Predictions of decreases in Barton Springs Discharge during drought conditions

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Abstract

During droughts, if the rate of decrease in Barton Springs discharge is a constant 0.02 cfs/day or 1 cfs in 50 days(BSEACD estimate), it would take 4 ½ months to drop from 15 cfs to 5 cfs. At 5 cfs, the dissolved oxygen is predicted to be at the LC50 for the Barton Springs salamander which would result in a major impact on the salamander population. The decreases in discharge are not constant, but the average rate in 2008 - 2009 is close to 0.02 cfs/day. The rates vary depending on both discharge level and rainfall. At the lowest rainfall, with flows ≤20 cfs, it takes less than 20 days to drop one cfs. There may be threshold flows when the rate of change increases abruptly. Salamander counts do drop dramatically during extended droughts, but have rebounded in the past. The predictions relative to discharge under 10 cfs and DO under 4 mg/L are outside the range of observed data and thus are subject to quite a bit of uncertainty. Hence we do not really know what will happen with flow, DO or the salamander counts.

Introduction
A drought started in the summer of 2008. By August of 2009, discharge from Barton Springs had remained low for a year and was still dropping. I was asked to predict how rapidly the discharge would decrease from the 15 cfs observed on August 1, 2009 if the drought continued, and what the impact would be on the salamanders.

Constant rate of decrease (BSEACD)
First I considered a constant rate of decrease in flow using an estimate obtained from the BSEACD. They estimated the flow decreases to be 0.02 cfs/day (phone call - Kirk Holland recollection). At this rate it takes 50 days to drop discharge levels by 1 cfs. Table 1 shows the dates, 50 days apart, for each 1 cfs decrease in predicted discharge from Barton Springs. The impact on the salamanders was estimated from the dissolved oxygen (DO) concentrations predicted from the flow (COA 2009), and the lethal concentrations (LCx) determined in a toxicity study (Woods 2010). LC50 is the concentration at which you would expect 50% of the population to die within 28 days. The regression equation used to estimate the DO was DO = -0.25268 + 1.50637*Ln(Discharge) [Pr>F<0.0001, R^2=0.66]. The data used in this regression was

collected from 1993 – 2009. There were no discharge levels below 15 cfs during this time period. Thus the extrapolation to discharge levels below 15 cfs is highly uncertain. There are alternate equations which could be fit to the data (COA 2007 Appendix E), and thus different estimates of the discharge level at which half of the salamanders would die. Note that the predicted DO for 15 cfs is 3.8 mg/L so the observed DO of 4.2 mg/L on August 1, 2009 was slightly higher than the predicted DO for that flow.

Table 1. Dates for Barton Springs flow to reach different levels if the rate of decrease is 0.02 cfs/day, with predicted DO levels and lethal concentrations for the Barton Springs salamander.

Expected Flow Level in cfs	On Date	Expected DO (mg/L)	Lethal concentrations
15 Actual	August 1, 2009	4.2 Actual	
14	September 20, 2009	3.7	LC5 (3.91)
13	November 9, 2009	3.6	
12	December 29, 2009	3.5	
11	February 17, 2010	3.6	
10	April 8, 2010	3.2	LC10 (3.41)
9	May 28, 2010	3.1	LC15 (3.12)
8	July 17, 2010	2.9	
7	September 5, 2010	2.7	
6	October 25, 2010	2.4	
5	December 14, 2010	2.2	LC50(2.12)

Variable rate of decrease

However, a constant rate of decrease is not what we have observed. As can be seen from the Figures 1-2 and Tables 2-3, the number of days that discharge stays at a given level changes with both the flow and the rainfall amounts. Notice the relationship between cumulative rainfall and the length of time needed to drop one cfs in flow (Table 2, Figure 2-3). At very low rainfall amounts the rate of decline increases to 0.05 to 0.06 cfs per day, or a decrease of one cfs in 15 to 20 days. There may also be threshold flows when the rate of change increases abruptly, such as at 13 cfs in Table 1.

Table 2. Rate of decrease in Barton Springs discharge

Discharge in cfs	# of days before dropping 1 cfs	Sum of Rainfall (in)*	Rate of decrease cfs/day
20	33	0.95	0.030
19	18	0	0.056
18	15	0.17	0.067
17	81	1.08	0.012
16	85	4.83	0.012
15	48	1.88	0.021
14	44	1.28	0.023
13	2	0.03	0.50
12	>6	≥1.08	<0.167

* The daily average from three FEWS gages, #1120, #1180 and #2600 at U.S 290 West, FM1826, and Goldenrod West.

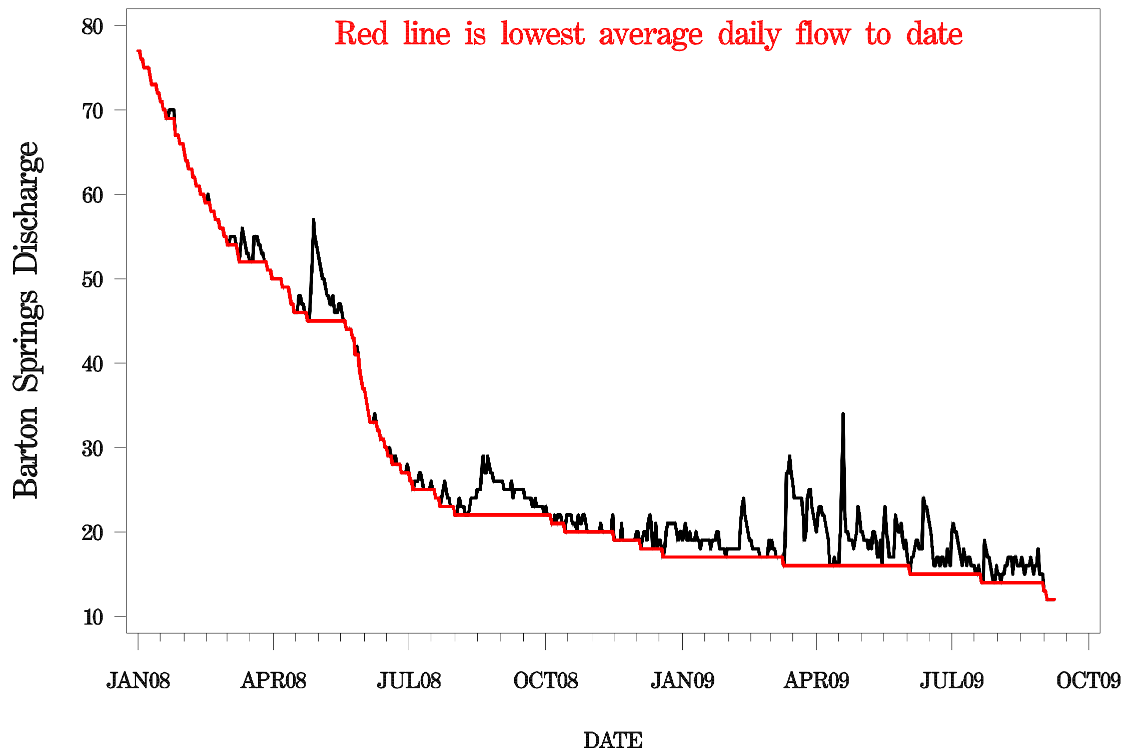


Figure 1. Barton Springs daily average discharge from January 2008 – August 2009 with minimum flow to date in red:

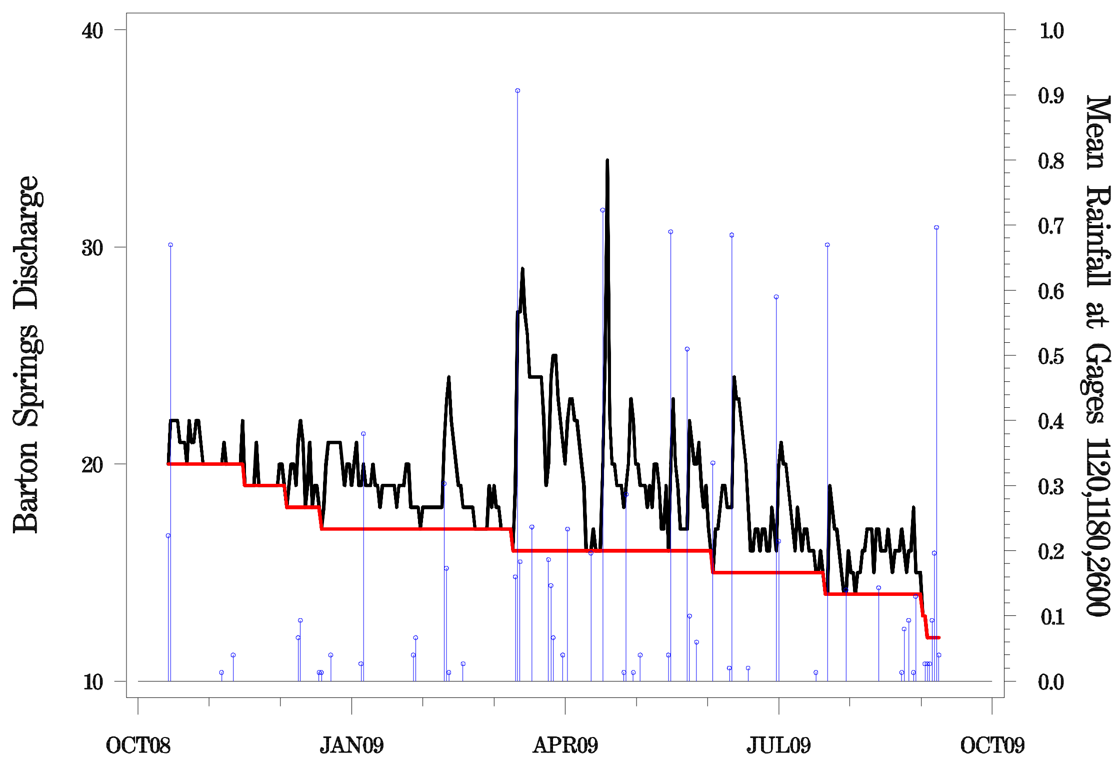


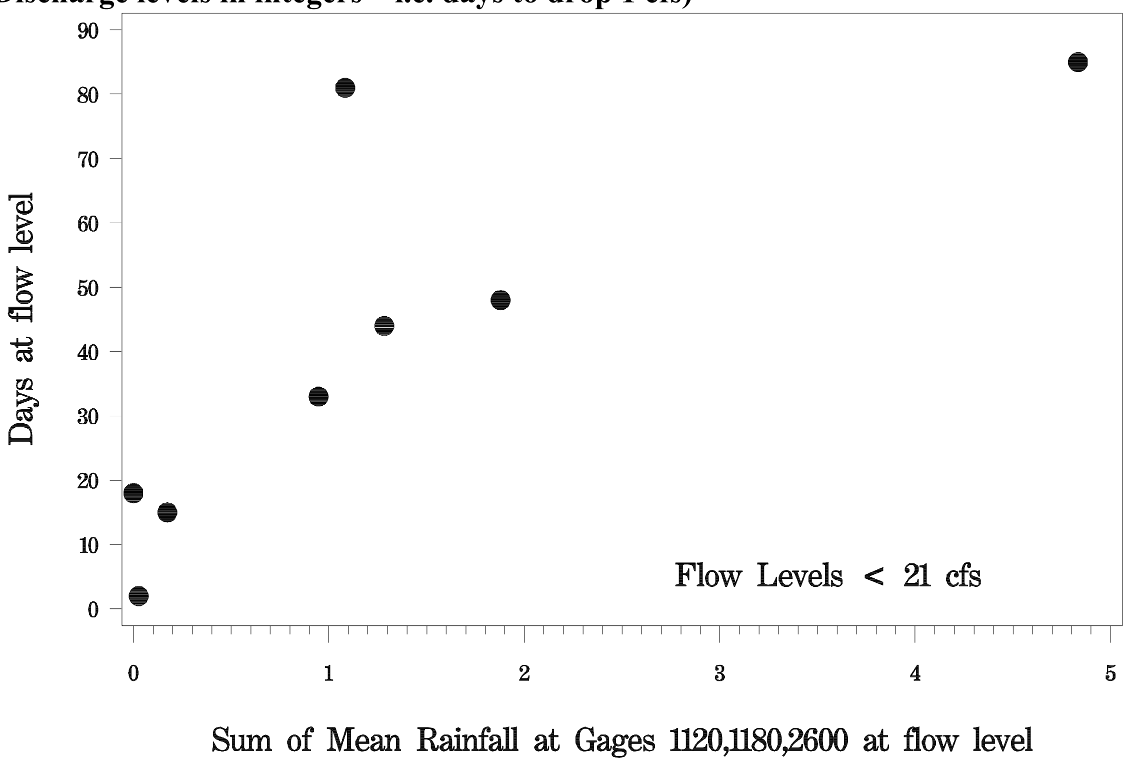
Figure 2. Barton Springs daily average discharge and rainfall from October 2008 – August 2009 with minimum flow to date in red:

Average rates of change over flow intervals between 14 cfs and up to 20 cfs are shown in Table 3. Notice that these average rates of change are close to the BSEACD estimate of 0.02 cfs/day.

Table 3. Rate of decrease in Barton Springs discharge over discharge ranges

Discharge range	Average days to drop 1 cfs	Rate of decrease cfs/day
14-20	46	.022
14-19	48	.021
14-18	55	.018
14-17	64	.016
14-16	59	.017
14-15	46	.022

Figure 3. Days at discharge level for different cumulative rainfall amounts. (Discharge levels in integers – i.e. days to drop 1 cfs)



Declines in Barton Springs Salamander counts

What do the decreases in flow mean for the salamanders? The declines in the salamander counts during the current drought are shown in Table 4.

Table 4. Decreases in salamander counts during the 2008- 2009 drought

	Barton Springs Pool	Eliza Spring	Old Mill Spring and Stream	Upper Barton
Peak 2008 Count	447	1234	126	30
Current August 2009 Count	5	35	0	0
Percent Remaining	1%	3%	0%	0%

We have seen declines before, followed by recovery. However the current drought is more severe than previous droughts when we have been monitoring salamanders in the springs. Salamanders did survive the drought of the 50s. However DO levels at that time were approximately 1 mg/L higher than they are now at the same flows (COA 2009). To compare recent droughts with the current one consider Table 5.

Table 5. Minimum Counts (down from previous maximum count) in Barton Springs Pool and Eliza Spring in Droughts

Drought Year	Barton Min.(Max)Count	Eliza Min.(Max)Count	Minimum Discharge	# Days with Discharge ≤ 25 cfs	Dates
1996	7 (45)	1 (29)	17	154	Feb96 - Sep96
2000	3 (78)	1 (12)	17	112	Feb00 - Oct00
2006	1 (300)	216 (738)	19	132	Jul06 - Dec06
2008/2009	5 (447)	35 (1234)	13	392+	Jul08 - ?

As of Aug 31, 2009

Projections

Projections of discharge, DO and salamander counts if the drought continues are very uncertain. We have not had such low flows since the 1950s and conditions are different now. There is increased pumping, increased irrigation and infrastructure leakage, and increased impervious cover. In addition the data from the 50s is spotty making interpretation of what happened then difficult.

DO is decreasing with flow as expected (Figure 4). However the regression equation relating flow and DO become much less certain once flows drop below 15 cfs.

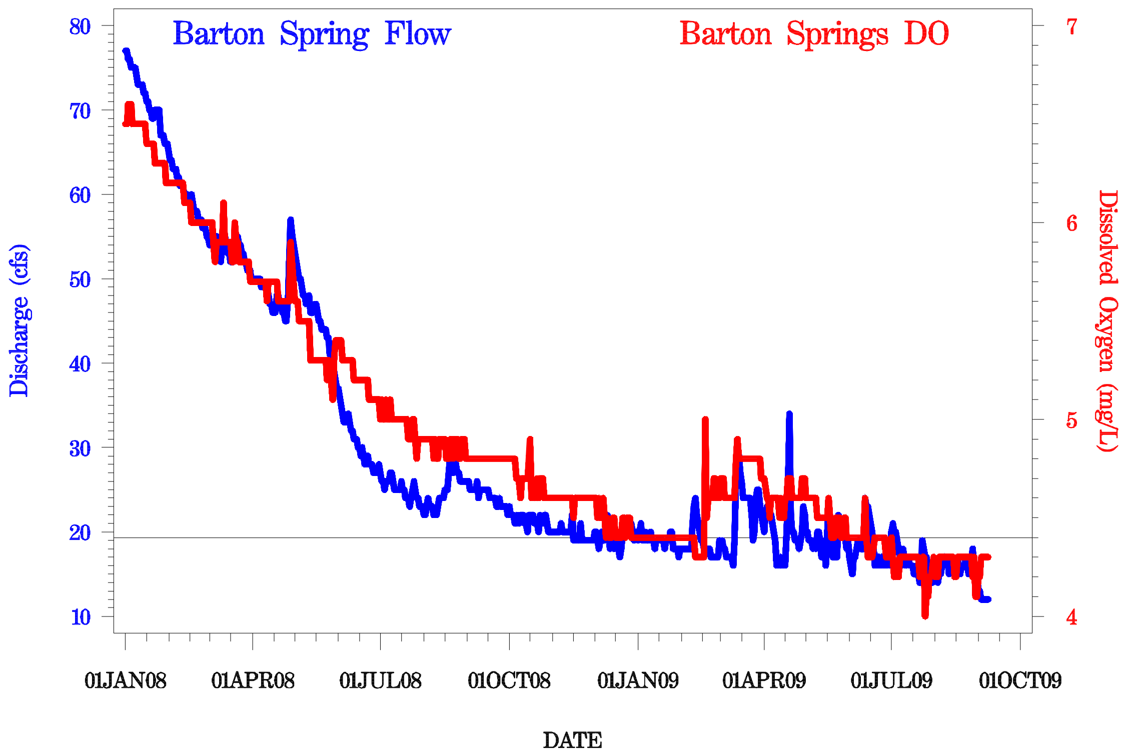


Figure 4. Dissolved oxygen and spring discharge during the drought of 2008-2009.

Summary

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- The decreases in discharge are not constant, but the average rate in 2008 - 2009 is close to 0.02 cfs/day. The rates vary depending on both discharge level and rainfall. At the lowest rainfall, with flows ≤20 cfs, it takes less than 20 days to drop one cfs.
- There may be threshold flows when the rate of change increases abruptly.
- Salamander counts do drop dramatically during extended droughts, but have rebounded in the past.
- The predictions relative to discharge under 10 cfs and DO under 4 mg/L are outside the range of observed data and thus are subject to quite a bit of uncertainty. Hence we do not really know what will happen with flow, DO or the salamander counts.

References

Woods, H.A., M.F.F. Poteet, P.D. Hitchings, R.A. Brain, B. W. Brooks. 2010. Conservation physiology of the plethodontid salamanders *Eurycea nana* and *E. sosorum*: response to declining dissolved oxygen. Copeia 2010:540-553.

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