Groundwater Quality Monitoring at Logan Cave National Wildlife Refuge

Final report for
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Cover photograph: Spring entrance of Logan Cave on the USFWS Logan Cave National Wildlife Refuge. Photograph by Ozark Highlands Office, The Nature Conservancy.

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Final Report, submitted by

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Introduction

Logan Cave has a diverse biotic community (over 43 species) that is home to several of Arkansas' karst species of greatest conservation need. The cave provides permanent habitat for the federally threatened Ozark cavefish (*Amblyopsis rosae*), habitat for a maternity colony of federally endangered gray bats (*Myotis grisescens*), the grotto salamander (*Eurycea spelaea*), and the Benton Cave Crayfish (*Cambarus aculabrum*). The entrance and approximately123 acres above the known cave are owned by the U.S. Fish and Wildlife Service with management by Holla Bend NWR.

In response to population growth occurring in northwest Arkansas, a significant proportion of the approximately 11 mi^2 recharge zone for this cave is undergoing rapid community growth. Northwest Arkansas is one of the top three fastest growing regions in the United States. Over the past two and half years the USFWS Arkansas Field office has completed numerous informal consultations with developers within the boundaries of the recharge zone. It is necessary to monitor the groundwater in the cave to determine if conservation measures that are being required are sufficient to protect cave water and the populations of rare and endangered species.

The cave's proximity to major transportation corridors also means that the recharge zone may be impacted by industrial projects. As identified in the USFWS Logan Cave National Wildlife Refuge Comprehensive Conservation Plan, species populations at Logan Cave are impacted by groundwater degradation such as nutrient enrichment, altered hydrologic and drainage patterns, and sedimentation from construction activities. Spills from highway accidents, pipelines, stormwater runoff from development, and residential sewage also pose threats.

It is much more difficult to monitor and reduce impacts such as these. Periodic monitoring may miss a one time release of a toxic chemical from a spill, illegal dumping or an initial flush of contaminants during a storm event. Alternately, a slow increase of pollution through time is difficult to assess without a strong understanding of baseline conditions for comparison. The United States Fish and Wildlife Service, Arkansas Natural Heritage Commission, Arkansas Game and Fish Commission, and The Nature Conservancy are actively pursuing conservation actions that reduce development pressures within the recharge area. Prior to this project, some groundwater quality monitoring has occurred, led by the Ozark Highlands Office of The Nature Conservancy. That project monitored dissolved oxygen, turbidity, pH, specific conductivity, temperature, and chloride levels in the groundwater that issues from the cave system. In addition, Arkansas Department of Environmental Quality provided several months of nutrient and metals analysis to develop a baseline for these parameters.

The purpose of the current project was to continue establishing a long term groundwater quality monitoring program at Logan Cave that would allow groundwater threats to be detected, provide a solid baseline characterization of groundwater quality, and track groundwater quality changes through time. Specifically, the objectives for this project, as outlined in the USFWS Logan Cave National Wildlife Refuge Comprehensive Conservation Plan, were:

1. Increase protection of two federally listed species.
2. Determine baseline groundwater conditions at Logan Cave.
3. Track water quality changes over time in relation to species population trends.

Methods

Grab samples of groundwater were collected monthly from the spring entrance of Logan Cave from September 2011 – August 2012 during baseflow conditions to minimize direct impacts from heavy precipitation events. Samples were analyzed for the following constituents: pH, Alkalinity, Conductivity, Turbidity, Coliform, *E. coli*, and Hardness; other specific analyses also include: Cl, F, SO4, NO3-N, PO4-P (as SRP), NH3-N, TN, TP, TOC, TSS and Dissolved Trace Elements (Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, S, Se, Ti, & Zn). The Arkansas Water Resources Center at the University of Arkansas, Fayetteville, conducted the analyses. In order to compare groundwater data to rainfall events, precipitation amounts (total rainfall in previous 72 hrs) were downloaded from Weather Underground.com using rainfall data recorded at the Siloam Springs Municipal Airport weather station (KSLG) located in Siloam Springs, Arkansas.

Results and Discussion

Water samples were collected from the stream emerging from Logan Cave on 11 occasions (Appendix 1). Chloride averaged 7.85 mg/L (SE ± 0.22 mg/L), with a minimum of 6.88 mg/L and a maximum of 8.99 mg/L. Conductivity averaged 297.18 (SE ± 9.25), with a minimum of 246.3 and a maximum of 335. Average *E. coli* was

111.55 MPN (SE ± 28.03 MPN), with a minimum of 4.1 MPN and a maximum of 290.9 MPN. Nitrate averaged 5.26 mg/L (SE ± 0.11), with a minimum of 4.79 mg/L and a maximum of 6.01 mg/L. Average pH was 7.61 (SE ± 0.07), with a minimum of 7.29 and a maximum of 6.01. Average total coliforms was 1332.32 MPN (SE ± 262.21), with a minimum of 127.4 MPN and a maximum of 2720 MPN. Turbidity averaged 1.03 NTU (SE ± 0.18 NTU), with a minimum of 0.49 NTU and a maximum of 2.5 NTU.

The highest values for chloride, conductivity, *E. coli*, pH, and total coliform occurred in the summer months of 2012, while the highest values for nitrate and turbidity occurred in the winter months of 2011 (Table 1). High values did not appear to be related to precipitation as very little precipitation occurred previous to sampling dates. There was also no observable pattern to occurrences of above average values ("+" in Table 1) or below average values ("-" in Table 1).

Table 1. Range of water quality measurements recorded from Logan Cave. Highest value is labeled as "H"; lowest value is labeled as "L". A minus (-) indicates a value below the mean, and a plus (+) indicates a value above the mean. "3 Day Precip" is the accumulated precipitation over the previous 3 days.

	2011				2012						
Water Quality Variable	21 Sep	17 Oct	17 Nov	20 Dec	19 Jan	23 Feb	29 Mar	1 May	30 May	9 Jul	1 Aug
Chloride	-	+	L	+	+	+	-	-	H	-	-
Conductivity	+	+	-	-	+	-	L	+	+	H	+
E. coli (MPN)	-	+	-	+	L	-	-	+	-	+	H
Nitrate	L	-	H	-	+	+	+	-	+	-	-
pH	-	-	L	-	+	+	-	-	H	+	+
Total Coliform (MPN)	+	+	-	+	-	L	-	+	+	+	H
Turbidity (NTU)	-	L	+	H	-	-	+	-	-	-	+
3 Day Precip (mm)	31.5	0	5.8	0	0	3.1	0	0	0.3	0.3	0

As expected, *E. coli* was positively correlated with total coliforms (Spearmen ρ = 0.75). Nitrate was negatively correlated with conductivity (Spearmen ρ = -0.69), *E. coli* (Spearmen ρ = -0.64), and total coliform (Spearmen ρ = -0.65). Conductivity was positively correlated with pH (Spearmen ρ = 0.87) and total coliform (Spearmen ρ = 0.61). Combinations of the remaining constituents were more weakly correlated.

The water quality values observed during this project were similar to previous nutrient and metals analysis that were conducted from 2000-2005 (Slay and Snell 2005) and reported by Graening et al (2001). The cave continues to experience elevated chloride, nitrate, *E. coli*, and total coliform levels. Logan Cave is home to a small maternity colony of endangered gray bats which roost in the cave during the summer months, and the presence of gray bats may explain the high values of *E. coli* and total coliform that occurred in the summer months. This observation seems to be supported by the above average values for total coliform from 2012 May-August. While elevated chloride and nitrate continue to be observed, the potential impact to groundwater

organisms such as the endangered Benton Cave Crayfish (*Cambarus aculabrum*) and the threatened Ozark Cavefish (*Amblyopsis rosae*) is unclear. Benton Cave Crayfish counts were similar in number from 1999-2006 (Graening et al. 2006), and the number of Ozark Cavefish has been significantly increasing (Graening et al. 2010).

This project provides an initial set of monthly water quality measurements for Logan Cave NWR, and it begins to establish a baseline of existing groundwater conditions over a one year period. However, a clearer picture of conditions would be gained through a multi-year effort to monitor water quality. Patterns such as elevated *E. coli* and total coliform during the summer months could be more strongly associated with presence of colonial bats if several years of groundwater observations were available. Therefore, a recommendation is made to continue water quality monitoring at Logan Cave NWR.

Acknowledgments

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Appendix 1

Water samples collected from the spring entrance of
Logan Cave from 2011 September to 2012 August

Table A-1. Nutrient and metals profile from groundwater samples collected from the spring entrance at Logan Cave. In alphabetical order from Alkalinity to Lead. N.R. = not reported. * indicates a value to be reported separately.

	2011				2012							
Water Quality Variable	21 Sep	17 Oct	17 Nov	20 Dec	19 Jan	23 Feb	29 Mar	1 May	30 May	9 Jul	1 Aug	Mean
Alkalinity	118.0	110.0	88.0	92.0	116.0	108.0	70.0	118.0	122.0	128.0	6.4	97.85
Aluminum	0.007	0.007	0.009	0.005	0.005	0.006	0.009	0.005	*	*	0.000	0.01
Ammonia	0.02	0.00	0.02	0.00	0.00	0.03	0.00	0.01	0.01	0.04	0.02	0.01
Arsenic	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*	*	0.000	0.00
Barium	0.045	0.044	0.052	0.046	0.041	0.247	0.052	0.039	*	*	0.036	0.07
Boron	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*	*	0.000	0.00
Cadmium	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	*	*	0.000	0.00
Calcium	54.501	48.408	38.728	41.464	47.505	44.757	32.185	50.689	*	*	57.040	46.14
Chloride	7.372	8.843	6.875	8.470	7.857	8.492	7.155	7.142	8.991	7.594	7.596	7.85
Chromium	0.000	0.000	0.000	0.000	0.000	0.003	0.016	0.000	*	*	0.000	0.00
Cobalt	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*	*	0.000	0.00
Conductivity	310.0	302.0	256.0	261.0	307.0	294.7	246.3	298.0	329.0	335.0	330.0	297.18
Copper	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	*	*	0.008	0.00
E. coli (MPN)	99.0	122.3	8.3	145.0	4.1	35.5	105.4	235.9	25.3	155.3	290.9	111.55
Fluoride	0.076	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.01
Hardness	144.0	138.0	110.0	116.0	140.0	128.0	72.0	134.0	144.0	150.0	150.0	129.64
Iron	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*	*	0.000	0.00
Lead	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*	*	0.000	0.00

Table A-2. Nutrient and metals profile from groundwater samples collected from the spring entrance at Logan Cave. In alphabetical order from Magnesium to Vanadium. N.R. = not reported. * indicates a value to be reported separately.

	2011				2012							
Water Quality Variable	21 Sep	17 Oct	17 Nov	20 Dec	19 Jan	23 Feb	29 Mar	1 May	30 May	9 Jul	1 Aug	Mean
Magnesium	1.577	1.574	1.772	1.684	1.508	1.682	1.660	1.667	*	*	1.585	1.63
Manganese	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*	*	0.000	0.00
Molybdenum	0.000	0.000	0.000	0.000	0.000	0.005	0.002	0.013	*	*	0.000	0.00
Nickel	0.003	0.000	0.018	0.000	0.000	0.000	0.008	0.000	*	*	0.000	0.00
Nitrate	4.792	4.993	6.013	5.172	5.428	5.351	5.749	5.222	5.328	4.894	4.886	5.26
Ortho Phosphate	0.024	0.032	0.041	0.038	0.028	0.037	0.027	0.028	0.025	0.027	0.020	0.03
pH	7.5	7.49	7.29	7.33	7.76	7.65	7.40	7.49	8.09	7.83	7.80	7.61
Phosphorus (ICP)	N.R.	0.000	0.000	0.093	0.118	0.000	0.000	N.R.	*	*	N.R.	0.04
Potassium	1.96	2.34	3.37	2.65	1.93	1.65	3.42	2.08	*	*	1.65	2.34
Selenium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*	*	0.00	0.00
Sodium	5.308	5.604	4.921	4.663	4.519	7.043	5.802	4.724	*	*	4.505	5.23
Sulfate	3.265	3.799	6.848	5.745	3.393	3.867	5.859	3.125	3.177	2.991	3.930	4.18
Titanium	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*	*	0.000	0.00
Total Coliform (MPN)	1413.6	1414	770.1	1413.6	142.1	127.4	517.2	2419.0	1732.6	1986	2720.0	1332.32
Total Nitrogen	2.56	6.51	6.40	6.12	5.27	5.26	5.53	5.26	4.59	N.R.	5.24	5.27
Total Organic Carbon UV	N.R.	N.R.	N.R.	N.R.	0.00	0.36	0.83	0.40	0.09	N.R.	0.12	0.30
Total Phosphorus	0.032	0.032	0.046	0.038	0.028	0.034	0.038	0.034	0.030	N.R.	0.036	0.03
Total Suspended Solids	0.5	0.6	0.7	0.8	0.1	1.1	0.8	0.9	0.3	N.R.	2.6	0.84
Turbidity (NTU)	0.6	0.5	1.1	2.5	0.7	0.9	1.3	0.6	1.0	0.5	1.6	1.03
Vanadium	0.000	0.000	0.000	0.000	0.000	0.003	0.006	0.000	*	*	0.000	0.00
Zinc	0.261	0.000	0.000	0.000	0.000	0.101	0.000	0.090	*	*	0.055	0.06