Hell Creek Cave Crayfish
(*Cambarus zophonastes*)

5-Year Review:
Summary and Evaluation

USFWS Photo (D. Kampwerth)

U.S. Fish and Wildlife Service
Southeast Region
Arkansas Ecological Services Field Office
Conway, Arkansas

5-Year Review

Hell Creek Cave Crayfish (*Cambarus zophonastes* Hobbs and Bedinger 1964)

I. GENERAL INFORMATION

A. Methodology used to complete the review:

We announced initiation of this review and requested information from the public in a published *Federal Register* notice with a 60-day comment period on March 12, 2018 (83 FR 10737). During the public comment period, we did not receive any additional new information about the Hell Creek Cave Crayfish. Additional information used in this report was gathered from peer-reviewed literature, published and unpublished data provided by species experts, and from U.S. Fish and Wildlife Service (Service) files. This review was completed by the lead recovery biologist in the Service's Arkansas Ecological Services Field Office (AES).

Comments and suggestions from peer reviewers regarding this 5-year review were evaluated and incorporated as appropriate (See Appendix A). No part of the review was contracted to an outside party. Recommendations are a result of thoroughly reviewing the best available information on this crayfish.

B. Reviewers

Lead Region: Southeast Region, Kelly Bibb, (404) 679-7132

Lead Field Office: AES - Pedro Ardapple, (501) 513-4485

C. Background:

1. **Federal Register Notice initiating this review:** March 12, 2018. (83 FR 10737)

2. **Species status:** Stable. There is no evidence since the last 5-year review to indicate a decline in population or habitat quality. A slight decline in mean number observed during the annual Hell Creek Cave survey (Table 1) warrants further monitoring, but due to unstandardized historical survey methodology and the fact that the survey represents such a small percentage of used habitat for *C. zophonastes,* the decline may not accurately represent a decline in the population. Three populations are extant and a fourth possible population has been suggested, but location has been withheld by the landowner and no genetic confirmation exists. Threats remain similar to our last 5-year review, in that habitat modification and possible fragmentation or destruction continues to be principally affecting the species.

3. **Listing history**
   Original Listing
   FR Notice: 52 FR 11170

Date Listed: April 7, 1987
Entity Listed: Species
Classification: Endangered

4. **Associated rulemakings:** None.

5. **Review History:**
Recovery Plan: 1988

Each year, the Service reviews and updates listed species information for inclusion in the required Recovery Report to Congress. Through 2013, we did a recovery data call that included status recommendations for this crayfish. We continue to show that species status recommendation as part of our 5-year reviews. The most recent evaluation for this crayfish was completed in 2018.

5-Year Reviews:

U.S. Fish and Wildlife Service. 2012. Hell Creek Cave Crayfish (*Cambarus zophonastes*): Summary and evaluation. Conway, Arkansas 19 pp.

November 6, 1991.
In this review (56 FR 56882), different species were simultaneously evaluated with no species-specific, in-depth assessment of the five factors as they pertained to the different species' recovery. In particular, no changes were proposed for the status of this crayfish in the review.

Status Reviews:

Smith, K. 1984. The status of *Cambarus zophonastes* (Hobbs and Bedinger 1964), an endemic cave crayfish from Arkansas. Arkansas Natural Heritage Commission. Little Rock, Arkansas. 15 pp.

Graening, G.O., J.B. Koppelman, B.K. Wagner, M.E. Slay, and C.L. Brickey. 2006. Range extension and status update of the endangered Hell Creek Cave Crayfish, *Cambarus zophonastes* (Decapoda: Cambaridae). Southwestern Naturalist 51 (1): 94-99.

6. **Species' Recovery Priority Number at start of review (48 FR 43098):**
5. This number indicates a high degree of threat and a low recovery potential.

7. **Recovery Plan**
Name of Plan: *Cambarus zophonastes* Recovery Plan
Date Issued: September 26, 1988

II. REVIEW ANALYSIS

A. Application of the 1996 Distinct Population Segment (DPS) policy

The DPS policy only applies to vertebrate species. Since this species is an invertebrate, the DPS policy is not applicable

B. Recovery Criteria

1. Does the species have a final, approved recovery plan containing objective, measurable criteria? Yes.

2. Adequacy of recovery criteria.

a. Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat? No. The recovery criteria calls for finding 9 populations in addition to the Hell Creek population for delisting. Having 10 separate populations may not be required for *C. zophonastes* to not be threatened with extinction as defined in 4(a)(1) of the ESA. In addition, two populations have been documented since the recovery plan was written. The recovery plan does not fully account for the protection of these populations.

b. Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria? Yes

3. List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:

Reclassification of *Cambarus zophonastes* from endangered to threatened could be considered when the following criteria are met:

1) Protection of the existing Hell Creek Cave population by minimizing present and future threats within the cave and its recharge area, by developing and implementing land use regulations, and obtaining conservation agreements or acquiring fee title on all private lands in the extremely high hazard area.
2) Excluding recreational cavers and collectors from the cave.
3) Location and protection (as above) of at least two other viable populations sufficiently removed from Hell Creek Cave and each other so that a single event is unlikely to impact any two populations. Viable populations are those with different age classes including males and females.

If other viable populations are discovered, the species could be considered for delisting when the following criteria are met:

1) The Hell Creek Cave population and at least nine others are known to exist.
2) At least five viable populations and their habitat are protected from present and foreseeable human related and natural threats that may interfere with the survival of any of the populations.

Since each recovery criteria was not specifically addressed in the previous 5-year review, we discuss each criteria below and identify new information obtained for criteria 1, 2, and 3 since the previous 5-year review.

Recovery Criteria 1: Protection of the Hell Creek Cave population. Criteria for downlisting has not been achieved as only 48% of the extremely high risk area of the Hell Creek Cave recharge zone has been protected through fee title acquisition and no land use regulations or conservation agreements have been implemented on the remaining 52%. In addition, less than 3% of the high risk, moderate risk, and low risk recharge zone has been protected (see Figure 1 below). Since the 2012 5-year review, the Arkansas Natural Heritage Commission (ANHC) has added 21 hectares to the 86 hectares of the Hell Creek Cave recharge zone already owned. None of the 1,841 hectares in the recharge zone for the Yellville site or the unknown acreage in the Nesbitt Spring Cave recharge have been protected.

Recovery Criteria 2: Excluding recreational cavers and collectors from the cave. Threats from recreational cavers and collectors have been minimized by gating both access points to Hell Creek Cave. However, the gate has been breached both before and after the last 5-year review. There is very limited law enforcement or staff presence at Hell Creek and the individuals responsible for the breaches were not identified. The Yellville population is inaccessible to humans except when crayfish are flushed from the grotto into the spring branch during high flow events. The Nesbitt Springs Cave is ungated and access is regulated by the owners. No changes in access and no known collections have occurred since the last 5-year review.

Recovery Criteria 3: Location and protection of two other viable populations. Although numerous cave bioinventories have been conducted, criteria for delisting have not been met. It is extremely difficult to determine population viability due to this species being a groundwater dweller with variable biannual counts. At some localities, such as the Yellville site, there is no human access to the cave system. Occupied habitat consists of open and water filled underground conduits, with a high probability that the majority of their habitat is totally inaccessible to

humans. Due to undocumented variability in historical survey routes and the limited area surveyed in only one of the three known populations, it is likely that the surveys do not accurately represent population trends.

Three populations of Hell Creek Cave Crayfish have been genetically verified. However, viability as defined by the presence of different age classes is unknown for the Yellville population. Historical viability was observed at the Nesbitt Springs Cave, but current status is unknown. The three populations are separated such that a single event is unlikely to impact any two populations. The existence of a fourth site has been suggested, but location has been withheld and the population is unverified.

C. Updated Information and Current Species Status

1. Biology and Habitat

C. zophonastes was first described based on five specimens collected from Hell Creek Cave (Hobbs and Bedinger 1964). This cave crayfish is stygobitic, lacks pigment and eyes, and has an overall body length reaching 2.5 to 3.0 inches. *C. zophonastes* biology and life history are not understood as no data is available regarding life span, fecundity, egg and fry survival, or other aspects of the species' ecology. An ovigerous (egg bearing) female was discovered in Hell Creek Cave, suggesting reproduction occurs in the late winter and spring months with higher water levels and nutrient inputs triggering reproduction (Smith 1984). Cave crayfish research in Florida suggests life spans of 40 years or more (Hobbs pers. comm.), although no research has been conducted on *C. zophonastes* to determine its life span. *C. zophonastes* is found on muddy stream bottoms, cave stream walls, and other in-stream habitats. Specific habitat preferences have not been studied and are not readily apparent to trained observers. Individuals demonstrate no response to light or observation; however, once attempts are made to capture the crayfish, they quickly recognize the threat and attempt to avoid capture.

Hell Creek Cave was the only known location for this species until Nesbitt Spring was verified in 2005, and the Yellville site in 2009. The Yellville site is not accessible to humans. Individuals collected at Yellville are typically caught in Town Branch, a normally dry stream bed, or an adjacent vent pipe, which appears to be where crayfish are occasionally expelled from during storm events. Interestingly, the location of the newest site is approximately 40 miles northwest of the other known sites, which are found near one another. This suggests a much wider subterranean distribution of the species than originally described.

Population genetics data are available, but not published (Koppelman, pers. comm.). Genetic data have been useful in confirming the identification of specimens from newly discovered populations of cave

crayfish throughout the Ozarks, including *C. zophonastes* from Nesbitt Spring Cave and Yellville.

Hell Creek Cave is a limestone phreatic conduit developed in the Plattin Formation of Ordovician age. Waters within the Hell Creek Cave are contributed to through surface losing stream reaches within the Hell Creek Cave delineated recharge zone (Figure 1; Aley and Aley 1985). Groundwater from Hell Creek Cave resurges below the cave and continues as surface flow along Hell Creek until its confluence with the White River. The cave is several thousand meters long and ends in a terminal sump only accessible to cave divers. A 53-meter cave pit was expanded during a mining scam in the early 1900's, ending at the terminal sump. This shaft allows for introduction of organic matter and terrestrial organisms directly into the cave system. The sump was explored by members of the Mid-Ozark Sump Team in 2000 and members of the Ozark Cave Diving Alliance (OCDA) in 2007, extending the known cave passage by 458 meters or more.

Nesbitt Spring Cave is also a limestone phreatic conduit developed in the Plattin Formation of Ordovician Age. During 2007, a groundwater tracing study was conducted to determine the size of the surface recharge zone for Nesbitt Spring (Figure 2; Gillip et al. 2009). Losing stream reaches and sinkholes within the predicted recharge zone are likely direct conduits for introduction of surface waters to the cave. In 1992, "dozens" of stygobitic crayfish were reported during a combined surface and cave dive survey, and in 2005, members of the OCDA sighted nine stygobitic crayfish and collected six with subsequent pereopod removal for genetic analysis. All specimens were returned to the cave alive, with the exception of one that was injured during capture and preserved as a voucher specimen. Genetic analysis conducted by Jeff Koppelman with the Missouri Department of Conservation determined these crayfish to be *C. zophonastes*. Cave divers are able to access two sumps with open air passage being found between. A third internal sump has not been explored to determine additional underwater passage. In 1961, Bedinger and Stephens located 5 individuals at Hell Creek Cave. Eight of the first nine *C. zophonastes* observed there were collected as the type series and as museum vouchers. The first *C. zophonastes* census (traversable and dive portions) in Hell Creek Cave occurred in 1983 and numbers have ranged from 1 to 15 (Table 1). Since 2001, partial surveys of the traversable passage have been conducted in lieu of difficult to complete census surveys (Table 1; Graening et al. 2006). When possible, partial census counts occur on a biannual basis. Surveys since 2009 have categorized individuals as small (less than one inch), medium (1 – 2 inches), and large (greater than 2 inches). No data is available to assess whether sufficient levels of reproduction and recruitment are occurring to sustain the population at historical levels. Mean number of observed crayfish is slightly below historical counts in

the traversable passage (Table 1). No counts have been conducted at Nesbitt Springs since the last 5-year review.

Table 1. *Cambarus zophonastes* survey data for Hell Creek Cave (HCC) and Nesbitt Spring Caves, 1961 – 2017; collected by U.S. Fish and Wildlife Service, Arkansas Natural Heritage Commission, and the Nature Conservancy.

Year	HCC (# Individuals)	HCC; small: medium: large	Nesbitt Spring Cave (# Individuals)
1961	5	NR[2]	NS[1]
1972	2	NR	NS
1980	2[3]	NR	NS
1983	15[4]	NR	NS
1990	13[4]	NR	NS
1992	2[3]	NR	"dozens"[4]
2000a	6[3]	NR	0[3]
2000b	2[3]	NR	NS
2001	8[5]	NR	0[3]
2002	NS	NR	2[3]
2004	6[3]	0:5:1	0
2005	NS	NR	9[4]
2007	12	NR	NS
2009	2[3]	0:0:2	NS
2013	4[3]	0:2:2	NS
2015	1[3]	0:1:0	NS
2017	2[3]	0:0:2	NS

1 – Not sampled
2 – Not recorded
3 – Partial count, traversable portion of cave
4 – Traversable and dive portions of cave
5 – Only dive portion of cave

The upwelling adjacent to Town Branch in Yellville has flushed two known *C. zophonastes* into Town Branch, one of which was sacrificed for genetic analysis and a second individual that was returned to the upwelling site. The groundwater system at this site is not accessible to humans. As such, it is impossible to conduct census counts at this site. In 2012, Kirkland and Aley delineated the groundwater recharge area for the upwelling adjacent to Town Branch and identified threats to *C.*

zophonastes within the recharge (Figure 3). The recharge area was determined to be 1,841 hectares.

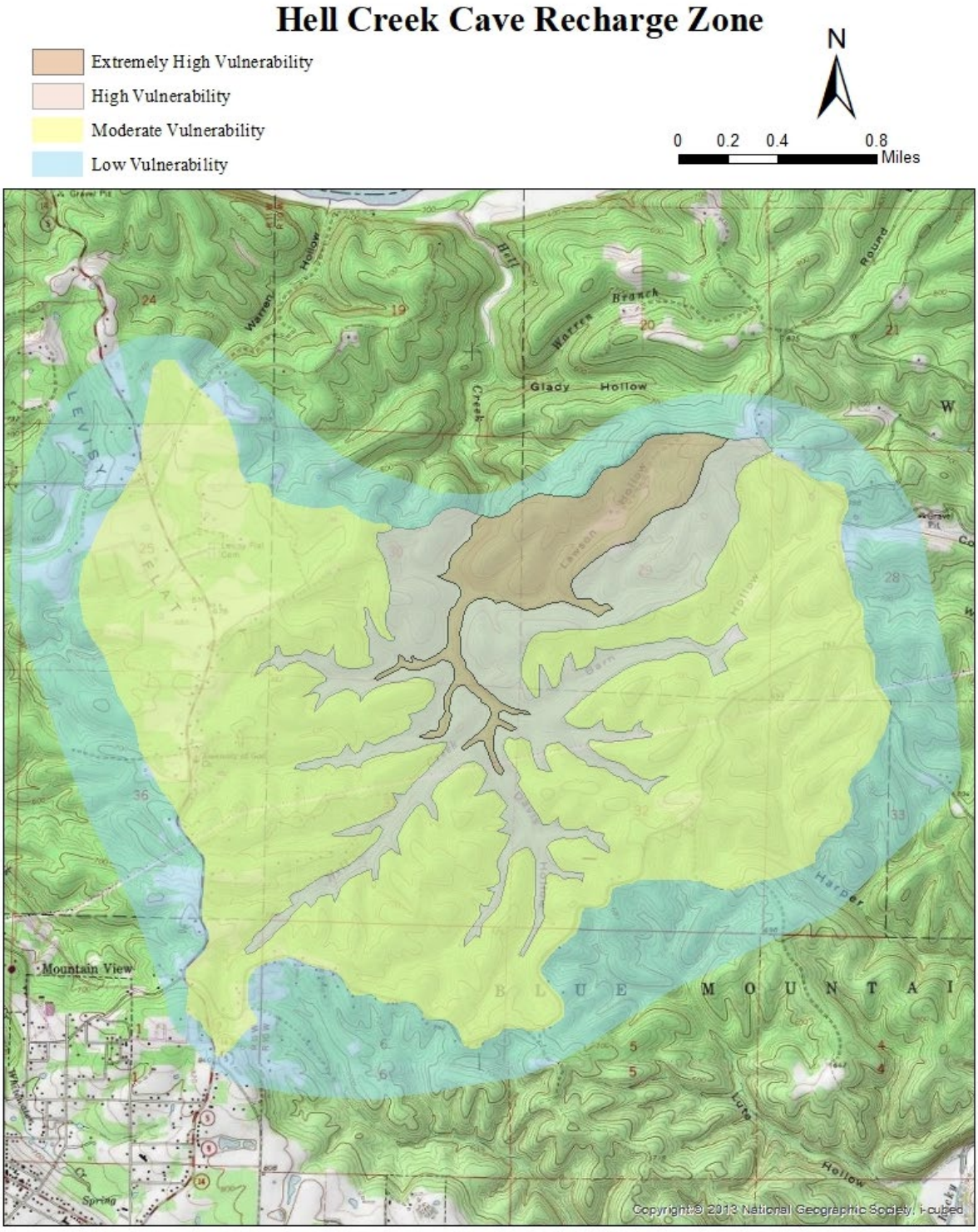

Figure 1: Groundwater recharge area for Hell Creek Cave delineated by low, moderate, high, and extremely high vulnerability.

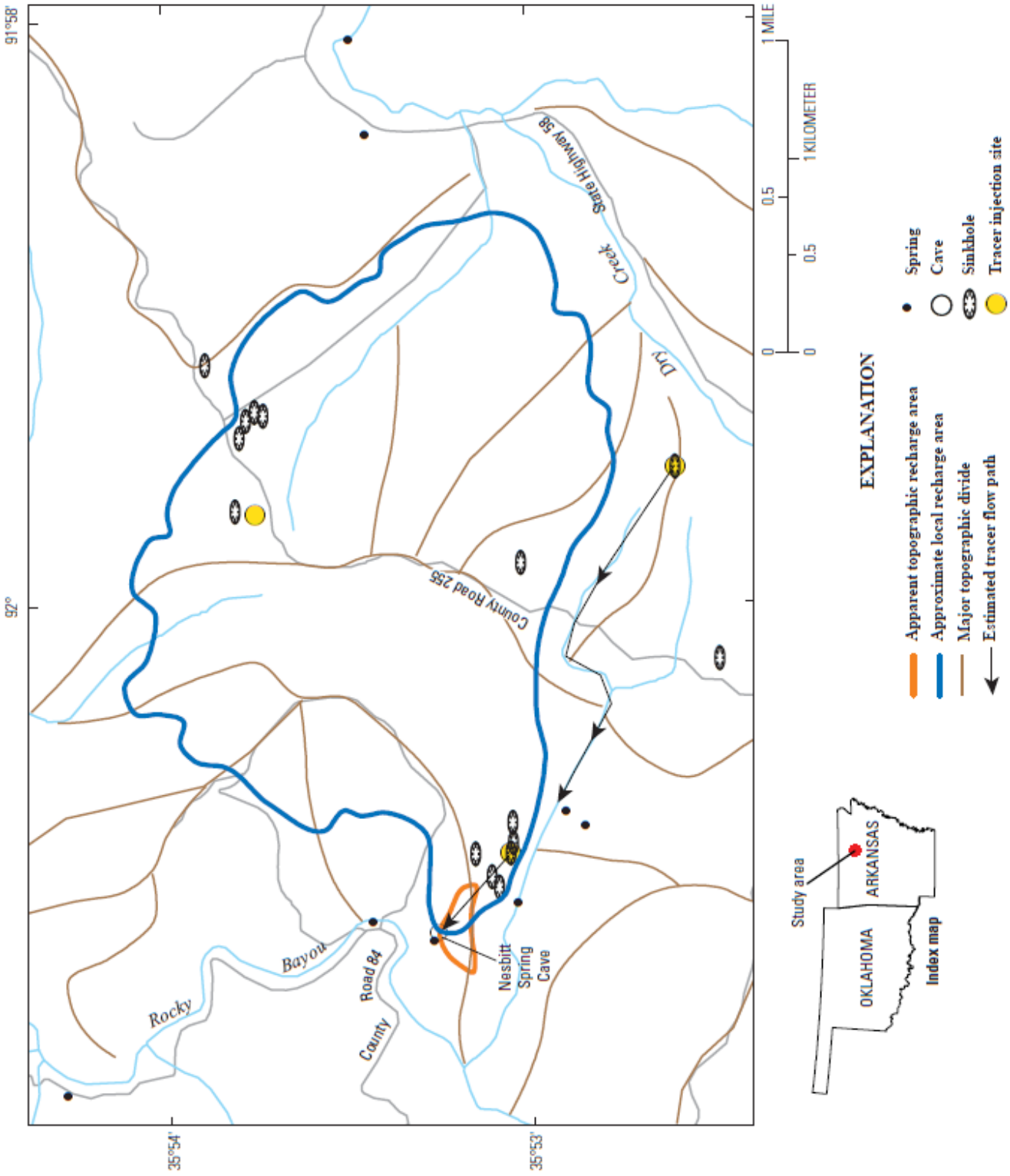

Figure 2: Groundwater recharge area and groundwater tracing results for Nesbitt Spring Cave (Gillip et al. 2009).

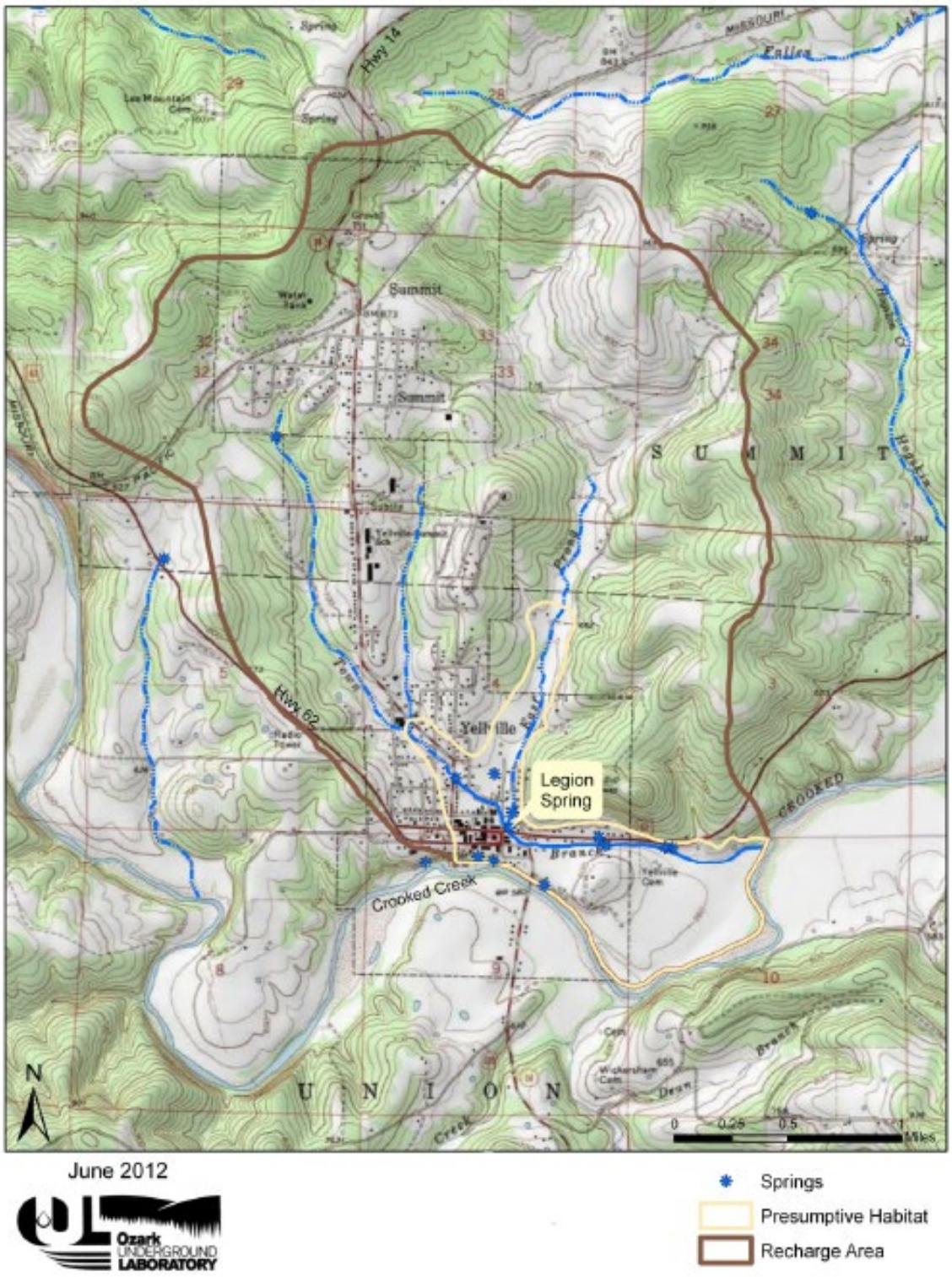

Figure 3: Recharge area for the upwelling at Town Branch in Yellville (Kirkland and Aley 2012).

2. Five-Factor Analysis

a. Present or threatened destruction, modification, or curtailment of its habitat or range:

As described under the Biology and Habitat section, it is difficult to ascertain what is occurring underground and the status of this species. Given an understanding of the functionality of the karst landscape in which this and other sites occur, the best indicator of population viability is the landscape above and threats posed by land management activities. Analysis of land use change in the Hell Creek Cave recharge area suggests that from 1994-2016 cleared land in the recharge zone increased roughly 25%. In addition, a gravel mine was initiated in the recharge zone during the same period, but it is currently inactive.

In 2006, a housing development adjacent to the Hell Creek Cave recharge zone failed to apply sufficient erosion control measures. As a result, creek sedimentation occurred. Service, ANHC, and ADEQ coordination with the developers occurred immediately. Erosion and sedimentation concerns were rectified and subsequently an ADEQ permit was issued. Stormwater runoff from this and other developments, potential hazardous material spills along adjacent highways, and land application of animal litter pose ongoing risks to the species and its habitat. Aley and Aley (1985) analyzed threats within the Hell Creek Cave recharge zone and identified 12 potential contamination sources including animal litter, illegal dumping of waste, underground petroleum storage tanks, maintenance of electrical transmission line right of ways, and unmanaged septic systems. Water quality sampling conducted in 2000 and 2001 determined all parameters met Arkansas Pollution Control and Ecology Standards and were comparable to regional levels reported by the National Water Quality Assessment Program (Graening et al. 2006).

The predicted recharge zone for Nesbitt Spring is mostly a rural setting and contains fewer identified threats than the Hell Creek Cave recharge zone. This is largely due to the fact that the predicted recharge is almost exclusively forest and contains no major roads, housing developments, or agriculture. Subsequent to determination of this site as being occupied by *C. zophonastes*, a timber management action within the predicted recharge zone removed trees from sinkholes thereby possibly increasing sedimentation to the cave, although no evidence has been collected to verify any adverse effects from the harvest. Current and future land management practices pose a potential threat to *C. zophonastes* at Nesbitt Spring.

The Yellville site is in an urban area (population 1,204 as of 2010 census). In 2011, there was an accidental release of gasoline from an underground storage tank. A dye trace study was being conducted at the time and

surveyors believe the majority of fuel remained above the most sensitive layer of the spring system that likely harbors *C. zophonastes*. This may have been due to the fact that the majority of the recharge area was upslope of the spill. In addition to urban runoff, threats typically associated with rural areas such as agriculture and septic field systems are possible threats to *C. zophonastes* at the Yellville site.

Ongoing recovery efforts are focused on cooperation and coordination with private landowners, the communities of Mountain View and Yellville, and establishing an appropriate response to a hazardous material spill with the Arkansas Department of Transportation (ArDoT).

b. Overutilization for commercial, recreational, scientific, or educational purposes:

While overutilization was a concern in the past, including the collection of 8 individuals from 1961 to 1980 at Hell Creek Cave and 2 from Nesbitt Spring Cave, additional voucher specimens are not permitted for collection. No collection has occurred since the last 5-year review. In 2005, 5 pairs of walking legs were collected for genetic analysis at both Hell Creek and Nesbitt Spring Caves. These crayfish were returned alive to the caves. One specimen was collected and preserved for genetic analysis at the Yellville site to confirm the species identity and one specimen was collected from Nesbit Spring due to a collection injury. Genetic material collection aids in establishment of a comparative baseline genetic library and allows the individual cave crayfish to be returned to its habitat.

Trampling of cave crayfish has been documented and is considered a continued threat to this species. While a cave gate and fence have been installed at Hell Creek Cave, no such human barrier has been installed at Nesbitt Spring Cave. Both caves have had unauthorized entries, increasing the risk for trampling as well as collection of this species for various purposes. However, collection or inadvertent trampling is currently thought to be a minimal threat.

c. Disease or predation:

We have no evidence of disease in *C. zophonastes*. Cave species' endemicity suggests that the potential exists for transport of unknown parasites or diseases from cave to cave by researchers or recreational cavers. It is a standard protocol (prior to White-nose Syndrome and now in accordance with the National White-Nose Syndrome Decontamination Protocol) that all cave gear be cleaned and decontaminated before biannual surveys. We have no evidence of predation on *C. zophonastes*, although numerous surface crayfish, fish, and small mammals enter the

cave making predation likely. Regardless, predation is likely minimal and not believed to be a threat to the continued existence of the species.

d. Inadequacy of existing regulatory mechanisms:

While surface streams have water quality standards that are monitored and enforced, existing regulatory mechanisms regarding the protection of groundwater resources are limited. Progress is being made by the Arkansas Natural Resources Commission and ADEQ for development of groundwater standards. ADEQ conducts groundwater quality monitoring throughout the state, but Hell Creek Cave Crayfish sites are not included in their scheduled sampling. Similarly, the EPA has regulations and standards outlining water quality conditions for groundwater based on human health standards. However, EPA regulations and management guidance necessary to protect groundwater from non-point source pollution do not exist.

States report that nonpoint source pollution is the leading remaining cause of water quality problems. The effects of nonpoint source pollutants on specific waters vary and may not always be fully assessed. However, these pollutants have harmful effects on fisheries and wildlife (http://www.epa.gov/owow_keep/NPS/whatis.html).

The objective of the Federal Water Pollution Control Act, commonly referred to as the CWA (33 U.S.C. 1251 *et seq.*), is to restore and maintain the chemical, physical, and biological integrity of the nation's waters by preventing point and nonpoint pollution sources and a stated goal that "…wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983." States are responsible for setting and implementing water quality standards that align with the requirements of the CWA. Overall, implementation of the CWA could benefit *C. zophonastes* through the point and nonpoint programs.

Sources of NPS pollution within the recharge areas occupied by *C. zophonastes* include timber harvest, clearing of riparian vegetation, urbanization, road construction, and other practices that allow bare earth to enter streams, sinkholes, and other conduits that transport surface waters to groundwater systems. Currently, the CWA may not adequately protect *C. zophonastes* habitat from nonpoint-source pollution. Point-source discharges within the range of *C. zophonastes* are primarily restricted to Yellville. However, because there is very little information known about water quality parameters necessary to fully protect cave crayfish, it is difficult to determine whether the CWA is adequately addressing point-source threats to this species. Given that a goal of the CWA is to establish

water quality standards that protect aquatic life, we take a conservative approach in favor of the species and conclude that the CWA regulations are insufficient to provide adequate protection and significantly reduce or remove threats from point source or NPS pollution.

e. Other natural or manmade factors affecting its continued existence:

C. zophonastes are cave stream/groundwater obligates that require sufficient stream flow for long-term survival. Research suggests that climate change will impact availability of ground and surface water, but the impacts to specific areas are hard to predict (Kumar 2012). The species' range is confined within the Ozark Aquifer which is currently being depleted (ANRC 2007). If climate change negatively impacts ground and surface water availability in the area or depletion of the aquifer for anthropogenic purposes continues, it may threaten species persistence. The species' limited range and low genetic diversity are likely to inhibit the ability of *C. zophonastes* to adapt to changing habitat conditions, further increasing the likelihood of extirpation.

3. Conservation Measures

Conservation measures in the Hell Creek Cave recharge zone are ongoing. Biannual population surveys have and will continue to be carried out. Biannual monitoring of water quality has been proposed and is expected to be implemented during the next biannual survey. The cave gates at the mine shaft and natural entrance are monitored for breaches several times a year. During 2018, ANHC acquired two properties totaling 21 hectares that were platted as part of a neighboring subdivision and effectively stopped the installation of 15 septic tanks. In addition, ANHC is in regular contact with neighboring landowners in case the opportunity to acquire additional land arises. Public outreach to raise awareness and cooperation in the local community is ongoing.

Conservation measures at Nesbitt Springs have stalled due to restricted access by the landowner. However, the Nature Conservancy has been in contact with the landowner and said they are unlikely to sell the property in the near future.

Due to the location of the Yellville population in an urban setting, conservation measures have been limited. Acquisition of large tracts is difficult and more costly than in many rural areas. However, public outreach to raise awareness, cooperation, and coordination with private landowners is ongoing.

D. Synthesis

C. zophonastes occurs with a broader distribution than originally described. Direct enumeration of populations does not assure stability due to the extreme difficulty of conducting surveys and the inability to survey more than what is believed to be a small section of *C. zophonastes* habitat. In addition, no data on reproduction exists to evaluate the threat of low or no reproduction, as identified in the recovery plan. As such, the presence of multiple size classes, as well as land management and water quality studies within the delineated and predicted recharge zones serve as predictors of population viability. Threats within the predicted or delineated recharge zones include point and nonpoint source contaminants from illegal refuse dumping, salvage yards, malfunctioning septic systems, and discharge of urban storm water and treated municipal sewage. While surface and groundwater quality sampling conducted to date in the recharge areas has not detected excessive nutrient, bacteriological, metals, or other contaminants, land management within the recharge areas continues to potentially threaten populations. Additional work should be focused on private landowner, city, county, and ArDoT coordination, thereby ensuring their knowledge of site sensitivity and building cooperative management strategies for conservation of groundwater resources. Continued biannual census counts and water quality monitoring will be essential for assessing population trends and re-evaluating the species' status. *C. zophonastes* and its habitat continue to be threatened by trampling or disturbance from amateur cavers and land use activities in the recharge areas. For these reasons, we believe *C. zophonastes* still meets the definition of an endangered species and do not recommend a change in status at this time.

III. RESULTS

A. Recommended Classification:

The status of *C. zophonastes* should remain unchanged.

B. Recovery Priority Number ___5__

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

The following priority actions should be undertaken: 1) continue efforts to prevent human disturbance to cave systems containing *C. zophonastes* through the use of outreach, signage, surveillance, and gating, 2) continue to establish partnerships with private landowners, local businesses, city officials, and county officials to share the importance of the cave ecosystem and solicit their support in conservation initiatives, 3) continue searching for additional sites, 4) establish a water quality monitoring program at currently known sites, 5) continue efforts to purchase conservation easements or acquire lands within recharge zones, and 6) continue biannual monitoring efforts.

V. REFERENCES

Arkansas Natural Resources Commission [ANRC]. Arkansas Ground Water Protection and Management Report for 2007. 186pp

Aley, Thomas and Catherine Aley. 1985. Water Quality Protection Studies Hell Creek Cave, Arkansas. Report to Arkansas Natural Heritage Commission and The Nature Conservancy. 44pp.

Hobbs, H.H., Jr., and M.S. Bedinger. 1964. A new troglobitic crayfish of the genus *Cambarus* (Decapoda, Astracidae) from Arkansas with a note on the range of *Cambarus cryptodytes* Hobbs. Proceedings of the Biological Society of Washington 77: 9-16.

Hobbs, H.H., Jr. 2007. Personal Communication. Horton Hobbs. Regarding studies conducted to determine possible life spans of cave crayfish in North America. Professor of Biology. Wittenberg University. Springfield, Ohio.

Gillip, J.A., Galloway, J.M., and Hart, R.M., 2009, Assessment of local recharge area characteristics of four caves in northern Arkansas and northeastern Oklahoma, 2004-07: U.S. Geological Survey Scientific Investigations Report 2009-5118. 25 pp.

Graening, G.O., J.B. Koppelman, B.K. Wagner, M.E. Slay, and C.L. Brickey. 2006. Range extension and status update of the endangered Hell Creek Cave Crayfish, *Cambarus zophonastes* (Decapoda: Cambaridae). Southwestern Naturalist 51:392-396.

Kirkland, S.L., and T. Aley. 2012. Groundwater recharge area delineation and vulnerability assessment of the cave crayfish (*Cambarus zophonastes*) site at Yellville's Legion Spring Marion County, Arkansas. Ozark Underground Laboratory, Protem, Missouri. 66pp.

Kumar, C.P. 2012. Climate change and its impact on groundwater resources. International Journal of Engineering and Science 1(5): 43-60.

Koppelman, J. 2005 and 2009. Personal Communication. Regarding the results of cave crayfish genetic samples collected in Arkansas. Resource Scientist. Missouri Department of Conservation. Columbia, Missouri.

Smith, Kenneth L. 1984. The status of *Cambarus zophonastes* (Hobbs and Bedinger), an endemic cave crayfish from Arkansas, Arkansas Natural Heritage Commission. 12 pp+ attachments.

U.S. Fish and Wildlife Service. 1987. Endangered and threatened wildlife and plants: Determination of endangered status for *Cambarus zophonastes*. U.S. Fish and Wildlife Service. Federal Register 52(66): 11170-11172.

U.S. Fish and Wildlife Service. 1988. Recovery plan for the cave crayfish (*Cambarus zophonastes*). Atlanta, Georgia. 18pp.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of Hell Creek Cave Crayfish (*Cambarus zophonastes)*

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__**X**_ No change needed

Review Conducted By: Pedro Ardapple, Arkansas Ecological Services Field Office

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve MELVIN TOBIN Digitally signed by MELVIN TOBIN Date: 2019.04.17 15:39:09 -05'00' Date _____

Appendix A. Summary of peer review for the 5-year review of Hell Creek Cave crayfish (*Cambarus zophonastes)*

A. Peer Review Method: We requested peer review from three species experts, Mike Slay (TNC), Bryan Rupar (ANHC) and Brian Wagner (AGFC). We received responses from Brian Wagner and Bryan Rupar and incorporated their suggestions into the document as appropriate.

B. Peer Review Charge: We asked peer reviewers to review the 5-year review and provide edits and comments. We did not request peer reviewers provide recommendations on the classification of the species.

C. Summary of Peer Review Comments/Report: Peer reviewers considered the 5-year review to be biologically defensible and based on the best available scientific information. They agreed with the species' status information and proposed conservation actions. Most comments were editorial in nature, with minor comments. Comments included (1) a request to remove the statement that genetic material collection not be authorized from Hell Creek or Nesbitt Springs Caves in the future because it implies that there is no important information to be gained from additional genetic samples and that sampling is harmful and (2) a correction that *C. zophonastes* are groundwater obligates, not cave stream obligates.

D. Response to Peer Review: We added accepted edits to the review as appropriate. Minor comments summarized above were addressed as follows, respectively: (1) the statement was removed, (2) the statement was adjusted to say cave stream/groundwater.