 35. Feature SW-5 with young grape vines growing from the entrance.



Figure 36. Interior of feature SW-5.

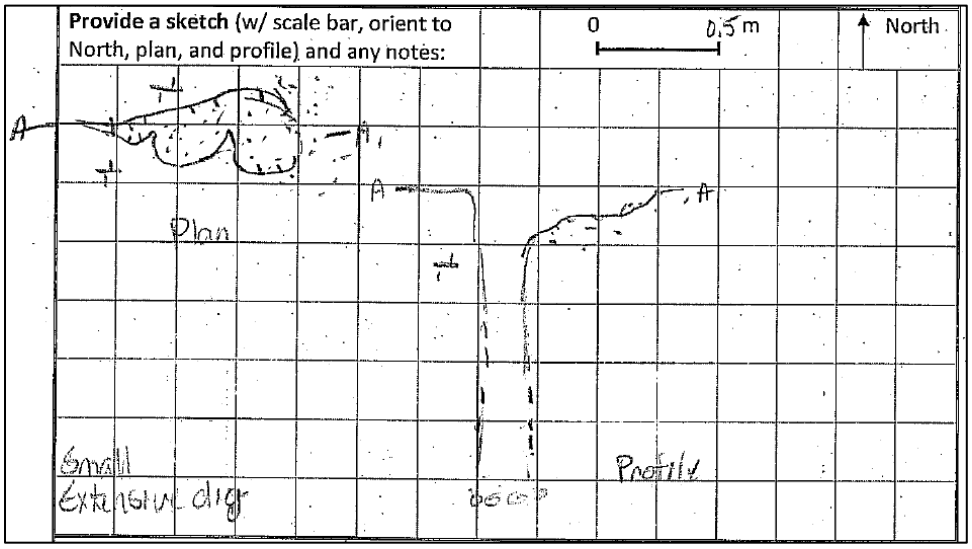


Figure 37. Field sketch of feature SW-5.

Feature SW-6; Enlarged Fracture

Feature SW-6 is an enlarged fracture located along the western fence line of the Kotrla Tract panhandle (Table 15; Figure 38 – Figure 40). This enlarged fracture measured 1 m long by 0.25 m wide by 2.5 m deep, and the feature trended along a bearing of 101˚ (Figure 40). The substrate consisted of rocks and modern soil. Mesocavernous voids were observed in this feature. No fauna was observed during the evaluation (Table 15).

Feature SW-6 meets the initial criteria for potential habitat due to modern soil, development along a fracture, and extending greater than 1 m in depth (Table 3). Feature SW-6 was not evaluated further during this investigation, as the required effort for excavation surpassed the allotted time. It is anticipated that a minimum of 3 to 4 days would be required to further determine whether this feature truly provides suitable karst invertebrate habitat. Karst fauna surveys are not recommended at this time.

Table 15. Feature SW-6 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
4 May 2017	1 (3.3)	0.25 (0.82)	2.5 (8.2)	N	modern, dark, fine-grained soil and rocks	None observed



Figure 38. Entrance to feature SW-6, an enlarged fracture.



Figure 39. Interior of feature SW-6 showing soil and rock infill.

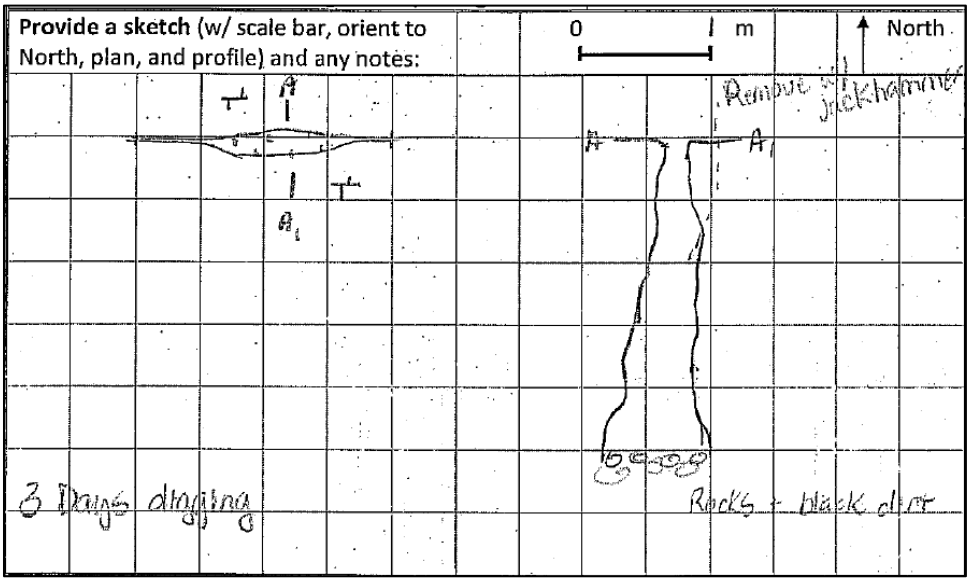


Figure 40. Field sketch of feature SW-6.

Feature SW-7; Enlarged Fracture

Feature SW-7 is an enlarged fracture located near the western fence line of the panhandle of the Kotrla tract (Table 16; Figure 41 – Figure 43). This enlarged fracture measured 0.3 m wide by 2.0 m long by 1.7 m deep, and the feature trended along a bearing of 102° (Figure 43). The substrate consisted of rocks and modern soil. A small drain was observed at the eastern end of the solid bedrock floor (Figure 42; Figure 43). No fauna was observed during the evaluation (Table 16).

While feature SW-6 meets the criteria for potential habitat due to modern soil, development along a fracture, and extending greater than 1 m in depth (Table 3), this feature was not prioritized for further excavation. Due to its small aperture and drain in limestone bedrock, excavation of SW-7 would require a jackhammer and an estimated minimum of 1 to 2 weeks to determine whether this feature truly provides suitable karst invertebrate habitat. Given the level of estimated excavation effort along with a low potential of reaching karst invertebrate habitat, excavation at this feature is not recommended. Karst fauna surveys are not recommended at this time.

Table 16. Feature SW-7 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
4 May 2017	0.3 (1)	2.0 (6.6)	1.7 (5.6)	N	modern, dark, fine-grained soil and rocks	None observed



Figure 41. Entrance to feature SW-7.



Figure 42. Interior of feature SW-7. Note the drain in the center of the photograph indicating mesocavernous extensions.

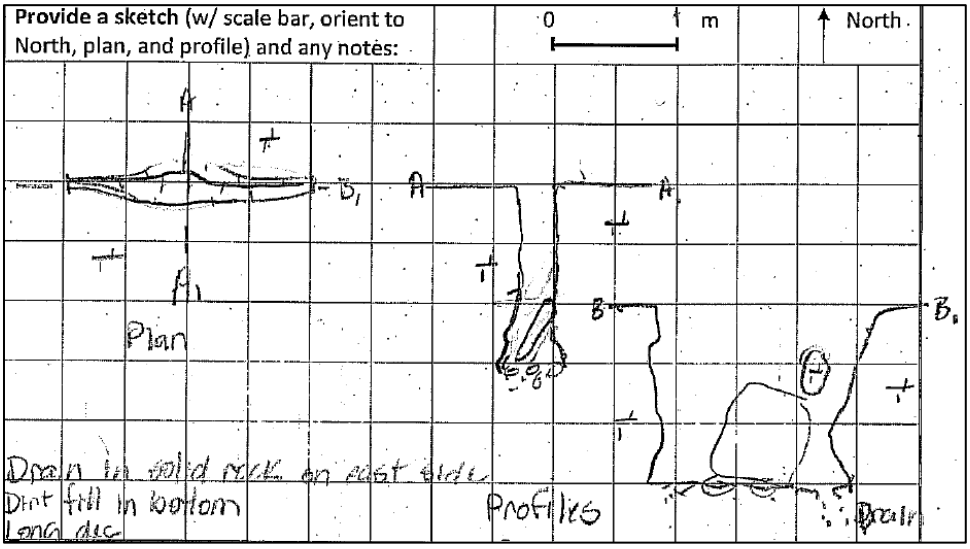


Figure 43. Field sketch of feature SW-7.

Feature SW-8; Cave

Feature SW-8 is a cave located west of the two-track access road on the western side of the Kotrla Tract panhandle (Table 17; Figure 44 – Figure 48). Prior to excavation, the substrate of this feature consisted of cleanly washed rocks, leaf litter, and modern soil. This feature was hand excavated for 2.5 person-hours on 16 June 2017, during which approximately 0.35 m^3 of rocks and black sediment, both loose and packed, were removed from the area directly below the entrance, effectively dropping the entrance floor 0.6 m to a total depth of 2 m. Excavation activities ceased when scientists reached compacted soil at the bottom of SW-8. However, mesocavernous voids were observed at the bottom of this feature. Cave-adapted fauna was observed, but no protected species were observed (Table 17). Climate data were collected at 09:15 on 23 May 2017. Temperature was recorded at 22.2°C and relative humidity was 90.7% inside SW-8. Above ground temperature was 21.5°C and relative humidity was 82.3%.

Feature SW-8 meets the initial criteria for potential habitat due to the presence of cave-adapted species, evidence of nutrient and water flow into the feature, its depth of greater than 1 m, and its enterable size (Table 3). Karst fauna surveys are recommended to continue the evaluation of this feature for protected species. Black plastic should be placed over the entrance to stabilize the temperature and humidity in the room prior to future fauna surveys. Feature SW-8 currently provides potential habitat for karst invertebrates and sufficient access. Additional excavation at this feature is not recommended.

Table 17. Feature SW-8 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
23 May 2017 and 16 June 2017	0.65 (2.1)	0.35 (1.1)	2.0 (6.6)	N	modern, dark, fine-grained soil and rocks	*Helicodiscus* sp. (snail) *Leiobunum townsendii* (harvestman); Araneae (surface spiders); Collembola (springtails); *Ceuthophilus secretus* Specimen ID Zara-9733, *Ceuthophilus* sp. nymphs (cave crickets); *Tachys* sp. (ground beetle) Specimen ID Zara-9734; Tenebrionidae (darkling beetles); Staphylinidae (rove beetle) Specimen ID Zara-9735; Coleoptera (beetle) Specimen ID Zara-9737; *Solenopsis invicta* (ant); *Mus* sp. (mouse)



Figure 44. Scientist entering feature SW-8.



Figure 45. Interior view of feature SW-8.



Figure 46. East terminus in bedrock in the bottom of feature SW-8.

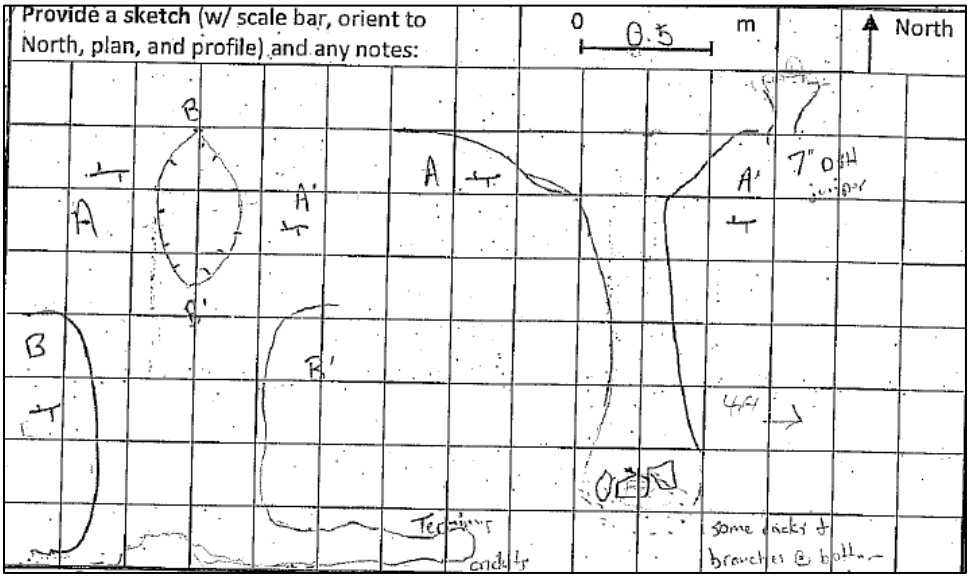


Figure 47. Field sketch of feature SW-8.

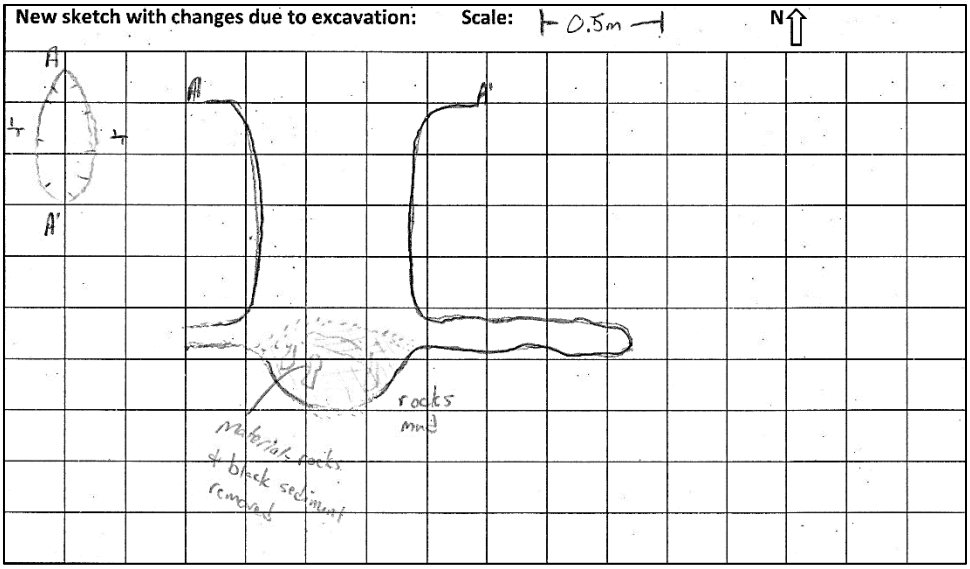


Figure 48. Feature SW-8 post-excavation field sketch.

Feature SW-9; Not Evaluated

Feature SW-9 was a secondary priority karst feature based on the initial list provided by the County. It was not evaluated to due lack of time and focus on high priority features. This feature should be evaluated for potential karst invertebrate habitat in the future.

Feature SW-10; Not Evaluated

Feature SW-10 was a secondary priority karst feature based on the initial list provided by the County. It was not evaluated to due lack of time and focus on high priority features. This feature should be evaluated for potential karst invertebrate habitat in the future.

Feature SW-11; Enlarged Fracture

Feature SW-11 is an enlarged fracture located in the north central area of the Kotrla Tract (Table 18; Figure 49 – Figure 52). A fracture with a bearing of 176° guided the feature, which measured 5 m long by 1 m wide by 0.7 m deep. Prior to excavation, the substrate consisted of rocks, modern soil, and leaf litter, and mesocavernous voids were observed. The feature was excavated on 21 June 2017 using hand tools to remove loose rocks, soil, and roots from the feature. This feature was hand excavated for 8 person-hours on 21 June 2017, during which approximately 1.5 m^3 of loose rocks, soil, and roots were removed. Three drains with air flow were exposed by the excavation (Figure 50). The feature became too narrow to continue digging on the north side; however, additional excavation to remove large rocks on the south side is recommended. No fauna was observed during the evaluation or excavation (Table 18).

Feature SW-11 meets the initial criteria for potential habitat due to modern soil, airflow, and development along a fracture (Table 3). Additional excavation with a jackhammer (1 to 2 weeks) is recommended determine the significance of airflow at this feature and whether it truly provides suitable karst invertebrate habitat. Karst fauna surveys are not recommended at this time.

Table 18. Feature SW-11 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
23 May 2017 21 June 2017	5 (16)	1 (3.3)	0.7 (2.3)	Y	modern, dark, fine-grained soil, leaf litter, and rocks	None observed



Figure 49. Partial view of the entrance to feature SW-11 prior to excavation.



Figure 50. A drain with air flow was observed at the bottom of feature SW-11 after excavation.

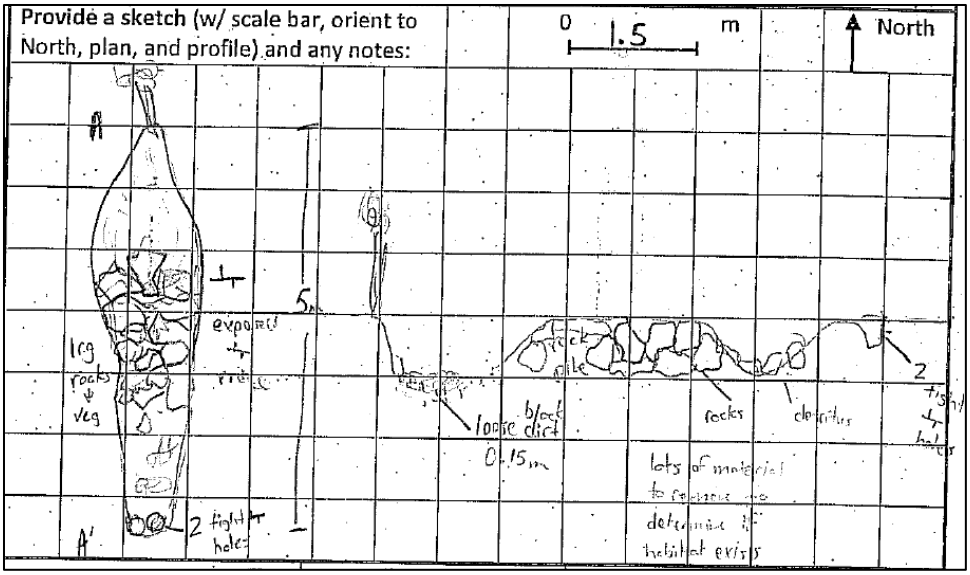


Figure 51. Field sketch of feature SW-11.

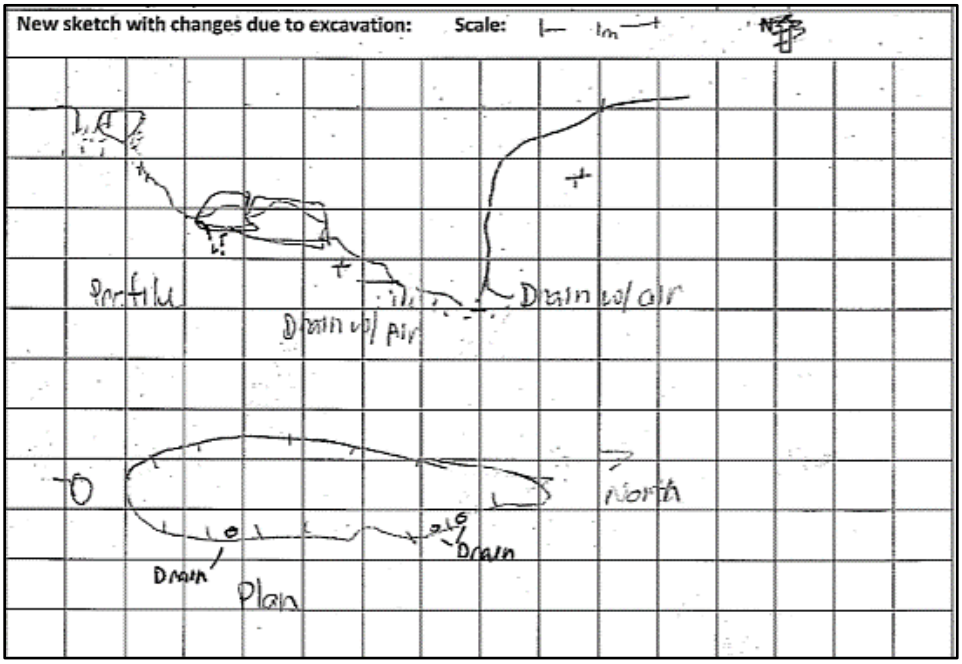


Figure 52. Field sketch of feature SW-11 after excavation.

Feature SW-12; Enlarged Fracture

Feature SW-12 is an enlarged fracture located in the north central area of the Kotrla Tract (Table 19; Figure 53 – Figure 55).The feature, which measured 1.2 m wide by 2 m long by 1.5 m deep, was guided by a fracture with a bearing of 0°. The substrate consisted of modern soil, cleanly washed rocks, leaf litter, and vegetation. Mesocavernous voids were observed. No cave-adapted fauna was observed during the evaluation (Table 19).

This feature meets the criteria for potential habitat due to modern soil, clean washed rocks, development along a fracture, and extending greater than 1 m in depth (Table 3), although further excavation is needed to fully evaluate it. Feature SW-12 was not evaluated further during this investigation, as the required effort for additional excavation surpassed the allotted time. Excavation would require the removal of several trees growing from the entrance (Figure 53) and the use of a jackhammer. It is anticipated that a minimum of 5 to 7 days would be required to further determine whether this feature truly provides suitable karst invertebrate habitat. However, recommended excavation activities at other features should be prioritized over SW-12 since the removal of several trees would be required, which could present an issue within protected habitat for the Golden-cheeked Warbler. Karst fauna surveys are not recommended at this time.

Table 19. Feature SW-12 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
23 May 2017	1.2 (16)	2 (3.3)	1.5 (2.3)	N	vegetation, modern, dark, fine-grained soil, leaf litter, and rocks	*Leiobunum townsendii* (harvestman)



Figure 53. Trees were observed growing from the opening of feature SW-12.



Figure 54. Interior of feature SW-12.

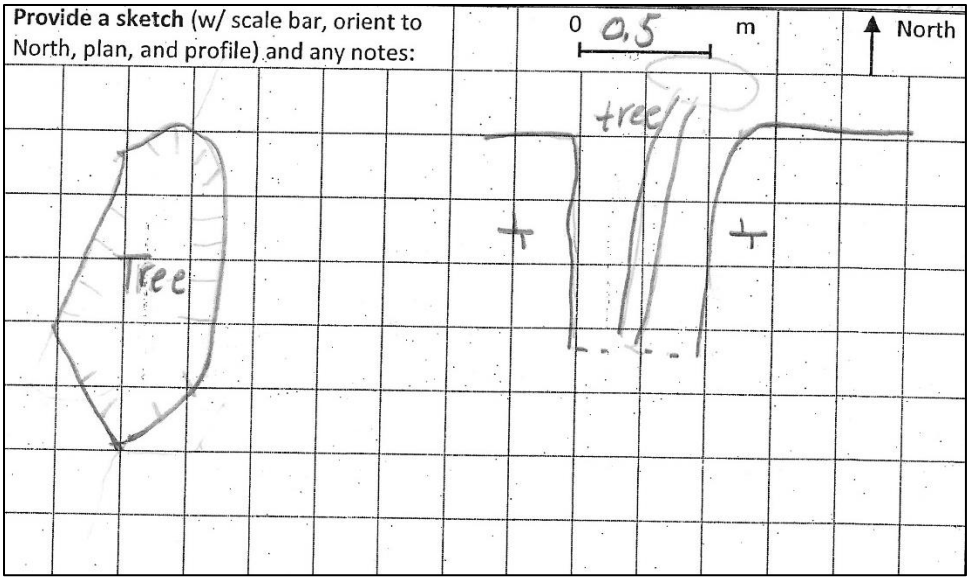


Figure 55. Field sketch of feature SW-12.

Feature SW-13; Cave

Feature SW-13 is a large solution sinkhole located in in the north central area of the Kotrla Tract panhandle near SW-12 (Table 20; Figure 56 – Figure 61). When the feature was evaluated on 23 May 2017, the overall dimensions of the sinkhole were 1.0 m wide by 1.5 m long by 2.5 m deep. Prior to excavation, the substrate consisted of loose modern soil, leaf litter, and rocks, and a mesocavernous void was observed. The feature was excavated on 20, 21, and 29 June 2017 for a total of 14 person-hours, during which approximately 0.75 m^3 of rocks and black sediment were removed to a depth of 4 m. At 4 m into the cave, the passage trends horizontal and is not enterable (Figure 59). However, strong airflow was felt coming from the passage. During excavation, cave-adapted fauna was observed (Table 20).

Feature SW-13 meets the initial criteria for potential habitat due to the presence of cave-adapted species, evidence of nutrient and water flow into the feature, airflow, collapse development, its depth of greater than 1 m, similarity to other nearby caves (SW Cave 4/McMac Cave, SW Cave 1, SW Cave 3, and SW 8), and its enterable size (Table 3). Karst fauna surveys are recommended to continue the evaluation of this feature for protected species. Black plastic should be placed over the entrance to stabilize the temperature and humidity in the room prior to future fauna surveys. Feature SW-13 currently provides potential habitat for karst invertebrates and sufficient access. Additional excavation at this feature is not recommended.

Table 20. Feature SW-13 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
23 May 2017 20, 21, and 29 June 2017	1.0 (3.2)	1.5 (4.9)	4 (13)	Y	modern, dark, fine-grained soil and rocks	Nematomorpha (horsehair worm) Specimen ID Zara-10016; *Leiobunum townsendii* (harvestman); Araneae (reduced pigment and eyes?) Specimen ID Zara-10099; Araneae (reduced pigment and eyes?) Specimen ID Zara-10017; *Cicurina varians* Specimen ID Zara-10015; *Speodesmus* sp. (subterranean millipede) Specimen ID Zara-10097; *Ceuthophilus secretus*, *Ceuthophilus* sp. nymphs (cave crickets) Specimen ID Zara-10098; Staphylinidae (rove beetle)



Figure 56. Entrance to feature SW-13 prior to excavation.



Figure 57. Bottom of feature SW-13 before excavation, with leaf litter covering the floor.



Figure 58. Soil and rocks were removed from feature SW-13 during excavation to reveal a small passage with blowing air.

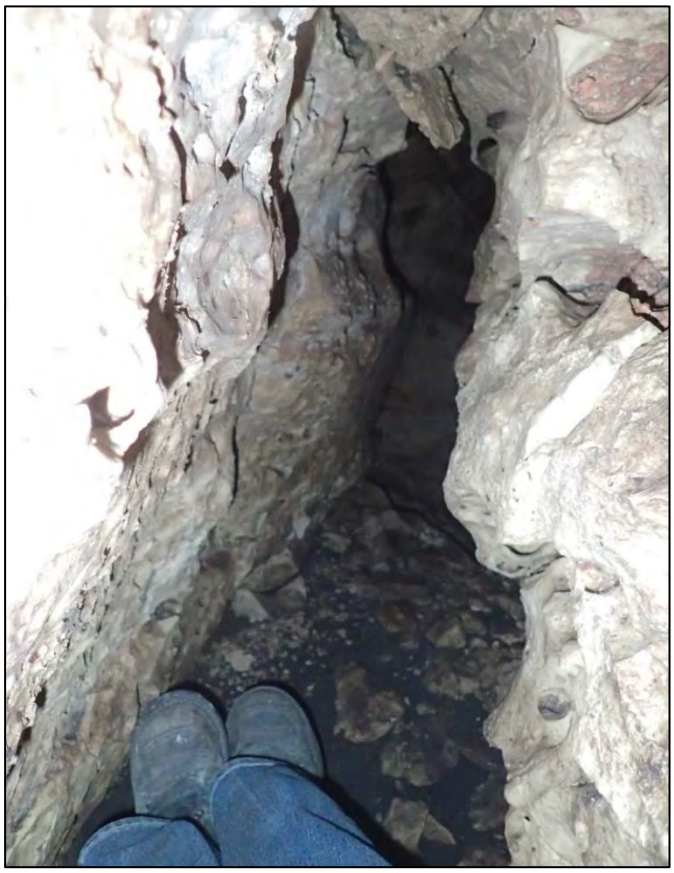


Figure 59. Horizontal passage at the bottom of feature SW-13.

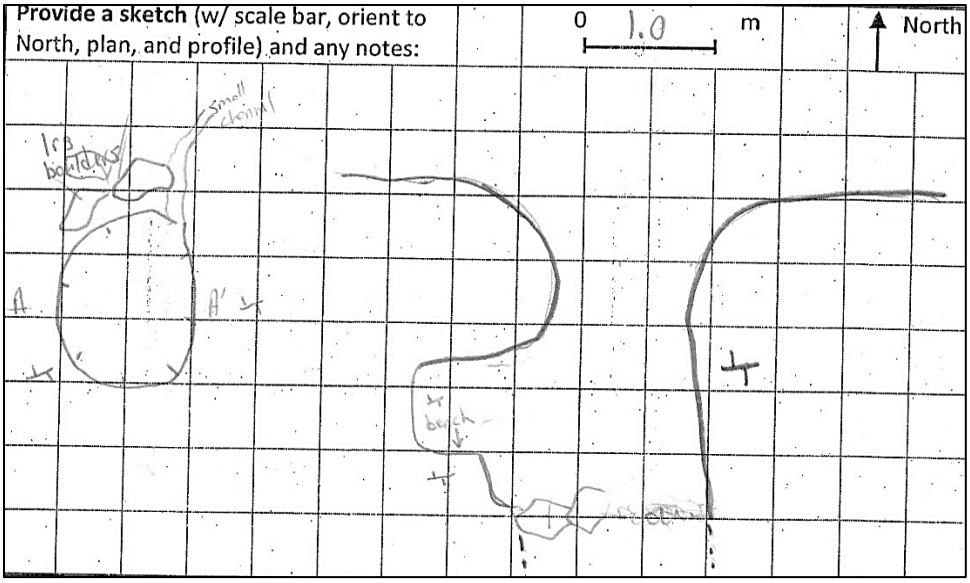


Figure 60. Field sketch of feature SW-13 before excavation.

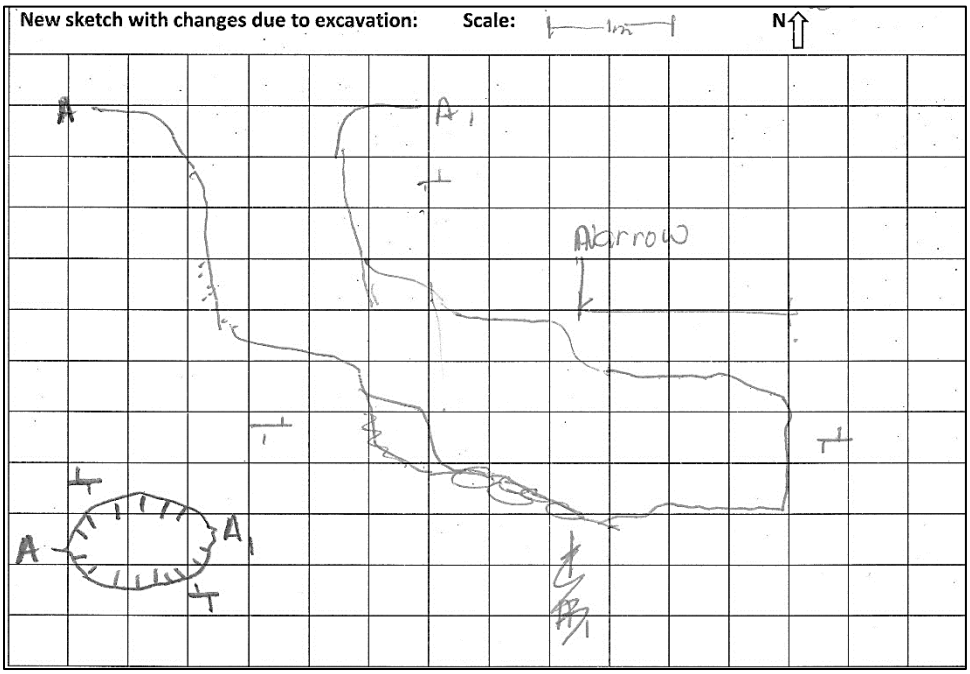


Figure 61. Field sketch of feature SW-13 after excavation.

Feature SW-14; Enlarged Fracture

Feature SW-14 is an enlarged fracture amidst a cluster of features located in the northeast area of the Kotrla Tract panhandle (Table 21; Figure 62 – Figure 64). The fracture guiding the feature, which measured 0.2 m wide by 0.5 m long by 0.7 m deep, was aligned along a bearing of 90°. The substrate consisted of modern soil, leaf litter, and rocks, and mesocavernous voids were observed. No fauna was observed at the entrance during the initial assessment (Table 21).

Feature SW-14 meets the criteria for potential habitat due to loose, modern soil and development along a fracture (Table 3). However, this feature was not prioritized for further excavation during this investigation. Due to its small aperture in limestone bedrock, excavation of SW-14 would require a jackhammer and an estimated minimum of 3 to 4 days to determine whether this feature truly provides suitable karst invertebrate habitat. Given the level of estimated effort along with a low potential of reaching karst invertebrate habitat, additional excavation at this feature is not recommended. Karst fauna surveys are not recommended at this time.

Table 21. Feature SW 14 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
30 March 2017	0.2 (0.6)	0.5 (1.6)	0.7 (2.3)	N	Modern, dark, fine-grained soil, leaf litter, and rocks	None observed



Figure 62. Overview of feature SW-14.



Figure 63. Entrance of feature SW-14.

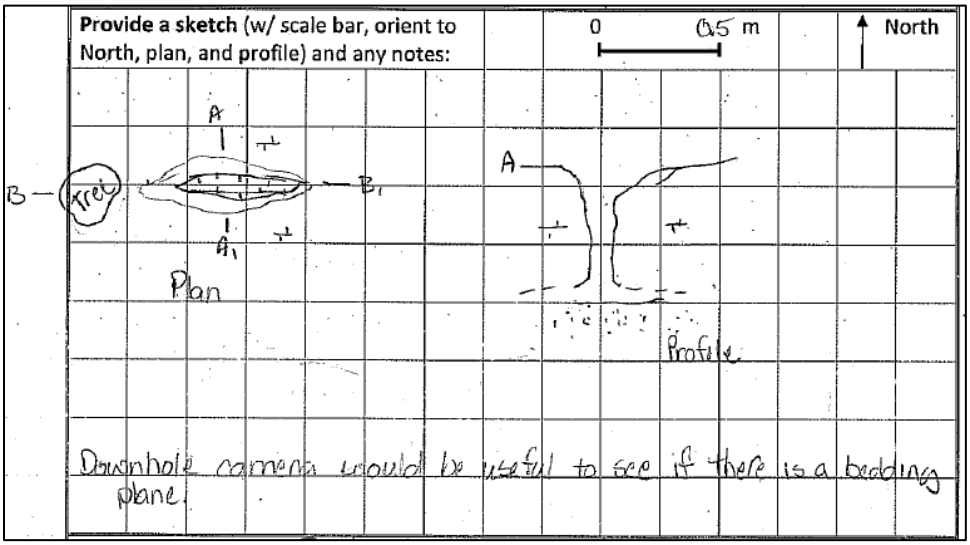


Figure 64. Field sketch of feature SW-14.

Feature SW-15; Enlarged Fracture

Feature SW-15 is an enlarged fracture located in in the northeast corner of the Kotrla Tract panhandle (Table 22; Figure 65 - Figure 67). A fracture with a bearing of 90° guided the feature, which measured 0.25 m wide by 0.3 m long by 0.75 m deep. The substrate consisted of modern soil, leaf litter, and rocks, and a mesocavernous void was observed. Claw and rub marks on the feature indicated a small mammal uses the feature for shelter. No fauna was observed at the entrance during the initial assessment (Table 22).

Feature SW-15 meets the criteria for potential habitat due to loose, modern soil and development along a fracture (Table 3); however, this feature was not prioritized for further excavation. Due to its small aperture in limestone bedrock, excavation of SW-15 would require a jackhammer and extensive effort (1 to 2 weeks) to determine whether this feature truly provides suitable karst invertebrate habitat. Given the level of estimated effort along with a low potential of reaching karst invertebrate habitat, additional excavation at this feature is not recommended. Karst fauna surveys are not recommended at this time.

Table 22. Feature SW 15 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
30 March 2017	0.25 (0.82)	0.3 (1)	0.75 (2.5)	N	Modern, dark, fine-grained soil, leaf litter, and rocks	None observed



Figure 65. Entrance to feature SW-15.



Figure 66. Interior of feature SW-15.

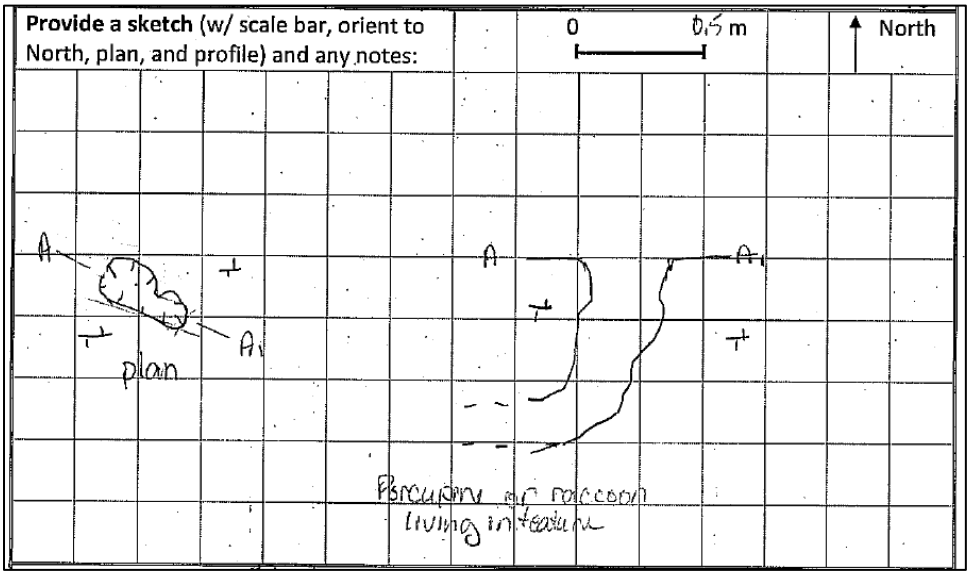


Figure 67. Field sketch of feature SW-15.

Feature SW-16; Cave

Feature SW-16 is a cave located in in the northeast corner of the Kotrla Tract panhandle near features SW-14, SW-15, and SW-19 (Table 23; Figure 68 – Figure 72). Feature SW-16 was initially assessed as a sinkhole that was 2 m wide by 9 m long by 1 m deep with a substrate of loose modern soil, rocks, leaf litter, and roots (Figure 71). The feature was excavated with hand tools on 8, 13, and 16 June 2017. A total of 10 person-hours were spent removing approximately 1.75 m^3 loose soil, rocks, and roots (Figure 72). Cave-adapted fauna was observed and collected during excavation. Bad air was detected in the bottom of the feature during excavation activities. No fauna was observed during the initial assessment (Table 23).

Feature SW-16 meets the initial criteria for potential habitat due to the presence of cave-adapted species, evidence of nutrient and water flow into the feature, collapse development, its depth of greater than 1 m, similarity to other nearby caves (SW Cave 4/McMac Cave, SW Cave 1, SW Cave 3, SW 8, and SW-13), and its enterable size (Table 3). Karst fauna surveys are recommended to continue the evaluation of this feature for protected species. Black plastic should be placed over the entrance to stabilize the temperature and humidity in the room prior to future fauna surveys. Continued excavation (1 to 2 weeks) is recommended to further evaluate this feature. Due to the poor quality of air in SW-16, future work in this feature should be performed with adequate ventilation using a blower and/or during the winter.

Table 23. Feature SW-16 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
30 March 2017 8, 13, and 16 June 2017	1.0 (3.2)	1.5 (4.9)	5.5 (18)	N	modern, dark, fine-grained soil, rocks, roots	*Leiobunum townsendii* (harvestman); Araneae (surface spiders); Araneae Specimen ID Zara-10101; Collembola (springtail) Specimen ID Zara-10102; *Ceuthophilus cunicularis, Ceuthophilus secretus*, *Ceuthophilus* sp. nymphs (cave crickets) Specimen ID Zara-10100; *Plethodon albagula* (salamander)



Figure 68. Opening of feature SW-16 before excavation.



Figure 69. Entrance to feature SW-16 after excavation.

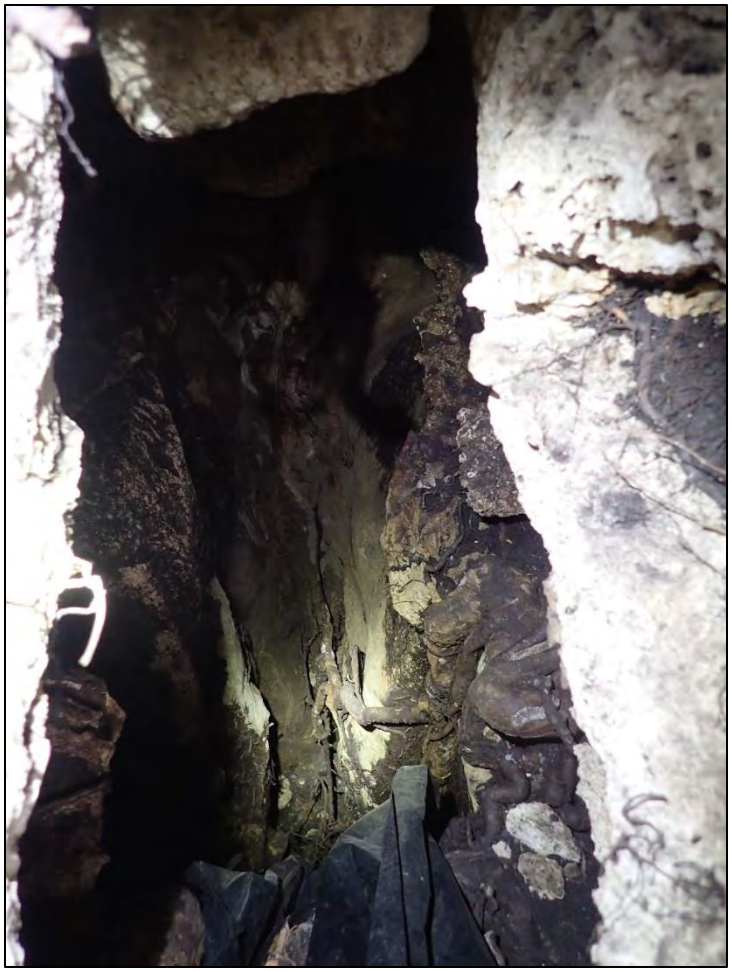


Figure 70. Interior view of feature SW-16 after excavation.

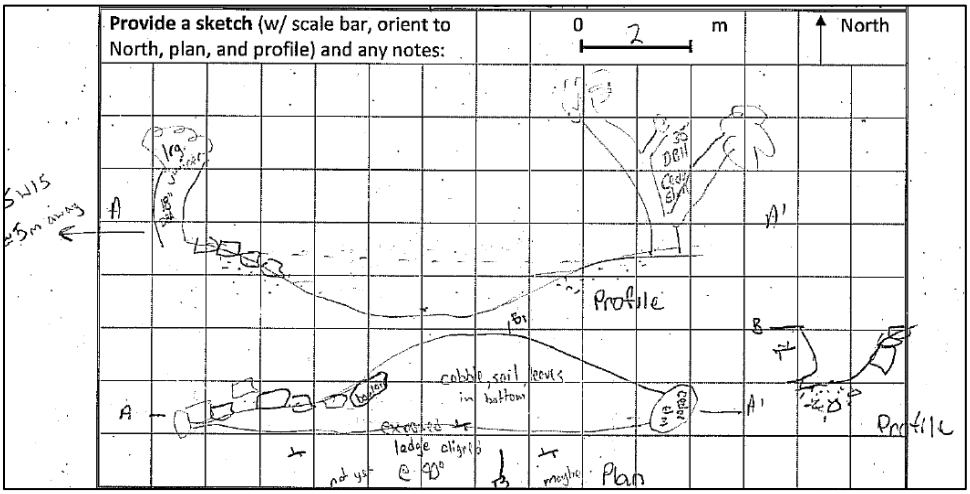


Figure 71. Field sketch of feature SW-16 before excavation.

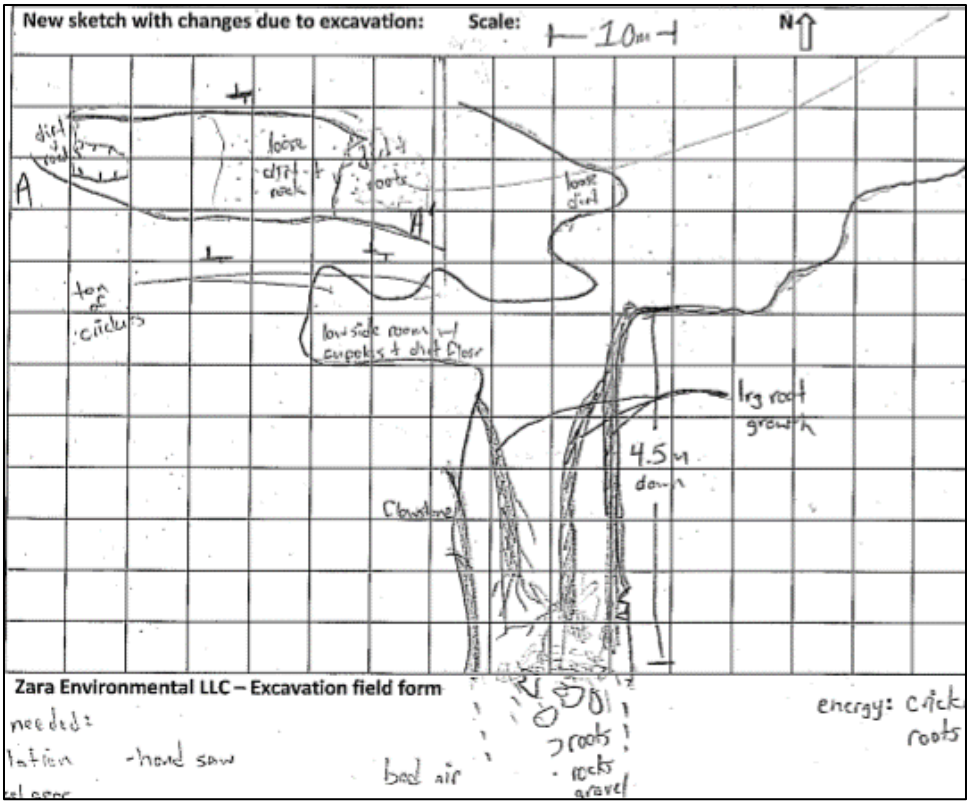


Figure 72. Field sketch of feature SW-16 after excavation.

Feature SW-17; Solution-formed Sinkhole

Feature SW-17 is a solution-formed sinkhole located in the eastern area of the Kotrla Tract panhandle and near feature SW-18, a large sinkhole (Table 24; Figure 73 – Figure 79). This feature, which measured 2.5 m long by 0.75 m wide by 3 m deep, was guided by a fracture with a bearing of 236°. Prior to excavation, the substrate consisted of loose modern soil, leaf litter, and rocks, and mesocavernous voids were observed. The feature was excavated on 20 and 26 September. A total of 18 person-hours were spent removing approximately 1.25 m^3 loose soil, rocks, and roots by hand (Figure 79). Although soil, rocks, and roots still remain in the feature, scientists noted on the final day of excavation that the walls of the sinkhole started to narrow considerably (Figure 79). Cave-adapted fauna was observed during excavation (Table 24).

Feature SW-17 meets the initial criteria for potential habitat due to the presence of cave-adapted species, evidence of nutrient and water flow into the feature, development along a fracture, its depth of greater than 1 m, and its enterable size (Table 3). Karst fauna surveys are recommended to continue the evaluation of this feature for protected species. Black plastic should be placed over the entrance to stabilize the temperature and humidity in the room prior to future fauna surveys. An estimated minimum of 3 to 4 days of excavation would be required to continue to remove soil from this feature, as well as to determine whether the feature terminates or continues and truly provides suitable karst invertebrate habitat. However, recommended excavation activities at other features should be prioritized over SW-17 since the likelihood of this feature continuing is probably relatively low.

Table 24. Feature SW 17 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
30 March 2017 20 and 26 September 2017	2.5 (8.2)	0.75 (2.5)	3 (9.8)	N	Modern, dark, fine-grained soil, leaf litter, and rocks	Collembola (springtail); *Ceuthophilus secretus*, (cave crickets); *Plethodon albagula* (salamander)



Figure 73. Overview of entrance to feature SW-17.



Figure 74. Opening of feature SW-17.



Figure 75. Interior of feature SW-17 before excavation.



Figure 76. Interior of feature SW-17 after excavation.



Figure 77. Plethodon albagula observed in SW-17.

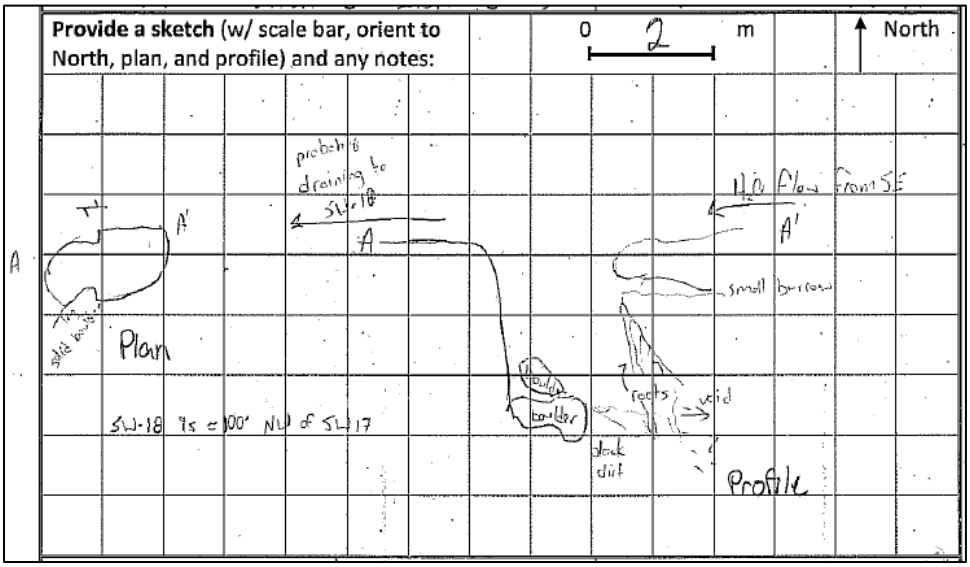


Figure 78. Field sketch of feature SW-17 before excavation.

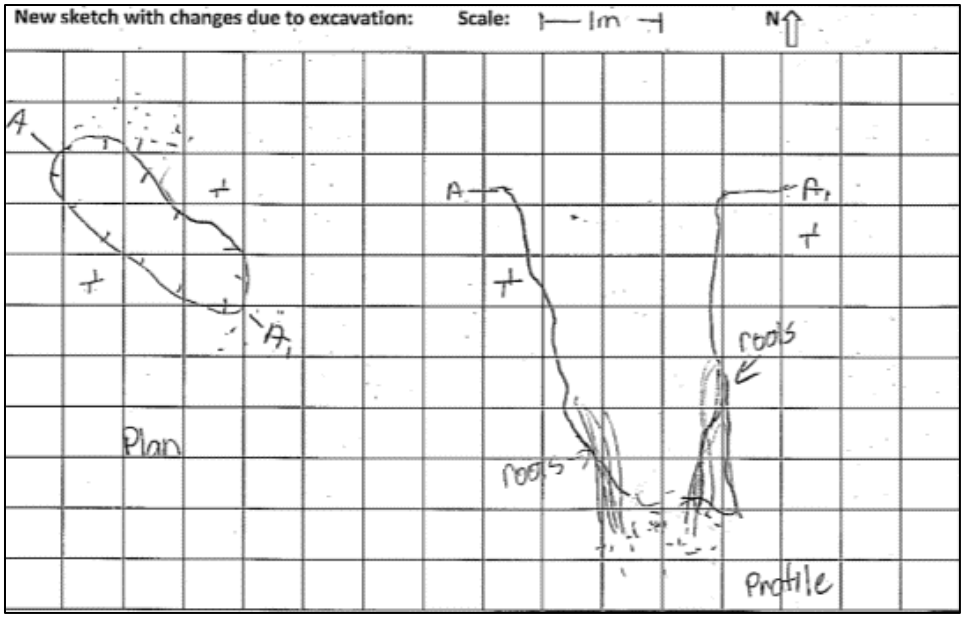


Figure 79. Field sketch of feature SW-17 after excavation.

Feature SW-18; Sinkhole

SW-18 is a large collapse-related sinkhole located in in the southeast area of the Kotrla Tract panhandle near SW-17 (Table 25; Figure 80 – Figure 83). This feature, which measured 10 m wide by 8 m long by 4 m deep, exhibited a high potential for recharge, draining sheetwash over an estimated recharge area of 40 m by 20 m. Substrate consisted of very loose modern soil, leaf litter, vegetation, and rocks, and mesocavernous voids were observed. Although no fauna were observed during the initial survey on 30 March 2017 (Table 25), Todd Bayless (Travis County – Balcones Canyonlands Preserve) mentioned observing *Ceuthophilus* sp. crickets during previous visits to SW-18.

This feature meets the initial criteria for karst invertebrate habitat due to the presence of loose, modern soil, evidence of high volumes of recharge, its formation by downward collapse, its depth of greater than 1 m, and the enterable size of the feature (Table 3). Excavation of this feature is recommended; however, due to the size of this feature, excavation efforts would likely require 3 to 4 people for an estimated 15 days. Karst fauna surveys are not recommended at this time.

Table 25. Feature SW 18 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
30 March 2017	10 (8.2)	8 (2.5)	4 (9.8)	N	Loose, modern, dark, fine-grained soil, leaf litter, rocks, breakdown, and boulders	None observed



Figure 80. View of feature SW-18 from the edge of a collapsed area.



Figure 81. Bottom of feature SW-18 with roots, soil, and boulders.

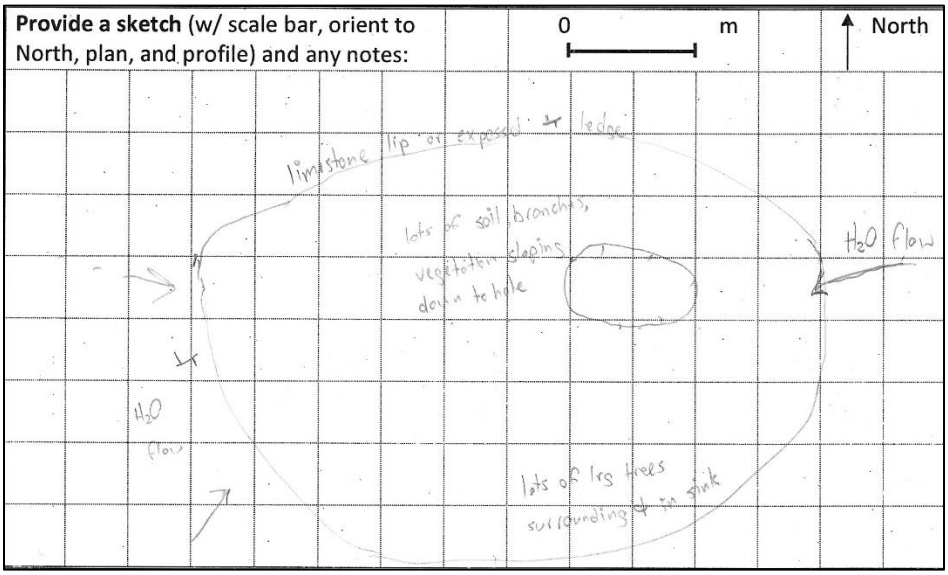


Figure 82. Field sketch of feature SW-18 in plan view.

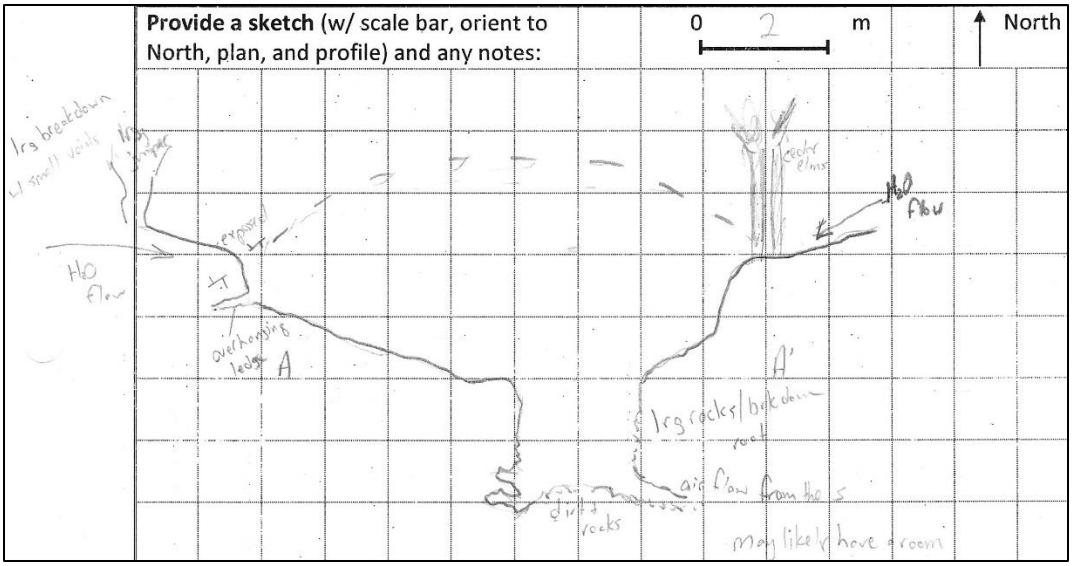


Figure 83. Field sketch of feature SW-18 in profile.

Feature SW-19; Solution Sinkhole

Feature SW-19 is a solution sinkhole located in the northeast corner of the Kotrla Tract panhandle (Table 26; Figure 84 – Figure 86). This small sinkhole measured 0.3 m wide by 0.25 m long by 0.5 m deep. Substrate consisted of loose modern soil and leaf litter, and a mesocavernous void was observed. Minor hand excavation to remove leaf litter and loose soils indicated that compact soils and roots were present at the bottom of the feature. No cave-adapted fauna was observed during the assessment; however, *Ceuthophilus* sp. crickets were observed (Table 26).

Feature SW-19 meets the criteria for potential habitat due to loose, modern soil and development along a fracture (Table 3). However, this feature was not prioritized for further excavation. Due to its small aperture in limestone bedrock, excavation of this feature would require a jackhammer and extensive time (estimated 1 to 2 weeks) to determine whether SW-19 truly provides suitable karst invertebrate habitat. Given the level of estimated excavation effort along with a low potential of reaching karst invertebrate habitat, additional excavation at this feature is not recommended. Karst fauna surveys are not recommended at this time.

Table 26. Feature SW 19 assessment.

Assessment date	Dimensions meters (feet)			Airflow	Sediment	Fauna Observed/ Comments
	X	Y	Z			
30 March 2017	0.3 (1)	0.25 (0.82)	0.5 (1.6)	N	Modern, dark, fine-grained soil, leaf litter, and rocks	*Leiobunum townsendii* (harvestman); *Ceuthophilus* sp. nymph (cave cricket)



Figure 84. Exterior view of feature SW-19.



Figure 85. Interior view of feature SW-19 after leaf litter was removed.

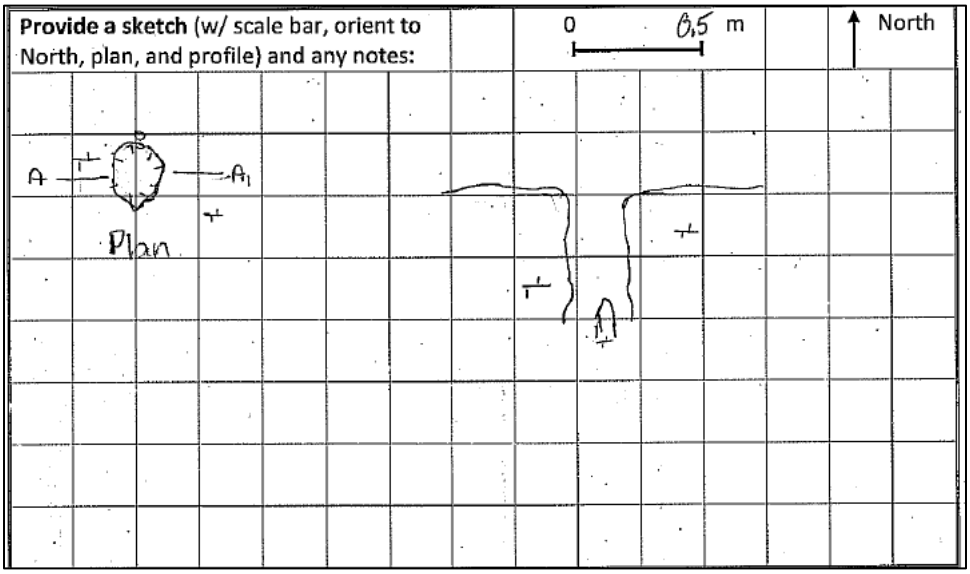


Figure 86. Field sketch of feature SW-19.

Recommendations

Twenty-two previously recorded karst features and one previously undiscovered cave were evaluated for potential karst invertebrate habitat during this investigation on the Kotrla Unit. All 22 features met the initial criteria for potential karst invertebrate habitat as provided by USFWS (2015). Six features were further evaluated for habitat during excavation activities (SW Cave 3, SW-8, SW-11, SW-13, SW-16, and SW-17).

Nine features are recommended for further excavation (KO-1, SW Cave 4 [McMac Cave], SW Cave 3, SW-6, SW-11, SW-12, SW-16, SW-17, and SW-18). Estimated minimum effort for additional excavation of these features range from as little as 1 to 2 days to as much as 15 days.

Eight features are recommended for karst fauna surveys (SW Cave 4 [McMac Cave], SW Cave 1, SW Cave 2, SW Cave 3, SW-8, SW-13, SW-16, and SW-17). Black plastic should be placed over the entrance of these recommended karst features to stabilize the temperature and humidity in the room prior to future fauna surveys.

In order to establish zones for repeated sampling, cave mapping is recommended for any cave that will be sampled on a regular basis. In addition, hydrogeological studies (i.e., focusing on surface and subsurface drainage areas at relevant features) are recommended to better delineate protection areas.

Bad air was noted during this investigation in two caves, SW Cave 3 and SW-16. Due to the poor quality of air in these two caves, future work in these features should be performed with adequate ventilation using a blower and/or during the winter.

Two previously undiscovered features were not addressed during this investigation (SW-9 and SW-10). These two features initially were designated by the County as secondary priority features and thus were not evaluated within the allotted time. However, features SW-9 and SW-10 should be evaluated for potential karst invertebrate habitat in the future.

A summary of the above results and recommendations is provided in Table 27. The table includes a breakdown of excavated features, whether features met the initial criteria for potential karst invertebrate habitat (USFWS 2015), recommendations for future excavation and karst fauna surveys, and other details as provided in the footnotes.

Table 27. Summary table of results and recommendations.

Feature Name	Excavated?	Potential Habitat?[1]	Future Excavation Recommended? (Estimated Minimum Effort for Recommended)	Future Karst Fauna Surveys Recommended at This Time?
KO-1	N	Y	Y (1 to 2 days)	N
KO-2	N	Y	N	N
SW Cave 1	N	Y	N	Y
SW Cave 2	N	Y	N	Y
SW Cave 3	Y	Y	Y (3 to 4 days)	Y
SW Cave 4 (McMac Cave)[2]	N	Y	Y (1 to 2 days)	Y
SW-1	N	Y	N	N
SW-2	N	Y	N	N
SW-3	N	Y	N	N
SW-4	N	Y	N	N
SW-5	N	Y	N	N
SW-6	N	Y	Y (3 to 4 days)	N
SW-7	N	Y	N	N
SW-8	Y	Y	N	Y
SW-9[3]	--	--	--	--
SW-10[3]	--	--	--	--
SW-11	Y	Y	Y (1 to 2 weeks)	N
SW-12	N	Y	Y (5 to 7 days)[4]	N
SW-13	Y	Y	N	Y
SW-14	N	Y	N	N
SW-15	N	Y	N	N
SW-16	Y	Y	Y (1 to 2 weeks)	Y
SW-17	Y	Y	Y (3 to 4 days)[4]	Y
SW-18	N	Y	Y (15 days)	N
SW-19	N	Y	N	N

[1] Features that initially meet the criteria for potential karst invertebrate habitat provided by USFWS (2015); further evaluation during future work may or may not determine whether features truly provides suitable habitat.

[2] Previously undiscovered feature.

[3] Features not evaluated during this investigation; should be evaluated for potential karst invertebrate habitat.

[4] Feature should be deprioritized for other features recommended for future excavation.

-- Feature not evaluated

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Appendix. Personnel.

Barrett Clark, Project Manager/Biologist. For this project, Barrett served as the Project Manager and was the primary author of this report. He has Bachelor of Science and Master of Science degrees in Biology from Louisiana Tech University. He has project experience throughout Texas, as well as in New Mexico, Oklahoma, Louisiana, Arkansas, Mississippi, Utah, Wyoming, Ohio, and Illinois. Barrett has extensive experience conducting and managing a wide range of ecological and environmental compliance projects for a variety of clients including pipeline, communications, chemical, energy, seismic, and electrical transmission companies; transportation departments; municipalities; utility and water districts; and other federal, state, and county/local agencies. Barrett has expertise in performing surveys and investigations including wetland delineations and waters of the U.S. determinations; rare, threatened, and endangered species habitat assessments and presence/absence surveys; biological monitoring; phase I and II environmental site assessments; and groundwater and subsurface studies. He is proficient in plant and freshwater mussel identification and taxonomy and skilled with GIS/GPS software and technology. He also conducts karst invertebrate surveys and coordinates cave management services. Barrett has been a primary and contributing author and preparer of National Environmental Policy Act (NEPA) documents including environmental impact statements, environmental assessments, and categorical exclusions, as well as Biological Assessments for section 7 consultation with the U.S. Fish and Wildlife Service. He also has experience with preparing U.S. Army Corps of Engineers (Section 404) permit applications and coordination and consultation with federal, state, and local agencies and stakeholders. He holds a Texas Parks and Wildlife Scientific Research Permit (SPR-0711-172) to collect and study freshwater mussels.

Jeanette "Jet" Joost (formally Larsen), Permitted Scientist/Biologist. For this project, Jet conducted karst feature habitat assessments and excavations and contributed to writing this report. Jet has a Bachelor's degree in aquatic biology, with a minor in chemistry. She began studying caves in 1995. She has worked as a karst technician since 2000. Much of her work has been in the San Antonio and Austin areas, and has included grid-searches for caves, excavation of caves and karst features, collection of invertebrate karst species for study, and biologically monitoring caves. She has also participated in several dye traces where she collected and analyzed samples. She has also participated in freshwater mussel surveys. She holds a USFWS permit (TE85077A-1) covering listed karst invertebrates, aquatic invertebrates, salamanders, and the Golden-cheeked Warbler.

Dr. Jean Krejca, Permitted Scientist/Subterranean Species Specialist. For this project, Jean conducted excavations. Jean has a Bachelor's degree in Zoology, and a Ph.D. in Evolution, Ecology, and Behavior from the University of Texas at Austin. Her dissertation work focused on cave adapted aquatic fauna, biogeography and hydrology of Texas and North Mexico. Since 1991, she has worked as a cave biologist and her experience in that area spans across the United States (Arkansas, California, Texas, Nevada, Illinois, Missouri, Indiana, Tennessee, North and South Carolina) as well as Mexico, Belize, Thailand, China and Malaysia. Her publication list on these areas is extensive. Her Texas consulting experience started in 1997 and includes endangered

species permit compliance and working as a Karst Invertebrate Specialist for the USFWS. In 2003, she co-founded Zara Environmental LLC where she continued her work from independent consulting and expanded to regional HCP's (Section 10(a)(1)(A) permits), endangered species litigation support, USFWS consultations, and performing custom research projects. The Zara team she supports includes species specialists (mussels, birds, herps), groundwater and geology specialists, and field crews. In addition, she has been involved with a variety of public outreach efforts such as public talks, field trips, and cave biology photography. She holds USFWS and TPWD rare and endangered species permits covering listed karst invertebrates, aquatic invertebrates, mussels, and salamanders in Texas.

Brian Cowan, Permitted Scientist/Hydrogeologist. For this project, Brian conducted excavations. Brian received a Bachelor of Science in Geology from the University of West Georgia and a Master of Science in Geology from the University of Texas at Austin. His thesis work focused on the temporal and spatial variability of cave-air CO_2 in central Texas and he also conducted extensive research on natural tracers of groundwater flow in karst settings and the preservation of paleoenvironmental signals in speleothems. Brian has a wide range of experience conducting hydrogeologic karst investigations, particularly in the application of technology to collect environmental data. Brian has conducted karst feature surveys on over 2,000 acres in central Texas since 2007. He holds Texas Professional Geoscientist license 11180. He also holds a USFWS Permit (TE85077A-1) to collect and study federally listed endangered karst invertebrate and aquatic species in central Texas. Brian's experience includes dye tracing, cave drip source delineation, groundwater evaluation for NEPA and USFWS processes, Geological Assessments, karst invertebrate habitat assessments and presence/absence surveys, and surface water quality. He is also familiar with issues in cave microclimates, groundwater geochemistry, and contaminant transport. Brian also has extensive experience conducting and overseeing freshwater mussel presence/absence surveys and relocation efforts and is a certified Advanced Open Water SCUBA Diver.

David McBee, Biologist. For this project, David conducted karst feature habitat assessments and excavations. David holds a Bachelor's Degree in Range and Wildlife Management from Texas A&M University-Kingsville. He is a scientific diving specialist with years of professional experience in dive team management and equipment maintenance. He has assisted researchers off the Texas coast tracking dispersal patterns in the red snapper fishery. As an undergraduate, he conducted research to determine freshwater wetland carrying capacity along the middle coast of Texas. David also has experience conducting field surveys and lab analysis for projects studying rangeland niche overlap, wetland delineation, and shorebird habitat preference. In addition to his biological background, David has been a professional SCUBA instructor and diving safety officer since 2007. In that time, he has led dive teams throughout Texas and Florida, as well as Micronesia and the Caribbean.

Jimmy MacMillan, Biologist. For this project, Jimmy conducted karst feature habitat assessments and excavations and contributed to writing this report. Jimmy is a biologist with a Bachelor's degree in Marine and Freshwater Biology as well as a certified commercial diver. He has over ten

years of experience diving in support of engineering and scientific projects and has participated in eleven projects studying mussel habitat, conducting presence/absence surveys and mussel relocation. Other assignments include aquatic ecology research, cave biology studies, technical geology documentation, bird surveys and bat population monitoring.

Clover Clamons, Permitted Scientist/Geologist. For this project, Clover provided background information, Quality Assurance/Quality Control review, and technical editing for this report. Clover received a Bachelor's degree in Geology from James Madison University and a Master's degree in Geology from Baylor University, where she studied soils and groundwater monitoring of seasonal wetlands on Galveston Island. She has worked on environmental compliance, project management, and inter-agency coordination for large-scale construction projects in the transportation, water, and electric utility industries since 1998 and has worked for Zara since 2010. She holds Texas Professional Geoscientist license 3639. She also holds a USFWS Permit (TE85077A-1) to collect and study federally listed endangered karst invertebrate and aquatic species in central Texas. Clover has extensive experience with National Environmental Policy Act (NEPA) and Endangered Species Act project documentation including the preparation and management of biological assessments, biological evaluations, categorical exclusions, environmental assessments (EAs) and environmental impact statements (EISs), and supporting technical documents.