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GROUNDWATER MACROINVERTEBRATE SURVEY AT WIND CAVE NATIONAL PARK, SOUTH DAKOTA



Calcite Lake in Wind Cave

Prepared for:
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Abstract

Zara Environmental conducted a survey for groundwater macro-invertebrate fauna in and around Wind Cave National Park, South Dakota in 2008 and 2009. Wind Cave is located in the Black Hills, a structural dome uplifted during the Laramide Orogeny. The high core of the Black Hills is flanked by outcrops of Pahasapa Limestone, which contains two of the world's longest caves, Wind Cave and Jewel Cave. Wind Cave reaches the Madison Aquifer, an important regional water resource. Lakes within Wind Cave were the focus of this study, but wells and springs in the surrounding area were also sampled (Figure 1). We used visual searches, plankton nets, drift nets and baited traps at 19 different sites in an effort to capture fauna. No groundwater macro-invertebrate fauna were detected at any of the sites.

Introduction

Geologic setting

The Black Hills have a unique geologic history. Caves in this region are formed exclusively in the Pahasapa Limestone (Madison equivalent) composed of 100-190 m of limestone and dolomite of early-middle Mississippian age. The Pahasapa Limestone is overlain by the Minnelusa Formation of Pennsylvanian age composed of quartz sandstone interbedded with shale, carbonates, and sulfates.

Wind Cave is a maze cave whose characteristic traits include the boxwork, remnant paleokarst, and dogtooth and nailhead spar crystalline calcite. Each of these traits is indicative of a different stage in the development of this polygenetic cave. Palmer (2000) emphasizes that these caves "have the unique distinction of having been cited as classic examples of three entirely different modes of origin: artesian, thermal, and rejuvenated paleokarst." The Pahasapa originally contained a significant amount of gypsum and anhydrite; the dissolution of these sulfates caused the first brecciation and dissolution voids. Reduction of the sulfates to hydrogen sulfide and then oxidation to sulfuric acid caused an aggressive chemistry for void formation which is typical in hypogene karst formation. The boxwork formed relatively early in the history of the cave. The bedrock was fractured by mechanical stresses when the anhydrite hydrated and was replaced by gypsum. Now calcite has replaced the gypsum, and the calcite veins are more resistant than surrounding bedrock which has been altered to friable sand.

During the late Mississippian karstification occurred with significant surface expression. These caves and dolines were later filled with early Pennsylvanian sediment of the Minnelusa Formation. This fill is visible in the cave as present day paleokarst. The next phase of cave formation was deep burial by late carboniferous and tertiary sediments. During this time period groundwater in the Pahasapa became nearly static. Quartz crystals were deposited in and around faults, and are occasionally visible at collapsed walls. Following the deep burial, uplift of Black Hills occurred during the late Cretaceous and early Tertiary. Steeper hydraulic gradients as a result of the uplift led to fresh groundwater flow through the Pahasapa Limestone. This caused phreatic cave enlargement of earlier voids. There is also evidence during this time period of diffuse recharge through overlying sandstone as well as rising thermal water.

Modern caves in this area have very few entrances. These entrances are "accidental" and are formed when cave passages are intersected by modern valleys. These caves

have little relationship to surface topography or to modern hydrology, and are largely insulated from surface influences by the non-karstic Minnelusa Formation. Palmer (2000) describes them as an example of relict hydrology. One of the most significant factors affecting the current cave environment may be the considerable human interaction with specific areas of the cave such as constructing and maintaining tour trails, leaving biological debris, and drilling near the cave area.

Biological setting

Wind Cave is not known for a diversity of troglobitic fauna. A literature review suggests that up to three potential cave adapted species, all springtails, exist in Custer County. In the family Entomobryidae, Christiansen and Bellinger (1980) list *Entomobrya troglodytes*. In the family Sminthuridae, multiple authors report on *Arrhopalites caecus* (Moore et al. 2005, Christiansen and Bellinger 1981). In the family Cyphoderidae Peck (1959) reports the presence of *Oncopodura cruciata*, also known from Montana. Other authors report on the terrestrial faunal assemblages in this cave (eg. Moore et al. 1996) and the NPS provides an excellent bibliography of cave biology (<http://www.nps.gov/wica/naturescience/bibliography-cave-biology.htm>).

No records exist of cave adapted aquatic fauna in Wind Cave, and for this reason our sampling effort was specifically aimed at the lakes and lake shore areas in the cave and other groundwater access points (wells and springs).

Methods

Water wells were sampled by attaching nets to outflow pipes, and recording the approximate water volume that flowed through them. Springs were sampled by conducting visual searches of submerged rocks and vegetation and by kick-netting with hand held nets. Nets were also placed over spring outlets and checked for fauna, usually on the following day. Nets used included 60 micron plankton nets, 500 micron drifts nets, and consumer-grade aquarium nets of varying mesh size. Locations of well and spring sites are shown in Figure 1.

Within Wind Cave, lake surveys consisted of visual searches of the water body and floor, and also of the shore area. Bait stations were set up in shallow and semi-shallow areas of the lake that consisted of dishes and small bottles with food bait (beef). Tomcat brand sticky traps with food bait (meat and cheese) were placed around the terrestrial shoreline search area. These were collected two days later and inspected for fauna in and around them. Visual searches of the lake floor and adjacent shore areas were made by delineating 1 m squares, characterizing substrate, and conducting timed searches for fauna. Visual searches were also conducted using a black light to try to detect fluorescent fauna (2009 survey only). Sub-aqueous substrate categories included flowstone, calcite raft debris, and black grit. Terrestrial substrate categories included tan dust, tan dust over flowstone, cemented rocks, and loose rocks. In order to compare terrestrial shoreline fauna with terrestrial fauna found on similar substrates away from water, a comparison site was selected in the same general level as the lake area, and the same survey methods were applied. Due to the lack of terrestrial fauna detected at these sites, an additional terrestrial fauna survey was conducted near the natural entrance to Wind Cave, at the bottom of the Warm Air Pit. This survey was a general search for fauna that did not include delineating 1 m squares or characterizing substrate.

Also within Wind Cave, samples were collected at a drip water monitoring station set up by other researchers studying water chemistry. A plastic sheet was suspended underneath a ceiling drip area that collected water, directing it down a drain tube. We attached a 60 micron plankton net to this drain tube and collected a water sample in a container at the end of the net. Sampling durations and methods are summarized in Table 1. Locations of study sites within Wind Cave are shown in Figure 2, and detail maps of the three primary study sites in the cave are shown in figures 4-6. Photographs of study sites are contained in figures 7-38.

Some of the above study sites were sampled twice, in November 2008 and June 2009, while others were sampled once during the 2009 field visit. Study sites are located in this report according to the nearest survey station designation. These designations were obtained from NPS staff files from their cave mapping program. Water temperatures were recorded using alcohol thermometers. Geographic coordinates for surface sites were recorded in NAD83 datum using a Magellan Explorist 500 global positioning system receiver.

Results

Wind Cave, Calcite Lake

Calcite Lake is located at the deepest point in Wind Cave. This survey was conducted adjacent to survey station 109, on both the November 2008 and June 2009 visits.

Wind Cave, Bungalow Lake

A second smaller lake site was surveyed near Calcite Lake. Our survey was conducted adjacent to survey station NO31D on the June 2009 visit.

Wind Cave, comparison site

A comparison site was selected that was similar, but away from Calcite Lake that would enable a comparison of terrestrial populations and habitat. This survey was conducted adjacent to survey station JF90, on both the November 2008 and June 2009 visits.

Wind Cave dripwater site

A dripwater collection study site in use by other researchers was sampled on the June 2009 visit. This site is near survey station UD17. 15.5 l of water were collected in a plastic sheet and filtered through a 60 micron plankton net.

Wind Cave, natural entrance

A site below the natural entrance was selected in order to compare near-surface terrestrial biodiversity with the deep cave comparison site. This survey was conducted adjacent to survey station FP2 in June 2009.

Cascade Springs

Cascade Springs is located in a canyon south of the town of Hot Springs. Alexander (1988) identified five spring outlets; we sampled in outlets A, B, D, and E.

At Outlet A (UTM 617488 4798996) we sampled in November 2008 using multiple methods. We hand sampled by looking under rocks and combing vegetation with an aquarium net. We kick-netted in high flow areas using a 500 micron drift net, and we set a 60 micron plankton net which was checked 20 hours later. In June 2009 kick-netting was conducted at this site, and an aquarium net was left for 24 hours. Outlet B (UTM 617491 4798990 approx.) was sampled using a 500 micron drift net.

Outlet D (UTM 617406 4799067) was sampled in November 2008 by kick-netting flow into a 500 micron net. A 60 micron plankton net was also set and retrieved 20 hours later. In June 2009 kick-netting was conducted at this site, and an aquarium net was left, but was found to be missing the next day. Outlet E (UTM 617403 4799067) was sampled in June 2009 by kick-netting and visual searches.

Cold Brook Spring (UTM 621953 4813215)

This spring is located north of Cold Brook reservoir, which it feeds. Alexander (1988) identified spring outlets A and B, we sampled at a third which we will call outlet C. It emerges from alluvium on the east side of the stream channel, from underneath the campground. It was sampled in June 2009 by kick-netting material into an aquarium net, and an aquarium net was also left for 237 hours with flow directed into it.

Cool Spring (UTM 617135 4799721)

This spring is located in a valley that feeds into Cascade Valley. It is in the Nature Conservancy's Whitney Preserve. There are two adjacent spring outlets at the base of the valley's east flank. The eastern one emerges from rubble, while the western one comes out of an alluvial conduit, which we chose for placing a net. It was sampled in June 2009.

Evans Spring (UTM 622830 4811073)

This spring is adjacent to the City of Hot Springs Evans Pumping Station. Water emerges from the base of a rubble slope that supports the edge of a roadway along a stream. Visual searches were conducted by examining the underside of rocks, and kick-netting was conducted. We sampled a pipe outlet inside of a concrete box by directing water flow through an aquarium net for 94.5 hours in June 2009.

Hot Brook Spring (UTM 620577 4812043)

This spring is adjacent to a City of Hot Springs water supply well. It goes dry whenever the well is pumped; we found it unsuitable for our sampling. It was sampled in June 2009.

Kidney Spring (UTM 622882 4810196 approx.)

This spring is a prominent parkland feature along the Fall River in downtown Hot Springs. It emerges from a spigot-type pipe in a pavilion, where its healthful properties are advertised and drinking by tourists is encouraged. Due to heavy public use we found it unsuitable for leaving a net installed, and we did not sample it.

Minnekahta Spring (UTM 622532 4810206)

This spring was highly modified by the construction of a spa, now ruined. Water emerges from a row of pipe outlets in the concrete wall of a pool. We sampled the eastern outlet, which has the most flow, by setting an aquarium net. Unfortunately this net had slipped out of the flow by the time it was checked 4 days later. It was the warmest water that we sampled; in fact *Minnekahta* is the Lakota word for warm water. It was sampled in June 2009.

Park Well no. 1 (UTM 625885 4823342)

This well is located in Wind Cave Canyon a few meters west of the park's eastern boundary, and south of Park Well no. 2. It is used as the water supply for the park. This well is 242 m deep (Hughes 2009) and is open in four different geologic formations: the Pahasapa (Madison), Englewood, Deadwood, and the Pre-Cambrian core. It probably derives most of its water from the Madison and Deadwood aquifers.

In November 2008, 32138 liters of water were flowed through a 500 micron net drift net. 10065 liters of water were flowed through a 60 micron plankton net in June 2009. No aquifer fauna were found.

Park Well no. 2 (UTM 625697 4823382)

This well is located in a canyon east of the entrance to Wind Cave. It is next to a pump house. It is 207 m deep (Hughes 2009) with a static water level at around 54 m. It was reportedly drilled as a backup water supply well, but is not used due to elevated arsenic and fluoride levels. In November 2008, 27255 liters of water were flowed, mostly through a 500 micron net, but with some flow diverted through a 60 micron plankton net. In June 2009, 7801 liters of water were flowed through a 60 micron plankton net. No aquifer fauna were found.

Rise of Beaver Creek at Buffalo Gap

Beaver Creek flows eastward through the park, normally sinking about 3 km northeast of Wind Cave. After leaving the park this drainage cuts through a ridge at Buffalo Gap (Figure 31). A series of spring outlets forms the rise of Beaver Creek at this point. Of the seven outlets were identified by Alexander (1988), we sampled outlets A, C, D, and F. These sites are located on private property. Sampling took place in November 2008 and June 2009.

Outlet A (UTM 631235 4820371) was sampled in November 2008 using a 60 micron plankton net left for 48 hours.

Outlet C was sampled in November 2008

At Outlet D (UTM 631246 4820345) a 60 micron plankton net was set for 48 hours.

At Outlet F (UTM 631294 4820307) kick-netting was conducted in November 2008 using aquarium nets, and a 60 micron plankton net was left in place over the spring boil for 72 hours.

Streeter Well (UTM 630332 4821214)

This well is located east of the park on private property. It is situated in a flat meadow to the west of Buffalo Gap. It is accessed via a metal door that is flush with the ground, and when the valve is turned on it produces under artesian flow at a rate of 10.9 liters per second. 35345 liters of water were sampled via this valve in November 2008 using a 500 micron net. A low flow outlet at a livestock trough was sampled in June 2009. 2756 liters were flowed through an aquarium net at the trough outlet. This sites is located on private property.

Discussion

Macro-invertebrate surveys of the lakes and adjacent terrestrial habitat in the deeper portions of Wind Cave resulted in no fauna detections. Moore (2005) notes the presence of the collembolan *Arrhopalites caecus* in a few pools in the tour trail sections of upper Wind Cave. Our visit detected a springtail we tentatively identify as *Oncopodura cruciata* (Figure 39) based on the species list by Peck (1959). Aside from these sparse records of springtails, terrestrial fauna appear to be absent from the deeper areas of Wind Cave that are far from the natural entrance, and human and troglodite inputs. The ancient origin of Wind Cave and the almost complete lack of surface nutrient and fauna input may explain the lack of invertebrates. Peck (1959) theorizes that organic debris, moisture and substrate limit the distribution of cavernicoles in Wind Cave. Typical karst systems have active surface landforms (dolines, swallets, karren) and an epikarstic zone just below the surface that provide extensive opportunities for invasion and adaptation of surface species to the cave

environment. These features are largely absent from the Wind Cave area. Epikarstic invasion routes may be considerably more significant in populating caves than the cave entrances that humans typically identify as the only way into the cave.

No aquifer-dwelling species were detected during this study. Stream-dwelling fauna collected (Table 2, figures 40-41) were similar to those found in Heakin (2004). Spring temperatures are generally elevated relative to cave lake and well temperatures, suggesting that they may undergo mixing from other sources or the water may be unrelated. This may also be the case at the Streeter Well, where water temperatures were measured to be considerably higher than both of the park wells and the lakes within Wind Cave (Table 3). No aquifer fauna were detected in any of these wells, despite flowing a total of 115,360 liters of water through sampling nets.

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Personnel

Dr. Jean Krejca, subterranean species specialist, participated in field work and report preparation. Jean has a Bachelor's degree in Zoology, and a Ph.D. in Evolution, Ecology and Behavior from the University of Texas. 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 and Malaysia. Her publication list on these areas is extensive. Texas cave biology experience started in 1997 and includes detailed collections of aquatic cave fauna for research, monitoring for endangered species, and working as a Karst Invertebrate Specialist for the U.S. Fish and Wildlife Service. In 2003 she co-founded Zara Environmental LLC where she continued her work from independent consulting and expanded to perform land management for landowners with endangered species, consult on endangered species permits, and perform custom research projects. 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 a USFWS endangered species permit (TE028652-0) and several state permits covering karst invertebrates and salamanders in Texas.

Krista McDermid analyzed specimens collected during this project. Krista holds a Master's degree in Wildlife Ecology from Texas State University in San Marcos and a bachelor's degree in Evolution, Ecology and Behavior from The University of Texas at Austin, where she worked on behavioral and genetic development of the zebra fish, *Danio rerio*. Krista has worked as a biologist for Texas Parks & Wildlife Department monitoring white-winged dove migration and population, and the City of Austin assisting with a mark-recapture study on the Jollyville Plateau Salamander, *Eurycea tonkawae*. Krista is a GIS technician; she received her certification in ArcView 3.x in 2005 and is currently pursuing further GIS education through Penn State University. She has worked with Zara since 2007 and in that time has participated in cave surveys, karst surveys, biomonitoring, aquifer faunal surveys and various other consulting activities. She holds Texas Parks and Wildlife Scientific Research Permit SPR-0608-082 (expires 5 June 2009) to collect and study aquifer fauna and U.S. Fish and Wildlife Service Permit TE192229-0 (expires 30 October 2011) to collect and study federally listed endangered Texas karst invertebrate species.

Peter Sprouse participated in field work and in report preparation on this project. He has been exploring and studying caves since 1970, having led the exploration of Sistema Purificación in Mexico, one of the longest and deepest caves in the world. He began collecting cave fauna for study by taxonomists in 1977, and has nine species named in his honor. He attended the University of Texas at Austin as a geology major, and since 1991 he has worked professionally in the fields of cave biology, land management, and cartography. He holds US Fish and Wildlife Service endangered species permit number TE014168-0 (covering endangered karst invertebrates in Texas) and Texas Dept. of Agriculture Pest Control License number 0362274. He has extensive experience in conducting karst surveys for invertebrate cave fauna habitat and biological inventories in caves and wells. He is a director of the Texas Speleological Survey and serves on the Balcones Canyonlands Preserve Scientific Advisory Committee Karst Subcommittee. The National Speleological Society has given him the prestigious Lew Bicking Award, named him an NSS Fellow, and he was the medal winner in the 1980 and 1986 NSS Cartographic Salons.

Sarah J. "Saj" Zappitello is a hydrogeologist specializing in karst and groundwater systems. On this project she conducted field work and report preparation. After graduating, Saj worked as a technician for the USGS, then became a hydrogeologist with INTERA Inc. She is currently a hydrogeologist with Zara Environmental LLC where her projects include aquifer dye traces, hydrogeological studies, and karst feature surveys and assessments. In addition to her education and professional background, Saj gains valuable experience recreationally caving volunteering for non-profit institutions like the Texas Cave Management Association and Proyecto Espeleológico Purificación. Previous efforts with these groups involved exploring and surveying new caves, searching for and mapping karst features, and leading beginner trips to expose the public to karst hydrogeology. She holds a USFWS endangered species permit (TE208531-0) covering geologic research in central Texas caves.

Table 1. Sampling durations and methods.

Site	Sample time (min.)	Outflow nets	Kick nets	Bait traps	Visual search
Calcite Lake	175			√	√
Comp. Site	78			√	√
Bungalow	46			√	√
Dripwater	2916	√			
Nat. Entr.	60				√
Cascade A	4050	√	√		√
Cascade B	1440	√			
Cascade D	1200	√	√		
Cascade E	6		√		√
Cold Brook	5460	√	√		√
Cool Spring	2880	√	√		√
Evans Spr.	5640	√	√		√
Pk. Well 1	3165	√			
Pk. Well 2	2970	√			
Rise A	2880	√			
Rise C	30				√
Rise D	5970	√			
Rise F	7410	√	√		√
Streeter Well	3174	√			

Table 2. Lists of fauna collected by site.

Site	Common name	Order	Family	Genus	Species
Wind Cave natural entrance					
	Spiders	Araneae			
	Centipedes	Chilopoda			
	Beetles	Coleoptera			
	Moths and Butterflies	Lepidoptera			
Cascade Springs Outlet A					
	Amphipods	Amphipoda			
	Gastropods	Gastropoda			
	Dragonflies	Odonata (larvae)			
	Creeping Water Bugs	Hemiptera	Naucoridae		
	Beetles	Coleoptera			
	Insecta	Undetermined (larvae)			
	Fish			<i>Rhinichthys</i>	<i>cataractae</i>
Cascade Springs Outlet B					
	Amphipods	Amphipoda			
	Spiders	Araneae			
	Beetles	Coleoptera			
	Insecta	Undetermined			
Cascade Springs Outlet D					
	Flatworms	Seriata	Planariidae		
	Gastropods	Gastropoda			
	Amphipods	Amphipoda			
	Creeping Water Bugs	Hemiptera	Naucoridae		
	Beetles	Coleoptera			
Cold Brook Spring					
	Isopods	Isopoda			
	Snails	Gastropoda	Planorbidae	? <i>Menetus</i>	
	Isopods	Isopoda			
	Amphipods	Amphipoda	Hyalellidae	? <i>Hyaella</i>	? <i>azteca</i>

Table 2. Lists of fauna collected by site continued.

Evans Spring					
	Beetle	Coleoptera	Elmidae (adults and larvae)		
Minnekahta Spring					
	Dragonflies	Odonata			
	Flies	Diptera			
Rise of Beaver Creek at Buffalo Gap Outlet A					
	Gastropods	Gastropoda			
	Copepods	Eucopepoda			
	Ostracods	Ostracoda			
	Insects	Undetermined	(larvae)		
Rise of Beaver Creek at Buffalo Gap Outlet B					
	True Bugs	Hemiptera			
	Water Boatmen	Hemiptera	Corixidae		
	Beetles	Coleoptera			
	Insects	Undetermined			
	Fish	Undetermined			
Rise of Beaver Creek at Buffalo Gap Outlet D					
	Flatworms	Seriata	Planariidae		
	Snails	Gastropoda	Hydrobiidae		
	Isopods	Isopoda			

Table 2. Lists of fauna collected by site continued.

Rise of Beaver Creek at Buffalo Gap Outlet F					
	Gastropods	Gastropoda			
	Copepods	Eucopepoda			
	Ostracods	Ostracoda			
	Amphipods	Amphipoda			
	Mayflies	Ephemeroptera	(larvae)		

Table 3. Water temperatures at sampling sites in degrees Celsius.

site name	November 2008	June 2009
Wind Cave Calcite Lake	13.2, 13.25	13.5, 13.6
Wind Cave Bungalow Lake	n/s	13.1
Wind Cave dripwater site	n/s	11.5
Cascade Springs outlet A	n/r	21.2, 21.3
Cascade Springs outlet C	n/r	n/s
Cascade Springs outlet D	n/r	19.3, 19.4
Cascade Springs outlet E	n/r	19.1
Cold Brook Spring	n/s	18, 18.2
Cool Spring	n/s	17.8
Evans Spring	n/s	27, 27.6
Minnekahta Springs	n/s	33.4
Park Well no. 1	>/=12	14
Park Well no. 2	13.8	14.6
Rise of Beaver Creek outlet C	18.5	n/s
Rise of Beaver Creek outlet D	n/r	17.2
Rise of Beaver Creek outlet F	17.9	18.9
Streeter Well	19.4	n/s
Streeter Well, trough outlet	n/s	22.8

n/r=not recorded n/s=not sampled

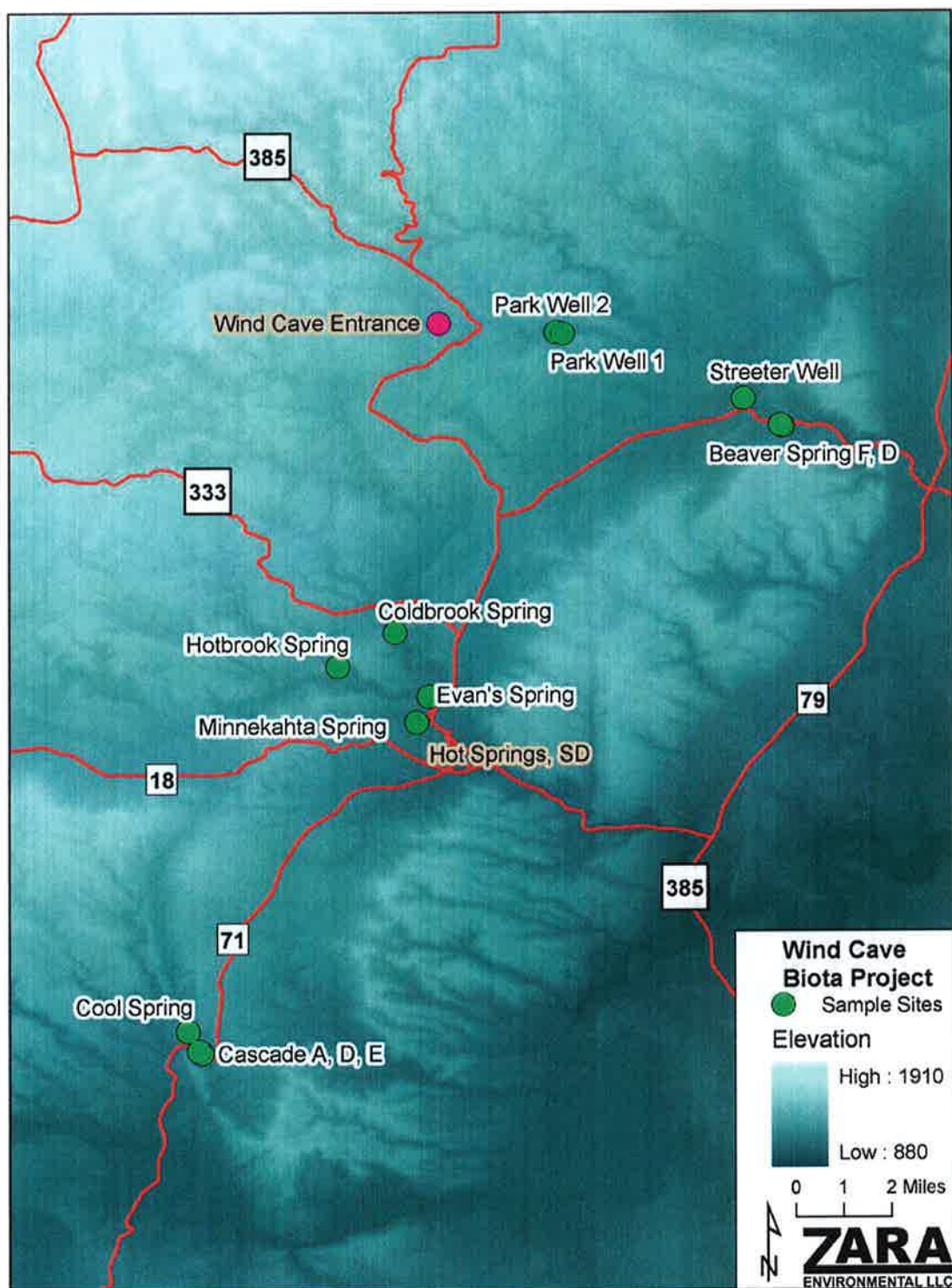


Figure 1. Surface sampling site locations.

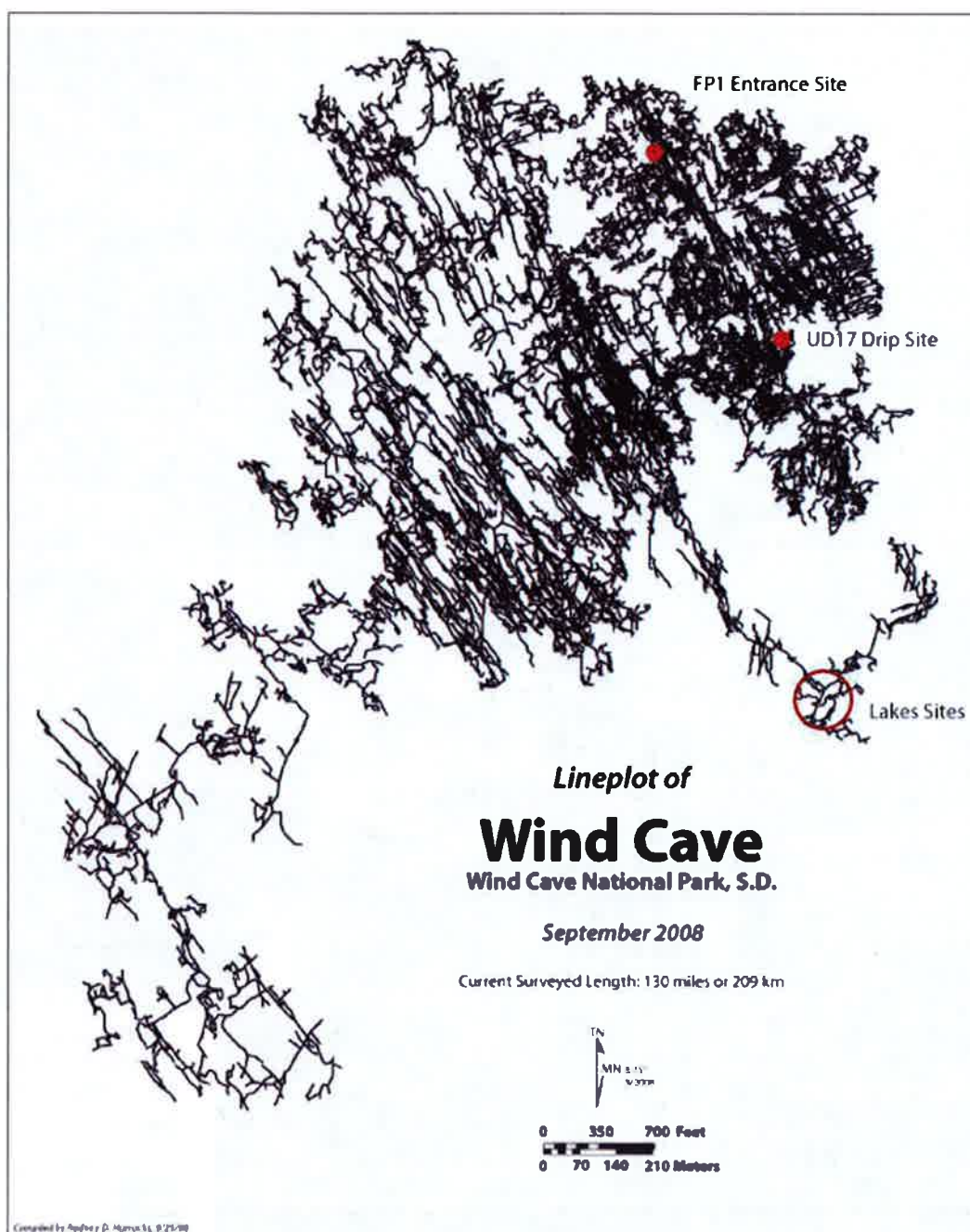


Figure 2. Study site locations within Wind Cave.

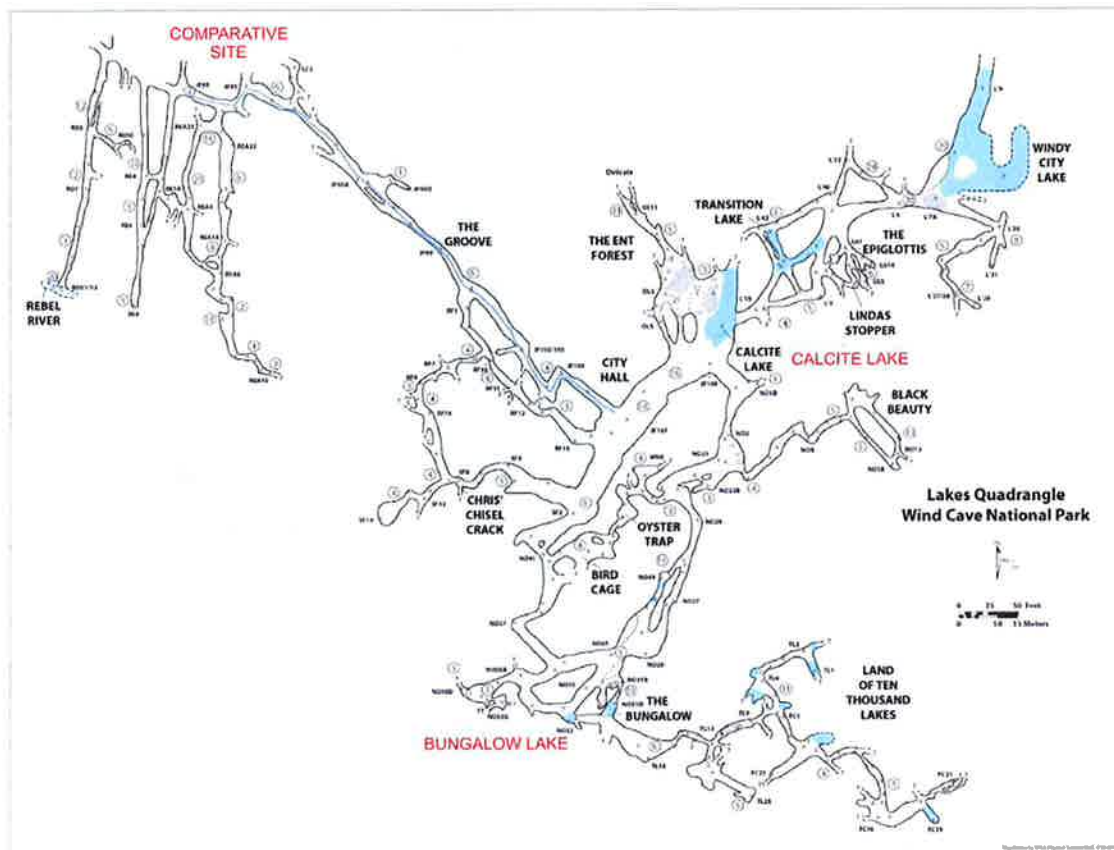


Figure 3. Lakes area study sites.

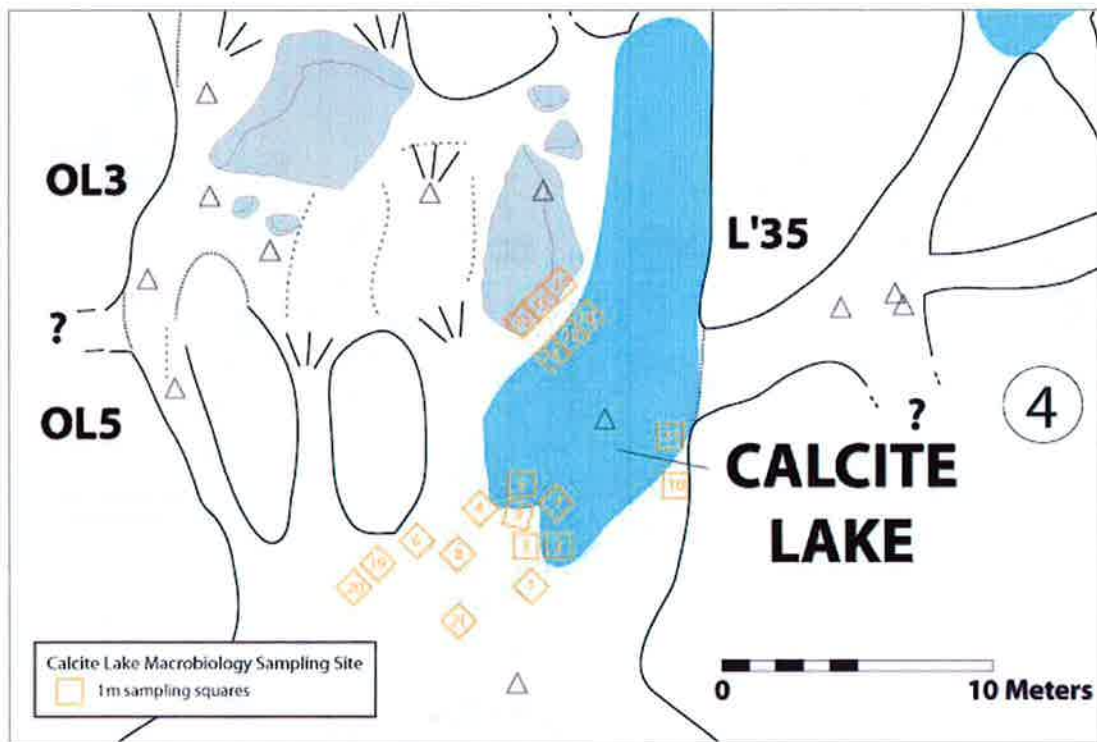


Figure 4. Calcite Lake sampling zones.

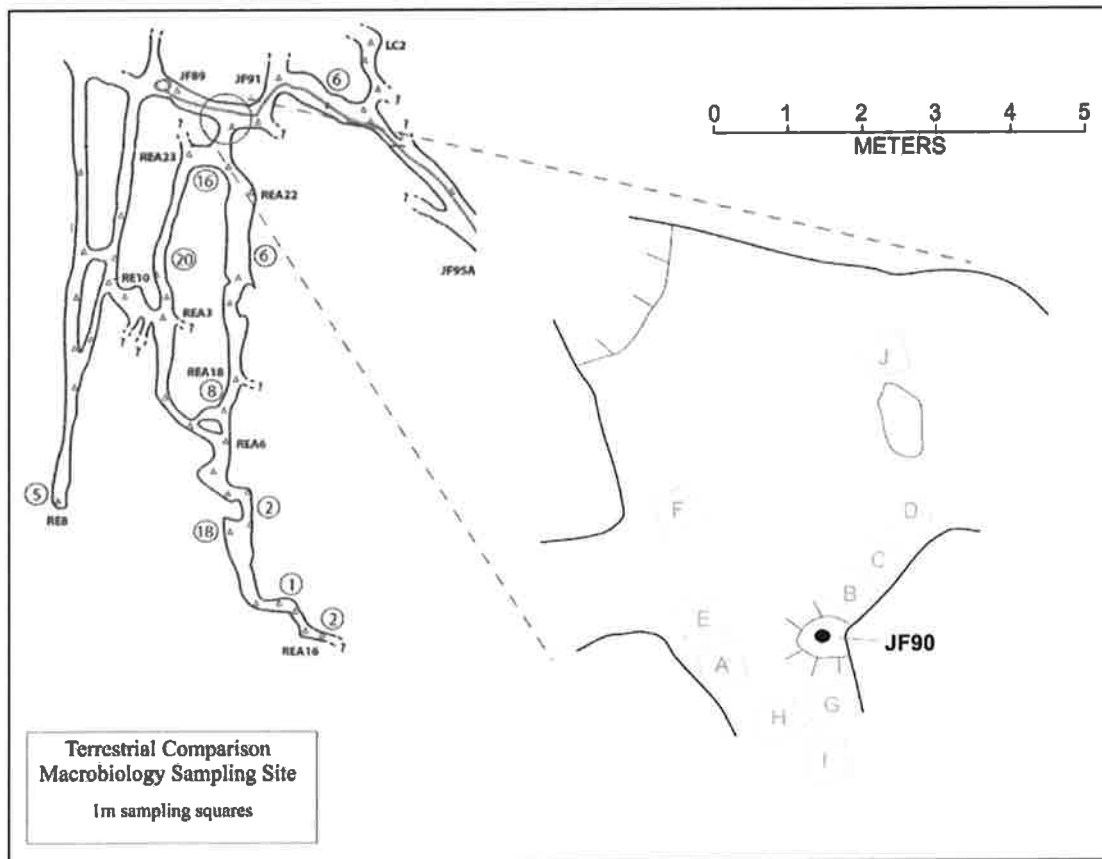


Figure 5. Comparison site sampling zones.

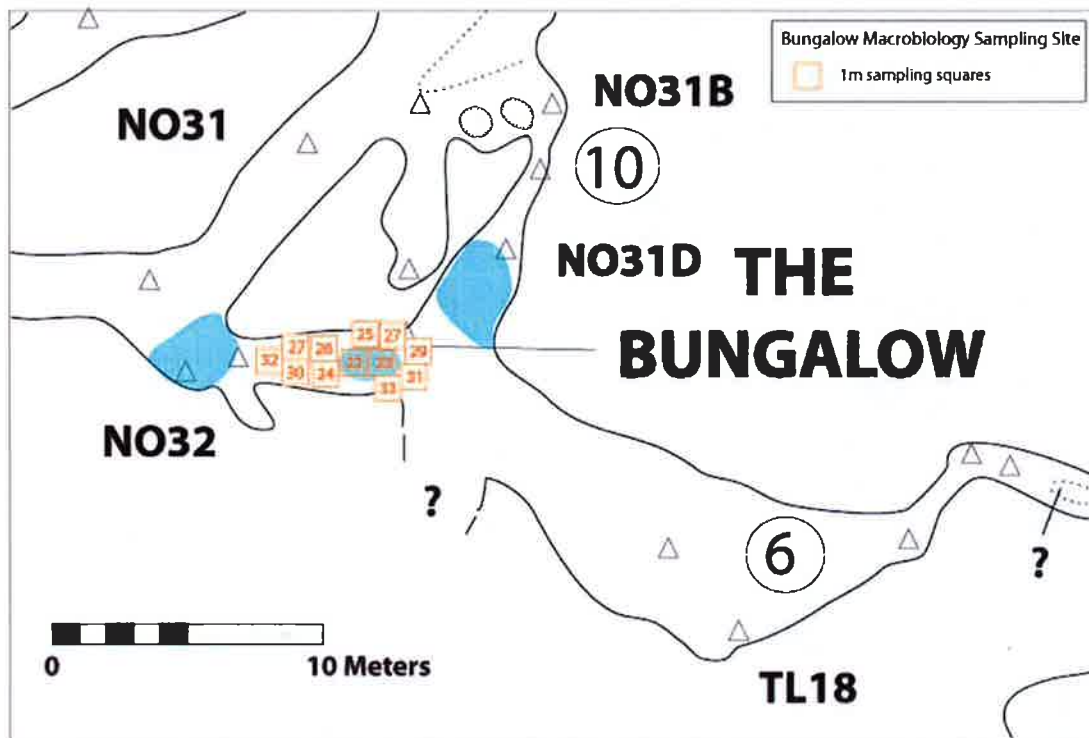


Figure 6. Bungalow Lake sampling zones.



Figure 7. Wind Cave Calcite Lake shoreline area, showing baited glue traps.



Figure 8. Wind Cave Calcite Lake terrestrial area, showing baited glue traps.



Figure 9. Wind Cave Bungalow Lake sampling area.



Figure 10. Wind Cave lakes level comparative terrestrial site.



Figure 11. Wind Cave dripwater study site, showing plankton net attached to dripwater collection hose.



Figure 12. Natural entrance to Wind Cave.



Figure 13. Wind Cave entrance area terrestrial comparative site, just below natural entrance.



Figure 14. Cascade Springs Outlet A.



Figure 15. Cascade Springs Outlet B.



Figure 16. Cascade Springs Outlet D.



Figure 17. Cascade Springs Outlet E.



Figure 18. Cold Brook Spring pool.



Figure 19. Cold Brook Spring outlet with thermometer in use.



Figure 20. Cool Spring, with aquarium net in place.



Figure 21. Evans Spring.



Figure 22. Interior of concrete structure at Evans Spring outlet, showing aquarium net over pipe outlet.



Figure 23. Hot Brook Spring area, showing municipal water supply pump buildings.



Figure 24. Hot Brook Spring. When the adjacent municipal water well is turned on, this spring temporarily dries up.



Figure 25. Minnekahta Spring, which emerges from pipes within an abandoned spa structure.



Figure 26. Taking water temperature at Minnekahta Spring pipe outlet.



Figure 27. Park Well no. 1.



Figure 28. Sampling water at Park Well no. 1 with a 60 micron plankton net.



Figure 29. Park Well no. 2.



Figure 30. Park Well no. 2 outlet. A black hose is run up the pipe to shunt some of the flow to a 60 micron net.



Figure 31. View of Buffalo Gap looking east. The rise of Beaver Creek is in this gap.



Figure 32. Beaver Creek Outlet A.



Figure 33. Beaver Creek Outlet D.



Figure 34. Plankton net placement at Beaver Creek Outlet D.



Figure 35. Beaver Creek Outlet F spring boil.



Figure 36. Streeter Well.



Figure 37. Streeter Well hose outlet, sampled with a 500 micron net.



Figure 38. Streeter Well trough outlet being sampled with an aquarium net.

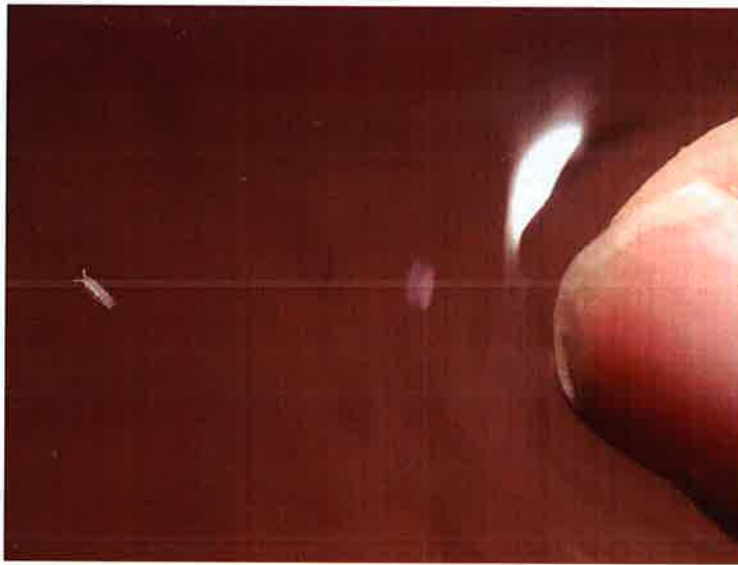


Figure 39. Probably the troglobitic springtail *Oncopodura cruciata* on the surface of a pool along tour trail, with fingertip for scale.



Figure 40. Amphipods commonly found in spring outlets



Figure 41. Beetle, probably Elmidae, found at some spring outlets

