History of Habitat Restoration and Management for Barton Springs and Austin Blind Salamanders (*Eurycea sosorum* and *Eurycea waterlooensis*)

SR-19-03, February 2019

Donelle Robinson Ph.D., City of Austin, Watershed Protection Department. 505 Barton Springs Road, Austin, TX 78704. Donelle.Robinson@austintexas.gov

Abstract

*The largest known populations of the endangered Barton Springs Salamander (*Eurycea sosorum*) and Austin Blind Salamander (*E. waterlooensis*) are found at four springs in Zilker Park, three of which were modified in the 1800s and early 1900s to the detriment of salamander habitat. Here, I summarize significant changes to the natural habitat and efforts by the City of Austin since the 1990s to improve salamander habitat.*

Introduction

The endangered Barton Springs Salamander (*Eurycea sosorum*) and Austin Blind Salamander (*E. waterlooensis*) are found at a small number of springs located on the Barton Springs segment of the Edwards Aquifer (Chippindale et al. 1993, Hillis et al. 2001, McDermid et al. 2015, Devitt and Nissen 2018). Four springs in Zilker Park (Parthenia, Eliza, Old Mill, and Upper Barton springs) were the first springs where Barton Springs Salamanders were found, with the largest known salamander populations currently occurring at Parthenia and Eliza springs (City of Austin 2013, Bendik and Dries 2018, Dries and Colucci 2018). These four springs are the only locations where Austin Blind Salamanders have been found (City of Austin 2013).

The major threats to these species include decreases in water quality, water quantity, and surface habitat modification (U.S. Fish and Wildlife Service 2016). Salamanders require aquatic vegetation and limestone substrate with interstitial spaces to hide, benthic macroinvertebrates for prey, clean spring water, and riparian vegetation (City of Austin 2013). Three springs in Zilker Park (Eliza, Old Mill, and Parthenia) were highly modified by humans in the late 1800s and early 1900s to the detriment of salamander habitat and the salamander populations (City of Austin 1998, 2013). In addition to permanent physical changes, recreation and associated maintenance can lead to ongoing disturbance of salamander habitat.

Since the Barton Springs Salamander was described in 1993 (Chippindale et al. 1993) and listed as endangered in 1997 (U.S. Fish and Wildlife Service 1997), the City of Austin has made significant changes to how these springs are managed to protect and improve the salamander habitat at the springs in Zilker Park. Many of these changes are included in the Barton Springs Pool Habitat Conservation Plan (City of Austin 1998, 2013), and some were established earlier in the City's Surface Habitat Management Plan (City of Austin 1996b). Measures in the HCP reduce threats to salamanders associated with maintenance at Barton Springs Pool and eliminate recreational take at Eliza Spring and Old Mill Spring by keeping these springs closed to the public. While aquatic habitats are expected to change with natural disturbance events such as floods and droughts, human disturbances can change habitat in ways that species are not adapted. Habitat restoration and management have improved salamander habitat and decreased the impacts of the human disturbance to these habitats. This report summarizes these efforts.

Habitat Modifications and Restoration at Each Spring

Parthenia Spring

Barton Springs Pool is constructed around Parthenia Spring (also known as Main Spring) and consists of dams to increase water depth and concrete walls to form the sides of the pool (Figure 1). Prior to these modifications, Parthenia Spring was contiguous with the rest of Barton Creek (Figure 2). Most of the permanent modifications for Barton Springs Pool occurred in the 1920s-1930s, and the 1970s, though other changes, such as temporary dams and water diversion to mills along Barton Creek, have occurred since the 1800s (Limbaucher and Godfrey Architects 2008, City of Austin 1998, 2013). During construction of the pool, the creek area surrounding Parthenia Spring was deepened, leveled, and widened (City of Austin 2013). The bypass tunnel that runs underneath the north sidewalk was constructed in 1974 to divert Barton Creek water from entering the pool until Barton Creek's upstream flow reaches approximately 700 cubic feet per second. The bypass tunnel helps maintain higher water quality at Parthenia Spring by reducing pollutants from upstream from entering salamander habitat, especially during small rain events (City of Austin 2000). However, the dams have several negative impacts to the salamanders. The dams deepen the water and disconnect Barton Springs Pool from the rest of the Barton Creek ecosystem, which probably changes the composition of plants and animals that occur in salamander habitat. The dams also slow water flow, which reduces the natural flushing of sediment from substrate. Sediment can embed the substrate that salamanders need and decrease salamander abundance (Bendik and Dries 2018, Dries and Colucci 2018).

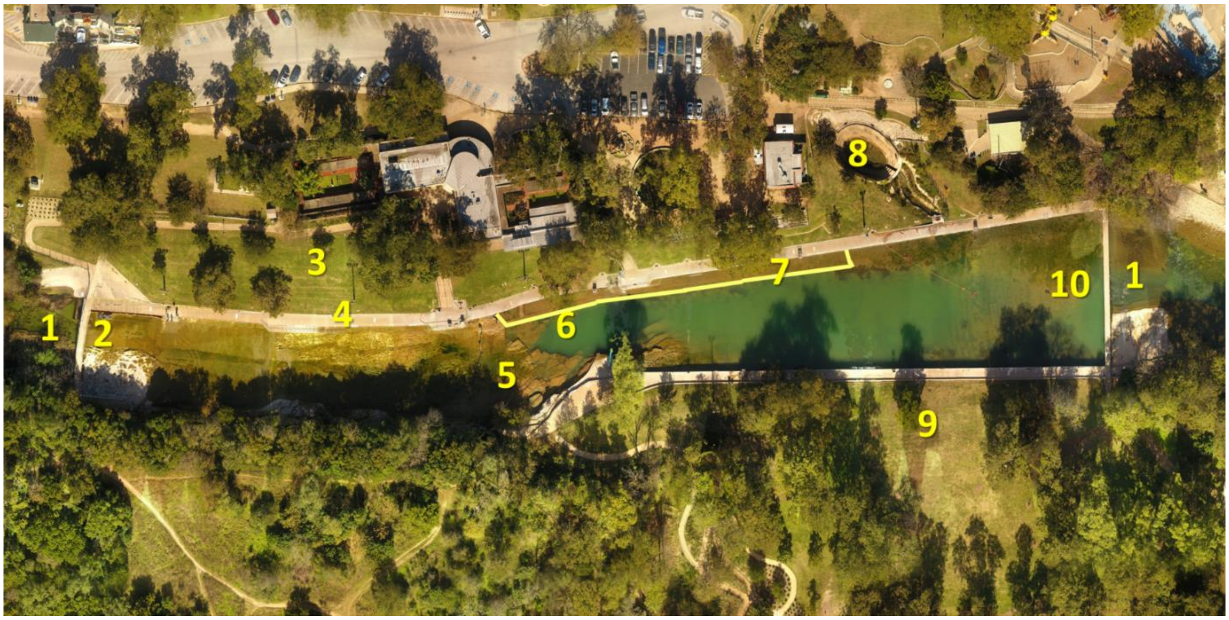

Figure 1. Aerial view of Barton Springs Pool during a full drawdown. Labels indicate: 1 Barton Creek, 2 upstream dam, 3 north lawn, 4 sidewalk with bypass tunnel underneath, 5 fissures, 6 Parthenia spring, 7 beach habitat (outlined), 8 Eliza spring, 9 south lawn, 10 downstream dam.

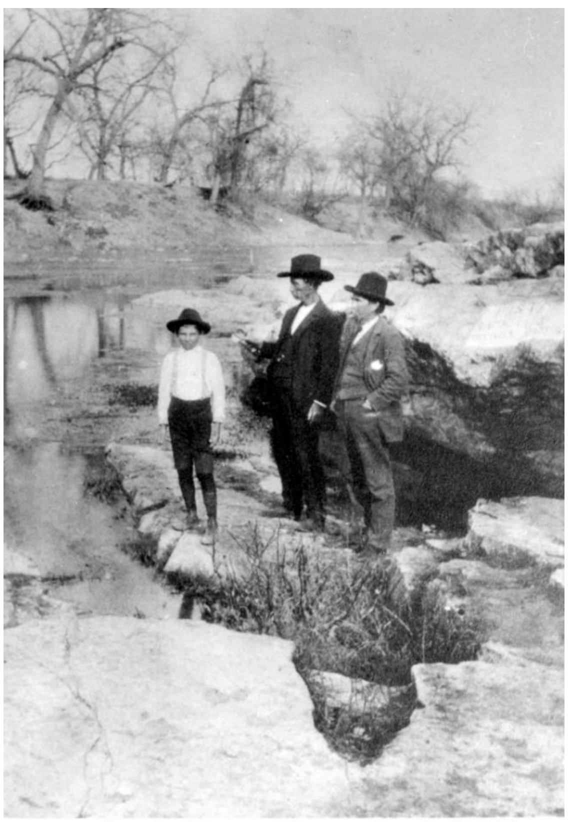

Figure 2. Barton Creek at Parthenia Spring before the water level was raised for Barton Springs Pool. Undated photo from the Austin History Center, C00078.

The 1998 Barton Springs Pool Habitat Conservation Plan (City of Austin 1998) led to major changes in how Barton Springs Pool was managed, allowing the spring ecosystem to return to a more natural state and protecting salamanders and their habitat. For example, chemicals, such as chlorine and copper sulfate, are now prohibited for pool cleaning. Cleaning procedures that used to disturb salamander habitat, including scrubbing algae and using high pressure fire hoses to remove sediment, are now banned in habitat (City of Austin 1996b, 1998, 2013). The frequency that the water level is lowered in the pool (i.e. pool drawdowns) has been reduced to decrease the amount of disturbance in salamander habitat. Drawdowns of the pool are limited to 4 full drawdowns of approximately 4 feet to reduce habitat disturbance and only occur when Barton Springs discharge is at or above 54 CFS to reduce the amount of habitat that becomes exposed. Once the downstream dam was modified to control the water level in 2000, 8 partial drawdowns were added to this annual limit. Salamander biologists are present during drawdowns to rescue stranded salamanders and reduce mortalities associated with the drawdown. Altogether, these changes reduce anthropogenic disturbances, resulting in a more natural aquatic ecosystem and better salamander habitat. These measures also substantially reduce the threat of chemicals contaminating the pool, allow aquatic vegetation to persist, and decrease the risk of injuring or harming salamanders during cleaning activities. In addition, lifeguards are trained to notice actions by swimmers that may disturb salamander habitat.

Other changes and maintenance practices have been implemented to counteract some of the effects of the impoundment caused by the pool. Salamander biologists flush sediment from salamander habitat near the springs regularly (City of Austin 1998, 2013, 2014, 2016, 2018a). After cleaning, the top 2–3" of substrate are clear of sediment for salamanders. Partial drawdowns have also been used to help clear sediment from the fissures area by mimicking a more natural hydrology without disturbing much salamander habitat. In the future, a project to reopen gates in the upstream dam would allow Barton Creek water to enter the pool periodically during baseflow with higher water quality in the creek and may help remove flood debris. This may also improve the connection to the creek and allow plant material, fish, and invertebrates to enter the pool. Barton Springs has had a naturally occurring habitat for predatory fish a long time (Jordan and Gilbert 1886). We do not expect the fish entering through the upstream dam to result in an increased density beyond what already occurs in the Parthenia spring ecosystem, because frequent flooding and gate openings downstream already allow predatory fish to enter and exit the pool. Native plants have been added to Barton Springs Pool several times since 1993 (City of Austin 1996a, 1998, 2013). Plants previously had disappeared due to dredging and cleaning procedures, flooding, and sometimes due to overconsumption by aquatic animals (Chippindale et al. 1993; City of Austin 1998, 2013).

Salamander habitat also occurs on a shallow concrete ledge along the north side of the pool called "the beach." This area is heavily disturbed by swimmers, so the City made the beach deeper in 1999 to reduce habitat disturbance by swimmers and to prevent it from being dewatered when the pool water level is lowered for cleaning (Figure 3). Original plans were to lower the entire beach from 4 feet to a minimum depth of 6.5 feet, but this was not possible in some areas because it would destabilize the concrete-encased skimmer drain (City of Austin 2002) and the bypass wall. Consequently, substantial habitat disturbance still occurs. The biggest benefit of lowering the beach is that salamander habitat remains wetted during pool drawdowns. Adjustable gates were also installed in the downstream dam, which control the water level during drawdowns so that partial drawdowns for pool cleaning can occur during low flow conditions (City of Austin 2013) without causing the beach to become exposed.

Figure 3. Beach area of the pool in 1998 before the beach depth was lowered (above) and after in 2008 (below). Both photos were taken during pool drawdowns.

Changes to the areas surrounding Barton Springs Pool also protect salamander habitat at Parthenia spring. Gasoline-powered equipment has several restrictions, including fueling and maintenance occurring away from the springs and using spill pads underneath equipment. Storm water from the south parking lot used to enter Barton Springs Pool, bringing with it pollutants and sediment runoff (City of Austin 2002). The parking lot was paved with concrete and a berm was added that diverts runoff away from the pool. On the southside, native vegetation was added to the south lawn and exotic species removed (City of Austin 2015), which can help reduce erosion and contribute organic matter to the food web in Barton Springs Pool.

Timeline of Significant Changes to Parthenia Spring
1920s–1930s Parthenia Spring vicinity altered to create Barton Springs Pool
1950s Concrete added to the shallow end
1974–1976 Bypass system constructed to reduce water entering from Barton Creek
1993 Aquatic vegetation planted (first of several plantings)
1996 Surface Habitat Management Plan in effect
1998 Elimination of drawdowns when flow less than 54 cfs
1998 First Habitat Conservation Plan in effect
1999 Beach habitat lowered
2000 Adjustable downstream gates installed to control water level during drawdowns
2004 Prohibit use of stiff brushes to clean salamander habitat
2013 Second Habitat Conservation Plan in effect
2015 Riparian vegetation planted on south lawn.

Eliza Spring
Eliza Spring (also known as Concession Spring, Polio Pit, Elks Spring, or Walsh Spring[1]) is located on the north side of Barton Springs Pool. Eliza Spring and its salamander habitat were highly modified during the 1900s (Figures 4–7). An amphitheater was constructed around the spring pool by Andrew Zilker and used as a meeting space for the Elks Club (Figure 5, City of Austin 1998, 2013, Limbaucher & Godfrey Architects 2008). The date of construction is uncertain. It may have been constructed for an Elks Club gathering in 1904 (Limbaucher & Godfrey Architects 2008), although the date 1917 is the most recent date stamped into the concrete. During the 1920s, the stream that entered Barton Creek from Eliza Spring was enclosed into a pipe underneath the lawn of Barton Springs Pool, which decreased the amount of salamander habitat at Eliza Spring (Figures 6, 7, City of Austin 2013). In the 1970s, this pipe was connected to the bypass tunnel that flows into Barton Creek. Over time, the water in the amphitheater became deeper due to a failing pipe and a grate that often clogged with debris. The increased water depth increased sediment deposition and reduced the interstitial spaces available for salamanders and their prey. In the 1950s, concrete was poured to cover the bottom of the spring pool, restricting the spring outflow to holes left in the concrete floor and sides (City of Austin 1998, 2013). The higher elevation from the concrete floor may have increased the number of salamanders stranded during pool drawdowns before management changes in the HCP prevented the floor of the amphitheater from going dry.

[1] According to the lease document for English mill from 1876 (Travis County 1877), Walsh Spring is located on the north side of Barton Creek. Springs of Texas (Brune 1981) states that Walsh Spring is an alternative name for Old Mill Spring, but this is not consistent with this historical record.

Figure 4. Eliza Spring before the amphitheater was built, circa 1870. Photo from the Austin History Center, PICA 00987.

Figure 5. Eliza Spring in the early 1900s. The amphitheater was built but the surface stream remained and flowed to Barton Creek. Photo from the Austin History Center.

Figure 6. Eliza Spring in 1953. The spring flow was buried into a pipe underneath the lawn of Barton Springs and the amphitheater keyway filled in with masonry. A chain link fence was also added to the top of the amphitheater. The natural substrate in the spring pool can be seen. Photo from the Austin History Center.

Figure 7. Eliza Spring in the 1960s. The water level is raised in the amphitheater, possibly due to issues with the pipe or grate clogging, or intentionally for recreation.

Substantial changes to Eliza Spring have resulted in a thriving salamander population. The City stopped harmful cleaning of the spring in 1992, which allowed a more natural ecosystem to establish (Chippindale et al. 1993). Although there is not documentation referencing the closure of Eliza Spring to the public, it most likely closed in then the mid-1990s to protect the salamander habitat from human disturbance. Sediment and non-native vegetation removal also occurred during 1995 and 1996 (City of Austin field notes). Salamander habitat disturbance decreased following the restriction of full drawdowns at Barton Springs Pool with the HCP (City of Austin 1998, 2013). Prior to 1998, drawdowns could occur during droughts and cause Eliza Spring to go dry. Since 1998, full drawdowns only occur when discharge is high enough to maintain water in Eliza Spring to prevent salamanders from being stranded (City of Austin 1998, 2013). Significant habitat improvements occurred in 2002–2004 (City of Austin 2004b, 2005) and the number of salamander at Eliza Spring increased substantially. The grate in front of the outflow pipe was cleaned regularly, which decreased the water level in the spring pool. This resulted in water speeds that helped flush sediment out of the spring pool. Native vegetation was restored, non-native species removed, and accumulated sediment flushed out using a submersible pump and by hand. Sediment depth decreased from 1–2' in places to less than 6". Salamander counts increased substantially and quickly when these changes occurred (City of Austin 2012), likely due both to the habitat improvement and drawdown restrictions that reduced stranded salamanders.

Ongoing management at Eliza Spring continues to benefit salamander habitat as well. Sediment is the most persistent issue at Eliza Spring. Large storm events push sediment through the aquifer and allow it to settle and embed substrate. Sediment is regularly flushed out by salamander biologists to maintain interstitial spaces for salamanders (City of Austin 2014, 2016, 2018a). The flora and fauna at Eliza Spring are also actively managed (City of Austin 1996b, 1998, 2004b, 2010, 2013, 2014, 2016, 2018a). Non-native Mexican tetras have been removed from the spring several times (City of Austin 2002, 2004a). Mosquitofish and crayfish, while native, are also periodically removed because they compete with and prey upon salamanders (Devitt and Owen 2016, Owen et al. 2016). Aquatic plants were planted in the spring pool to create more heterogeneous habitat and provide food for invertebrates (City of Austin 2004b). Trash used to be removed regularly from the spring pool. The amount of trash has decreased over the years as education signs and general awareness of the salamanders has increased (City of Austin 2002). Storm runoff also contributed sediment and pollutants to Eliza Spring. A layer of mortared rock was added to the top of the amphitheater walls to prevent local runoff into the spring (City of Austin 2004b).

Daylighting Eliza Stream

There are few opportunities to increase the amount of habitat available for Barton Springs Salamanders. Salamander habitat at Eliza Spring was limited to 800 square feet by the concrete boundaries of the amphitheater surrounding the spring pool and the outflow pipe. The salamander population at Eliza Spring shows density dependence (Bendik and Dries 2018) and may be limited by the amount of available habitat. The City replaced the failing outflow pipe with a surface stream surrounded by native riparian vegetation in 2017, a process known as daylighting (Figures 8, 9, City of Austin 2018b). This project restored approximately 250 square feet of salamander habitat at Eliza Spring.

Figure 8. Eliza Spring in November 2018. The surface stream is reestablished and masonry removed from the keyway. The floor of the spring pool is covered in concrete, with limestone gravel added on top for salamander habitat. Lines of gravel substrate connecting the edge of the spring pool to the center follow the path of water leaving spring outlets along the concrete steps.

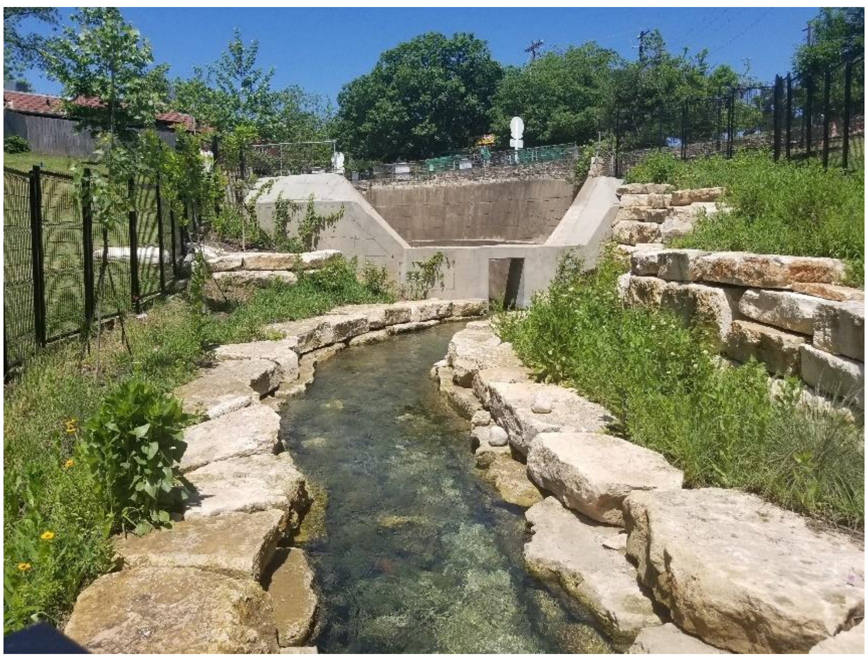

Figure 9. The north lawn of Barton Springs Pool before (above) and after (below) the Eliza Spring Daylighting project. The Eliza Spring amphitheater is also visible from the lawn after construction due to regrading around the stream that removed soil.

Ideally the recreated stream would have connected to Barton Springs Pool, but this was not possible due to the presence of the bypass tunnel and the lack of elevation difference between Eliza Spring and the pool (City of Austin 2011). The end of the stream terminates at what was an existing connection to the Barton Springs bypass tunnel for storm drains. The stream was designed to keep channel velocities low enough for salamanders to persist in the flowing water.

This was achieved by gradually decreasing the elevation to the extent possible, and by placing larger rock cover objects that reduces velocity at the substrate. While the large rock has been effective at reducing velocity at the substrate, smaller substrate will need to be added in the future as current interstitial spaces in some areas of the stream are too large for salamanders. A gate at the end of the stream helps maintain the water level in the stream and amphitheater as spring flow changes. Native riparian vegetation was also added surrounding the stream that will eventually shade the stream.

Salamanders were first found in the stream in May 2018. Monitoring of the new stream habitat is underway to evaluate colonization by salamanders and to determine whether other habitat changes are needed. Habitat in the Eliza Spring amphitheater also has improved since construction ended by reducing the water depth and sediment accumulation.

Timeline of Changes to Eliza Spring

1904–1917 Amphitheater constructed at Eliza Spring

1920s Eliza Spring water diverted from stream habitat into concrete pipe that flows into Barton Springs Pool

1950s Fill added to increase elevation of land around spring pool

1950s Concrete floor installed on top of Eliza Spring

1976 Concrete pipe with Eliza Spring water connected to the bypass system, releasing spring water into Barton Creek

1992 City stopped cleaning of Eliza Spring

Mid 1990s Eliza Spring amphitheater closed to the public

1995-1996 Sediment and non-native plants were completely removed

1998 Drawdown limits at Barton Springs Pool prevent stranded salamanders at Eliza Spring

2002–2004 Substantial habitat restoration efforts resulting in higher salamander counts

2004 Increase height of amphitheater wall to prevent surface runoff into Eliza spring

2017 Outflow pipe replaced with overland stream. Additional 250 square feet of salamander habitat added

Old Mill Spring and Stream

Old Mill Spring (also known as Sunken Garden Spring, Zenobia Spring, and Paggi's Mill) is located on the south side of Barton Creek downstream of Barton Springs Pool. Old Mill Spring and its salamander habitat were modified during the 1800s for a grist mill (Figure 10) and then again in the 1930s by the National Youth Administration, which built rock walls around the stream (Figure 11, 12, Limbaucher & Godfrey Architects 2008). Together these modifications have artificially increased the water depth, increased sediment deposition in the spring pool, reduced the riparian habitat around the spring pool, reduced the connection between the spring pool and the stream, and channelized the stream. Later, a pipe was added that diverted the flow from the streambed and decreased salamander habitat. Installation of the pipe was not documented but City of Austin staff believe it occurred during the 1970s.

Figure 10. Photo of the Old Mill Spring and Paggi's Mill circa 1876. This is the earliest known photo of Old Mill Spring. The wall impounded the spring pool, slowing down the water velocity and increasing the water depth. Today most of the rock wall from the 1800s is gone. Photo from Austin History Center, C03293.

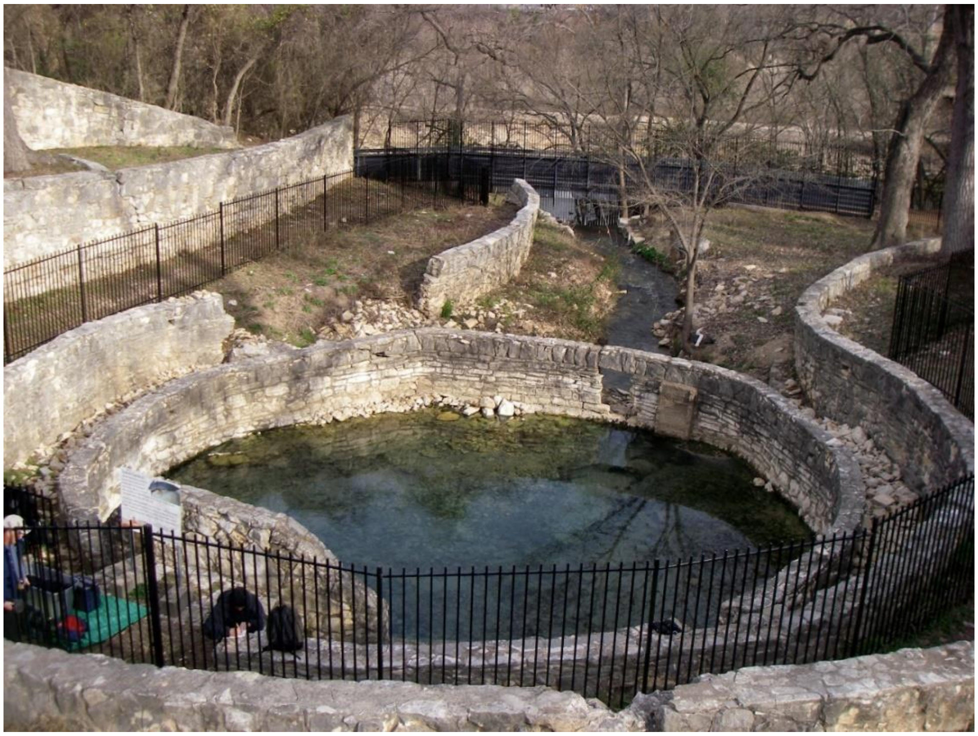

Figure 11. Old Mill Spring in 2008. The historical walls and wetted area of salamander habitat are the same as today (2018). The National Youth Administration walls remain surrounding the spring pool.

Figure 12. Old Mill Spring in November 2018. Significant vegetation has grown around the spring pool in the past 10 years.

Several changes have been made at Old Mill Spring to improve habitat. Old Mill Spring was closed to the public in 1998 (City of Austin 1998). An outflow pipe to Barton Creek was plugged in 2000 to allow increased water flow to the stream channel (City of Austin 2001), and plugged again in 2006 due to continued leaking (City of Austin 2010). Additional habitat improvements include the reestablishment of native terrestrial plants around the spring pool (Figure 12), removal of trash and concrete, and removal of non-native aquatic plants, fish, and snail species (City of Austin 2001, 2002). Riparian vegetation benefits salamanders by shading the aquatic habitat, providing detritus input into the spring ecosystem, which also provides habitat for invertebrates that the salamanders prey upon, and the vegetation can reduce erosion and help filter storm water before it reaches salamander habitat (City of Austin 2013). Other changes have occurred but were not able to permanently increase the salamander population. A waterfall was added to the stream in 2004 (Figure 13, City of Austin 2005, 2010, 2013) and screens were added in 2002 and 2015 to reduce the number of predatory fish from swimming upstream to colonize the spring pool during floods. However, it’s impossible to completely block fish from entering the stream during floods, so removal of predatory fish continues as needed. The center of the spring pool was excavated from 2005–2012 to reduce water levels, remove trash and foreign materials, look for bedrock, expose spring openings, and prevent debris from reducing spring flows (City of Austin 2010, 2013). However, bedrock was never found, and the changes did not increase the salamander population in the spring pool. The spring pool remains impounded by the National Youth Administration walls, so the spring pool remains pond like habitat with high sedimentation rates that results in poor salamander habitat. Sediment deposition at Old Mill Spring occurs at rates too high to flush out, resulting in embedded substrate.

A larger scale restoration project at Old Mill Spring is needed and is currently the best opportunity to improve Barton Springs Salamander habitat. The impoundment caused by the wall surrounding the spring pool needs to be modified or removed to reduce the water level, allow for natural sediment flushing, and improve the connection between the spring pool and stream. Shallower water would also reduce or eliminate habitat available for predatory fish. The stream needs to be regraded and widened to reduce the high velocities that currently occur with moderate and high spring flows due to channelization and the steep stream run down to Barton Creek. Currently, during periods of high discharge, the stream velocities are so high that salamanders and substrate can be flushed downstream.

Figure 13. Waterfall installed at the Old Mill stream near Barton Creek in 2004 (left) and in 2019 (right) with the barrier fence installed. Concrete was removed from the water after construction. In the right, water is bypassing the waterfall and exiting through a cavity on the right bank near Barton Creek.

Timeline of Changes to Old Mill Spring

1870s Paggi's Mill constructed at Old Mill Spring, modifying the spring and stream
1937 National Youth Administration built amphitheater surrounding Old Mill Spring
1970s Pipe added to divert more water to Barton Creek to lower the water level
1998 Closure of Old Mill Spring to the public to protect salamander habitat. Fish removal as needed
2000 Capped concrete pipe within spring walls to prevent spring flow from entering pipe
2002 Installed screens in stream to attempt to prevent fish movement from Barton Creek
2003 Cleared materials from outflow window in spring pool wall. Remove collapsed foot bridge and culvert to improve stream
2004 Increased opening in spring wall for spring flow to exit. Transplant aquatic plants into stream. Constructed waterfall at end of stream
2005 Reopened drain holes in stone walls to divert surface runoff around salamander habitat toward the creek
2006 Plugged concrete pipe in stream to prevent spring flow from entering pipe
2005-2009 Removed old concrete pipe from inside spring pool and outflow stream. Plug remaining pipe outside of spring pool to prevent water from entering pipe

2005-2012 Excavated rocks, concrete, asphalt, trash, sand and sediment from the spring pool upwellings
2006-2012 Excavated stream channel during droughts to increase stream flow
2015 Installed screens in stream to prevent upstream fish movement into spring

Upper Barton Spring
Upper Barton Spring is located on the Barton Creek Greenbelt upstream of Barton Springs Pool. Upper Barton Spring does not have permanent modifications. It is smaller than the other springs and stops flowing during droughts. Significant human disturbance occurs here because of its location along the Barton Creek Greenbelt. Small rock dams are often built and need to be removed by city staff to protect habitat, and salamander habitat is trampled by humans and dogs entering the spring pool. Other issues, such as trash and graffiti also occur and are removed as needed. Interpretive signs have been installed here to educate citizens and reduce human disturbance. Beyond this, there is little modification at this site and no need for major habitat improvements.

Summary

Two types of habitat improvements have lasting benefits to salamander habitat. The first is measures that prevent damage to the fragile spring ecosystems, such as limiting the number of drawdowns and prohibiting chemicals and detrimental cleaning procedures near the spring. The second type is permanent modifications that increase or improve salamander habitat, such as removing spring impoundments and improving water flow to promote sediment flushing. Other measures, such as sediment flushing by hand, plant management, and predator management, can also improve salamander habitat. However, these changes tend to be short-term rather than a permanent ecosystem improvement and require ongoing attention to benefit the salamander population. These measures are most useful when permanent changes cannot be made, or as a stopgap measure until permanent improvements allow for better salamander habitat.

References

Bendik NF, Dries LA. 2018. Density-dependent and density-independent drivers of population change in Barton Springs Salamanders. Ecology and Evolution 8: 5912-5923 doi: 10.1002/ece3.4130

Brune G. 1981. Springs of Texas. Volume 1. Branch-Smith, Inc. Fort Worth, Texas, USA. 530 p.

Chippindale PT, Price AH, Hillis DM. 1993. A new species of perennibranchiate salamander (*Eurycea*: Plethodontidae) from Austin, Texas. Herpetologica 49: 248–259.

City of Austin. 1996a. Summaries of City of Austin projects and programs supporting Barton Springs Salamander conservation. Drainage Utility Department, Austin, Texas, USA.

City of Austin. 1996b. Surface Habitat Management Plan for the Barton Springs Salamander (*Eurycea sosorum*). Drainage Utility Department, Austin, Texas, USA. 14 p.

City of Austin. 1998. Habitat Conservation Plan for the Barton Springs Salamander (*Eurycea sosorum*) for the operation and maintenance of Barton Springs Pool and adjacent springs. Watershed Protection and Development Review Department, Austin, Texas, USA. 87 p.

City of Austin. 2000. Identifying sediment contamination sources in the Barton Creek watershed of Austin, Texas. SR-00-01. Watershed Protection Department, Austin, Texas, USA. 10 p.

City of Austin. 2001. Endangered Species Act Section l0(a)(l)(B) Permit for incidental take of the Barton Springs Salamander (*Eurycea sosorum*) for the operation and maintenance of Barton Springs Pool and adjacent springs. Watershed Protection and Development Review Department. Austin, Texas, USA. 50 p.

City of Austin. 2002. Annual report on the operation and maintenance of Barton Springs Pool and adjacent springs (January 1 – December 31, 2002). Watershed Protection and Development Review Department. Austin, Texas, USA. 90 p.

City of Austin 2004a. 2004 Annual Report. U.S. Fish and Wildlife Service Scientific Permit (TE-833851). Watershed Protection and Development Review Department. Austin, Texas, USA. 7 p.

City of Austin. 2004b. Eliza Spring management plan. Unpublished report. Watershed Protection and Development Review Department. Austin, Texas, USA. 10 p.

City of Austin. 2005. 2005 Annual report. U.S. Fish and Wildlife Service Scientific Permit (TE-833851). Watershed Protection and Development Review Department, Austin, Texas, USA. 9 p.

City of Austin. 2008. Annual report October 1, 2007 — September 30, 2008 Endangered Species Act Section 10(a)1(B) Permit for the incidental take of the Barton Springs salamander (*Eurycea sosorum*) for the operation and maintenance of Barton Springs Pool and adjacent springs Permit # PRT – 83903. Watershed Protection and Development Review Department. 19 p.

City of Austin 2010. Old Mill Spring and Sunken Garden amphitheater reconstruction and restoration. Unpublished Report. Watershed Protection Department. Austin, Texas, USA. 10 p.

City of Austin 2011. Eliza Springs stream restoration preliminary engineering assessment. Unpublished report. Watershed Protection Department. Austin, Texas, USA. 4 p.

City of Austin. 2012. Variation in abundances of *Eurycea sosorum* and *Eurycea waterlooensis* (Plethodontidae: Hemidactyliini: *Eurycea: Notiomolge*), with examination of influences of flow regime and drought. SR-12-16. Austin, Texas, USA. 46 p.

City of Austin. 2013. Major amendment and extension of the Habitat Conservation Plan for the Barton Springs Salamander (*Eurycea sosorum*) and the Austin Blind Salamander (*Eurycea waterlooensis*) to allow for the operation and maintenance of Barton Springs and adjacent springs. Watershed Protection Department, Austin, Texas, USA. 275 p.

City of Austin 2014. Habitat Management plan for the Barton Springs and Austin Blind salamanders. SR-14-17. Watershed Protection Department. Austin, Texas, USA. 9 p.

City of Austin. 2015. Barton Springs riparian restoration: summary of 2014-2015 progress. DR-15-10. Watershed Protection Department, Austin, Texas, USA. 18 p.

City of Austin 2016. Habitat Management Plan for the Barton Springs and Austin Blind salamanders. SR-14-17. Version 2. Unpublished Report. Watershed Protection Department. Austin, Texas, USA. 9 p.

City of Austin 2018a. Habitat Management Plan for the Barton Springs and Austin Blind salamanders. SR-14-17. Version 3. Unpublished Report. Watershed Protection Department. Austin, Texas, USA. 8 p.

City of Austin. 2018b. Restoring Eliza Spring's stream. Watershed Protection Department. Austin, Texas, USA. www.austintexas.gov/blog/restoring-eliza-spring

Devitt TJ, Nissen BD. 2018. New occurrence records for *Eurycea sosorum* Chippindale, Price & Hillis, 1993 (Caudata, Plethodontidae) in Travis and Hays counties, Texas, USA. Check List 14 (2): 297–301. doi: 10.15560/14.2.297

Devitt TJ, Owen JD. 2016. *Eurycea waterlooensis* (Austin Blind Salamander). Predation. Herpetological Review 47: 275-276.

Dries LD, Colucci LA. 2018. Variation in abundance in the Barton Springs Salamander associated with flow regime and drought. Herpetological Conservation and Biology 13(1): 302-316.

Hillis D, Chamberlain DA, Wilcox T, Chippindale P. 2001. A new species of subterranean blind salamander (Plethodontidae: Hemidactyliini: *Eurycea*: *Typhlomolge*) from Austin, Texas, and a systematic revision of central Texas paedomorphic salamanders. Herpetologica. 57. 266-280.

Jordan DS, Gilbert CH. 1886. List of fishes collected in Arkansas, Indian Territory, and Texas, in September, 1884, with notes and descriptons. Proceedings of the United States National Museum 9: 1–25.

Limbaucher & Godfrey Architects. 2008. Barton Springs Pool Master Plan. Prepared for City of Austin, Parks and Recreation Department, February 19, 2008. Austin, Texas, USA. 352 p.

McDermid K, Sprouse P, Krejca J. 2015. *Eurycea sosorum* (Barton Springs Salamander) geographic distribution. Herpetological Review 46: 556.

Owen, JD, Devitt TJ, Colucci LA, & Bendik NF. 2016. *Eurycea sosorum* (Barton Springs Salamander). Predation and diet. Herpetological Review 47: 275.

Travis County. 1877. Deed Record 39:97-100. Travis County Clerk's Office, Travis County, Texas, USA. Accessed via texashistory.unt.edu

U.S. Fish and Wildlife Service. 1997. Endangered and threatened wildlife: final rule to list the Barton Springs Salamander as endangered. Federal Register 62: 23377–23392.

U.S. Fish and Wildlife Service. 2016. Barton Springs Salamander (*Eurycea sosorum*) Recovery Plan. Amended to include Austin Blind Salamander (*Eurycea waterlooensis*). U.S. Fish and Wildlife Service, Albuquerque, New Mexico, USA. 148 p.