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Sediment accumulation in the Barton Springs complex

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Abstract

The four springs located in the Zilker Park area of Austin, Texas are the only known habitat of the endangered species Eurycea sosorum and E.waterlooensis. Sediment deposition in these springs contributes to the temporary degradation of salamander habitat due observed during salamander counts. The sediment transport in the area of the springs is dynamic with deposition/resuspension rates varying spatially and temporally over the substrate. Accumulation of sediments in these habitats has been a concern because sediment loading is anticipated to increase as a result of human activities in the Barton Springs watershed. This study documents the baseline rate of sediment accumulation in 3 of the 4 springs under low flow conditions over varying periods of time during 2002-2003. Sedimentation rates varied from 0.5 to 2.2 inches/year across the tests performed with an average of 0.9 inches/year. Results indicate that during low rainfall (decreasing flows), the sediment accumulation rates decrease. As rainfall and flows increase the sediment accumulation rate increases. Transport of sediment out of spring areas during runoff events and maintenance cleaning of spring outlets prevents these sedimentation rates from being problematic for maintenance of salamander habitat.

Introduction

The objective of this study was to document baseflow sediment accumulation rates in the springs in the Zilker Park area of Austin, Texas, including Barton (Main or Parthenia), Eliza, Old Mill (Sunken Gardens), and Upper Barton Springs as shown in Figure 1.

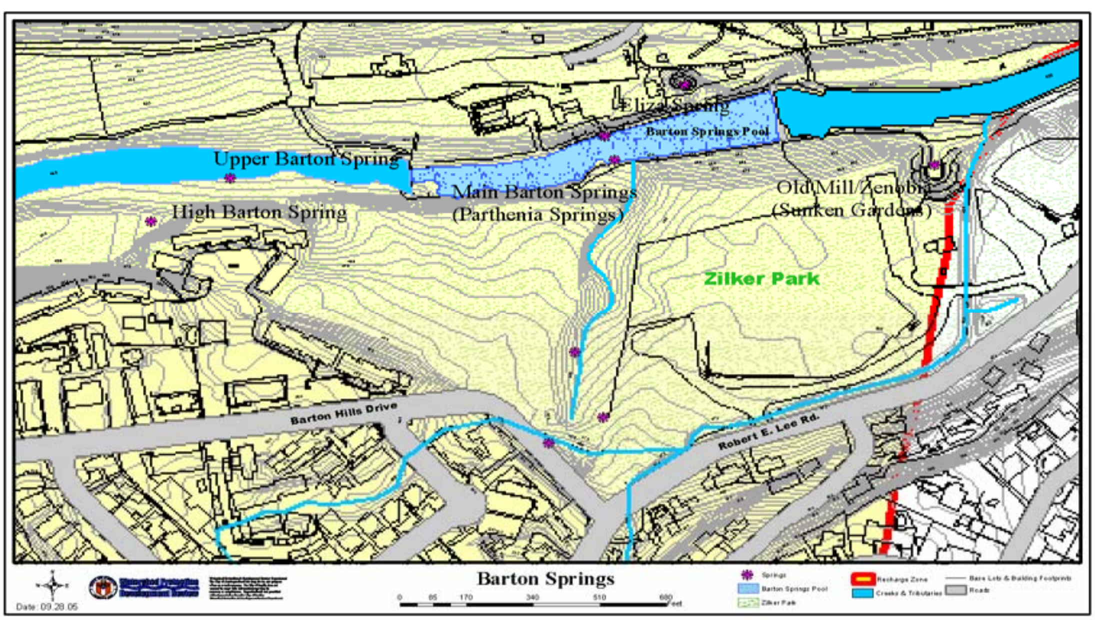


Figure1. Zilker Park, Austin, Texas. Showing locations of Barton, Eliza Sunken Gardens and Upper Barton Springs.

These four springs, collectively the Barton Springs complex, are the only known habitat of the endangered species, Barton Springs salamander, (*Eurycea sosorum)* and the Austin Blind salamander, (*E. waterlooensis).* The salamanders inhabit the surface substrate and subterranean areas of these four springs, thus it is imperative that changes to and effects on these habitats are well documented.

Potential degradation of salamander habitat due to accumulation of sediments has become a serious concern for those managing the immediate surroundings of the spring outlets. Particulate sediments discharging from the karst aquifer that supports Barton and its related springs play a fundamental role in determining water quality and habitat conditions (Mahler et al. 1999). Field observations by City of Austin (COA) biologists and United States Geological Services (USGS) have documented fine grained or sandy sediments discharging from the spring outlets (Mahler 2003), and settling on the substrate in these spring systems.

Excess sediment accumulation has the potential to cause degradation in habitat conditions affecting long-term survival of these species. Accumulation of sediments can cover habitat, smother substrates and can lead to declines in vegetation abundance and diversity. This can eliminate populations of the more sensitive benthic species (Runde 1999). Sediments can have a direct impact on habitat quality by acting as a sink for contaminants, increasing the pollutant loads and bioaccumulation in aquatic organisms (Roell 1999). Sediments can also be a transport mechanism for other contaminants (Menzer and Nelson 1980). This purpose of this study was to provide a current baseline reference of sediment accumulation rate during low discharge flow (near drought conditions) from Barton Springs.

Background
The Contributing and Recharge zones of Barton and its related springs are in Southern Travis and Northern Hays Counties in Central Texas. These zones are associated with a part of a large karst aquifer system known as the Edwards Aquifer. Karst aquifer systems are more vulnerable to the effects of pollution because of their thin surface soils and relatively short time water is resident within the system (Ford and Williams 1994). Data show that contaminants in Barton Creek can enter the aquifer near Barton Springs and discharge from springs within hours or days of storm events (Slade et al. 1986, City of Austin 1991). Thus, water quality at Barton Springs is directly affected by the quality of water in the six creeks, Barton, Williamson, Onion, Bear, Little Bear and Slaughter, that feed the karst aquifer in the recharge zone (Slade 1986). A decline in water quality in the contributing and recharge zones would be evident in similar water quality degradation in Barton Springs. Although water quality degradation has been difficult to show using standard trend analyses, the period of record is such that now some statistically significant regressions have been documented (COA, 2000)

Sediments discharging from karst systems originate from both surface sources and sources within the aquifer (White and White 1968, Ford and Williams 1994, Mahler 1999). Surface derived sediments have the greatest potential to concentrate and transport contaminants because of their high organic content and potential for hydrophobic pollutants from the surface to attach to them (Burton 1992, Mahler and Lynch 1999). It has been demonstrated that sediments can enter from the surface, flow through the aquifer and discharge at Barton and its related springs (Mahler and Lynch 1999). Mahler and Lynch found that pulses of storm water runoff were the dominant mechanism for sediment transport to the spring discharge outlets. Approximately one metric ton of sediment was transported during each of the two storms monitored by USGS, with the peak concentration of total dissolved solids in spring discharge occurring 15-16 hours after rainfall. Storm water runoff also transports sediments deposited in the aquifer previously and those that are the products of erosion within the aquifer itself.

In addition to storm-related sedimentation, recent observations of COA biologists during baseflow indicate that there is now a small, continual amount of sediment discharge from Barton Springs (Laurie Dries, personal communication). Some groundwater originating as surface water from Barton and Williamson Creeks (and possibly others) remains in the aquifer for relatively short periods before discharging at the springs (Hauwert et al. 1998) with short periods for attenuation of sediments and pollutants before discharging at Barton Springs (Slade et al. 1986, City of Austin 1991).

Water quality in the more heavily developed areas of the Barton Springs segment and at Barton Springs is beginning to show signs of degradation (Slade et al. 1986, City of Austin 1991, 1993, Slade 1992, Hauwert and Vickers 1994). Problems with increasing sedimentation and turbidity began in Travis County in the 1980's, several areas began showing increased sedimentation by 1993. One spring, two abandoned wells, one USGS well and one municipal well in the Sunset Valley area experienced problems with increased sedimentation in 1993. Gradual increases in observable siltation in these wells were documented from 1990-1993. After clearing the municipal well in 1993, a well operator observed 1.0 – 1.5 feet of accumulation in each of the 44,000 gallon tanks (Hauwert 1994). As early as 1995, episodes of turbidity (a measure of fine suspended solids or sediment) persisting for several days after storm events were reported (TNRCC 1996). Increases in turbidity, algal growth, nutrients, and fecal-group bacteria have been documented along Barton Creek between State Highway 71 and Loop 360 and at Barton Springs, and have been largely attributed to construction activities and the conveyance and treatment of sewage in this area (Slade et al. 1986, City of Austin 1991, 1993). The Barton Springs/Edwards Aquifer Conservation District found elevated levels of sediment, fecal-group bacteria, trace metals, nutrients, and petroleum hydrocarbons in certain springs and wells between Sunset Valley and Barton Springs (Hauwert and Vickers 1994). Slade (1986) also reported that levels of fecal-group bacteria, nitrate nitrogen, and turbidity were highest in wells near creeks draining developed areas. Past rainfall events (i.e. May 8, 1980) have shown turbidity measures in Barton Springs Pool increasing from zero to over eighty NTUs and back to zero within 24 hours (Slade 1986). Since the 1990s through the present, it has been observed that a rainfall event can now increase turbidity substantially with recovery to pre-rainfall conditions often taking several weeks (Laurie Dries- personal communication, TNRCC 1996)

The problem of excess sediment accumulation is evident in a City of Austin (1995, 1997a) study that estimated that total suspended sediment loads have increased 270% over pre-development loadings within the Barton Springs segment of the Edwards Aquifer. The sediment load increases in storm water runoff are expected to be dominated by sediment derived from activities related to urbanization. The City of Austin (1995) estimated that sediments from construction activities (City of Austin 1997a) and stream channel erosion (City of Austin 1997b) accounted for about 80% of the average annual sediment load in the Barton Springs watershed. For example, Williamson Creek, which has the highest density of development of any streams in the Barton Springs watersheds, has the highest loadings (per unit area) of total suspended sediment and total nitrogen (City of Austin 1995).

The increases in sediment loads and degradation of water quality and their threat to the survival of Barton Springs and Austin blind salamanders indicate the need to document the current sedimentation accumulation rates in Barton and its related springs. The data collected in this study will not only provide this critical current baseline information but will also show where resuspension velocities in substrate can be improved to aid in the protection of the endangered salamanders and restoration of their habitats.

Intended uses of data collected within the scope of this study are:

- Develop a method to determine appropriate physical reference conditions for these particular spring habitats that are related to sediment influx into the system by recording the amount of sediment accumulation temporally in each separate spring.

- Gauge the extent of degradation of habitat and assess progress in restoration projects such as native revegetation. Baseline conditions could also be used in conjunction with other types of data for future determinations of the status of the Barton Springs ecosystems.

- Provide site-specific baseline data. This could assist with alleviation of stressors and their effects on the habitats at these springs in the future. Contour maps illustrating spatial distribution of sediment in each spring pool could be developed to determine problem areas in need of special attention and restoration.

- Evaluate the integrity of the springs exposed to various levels of habitat alteration. Data could be used to develop site-specific diagnostic indicators and monitoring strategies for guiding the identification of springs with degraded ecosystems and tracking changes temporally under different management practices.

- Determine particle size and embeddedness of sediment that is accumulating in each spring pool. Determination of embeddedness with standard methods (Sylte 2002) may not be possible due to the large amounts of sediments accumulating in these areas, which may completely submerge any cobble.

Site Descriptions

Barton Springs Pool is a large (surface area 82,650 $ft^{2,}$ 1.9 acre) impounded system that is used recreationally by citizens and tourists. Main Barton (Parthenia) Springs feeds Barton Springs Pool, shown in Figure 2, which is dammed upstream and downstream of the spring influent.

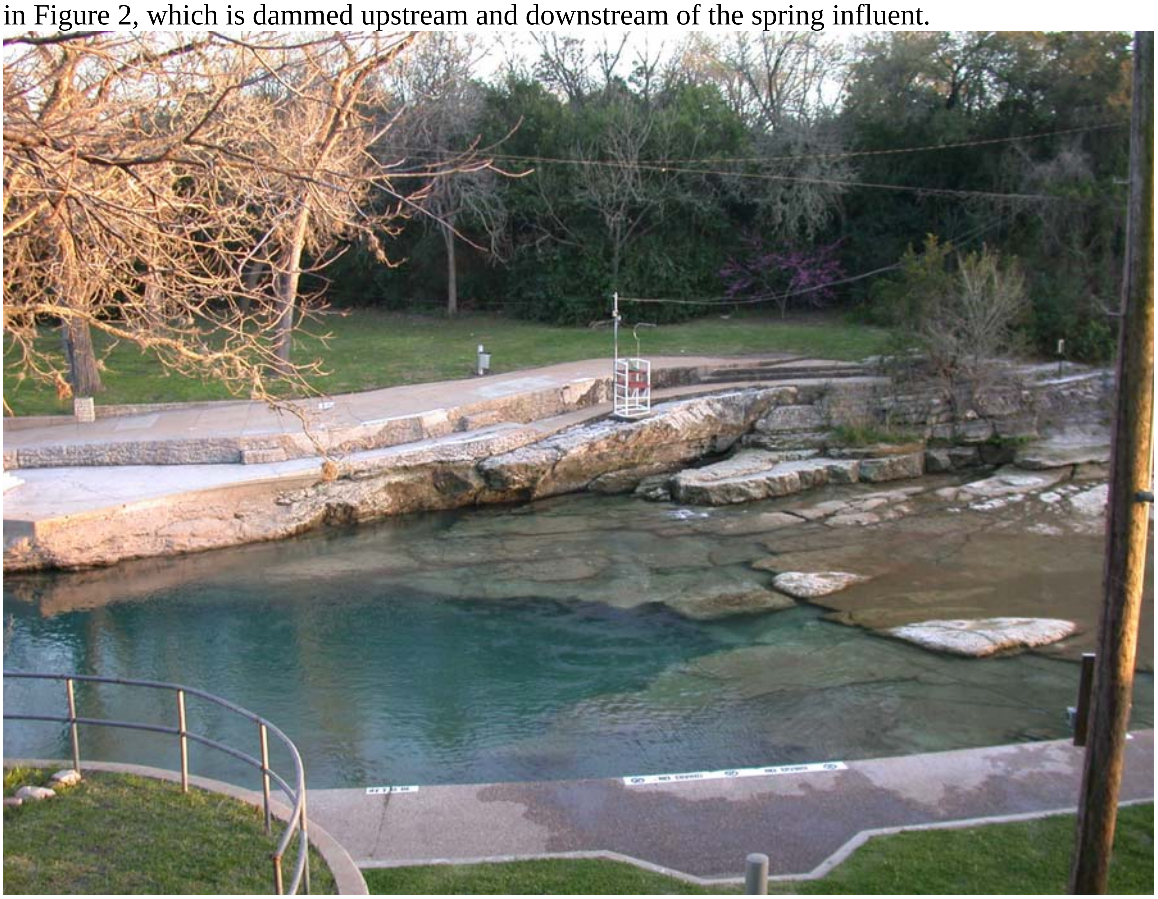


Figure 2. Barton Springs Pool with substrate exposed during drawdown January 2005

Average discharge from spring outflows is 53 cubic feet per second (cfs), although discharges have been recorded as high as 166 cfs and as low as 9.6 cfs (Slade 1986). Varying water depths in the impoundment range from 0.5 – 20.0 feet.

The area directly under the diving board has the largest spring outflows and is the deepest (depths average 17 ft). This area has sediment accumulation ranging from minimal to ~1 foot depths, around the edges, but the area directly in front of the discharging springs is relatively clear of sediment. The substrate in the shallower fissure area (depths ranging from 0.5- ~6ft.) consists of bedrock shelves bisected with fissures that contain areas of cobble and gravel. The areas immediately adjacent to the outflows lack sediment, due to the high flows associated with these springs; however, much of the remaining bedrock is covered with a layer of sediment that can range in thickness from very minimal amounts to accumulations of 6 inches and more. These areas are maintained by the COA Aquatics staff, and sediment is removed periodically to prevent resuspension and maintain water clarity.

The fissures contain scattered clumps of the moss, *Amblysteum riparim*, and various green and red algae inhabit the substrate nearest outflows. In addition to algae near the outflows, the substrate in the deep end of the pool (closest to the effluent) has had varying populations of algae, ranging from types of blue-greens to filamentous greens. The south bank in the deep end has a large stand of *Saggitaria latifola*. The pool also contains an artificially reconstructed area of habitat on the north side, referred to as gravel beach. The substrate here consists of a contoured gravel and cobble, which is covered with sediment from 0.25- 3 inches deep, and includes stands of the macrophyte *Saggitaria latifola*. Remaining areas of the impoundment consist of limestone bedrock and cement. Barton Springs is a popular recreational swimming pool and public access is not strictly limited. Crowds in the summer can exceed 5,000 people per day on weekends and patrons tend to disturb scientific equipment; therefore, sediment traps in the pool were put in place during winter months only, when attendance is much lower.

Eliza and Sunken Garden Springs, as shown in Figure 3, are enclosed manmade structures that form ponded areas of similar size with spring influents upwelling from the bottom of the structures.


Figure 3. Eliza and Sunken Gardens Springs 2004

Eliza is a large, oval shaped cement structure that has five sets of cement benches encircling an impounded center. The total measurement is 45’ x 60’ including the benches and 21’ x 41’ (676 sq. ft.) excluding the benches. For the purposes of this study, the bench areas were excluded, due to inconsistent water coverage and depth. The substrate in Eliza Springs consists of flat concrete with seven circular openings for the spring influent, which wells up from beneath the cement substrates' surface. Spring water is also discharged from ten rectangular vents at regular intervals along the bottom of the riser to the first bench. The effluent from this spring exits through a grate at the southeast edge of the ponded area, and flows through a buried concrete culvert into the Barton Springs pool bypass tunnel and out into lower Barton Creek. During extremely high flows and floods it can overflow into a grassy swale directly into Barton Springs Pool. Water depths in this spring can vary widely with spring flow, at the time of initiation of this study (June 2003), the water depth of the ponded area was between 1.5-2.0 feet and remained relatively stable throughout the study period.

Old Mill/ Sunken Gardens/Zenobia Springs is an area impounded by a circular rock structure (radius ~21 feet, Area ~ 1,385 sq. ft.) built to enclose the springs. The substrate remains in a natural state. Large boulders, cobble, sand, marl and sediment have accumulated to form a bottom structure that varies in both composition and depths. At this time, and during the majority of the study period, water depth was between 6-7 feet in the center and 4.5 - 5 feet around the edges. The outfall of this structure is built into the north wall approximately five feet above the substrate. Holes undermining the walls lead into a stream that flows directly into Barton Creek. In addition there is a pipe located in the substrate of the spring, which discharges into Barton Creek approximately 25 feet downstream of the main culvert.

These two spring structures are similar in size and flow capacity and both are located near spring upwellings within the substrate, leading to relatively tranquil water conditions. Sunken Gardens water depth is generally greater, leading to less riffling of the flow. Neither Eliza nor Sunken Gardens have additional inflows from other sources, except during storm events when Eliza experiences sheet flow influent from Zilker Park. Public access is very limited to both of these structures; therefore, a period of one year was used to determine accumulation rates.

Upper Barton Springs is located on the south bank of Barton Creek approximately 1/8- mile upstream of Barton Springs Pool. This spring has been left in a natural state, with a large percentage of the immediate habitat consisting of riffles flowing from the spring area into Barton Creek. Discharge rates vary considerably at this spring from 0 to about 2 cfs. Frequent periods occur where the entire surface of the spring area is dry. In addition, this site can be inundated with flow from Barton Creek during periods of high flow and heavy rainfall. The pooled spring area was approximately 10' x 17' at the initiation of this study (June 2003). The riffle area consists of shallow cobble and pebble filled runs. The water depth is relatively shallow compared to the other 3 springs in the area, with depths ranging from 2.5 feet at the discharge point of the spring, to about 6 inches, with 6 inches being the average depth in the riffle areas.

Public access to this spring is unregulated and several attempts were necessary to keep traps in place. Regular monitoring was performed and accumulation jars removed and replaced as needed. Field personnel were unable to keep traps in place this spring due to interference by the public. Therefore, accumulation studies at this site were discontinued.

Site Selection

Placement of sediment traps was made to equally represent all substrate conditions and/or habitat regimes in each of the springs. Specific depth and substrate criteria were noted for each placement and layout of samples was mapped for each spring. In order to determine degradation or improvement of conditions, the ability to replicate this study in the future is important. Since three of the springs are enclosed by manmade structures, and a map of trap placement was made, subsequent sampling should be able to replicate similar conditions and placements of traps.

The Eliza and Sunken Garden Springs structures are similar in size and characteristics, have similar physical and hydrologic characteristics (see above). Therefore, similar protocols were used to determine sediment accumulation in these two structures. Ten traps were placed in each of these spring structures. Eliza Springs had 10 –500 ml. cylindrical glass jars and Sunken Gardens had 10 one-liter jars with the same diameter. The possibility existed that water depths would increase in Eliza, and there was the option to replace 500-ml jars with one-liter jars if needed.

Twenty sediment traps with 1- liter plastic jars were placed in Barton Springs Pool in November 2003 and February 2004 when there was less chance that the traps would be disturbed. Public access is not limited in the pool area; therefore, accumulation jars were attached to metal plates and buried in the cobble, where possible, or placed in deep, relatively inaccessible areas. Access to the deep spring area is difficult, but not impossible. All jars were monitored regularly for disturbances. No jars were placed in the shallow area due to potential for disturbance by pool patrons. Thanks to the vigilance of COA's Aquatic staff all traps remained relatively undisturbed. Eight traps were placed in the diving well of the pool, four on either side of the diving board. Six traps were placed along the gravel beach, with the remaining six placed in the deep end. There was only one instance of known interference, trap #12 was removed from the water for 24 hours, and was immediately replaced.

Data Management

Data management procedures performed by the COA ensure that data meet quality objectives of TCEQs Clean Rivers Program. Sufficient accuracy and precision are comparable with TCEQ and LCRA data programs.

Field and laboratory data in the field were recorded on standard forms designed for the project. Data were then entered in the COA Field Sampling Database (FSDB) in Oracle, checked twice for accuracy and error, and range check programs were run to help identify entry errors. All data outside normal ranges were flagged for further attention. All FSDB files on the computer system are regularly backed up and original bench sheets and field books were archived for reference.

Methods

The initial sampling consisted of studies measuring sediment accumulation rates over a specific period of time in springs in the Zilker Park area. Barton Springs Pool, Eliza Springs, Sunken Garden Springs and Upper Barton Springs were all included.

While determining the type of containers to use for traps several points were taken into consideration:

1. Container geometry is an important aspect when determining sedimentation rates. Several experiments comparing cylindrical vs. funnel shape traps lead to the conclusion that cylinders will compare well with sedimentation rates. Whereas, funnel collection devices collected only 50% volume of the sediment accumulation in surrounding areas (Gardner 1980).
2. The primary control on fluid exchange and fluid residence time in a container is its shape. Containers with small openings and large bodies having the longest residence times. However, the size distributions of particles removed from wide mouthed jars are nearly identical to those obtained from a flume bed in several experiments (Gardner 1980).
3. The average capture efficiency of cylinders was closer to 100% in both flowing and still water. The Height/Width (H/W) ratio showed no definite influence on the trapping efficiency of cylinders (Gardner 1980).

4. Particles are collected in traps through a process of fluid exchange, whereas a cylinder with H/W ratio of 2.3 gives a poor estimate of horizontal flux, it "yields a surprisingly accurate measurement of what is collecting on a flume bed" (Gardner 1980).
5. Cylinders with H/W ratios between 2.3 and 4 have the maximum collection efficiency. When H/W ratio exceeds four, the efficiency decreases (Gardner 1980).

Cylindrical wide mouth glass or plastic containers were placed throughout the springs in optimal locations. These jars have screw top lids, which enabled personnel to replace the lids during removal, so as not to lose any sediment that has accumulated. In addition, an attempt was to cap jars when other agencies were performing work in the springs and disturbing sediment to the point where it interfered with study results. Interference and disturbances were noted and jars replaced. Upon retrieval, the samples were allowed to settle and overlying water was siphoned off. In addition to sediment depth, the samples were dried and weighed at an accredited laboratory to determine mass. Actual jar sizes were determined depending on water depth at each individual spring site at the time of deployment.

The diameter of the jars was extrapolated to the total area of each structure to determine accumulation. The period of time the jars were in place, average flows and measurements of sediment accumulation were used to calculate estimates of the mass and possible accumulation of sediment into the systems. Additional measurements were taken to determine depths of sediment accumulation in specific areas and the water depths of the ponded areas. These measurements were in addition to accumulation and not used in the calculations.

Records of rainfall and flowrates were maintained during the time that the traps were in place, in order to determine if unusual weather conditions may have been a contributory factor in the results. After storm events and periodically (biweekly), traps were checked to ensure that they are remaining in the locations chosen and had not been vandalized or broken. Replacement containers were noted with the dates and locations.

Water depths and flows of the springs were measured on a regular basis during this study period with Marsh McBirney flowmeters and standard depth rods. Flows were measured at all effluents or culverts discharging from the springs. Water depths at Upper Barton, Eliza and Old Mill/ Sunken Gardens Springs were measured on a weekly basis by COA biologists. The following table provides information on the number of jars and sizes used in individual spring sites.

Table 1. Sampling conditions for sediment accumulation in Barton Springs complex.

	Upper Barton Springs #183	**Eliza Springs #422**	**Sunken Garden Springs #428**	**Barton Springs Pool #35**
Jar size	250 ml	500 ml	1 liter	1 liter
Water Depth	.5-1.5 feet	1.5-2.5 feet	4.5-8 feet	0.5-20 feet
Area	170 sq. ft.	650 sq. ft.	1385 sq. ft.	86,250 sq. ft.
Number of jars	6	10	10	20
Date of Initial Placement	6/18/2003-discontinued	6/18/2003-6/21/2004	6/27/2003-6/21/2004	12/8/2003-2/26/2004

Sediment accumulation is checked visually 6 days/week by COA biologists as part of daily monitoring of each spring sites. Water depth at Upper Barton, Eliza and Old Mill Springs are measured on a weekly basis by COA biologists.

Results

Difficulties in performing this study at Upper Barton Springs occurred from the initial placement of traps. Public access to Upper Barton Springs is not restricted and the area is located on a recreational hiking trail. In addition, shallow water conditions in this spring made the traps visible to the public. Although attempts were made to collect sediment at Upper Barton Springs, disturbance of the traps by the public (both human and canine), made it impossible to get data at this site.

Restricted access at both Eliza and Sunken Gardens Springs ensured the traps would not be disturbed. Water depths and the vigilance of COA's Aquatics staff made it possible to obtain results in Barton Springs Pool. Ten traps were in place for an interval of one year at both Eliza and Sunken Gardens Springs, from June 2003 to June 2004. In Barton Springs Pool, twenty traps were in position from December 8, 2003 to February 26, 2004.

During the initial period of placement (June '03 – March'04) flows steadily decreased at all spring sites, due to low to no rainfall in western Travis and Hays counties. (Figure 4). From February through June of 2004, several large rainfalls were recorded, and flows at all spring sites increased.

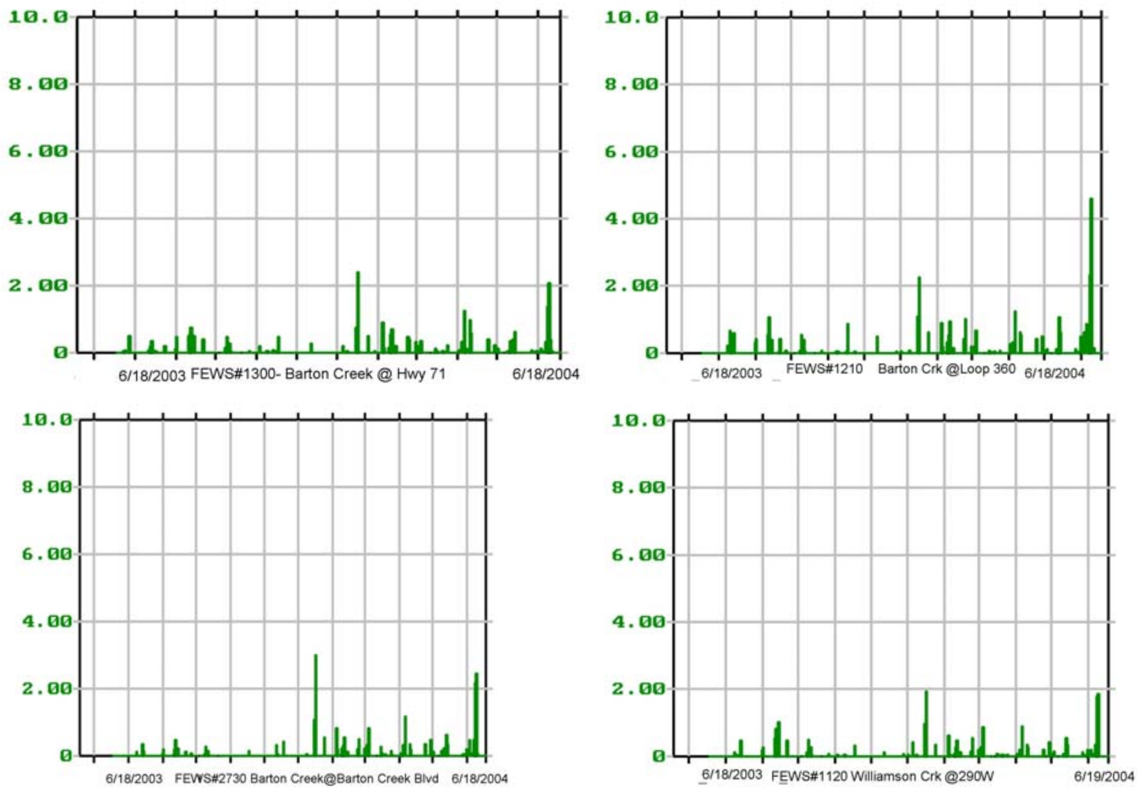


Figure 4. Rainfall gages during study in Barton Springs watershed

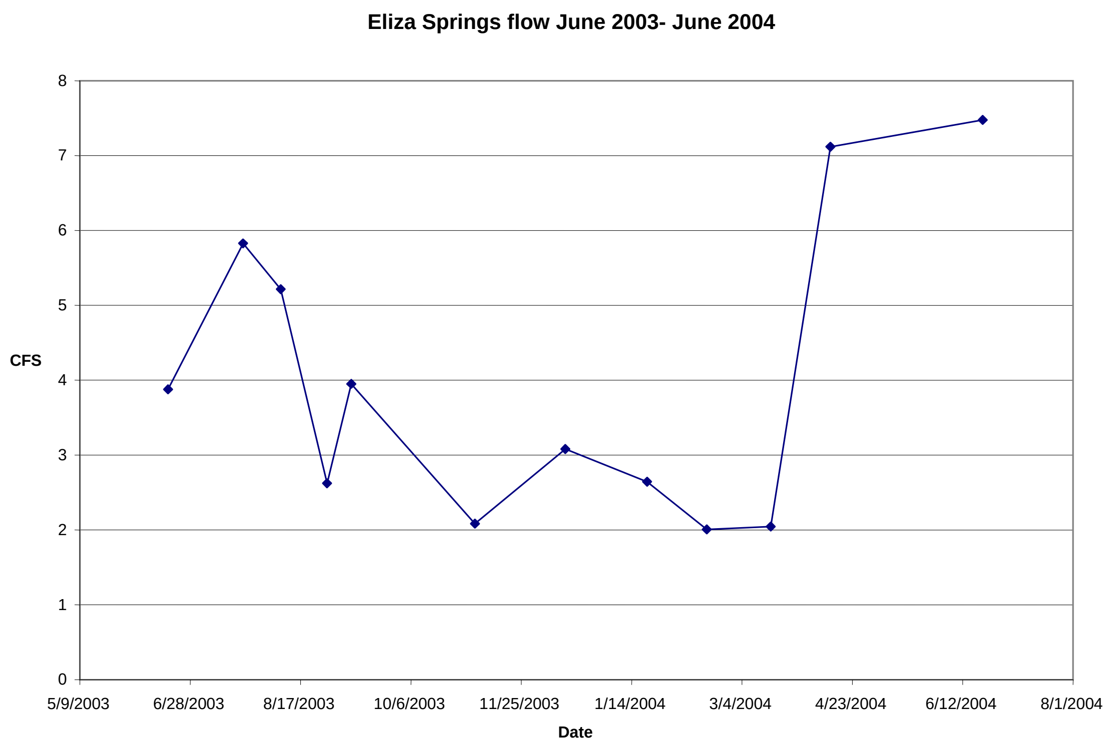
Calculations using area, time periods and sediment amounts were used to determine the time it would take to fill each spring with sediment to a depth of one foot.

Table 2. Results for sediment accumulation testing in Barton Springs complex

Site name	Time period	Time to fill to depth of 1 Foot	Sediment Rate (in/yr)	Average flow	Flow increasing / decreasing
Eliza	90 days	9.04 years	1.32	5.68 cfs	decreasing
	91 days	20.7 years	0.58	2.08 cfs	decreasing
	94 days	5.36 years	2.24	5.55 cfs	increasing
Sunken Gardens	164 days	9.8 years	1.22	6.58 cfs	decreasing
	185 days	20.9	0.57	5.45 cfs	increasing last 3 months
Barton Springs Pool	80 days	14.3	0.84	39 cfs	decreasing

Eliza Springs

The initial time period traps were in place in Eliza Springs was 90 days, and according to calculations it would take approximately 9.04 years to fill Eliza with sediment to a depth of one foot, with average (5.68 cfs) decreasing flows ranging from an initial measurement of 6.8 cubic feet per second (cfs) to 4.2 cfs (average 4.3 cfs). The second period of time in Eliza was 91 days, with flows again decreasing to 2.08 cfs (average flows of 2.58 cfs); it would take 20.7 years to fill Eliza to a depth of one foot. During the period from 12/03 through 2/03, there was little flow in any of the springs, and several jars in Eliza were not submerged. This period of time is excluded from Eliza calculations. The third time period from 3/17/04 – 6/21/04 average flow increased to 5.55 cfs (flows ranged from 2.04 cfs on 3/17 and increased to 7.477 cfs on 6/21) and calculations indicate a 5.36-year period would be necessary to fill Eliza with sediment to a depth of one foot. (Figure 5)



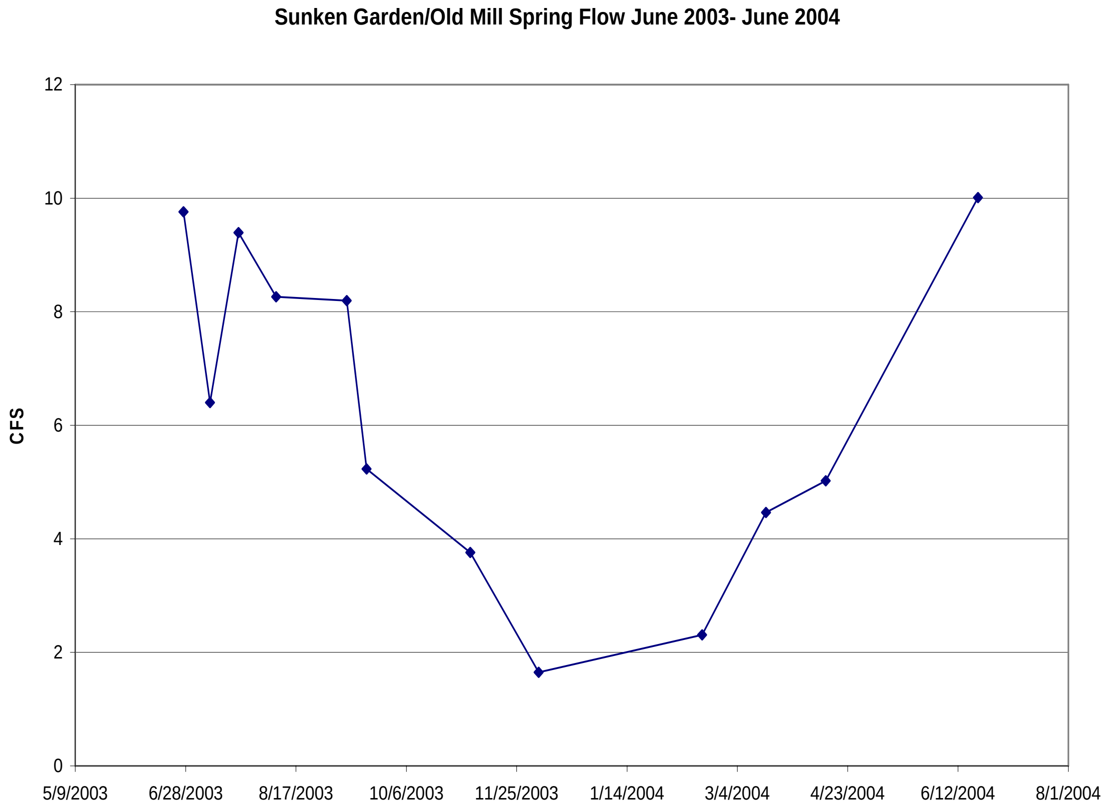


Figure 5. Flow Measurements In Eliza and Sunken Gardens Springs 2003-2004

Sunken Gardens (Old Mill Springs/Zenobia)

Two time periods were measured in Sunken Gardens Springs, both equaling approximately six months. The first was from June through December of 2003 and the second from December 2003 through June of 2004. At no time were any jars removed; however there is a possibility that accumulation rates were overestimated in the first period. During this period there was work going on in the spring and the traps were not covered. The first period with average decreasing flows of 6.58 cfs, (ranging from 9.7 cfs to 1.65 cfs) indicates it would take 9.8 years to fill the spring to a depth of one foot. The second period flows averaged 5.45 cfs and calculations indicate it would take 20.9 years to fill the springs to a depth of one foot. (The period of time between 12/5/2002 and 2/17/2003 showed extremely low flows with no flow discharging from the culvert and flow of 1.65 cfs discharging from the pipe only. Flows during this time period began increasing in March 2004 and eventually reached 10.01 cfs by 6/21/2004. (Figure 5) After the final jars were removed, COA biologists started habitat restoration in Sunken Gardens Springs, that included enhancement of directional surface water flow. It was reported that some spring upwellings in Sunken Gardens were clogged with cobble and sediments and upward flow from the substrate was impeded to a point that it had probably affected the results of the second half of the study (12/03 – 6/04)

Barton Springs Pool

Barton Springs Pool averaged of 39 cfs during the four months (80 days) the traps were in place. Calculations indicate it would take 14.3 years to fill the entire pool with sediment to a depth of one foot.

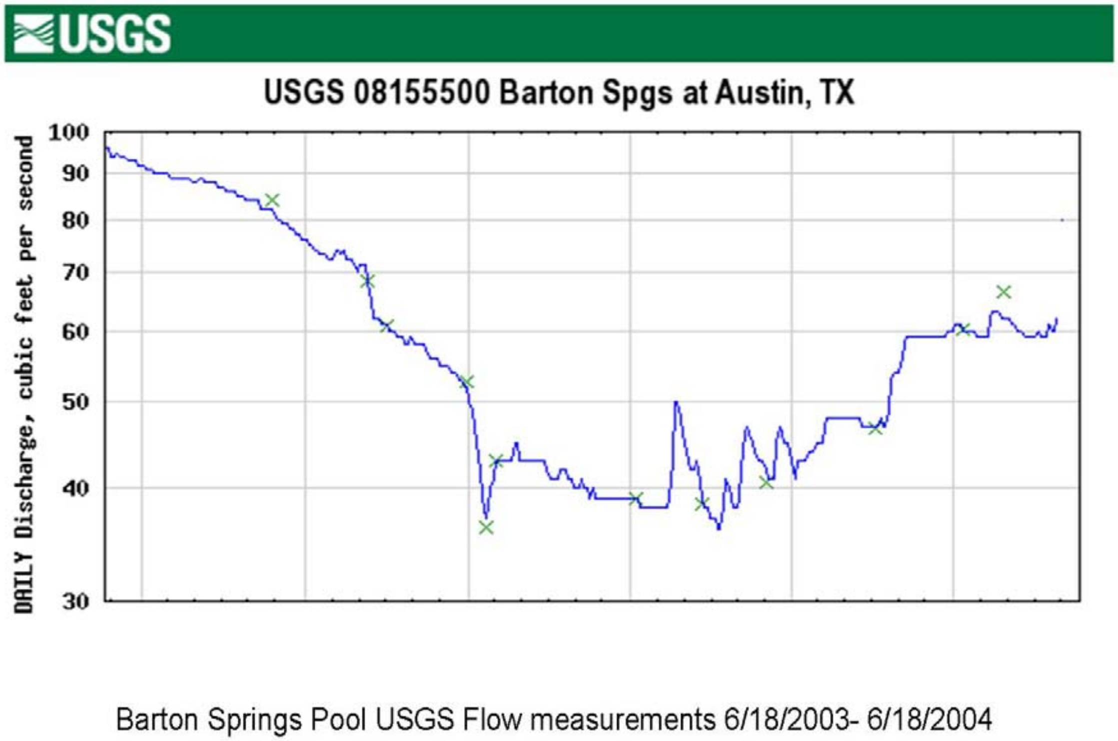


Figure 6. Barton Springs Pool USGS gage flow measurements

Conclusions

The results of this study indicate there are settleable solids discharging through the springs, even during baseflow conditions. Visual observations from the 1970's indicate no sediment was discharging from Barton Springs during baseflow conditions. From the 1980's on there have been reports of continual discharge of small amounts of sediment from the spring outlets in Barton Springs. (TNRCC 1994). It appears that all springs in the Barton Springs complex would eventually fill with sediment, without maintenance and removal, even without flood events. Storm events, with the large amounts of siltation that are associated with them, could increase sedimentation rates substantially. Constant maintenance of all springs associated with the Zilker park area would appear to be necessary to ensure preservation of habitat and recreational utilization. Large floods tend to deposit more sediments in these springs. Due to the dams at both ends of the pool, the natural scouring processes of flooding seem to be impeded.

Shorter collections periods appeared to provide enhanced results, with better correlations between sediment influx and flows. The short duration of time that traps were in place in Eliza Springs seemed to give more detailed results. Measuring sediment captured in shorter time periods led to better correlation of the amount of accumulation to flows, whether the flows were increasing or decreasing. Results obtained from Sunken Gardens during the first 6 months appeared to follow similar trends with the other springs; however, the second time period in Sunken Gardens showed unusually low accumulation rates. Post study, maintenance performed in this spring revealed increased buildup of sediments and cobble in the spring influents, clogged to the point that no additional sediments were able to enter the system. When maintenance removed cobble and sediments, a flush of sediment entered the system. This event indicated that sediments were prevented from entering the system during the second time period.

The study did not provide enough data for statistical comparisons between sites or between time periods. Future studies could be conducted for longer periods of time with shorter measurement intervals to provide additional data.

Recommendations

This study provided a current evaluation of the amount of sediment entering these systems during mild weather conditions (baseflow and low rainfall) and can be easily replicated in the future to determine if changes are occurring in the conditions of the springs. Recommendations for additional study are as follows:

- Further study during high flows and high rainfall periods could be done to detect variations in sedimentation rates.
- Results indicate frequent (90 day) measurements of sediment depths show better correlations to flow increases and decreases, therefore, future studies should be planned to remove and measure sediment depths at more frequent time periods.
- Additionally, evidence that enhancement of strong directional flow would help impede sediment accumulation in Eliza needs research.
- Habitat restoration work in Eliza may have effected sediment accumulation; that is, it is uncertain what the accumulation rate is for the period post-habitat restoration conditions.
- Additional testing is needed to determine if there is a statistical difference in sediment accumulation rates between Sunken Garden and Eliza.

References

Burton, G. and C. Ingersoll. 1994. Evaluating the toxicity of sediments. In The ARCS Assessment Guidance Document. EPA/905-B94/002. Chicago, Illinois.

City of Austin. 1991. Report of the Barton Springs Task Force to the Texas Water Commission. Austin, Texas.

City of Austin. 1995. Barton Springs zone retrofit master plan study. Prepared By Santos and Associates, Loomis and Associates, LOK, Tetra Tech Incorporated and Glenrose Engineering for City of Austin Environmental and Conservation Services Department. October 1, 1995. Austin, Texas.

City of Austin. 1997a. The Barton Creek report. City of Austin, Drainage Utility Department, Environmental Resources Management Division. Water Quality Report Series COA-ERM/ 1997. April 22, 1997. Austin, Texas.

City of Austin. 1997b. Regulatory approaches for managing stream erosion project number 485-617-2000. Prepared by Raymond Chan and Associates, Aquafor Beech Limited, Crespo Consulting Services for the City of Austin, Drainage Utility Department, Environmental Resources Management Division. February 1997. Austin, Texas.

Ford, D.C., and P.W. Williams. 1994. Karst geomorphology and hydrology
Chapman and Hall. New York, New York.

Gardner, Wilford D. 1980, Field Assessment of Sediment Traps, Journal of Marine Research, Vol. 38(1), pp.17-39 & pp.41-52

Hauwert, N.M., and S. Vickers. 1994. Barton Springs/Edwards aquifer hydrogeology and groundwater quality. Grant Contract No. 93-483-346. Prepared for the Texas Water Development Board by the Barton Springs/Edwards Aquifer Conservation District. Austin, Texas.

Hauwert, N.M., D.A. Johns, T.J. Aley. 1998. Preliminary report on groundwater tracing studies within the Barton Creek and Williamson Creek watersheds, Barton Springs/Edwards Aquifer. Report prepared by Barton Springs/ Edwards Aquifer Conservation District and the City of Austin. Austin, Texas.

Hauwert, N., David Johns, James Sansom, and Tom Aley, 2002b. *Groundwater tracing of the Barton Springs Edwards Aquifer, Travis and Hays Counties, Texas:* Gulf Coast Assoc. of Geological Soc. Trans., vol. 52, p. 377-384.

Mahler, B. J. 2003. Quality of sediment discharging from the Barton Springs system, Austin, Texas, 2000-2002. U.S. Geological Survey Fact Sheet 089-03.

Mahler B.J., and F.L. Lynch. 1999. Muddy water: temporal variation in sediment discharging from a karst spring. Journal of Hydrology

Menzer, R., and J. Nelson. 1980. Water and soil pollutants. Pages 632-657 *in* J. Doull, C. Klaassen, and M. Amdur (editors), Casarett and Doull's Toxicology: The Basic Science of Poisons. Macmillan Publishing Co., Inc. New York, New York.

Roell, Michael J. June 1999. Sand and Gravel Mining in Missouri Stream Systems: Aquatic Resource Effects and Management Alternatives. Missouri Dept of Conservation Research Center. 1110 S. College Ave. Columbia MO. 65201

Runde, J.M. April 1999. Hydrodynamic & Behavioral Responses to Sediment Transport by Hydropsyche Sparna (Trichoptera). Department of Biological Science, Notre Dame University. Indiana.

Slade, R., M. Dorsey, and S. Stewart. 1986. Hydrology and water quality of the Edwards aquifer associated with Barton Springs in the Austin area, Texas. U.S. Geological Survey Water-Resources Investigations Report 86-4036. 117 pp. Austin, Texas.

Spellman, F. R., and J. E. Drinan. 2001. Stream Ecology and Self-Purification, an Introduction. Technomic Publishing Company, Inc., Lancaster, Pennsylvania, U.S.A.

Sylte, Traci and Fischenich, Craig. Sept. 2002. Techniques for Measuring Substrate Embeddedness, emrrp. ERDC TN- EMRRP-SR-36.

Texas Natural Resources Conservation Commission May 1994. Joint Groundwater and Contamination Report 1993. Texas Groundwater Protection Committee. TNRCC Publication. Austin, Texas.

Texas Natural Resources Conservation Commission April` 1996. Joint Groundwater and Contamination Report 1995. Texas Groundwater Protection Committee. TNRCC Publication. Austin, Texas.
White E.L. and W.B. White. 1968. Dynamics of sediment transport in limestone caves. The National Speleological Society Bulletin. Volume 30, Number 4, October 1986.