Watershed Protection
Development Review

Update of Barton Springs Water Quality Temporal Trend Analysis—2005.

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Long-term temporal trends were assessed in Main Barton Springs under non-storm recharge, non-storm non-recharge and storm-influenced conditions by multiple linear regression using data from multiple agencies in combination with Barton Springs mean daily discharge. Degrading trends over time were observed for 15 parameters, including dissolved oxygen and nitrate/nitrite, over the general period of record (1978-2005). Potential improvement was observed only in decreasing total Kjeldahl nitrogen. The predicted decrease in dissolved oxygen could reach levels problematic to the endangered Barton Springs Salamander under low spring discharge conditions (Barton Springs mean daily discharge of 26 ft^3/s) by 2011. Several parameters with no statistically significant temporal trends observed in previous City of Austin analyses completed in 2000 now show statistically significant degradation over time These statistics do not indicate cause and effect. Such testable hypotheses should now be formulated explaining causes and effects of these trends using appropriate experimental design . Once hypotheses are supported by well designed experiments they may indicate the best methods to reverse negative trends and promote recovery trends.

Introduction

Like the historical clarity of the cold waters of Barton Springs pool, the resource value of Barton Springs is clear. It is home to the endangered Barton Springs Salamander (*Eurycea sosorum*), receives approximately 250,000 human visitors per year (COA 1998) and contributes to the drinking water supply of the City of Austin.

Barton Springs consists of four spring outlets, Main, Eliza, Old Mill, and Upper Barton (Brune, 1981 and Hauwert et al. 2000a). In this report, only the water-quality of Main Barton Springs, which discharges into Barton Springs pool, is considered because this outlet has a much longer and consistent water-quality record. The water quality of the four springs are distinct as they receive flows from different sources in the aquifer (Hauwert, et al, 2004b). Barton Springs flow as referred to in this report is the combined flows of Main Barton, Eliza, and Old Mill Springs reported by the USGS at gauging station 08155500. These flows are based on stage relations between the water levels in a nearby well to measured flows.

Main Barton Springs (hereafter referred to simply as Barton Springs) is the main discharge point from the Barton Springs segment of the Edwards Aquifer south of the Colorado River. The aquifer extends south to the Buda and Kyle areas roughly along FM 150 south of Onion Creek, east to Interstate 35 (IH35) and west to FM 1826. Loop 1 or MoPac roughly traverses the middle of the aquifer Recharge Zone. Critical areas for the aquifer include the Contributing Zone, areas west of the outcrop and locally on the east side of the outcrop, the Recharge Zone, where the aquifer is at or crops out the land surface (roughly straddled by MoPac),and the Artesian Zone, located east of the outcrop where the aquifer is buried by other geologic units.

Primary threats to the water quality of Barton Springs are due to increasing development in areas feeding the aquifer, rapid recharge to the aquifer from point recharge features in creek beds and uplands, and rapid underground flow through conduits that permit limited filtration of pollutants in the water to wells and springs. In karst terrains such as the Edwards, areas where the subsurface "plumbing" is well connected, single recharge points in creek bottoms can introduce large volumes of creek flow directly into the aquifer. Tracing flow paths through the aquifer have demonstrated that each of the springs are fed by specific creek reaches and upland areas that in turn affects water quality in that spring outlet (Hauwert and others, 2004). A detailed revision of the water balance of the Barton Springs Edwards Aquifer currently underway, including measurements of creek and upland recharge and evapotranspiration, is likely to increase the amount of recharge to the aquifer attributed to upland sources.

Degrading temporal trends in Barton Springs water quality were identified for several parameters in 2000 (COA 2000), including conductivity and dissolved oxygen (Table 1). Previous analyses had not found statistically significant changes over time in Barton Springs water quality (TNRCC 1995; Barrett 1996; COA 1997).

Table 1. Results of temporal trend analysis from 2000 analyses (COA 2000).

		Model		**Discharge**			**Date**		
Parameter	**Flow Condition**	**Pr > F**	**R-Square**	**Pr > |t|**	**Coefficient Estimate**	**Std Error**	**Pr > |t|**	**Coefficient Estimate**	**Std Error**
Conductivity	Baseflow without Recharge	<0.0001	0.34	<0.0001	-1.19	0.14	0.0663	0.0037	0.002
	Baseflow with Recharge	0.0002	0.18	0.0304	-0.45	0.21	<0.0001	0.0106	0.0024
	Storm Flow	<0.0001	0.29	<0.0001	-0.98	0.14	0.0257	0.0051	0.0023
Dissolved Oxygen	Baseflow without Recharge	<0.0001	0.59	<0.0001	0.03	0.004	0.0016	-0.00015	0.00004
Organic Carbon	Storm Flow	0.0404	0.1	0.7538	0.01	0.03	0.0116	0.0009	0.0003
Sulfate	Baseflow with Recharge	0.0062	0.36	0.0163	-0.15	0.06	0.0016	0.0023	0.0006
Turbidity	Storm Flow	<0.0001	0.19	0.0001	-0.12	0.03	0.064	0.001	0.0005

Intensive collection of data at Barton Springs by multiple agencies has continued to the present. The United States Fish and Wildlife Service (USFWS) effectively transferred regulatory oversight of the endangered salamander to the Texas Commission on Environmental Quality (TCEQ) in February 2005 (TCEQ 2005), and the Lower Colorado River Authority (LCRA) recently removed impervious cover development measures previously used as a condition of water service to new development throughout the Edwards Aquifer recharge zone. Both agencies have stressed the need for adaptive management in endangered species conservation. Therefore, an update of the 2000 temporal trend analysis is timely in order to assess patterns in data collected to date, provide a baseline for adaptive management decisions, and indicate the likely need for additional water quality regulations to reverse worsening trends.

Observed changes in long-term Barton Springs water quality over time, though still potentially below environmental effect thresholds, are indicative of degradation from increasing development throughout the contributing watershed. However, this analysis is not intended to investigate specific causation or relate trends in spring chemistry to specific land use changes in contributing watersheds. Similarly, this analysis provides no new data on thresholds for impacts of these trends on the Barton Springs salamanders. Limited information is available about the environmental requirements for viable salamander populations in Barton Springs. Reproductive and toxicological thresholds for the salamanders are unknown relative to most water quality constituents and comparative species information is unsatisfying. However, it is certain that the continued influence of declining water quality may have a cumulative negative impact on both the endangered salamander and the swimmability of the pool as well as drinking water supplies.

Methods

Sample collection entities included the City of Austin Environmental Resource Management Division (ERM), the United States Geological Survey (USGS) and the Austin Health Department (formerly known as the Austin-Travis County Health Department, ATCHD). All data included in the analyses is stored in the City of Austin Field Sampling Database (FSDB) and is available upon request. Data collected specifically by ERM is available at http://www.ci.austin.tx.us/wrequery/, and data collected by the USGS is available at http://waterdata.usgs.gov/tx/nwis/inventory/?site_no=08155500. These agencies represent the most comprehensive resources in terms of both number of samples and period of record for Barton Springs water quality data.

Data not included

Citizen monitoring data was not included in the analysis due to a lack of consistent analysis methods and documented quality assurance/quality control (qa/qc) data, although this consisted of samples only on three distinct dates in 1991. More than 750 vertical Secchi disk depth measurements from the City of Austin Parks and Recreation Department (PARD) from 1994 to 1997 were excluded as the measurement is conducted in the pool from the diving board and not necessarily reflective of spring discharge clarity. One water quality sampling event collected by TCEQ in January 2003 was not intentionally excluded, although all parameters (all semi-volatile parameters) for that sample were below detection limits.

Field parameters (conductivity, dissolved oxygen, pH, turbidity and water temperature) measured in the laboratory were excluded from the analysis (except for USGS conductivity measurements analyzed in the lab). This data was not excluded from the 2000 analysis (COA 2000).

Lead, iron and zinc were excluded from analysis due to suspected laboratory or sample preservation procedure contamination in recent data collected by ERM. Investigation of the validity and scope of the possible contamination is on-going. **Lead, iron and zinc data from Barton Springs should be analyzed for temporal trends with valid data once this investigation is complete.**

Parameters with no data collected after 1999, the end of the period of record for the 2000 analysis (COA 2000), parameters with no data points above detection limits, parameters with less than 3 data points above detection limits or parameters sampled on less than 3 distinct dates were also excluded from the analysis. The resulted in the exclusion of 509 parameters for which no temporal trends could be assessed (appendix 1).

Exclusion of abnormal conditions

Some data were excluded from analyses to remove the effect of abnormal short-term conditions in Barton Springs water quality that could obscure long-term watershed-level impacts. All data from 1981 and 1982 were excluded from the analysis in accordance with previous procedures (COA 2000) due to a documented sewer line break (USGS 1986).

Samples affected by pool drawdown for maintenance were excluded from the analysis, as pool drawdown results in increased conductivity and turbidity and decreased dissolved oxygen (COA 2000). Drawdown sample dates excluded from the analysis are: February 24, 1997; September 16-18, 1998; August 13, 1998; August 27-28, 1998; May 3, 1999. Routine USGS and ERM monitoring is not conducted during pool drawdown periods.

Storm influence and recharge conditions

Data were partitioned into three groups for analysis: base flow with recharge, base flow without recharge and storm flow. Recharge condition was determined using mean daily flow at the Barton Creek at Loop 360 USGS gage (USGS 08155300, available at http://waterdata.usgs.gov/tx/nwis/inventory/?site_no=08155300). Dates with non-zero mean daily flow at the gage were classified as "recharge" while dates with zero mean daily flow at the gage were classified as "non-recharge" conditions. During recharge conditions, Barton Springs water quality is reflective of the current water quality of total recharge, creeks and upland areas within the recharge zone (COA 1997; COA 2000). During non-recharge (springflow recession) periods, Barton Springs discharge is primarily a reflection of long-term water quality of the aquifer (COA 2000).

Storm designation was determined by examination of fecal coliform or total suspended solids (TSS) results for each sample. If the sample yielded either a fecal coliform bacteria count of greater than 100 colonies/100mL or the TSS was greater than 10 mg/L, the sample was designated as potentially storm-influenced. During previous analyses (COA 2000), any sample without a corresponding value for fecal coliform or TSS was excluded. For the purposes of this analysis, antecedent rainfall at the National Weather Service Camp Mabry gage was used in combination with the mean daily flow at Barton Springs as recorded by the USGS and an examination of water quality data and field staff notes to determine if a sample without fecal coliform or TSS data was storm-influenced. By individually examining each sample without fecal coliform or TSS data, an additional 87 sample dates were included in the analysis.

Outliers/Additional exclusions

Outliers as determined from visual inspection of the graph were examined individually. Invalid data was removed prior to analysis, and parameters with questionable data were analyzed with and without outliers to compare the change in results (Table 2). Included outlier data had no effect on overall conclusions.

One USGS sample from 23 June 1986 (printed in yearbook) yielded unusually low results for ions at a period of time when the mean daily flow record of Barton Springs was varying (and not related to antecedent rainfall). This sample may have been collected during a drawdown event, but was not excluded from the analysis.

Table 2. Summary of outliers removed/included in analysis

Parameter	Extreme Values	Action
Alkalinity, total	5 values ≥ 496 mg/L as $CaCO_3$ collected by ATCHD in May/June 1993 analyzed in the lab were approximately 2 times greater than all other values	Removed
Ammonia, total	High value of 0.21 mg/L in July 2001 was substantially greater than all other data, and ammonia value was greater than TKN for that sample	Removed
Calcium, total	07/02/1997 One sample from 02 June 1996 excluded because cations out of balance	Removed
Fluoride	2 non-detect values for fluoride (USGS-dissolved in April 1990 and ERM-total in April 1995)	Included (not influential)
Hardness, total	All ATCHD data (24 measurements collected in 1991) substantially lower than all other data	Removed
Magnesium, total	2 high values of 39.1 mg/L from 01 June 1996 during a recharge event	Included
NO_3+NO_2-N	Low dissolved value of 0.089 mg/L from 18 March 1993 collected by the USGS printed in yearbook	Included
Non-carbonate hardness	High value of 120 mg/L collected by the USGS on 14 August 1995 printed in yearbook	Included
Sodium	High value 85.141 collected by ERM on 20 September 2000	Included (not influential)
Sulfate	High value 57.7 mg/L collected by ERM	Included
TKN	High value of 1.43 mg/L on 09 February 1998 collected by ERM	Included (not influential)
Turbidity	High value of 10.2 NTU on 31 July 2002 collected by ERM in the field in non-storm conditions	Excluded
VSS	High value of 32 mg/L on 04 May 1993 collected by the USGS in yearbook but TSS for same sample <1 mg/L	Excluded
Water Temp	High value of 28C on 23 June 1986 measured by the USGS possibly due to pool lowering	Excluded

Change in field equipment, filter fraction or collection entity

Changes in analytical methods, field equipment, filter fraction (dissolved or total analyte) and collection entity/frequency over time complicate long-term trend analysis of Barton Springs water quality. Balancing the need for a robust dataset with a long period of record against the variability introduced by combining multiple data streams makes both the analysis of data and interpretation of results complex (Smith and McCann 2000).

In cases with multiple collectors or methods, data were analyzed with the method or collector change as a quantized variable in the regression equation (Neter et al 1990, Helsel 2005) entered first before other variables. In 2001, for example, the ERM staff switched from the Horiba water quality probe to the Quanta probe. The lack of agreement between the instruments for some parameters complicates data analysis. Specific USGS field instrumentation used was unknown, and although assumed to be consistent it is unlikely that the same field instrument has been used since 1978. The change in City of Austin method and difference between USGS methods were accounted for by assigning the methods code numbers (USGS Unknown = 1, Horiba = 2, Quanta = 3) and entering the quantized method variable into the regression equation (result = method method*date flow date).

A backward elimination model removed parameters with regression coefficients yielding a significance value of less than 0.10 (SAS 2004). Generally, if there was no change in slope (quantized method or collector variable*date) and no change in intercept (quantized method or collector variable) for the model as determined by non-statistically significant regression coefficients, then the results for the regression with all collectors or methods combined for analysis were assumed to be appropriate.

Flow effects

Some water quality parameters in Barton Springs are strongly influenced by spring discharge (Senger and Kreitler 1984, COA 1997, COA 2000). Parameter relationships with spring discharge were initially examined with Spearman rank-order correlation test and by plotting concentrations versus mean daily Barton Springs discharge. Barton Springs mean daily discharge was entered into the multiple linear regression equations before date to account for variation in concentration with discharge in temporal trend analyses, as in previous City of Austin analyses (COA 2000).

Non-linear relationships (Figure 1) with discharge were observed visually for multiple dissolved solids parameters (chloride, sulfate, sodium, potassium, strontium, TDS and conductivity) at low discharge values. These parameters are all negatively correlated to Barton Springs discharge.

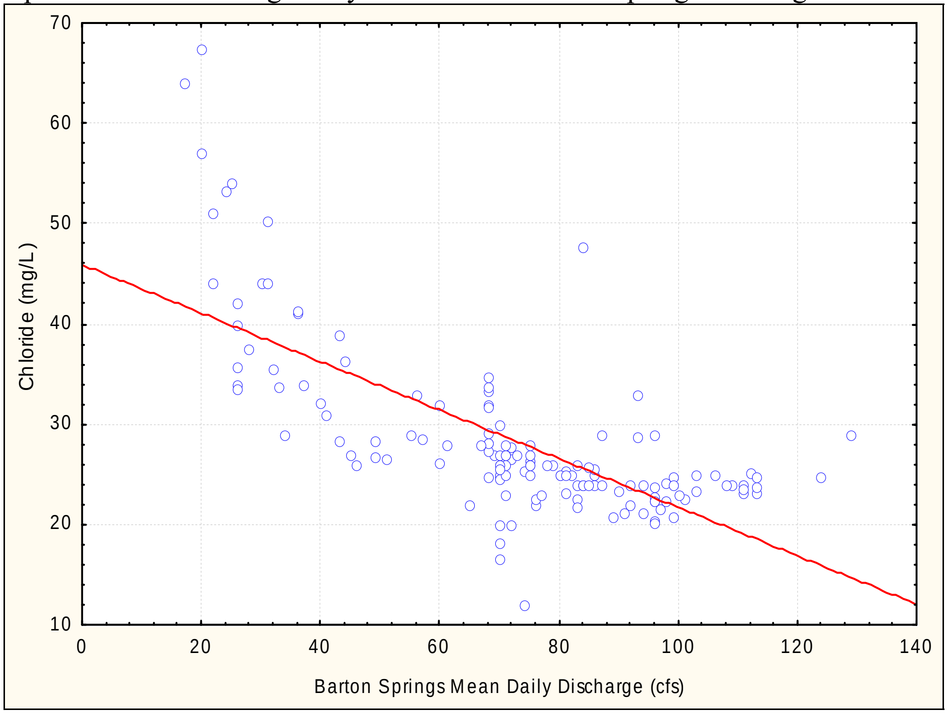

Figure 1. Example of non-linear relationship between non-storm concentration and discharge using chloride (with linear regression line for all data, r^2=0.22).

Inclusion of discharge into the multiple linear regression analyses for the parameters with non-linear correlation to discharge can reduce the prediction accuracy and model fit. Regression (concentration versus discharge) r^2 values for these parameters were improved by log transformation of both concentration and discharge values (Table 3). To more completely document the non-linear effect and improve future concentration predictions, the estimated discharge value at which the relationship between concentration and discharge changed in slope was estimated for each parameter. The variable “low_flow” was added to the discharge regression equation (model equation: *concentration = low_flow discharge*) with values of 0 (if below the discharge threshold) and 1 (if above the discharge threshold). The mean daily discharge threshold value (or critical flow value) was then varied for each parameter from 25 to 50 ft^3/s in 1 ft^3/s intervals to yield the regression with a maximum r^2 (Table 3). Visual inspection of concentration versus discharge plots showed change in slope around 40 ft^3/s discharge for most parameters. Critical flow values from the varied regression analysis for the 7 parameters ranged from 31-48 ft^3/s, with a overall average critical flow value of 38 ft^3/s, near the 25th percentile (39 ft^3/s) of Barton Springs mean daily discharge from 1978-2004. Model r^2 values generally improved using the "low_flow" variable over the log-log transformation (Figure 2).

Table 3. Change in regression (concentration versus discharge) r^2 for parameters with non-linear relationship to discharge.

Parameter	**Discharge value with max r^2 (ft^3/s)**	**original r^2 (conc=flow)**	**r^2 for log-log transform**	**r^2 with "low_flow"**
Chloride	31*	0.506	0.618	0.680
Conductivity	38	0.225	0.284	0.525
Sulfate	36	0.177	0.248	0.293
TDS	36, 43-44	0.142	0.192	0.306
Potassium (diss+tot)	46-48	0.264	0.296	0.295
Sodium (diss+tot)	36	0.519	0.665	0.672
Strontium	36 - 44	0.738	0.809	0.880
Overall average	***38***			

*local maxima at 25 ft^3/s for chloride not considered due to small number of data points measured at flows < 25 ft^3/s.

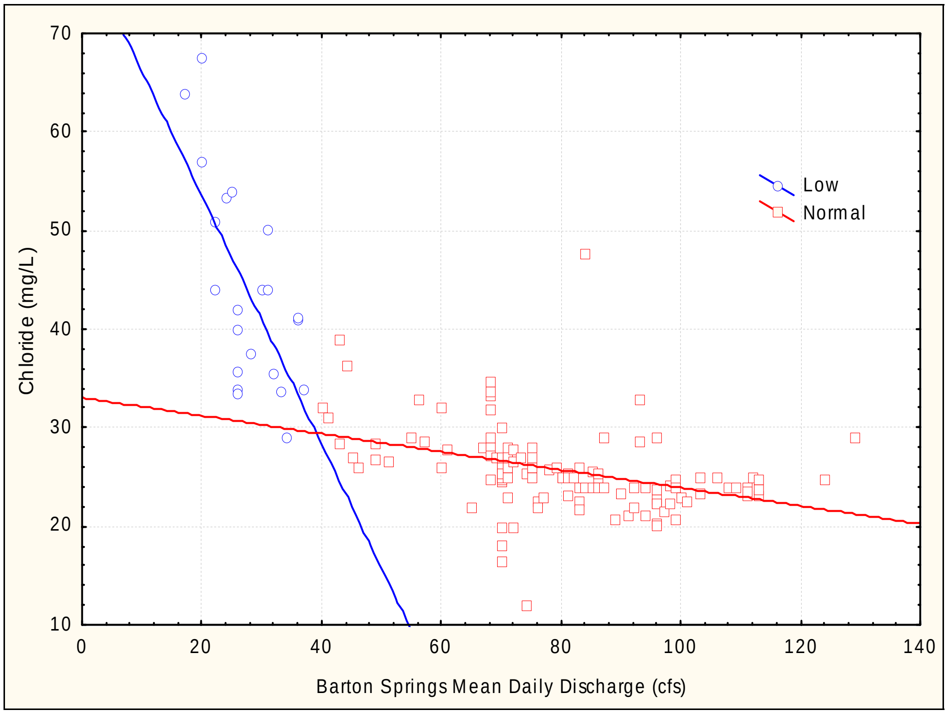

Figure 2. Example of multiple linear relationship between non-storm concentration and discharge using chloride with 38 ft^3/s as critical flow value (combined r^2=0.680).

The overall average critical low flow value of 38 ft^3/s was used for all 7 parameters (as the low_flow variable) in the temporal regression equations. This improves prediction accuracy by removing the non-linearity of the discharge coefficient for these parameters and enables prediction of change in values at both very low discharge and at long-term average discharge.

Multiple regression methods
Multiple linear regression was used to determine if parameter results were changing over time, the direction of the change and the statistical significance of the change, following the methodology of previous studies (COA 2000). Analysis groups (non-recharge, recharge and storm-influenced) were analyzed separately. Mean daily flow at Barton Springs as determined by the USGS gage (08155500) was associated with every sample collection date. The "low_flow" variable was included for the parameters with non-linear relationships to flow. Quantized method/collector variables were entered into the regression equation, followed by Barton Springs flow and then date. A backward elimination model was used in PROC REG (SAS 2004) to eliminate non-significant regression coefficients from the model. The full model is thus:

$$\text{Concentration} = (\text{Collector or Method or Filter}) + (\text{Collector or Method or Filter} * \text{date}) + (\text{low\_flow}) + (\text{discharge}) + (\text{date})$$

Multiple linear regression results for parameters with censored observations (non-detect) were confirmed using the semi-parametric Cox proportional hazards regression (Allison 1995). Plots of data were examined for all parameters to assess the validity of the analytically-determined trends. Flow-adjusted plots were also examined, wherein the concentration was normalized to the expected concentration at an average long-term discharge (50 ft^3/s) using the equation:

$$\text{Normalized concentration} = \text{original concentration} + (\text{regression coefficient for discharge}) * (50\ ft^3/s - \text{spring discharge in } ft^3/s)$$

The predicted magnitude of change was estimated from earliest year of sampling to latest year of sampling, and predicted concentrations are presented with 95% confidence limits. For discharge coefficients, the long-term discharge of Barton Springs (50 ft^3/s) from previous analysis (COA 2000) and the 10th percentile (26 ft^3/s) were used to predict change in average and low-flow conditions. Values of the "low_flow" variable for the parameters with non-linear relationships to discharge were chosen accordingly. Values for quantized collection entity or method codes were chosen to reflect the current collection entity or method at the time data was collected. Thus, initial concentrations are generally calculated using USGS codes and current values calculated using current City of Austin codes. Following final model selection, a plot of residuals versus predicted values were examined for the absence of any marked trends to verify model fit and insure that no model assumptions were violated.

As with any trend analysis, statistical results should be interpreted with caution. The lack of statistical power to detect a significant trend at the specified critical level for some parameters does not imply that those parameters do not change over time. Trend analysis does not attempt to explain causation of observed patterns. Estimates of the magnitude of future changes generated for statistically significant trends are based on current rates of change in long-term average for the selected model, and are intended to be used only as descriptors of potential future conditions. Predicted changes may or may not be greater than actual quantitative abilities of laboratory analysis methods.

Assessed parameters yielding no statistically significant change over time as determined by a non-statistically significant date regression coefficient in any analysis group are presented in Appendix 2. Results are presented only for parameters yielding a statistically significant ($\alpha \leq 0.05$) regression coefficient for date.

Results

Confirmation of 2000 Analyses
To compare the results of the data selection procedures used in this analysis with the data selection procedures used in the 2000 analyses, the 2005 dataset was curtailed at 31 December 1999 and the

temporal trend analysis was repeated for the parameters exhibiting statistically significant change over time in 2000 (table 4).

Table 4. Repeat of 2000 analyses using 2005 data selection procedures (departure from 2000 analysis result conclusions in red).

Parameter	Flow Condition	Model		Discharge			Date		
		Pr > F	r^2	Pr> |t|	Est	StdErr	Pr> |t|	Est	StdErr
Conductivity	Base_NonRecharge	0.0000	0.40	0.0000	-1.257	0.152	0.1532	0.0027	0.002
	Base_Recharge	0.0000	0.37	0.6684	0.115	0.267	0.0000	0.0132	0.003
	Storm	0.0004	0.16	0.0002	-0.742	0.194	0.1863	0.0033	0.002
Dissolved Oxygen	Base_NonRecharge	0.0000	0.52	0.0000	0.036	0.005	0.0265	-0.0001	0.000
	Base_Recharge	0.1277	0.27	0.1453	0.012	0.008	0.0672	-0.0002	0.000
	Storm	0.0000	0.60	0.0000	0.033	0.004	0.4768	0.0000	0.000
Organic Carbon	Base_NonRecharge	0.2350	0.08	0.3114	0.027	0.027	0.1262	-0.0005	0.000
	Base_Recharge	0.0568	0.19	0.0176	-0.079	0.031	0.3458	0.0003	0.000
	Storm	0.0591	0.08	0.8917	-0.003	0.025	0.0194	0.0007	0.000
Sulfate	Base_NonRecharge	0.0007	0.33	0.0002	-0.214	0.051	0.0681	0.0010	0.001
	Base_Recharge	0.0445	0.28	0.5113	-0.043	0.064	0.0142	0.0019	0.001
	Storm	0.0000	0.29	0.0000	-0.120	0.022	0.7245	-0.0001	0.000
Turbidity*	Base_NonRecharge	0.0000	0.28	0.0124	-0.004	0.001	0.0000	0.0002	0.000
	Base_Recharge	0.0000	0.31	0.3283	-0.005	0.005	0.0000	0.0007	0.000
	Storm	0.0000	0.29	0.0000	-0.126	0.026	0.1958	0.0011	0.001

*includes ATCHD turbidity data from 1991-1993.

The updated selection procedures yielded reasonably similar conclusions to previous analysis (COA 2000) when analyzed through 1999. Conductivity yielded a statistically significant increasing trend only during non-storm recharge conditions (previous analysis yielded increasing temporal trend in all conditions) when more than 250 measurements of conductivity (collected by the City of Austin) in the lab from 1991 to 1999 were excluded. Turbidity (including suspect ATCHD data from 1991) yielded increasing trends in non-storm conditions, but no trend in storm conditions (previous analysis yielded increasing temporal trend in storm).

Alkalinity

The USGS switched from lab to field measurement of dissolved alkalinity in 2000. Only the USGS measures dissolved alkalinity (table 5), and there is little overlap between collection entities for total alkalinity. Dissolved alkalinity yields no statistically significant trends over time. A quantized lab variable (0=lab, 1=field) was included to account for the field lab/switch in 2000 in the regression model. Although dissolved alkalinity yields a graphically increasing trend over time in non-recharge and storm conditions, the trend may be obscured by the field/lab switch in 2000.

Table 5. Summary of alkalinity data.

COLLECTOR	FILTER	NOBS	FIRST	LAST
ATCHD	Total	95	1992	1993
ERM	Total	136	1991	2005
USGS	Dissolved	120	1990	2005
USGS	Total	37	1978	1992

Total alkalinity was generally measured in the lab. Approximately 25 measurements of total alkalinity were measured in the field (24 by ERM from 2004-2005, 1 by USGS in 1980). The varying labs were accounted for with a quantized lab variable (0=field, 1=lab). Although total data was collected by three different agencies (Table 5), analysis methods for each collection entity were generally consistent. The varying collecting entities were accounted for with a quantized collector variable (0=USGS, 1=ATCHD, 2=ERM).

Prior to backward elimination, the full model for total alkalinity is:

*Alkalinity (tot) = collector + collector*date+ lab + lab*date + discharge + date;*

Total alkalinity is significantly increasing over time in recharge condition, yielding a predicted increase in mean value of 10.4% from 1985 to 2005 (Table 6). Although examination of both raw and flow-adjusted total alkalinity in non-recharge and storm conditions yield graphically increasing trends over time, these trends may be obscured by changing collection entities and analysis labs.

Table 6. Results for total alkalinity (mg/L as $CaCO_3$). Predicted change in values presented with 95% confidence limits in parenthesis from first to last observation.

Condition	**Model**		**Regression Coefficients**				**Predicted Change**	
	Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C_{1985}	C_{2005}
Base_Recharge	<0.0001	0.527	intercept	1.6E+02	1.1E-15	1.6E+01	229.8 (216-244)	256.6 (239-274)
			coll_date	-7.8E-04	2.2E-03	2.5E-04		
			lab_date	8.0E-04	3.6E-02	3.8E-04		
			bs_flow	3.2E-01	4.0E-03	1.1E-01		
			date	5.9E-03	5.2E-08	9.8E-04		

Calcium

Dissolved calcium was collected only by the USGS (Table 7), and yields statistically significant increasing trends over time in all conditions (Table 8) with a maximum predicted increase in mean of 15.3% in recharge from 1985-2005. Total calcium was collected by ERM, and yields a statistically significant increasing trend over time in non-recharge conditions with a predicted change in mean of 37% from 1995-2004. There is no statistically significant trend over time in total calcium in recharge or storm conditions.

Table 7. Summary of calcium data.

COLLECTOR	FILTER	NOBS	FIRST	LAST
USGS	Dissolved	121	1978	2005
ERM	Total	93	1991	2005

Prior to backward elimination, the full models for calcium are:

Calcium (diss) = low_flow discharge date;
Calcium (total) = low_flow discharge date;

Table 8. Results for calcium (mg/L as Ca). Predicted change in values presented with 95% confidence limits in parenthesis from first to last observation.

Filter	Condition	Model		Regression Coefficients				Predicted Change	
		Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C_0	C_1
Dissolved	Base, NonRecharge	<0.0001	0.619	intercept	6.9E+01	2.2E-27	2.3E+00	77.8 (75.4-80.3)	90.9 (89.3-92.5)
				low_flow	.	.	.		
				bs_flow	.	.	.		
				date	1.3E-03	2.8E-09	1.7E-04		
	Base, Recharge	0.0005	0.424	intercept	4.9E+01	2.0E-05	9.2E+00	73.6 (65.5-81.6	86.9 (79.2-94.6)
				low_flow	.	.	.		
				bs_flow	1.7E-01	3.9E-02	7.7E-02		
				date	1.8E-03	1.4E-03	5.1E-04		
	Storm	<0.0001	0.444	intercept	7.0E+01	5.3E-33	2.6E+00	80.4 (78.1-82.7)	90.0 (87.9-92.1)
				low_flow	.	.	.		
				bs_flow	6.2E-02	1.4E-02	2.4E-02		
				date	1.0E-03	2.7E-07	1.7E-04		
Total	Base, NonRecharge	0.0218	0.260	intercept	3.4E+01	1.9E+01	8.4E-02	54.3 (30.4-78.2)	86.5 (79.4-93.6)
				low_flow	-8.9E+00	4.4E+00	5.3E-02		
				bs_flow	1.5E-01	8.5E-02	8.6E-02		
				date	3.3E-03	1.4E-03	3.0E-02		

Conductivity

Conductivity was collected by multiple agencies over time (Table 9), and ERM used different field equipment (switching from the Horiba Water Quality Meter to the Quanta Probe in 2001). ERM measured conductivity in the field. USGS measured conductivity in the lab. The varying collecting entities and analysis methods were accounted for by using a quantized method code variable (0=unknown, 1=Horiba, 2=Hydrolab, 3=Quanta). Conductivity yields a slightly non-significant ($p=0.09$) increasing trend over time in recharge conditions, with a predicted 8.5% increase in mean conductivity from 1980-2005. There is no statistically significant trend over time in non-recharge or storm conditions. Current conductivity levels are below the 1,100 µS/cm level (Figure 3) identified in the toxicity testing of the Jollyville Salamander (COA 1999). The maximum conductivity measured in Barton Springs is 827 µS/cm on 16 July 1996 during non-recharge.

Prior to backward elimination, the full model for conductivity is:

*Conductivity = method + method*date + low_flow + discharge + date*;

Table 9. Summary of conductivity data.

COLLECTOR	LAB	NOBS	FIRST	LAST
ERM	Field	271	1995	2005
USGS	USGS	227	1978	2005

Table 10. Results for conductivity (µS/cm). Predicted change in values at average flow (50 ft^3/s) presented with 95% confidence limits in parenthesis from first to last observation.

Condition	Model		Regression Coefficients				Pred. Change	
	Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C_{1980}	C_{2005}
Base, Recharge	<0.0001	0.299	intercept	5.9E+02	2.1E-36	3.3E+01	559.7 (534-585)	611.7 (589-634)
			method_code	8.9E+01	4.6E-02	4.4E+01		
			method_date	-5.0E-03	7.5E-02	2.8E-03		
			flow_group	-7.9E+01	2.1E-03	2.5E+01		
			bs_flow	5.5E-01	1.5E-03	1.7E-01		
			date	2.9E-03	9.0E-02	1.7E-03		

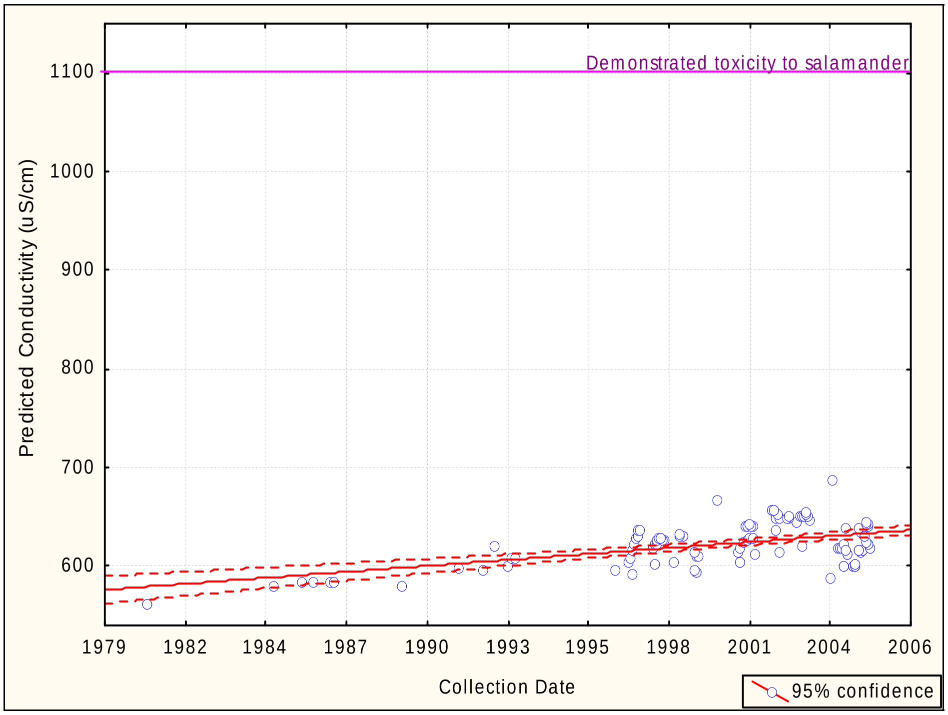

Figure 3. Predicted conductivity over time in recharge conditions with 95% confidence limits with the 1,100 µS/cm toxicity level for Jollyville salamanders.

Dissolved Oxygen

Dissolved oxygen was measured only by the USGS and ERM in the field (Table 11). The ERM switch of field instrumentation in 2001 and the difference between USGS- and ERM-collected data were accounted for with a quantized method code variable 0=unknown, 1=Horiba, 2=Hydrolab, 3=Quanta). Dissolved oxygen is decreasing (degrading) over time in non-recharge and recharge condition (Table 12), with a maximum predicted decrease in mean concentration of 15% during recharge from 1980-2005. Dissolved oxygen as the percentage of the saturated DO value (APHA 1995) also yielded decreasing temporal trends in both non-recharge and recharge conditions. The change in method was not included in the model for recharge, but the change in slope due to method term (method*date) was significant in the non-recharge model. The predicted decrease in dissolved oxygen concentration during non-recharge conditions is reduced (from a decrease of 1.02 mg/L to a decrease of only 0.52 mg/L) due to the change in methods over time. There is no statistically significant trend in dissolved oxygen during storm conditions.

Prior to backward elimination, the full model for dissolved oxygen is:

*Dissolved Oxygen = method + method*date + discharge + date*;

Table 11. Summary of dissolved oxygen data.

COLLECTOR	METHOD	LAB_CODE	NOBS	FIRST	LAST
ERM	HORIBA WATER QUALITY METER	Field	40	1995	2000
ERM	HYDROLAB	Field	14	2000	2004
ERM	Quanta Probe	Field	69	2001	2005
USGS	UNKNOWN	Field	121	1978	2005

Table 12. Results for dissolved oxygen (mg/L). Predicted change in values at average discharge presented with 95% confidence limits in parenthesis from first to last observation.

	Model		**Regression Coefficients**				**Predicted Change**	
Condition	Pr>F	Adj. r^2	Type	Estimate	Pr > F	StdError	C_0	C_1
Base, NonRecharge	<0.0001	0.606	Intercept	5.6E+00	5.9E-26	3.8E-01	6.4 (6.01-6.79)	5.88 (5.64-6.14)
			method_code	.	.	.		
			method_date	1.0E-05	1.5E-02	4.2E-06		
			bs_flow	3.0E-02	2.0E-18	2.8E-03		
			Date	-1.0E-04	2.2E-03	3.3E-05		
Base, Recharge	<0.0001	0.294	Intercept	6.3E+00	1.5E-17	5.5E-01	6.68 (6.13-7.25)	5.80 (5.38-6.23)
			method_code	.	.	.		
			method_date	.	.	.		
			bs_flow	2.2E-02	5.3E-07	4.1E-03		
			Date	-9.7E-05	8.4E-03	3.6E-05		

A value of 5 mg/L may adversely affect salamander (COA 2004) and is the TCEQ surface water quality standard for Barton Creek. At the current predicted rates of decrease, predicted mean dissolved oxygen in Barton Springs will be less than 5 mg/L by 2027 in recharge conditions at average discharge (50 ft^3/s). Predicted mean dissolved oxygen levels during non-recharge will be less than 5 mg/L by 2011 at low flow (26 ft^3/s).

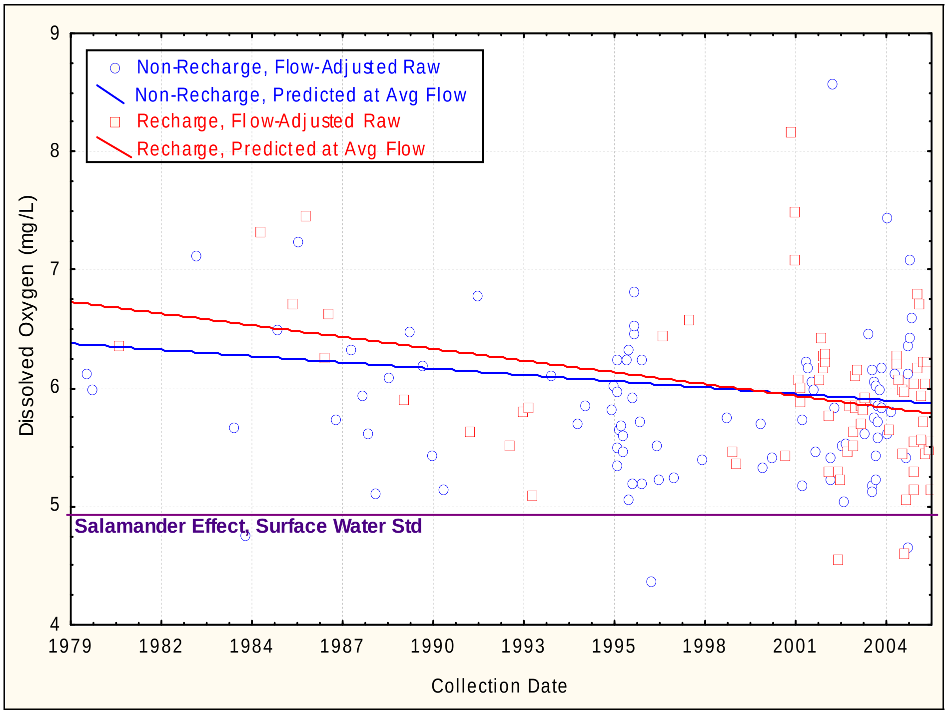

Figure 4. Flow-adjusted dissolved oxygen (mg/L) and model predictions at average discharge (50 ft^3/s) over time with the 5 mg/L surface water quality standard and potential salamander effect level.

Fecal coliform bacteria

Fecal coliform bacteria was collected by ERM, USGS and ATCHD (Table 13) and analyzed by consistent methods over time. Collecting entity variation was accounted for as a quantized variable collector (0=USGS, 1=ATCHD, 2=ERM) in the regression equation. Fecal coliform bacteria is increasing over time in recharge and storm conditions. There is no statistically significant trend over time in fecal coliform bacteria in non-recharge conditions.

Prior to backward elimination, the full model for fecal coliform bacteria is:

*Fecal coliform = collector + collector*date + discharge + date*;

Table 13. Summary of fecal coliform bacteria data.

COLLECTOR	LAB	NOBS	FIRST	LAST
USGS	USGS	106	1978	2003
ATCHD	W/WW	1522	1991	2005
ERM	W/WW	138	1986	2003

Table 14. Results for fecal coliform bacteria (col/100mL). Predicted change in values presented with 95% confidence limits in parenthesis from first to last observation.

	Model		**Regression Coefficients**				**Predicted Change**	
Condition	Pr>F	Adj. r2	Type	Estimate	Pr > F	Std Error	C0	C1
Base, Recharge	0.0226	0.007	intercept	5.8E+00	4.4E-01	7.5E+00	15 (7-22)	26 (23-29)
			collector_group					
			coll_date					
			bs_flow					
			date	1.2E-03	2.3E-02	5.3E-04		
Storm	<0.0001	0.058	intercept	-9.0E+02	1.6E-01	6.3E+02	0 (0-503)	539 (297-782)
			collector_group	2.6E+03	9.0E-05	6.7E+02		
			coll_date	-2.3E-01	4.7E-05	5.5E-02		
			bs_flow	-7.7E+00	1.1E-04	2.0E+00		
			date	1.8E-01	9.5E-04	5.3E-02		

Fecal coliform counts in Barton Springs have exceeded the 400 col/100mL single sample TCEQ standard for contact recreation in only 5.5% of samples (98 out of 1,768 samples). The annual geometric mean of fecal coliform bacteria counts in Barton Springs has not exceeded the 200 col/100mL TCEQ contact recreation standard since 1991, and there is no statistically significant trend in annual geometric mean fecal coliform bacteria counts since 1991 (p=0.38). The current predicted mean value for fecal coliform bacteria during storm conditions is 539 col/100mL (at average discharge based on ATCHD collecting the sample), greater than the 400 col/100mL TCEQ single sample standard for contact recreation.

Fluoride

The USGS measured dissolved fluoride in Barton Springs from 1978 to 1999 (Table 15). Dissolved fluoride is significantly decreasing over time in recharge and storm conditions through 1999. ERM measured total fluoride from 1991 (with most measurements after 1995) to 2005. Total fluoride is decreasing over time in storm conditions, but significantly increasing over time in recharge (Table 16). The decreasing trend in storm conditions is driven by a single high (0.65 mg/L) total fluoride measurement in 1991. After exclusion of this single high value, there is a statistically significant increasing temporal trend in fluoride over time in storm conditions. There are only 10 storm events for total fluoride and 80% of the data (36 of 45 measurements) are from only 2 storm events. Due to the influence of this single point and the general temporal sparseness of storm data, only the trend in recharge will be considered. There is no statistically significant trend over time in total fluoride during non-recharge. Predicted mean total fluoride concentrations increase 54.8% in recharge from 1995-2005.

Table 15. Summary of fluoride data.

FILTER	COLLECTOR	NOBS	FIRST	LAST
Dissolved	USGS	72	1978	1999
Total	ERM	90	1991	2005

Prior to backward elimination, the full model for total fluoride is:

Fluoride = discharge + date;

Table 16. Results for total fluoride (mg/L). Predicted change in values presented with 95% confidence limits in parenthesis from first to last observation.

Condition	**Model**		**Regression Coefficients**				**Predicted Change**	
	Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C_{1995}	C_{2005}
Base, Recharge	0.0008	0.539	intercept	-3.8E-01	2.8E-02	1.6E-01	0.14 (0.06-0.22)	0.31 (0.23-0.39)
			bs_flow	-1.4E-03	7.7E-02	7.3E-04		
			date	4.6E-05	2.9E-04	1.0E-05		

Hardness (as $CaCO_3$)

Hardness was collected primarily by the USGS (Table 17) and ERM (with ATCHD excluded as discussed in section on outliers) and analyzed in the laboratory by consistent methods. The variation in collecting entity was accounted for with a quantized collector variable (0=USGS, 1=ERM) in the regression model. Hardness yields statistically significant increasing trends over time in all conditions (Table 18), with a maximum increase in predicted values of 12.9% in recharge conditions from 1985-2005.

Table 17. Summary of hardness data.

COLLECTOR	LAB	NOBS	FIRST	LAST
USGS	USGS	121	1978	2005
ERM	W/WW	13	1999	2005

Prior to backward elimination, the full model for total hardness is:

*Hardness = collector + collector*date + discharge + date;*

Table 18. Results for total hardness (mg/L as $CaCO_3$). Predicted change in values presented with 95% confidence limits in parenthesis from first to last observation.

	Model		**Regression Coefficients**				**Predicted Change**	
Condition	Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C_0	C_1
Base, NonRecharge	0.0001	0.326	intercept	2.7E+02	1.3E-28	9.5E+00	284 (272-296)	326 (318-334)
			collector_group	.	.	.		
			coll_date	.	.	.		
			bs_flow	-2.8E-01	1.9E-02	1.1E-01		
			date	4.3E-03	2.8E-05	9.0E-04		
Base, Recharge	0.0002	0.408	intercept	1.9E+02	3.8E-09	2.3E+01	262 (242-282)	297 (278-315)
			collector_group	.	.	.		
			coll_date	.	.	.		
			bs_flow	4.8E-01	1.4E-02	1.9E-01		
			date	4.7E-03	1.3E-03	1.3E-03		
Storm	<0.0001	0.322	intercept	2.5E+02	2.0E-31	1.0E+01	276 (266-287)	316 (308-323)
			collector_group	.	.	.		
			coll_date	.	.	.		
			bs_flow	.	.	.		
			date	4.1E-03	2.1E-06	7.8E-04		

An effect level for total hardness of 590 mg/L (as $CaCO_3$) was estimated in the Jollyville salamander toxicity testing (COA 1999). No measurement of hardness in Barton Springs has exceeded 340 mg/L. At projected rates of increase, hardness in non-recharge or recharge conditions would not reach 590 mg/L at average flow (50 ft^3/s) until 2174 (Figure 5).

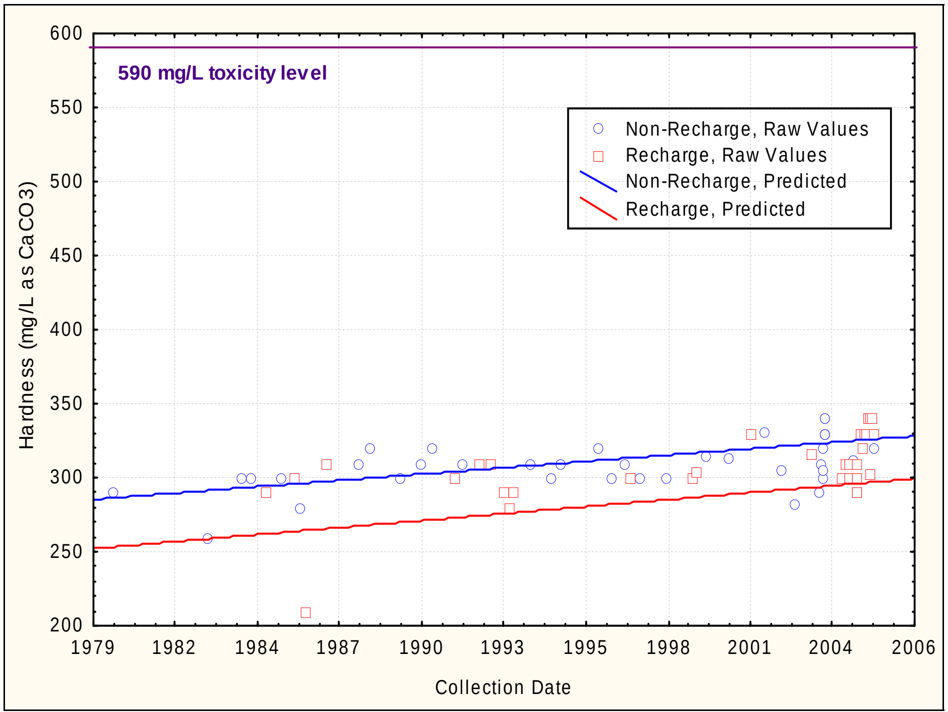

Figure 5. Total hardness raw values and model predictions at average discharge (50 ft^3/s) during non-recharge and recharge conditions.

Magnesium

The USGS measures dissolved magnesium, and ERM measures total magnesium by generally consistent methods (Table 19). Dissolved magnesium is increasing over time in non-recharge and storm conditions. Total magnesium yields a statistically significant increasing trend over time in recharge conditions, but no temporal trend in non-recharge or storm.

Table 19. Summary of magnesium data.

FILTER	COLLECTOR	NOBS	FIRST	LAST
Dissolved	USGS	121	1978	2005
Total	ERM	99	1991	2005

Prior to backward elimination, the full model for total and dissolved magnesium is:

Magnesium (tot or diss) = discharge + date;

Table 20. Results for dissolved and total magnesium (mg/L). Predicted change in values at average discharge presented with 95% confidence limits in parenthesis from first to last observation.

		Model		Regression Coefficients				Predicted Change	
Filter	**Condition**	Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C_0	C_1
Dissolved	Base, NonRecharge	<0.0001	0.495	intercept	2.3E+01	1.1E-23	9.3E-01	21.3 (20.1-22.5)	24.3 (23.4-25.1)
				bs_flow	-7.1E-02	4.8E-07	1.2E-02		
				date	3.0E-04	1.9E-03	8.9E-05		
Dissolved	Storm	0.0008	0.203	intercept	2.0E+01	3.3E-15	1.8E+00	19.0 (17.4-20.6)	22.1 (20.7-23.5)
				bs_flow	-5.8E-02	1.2E-03	1.7E-02		
				date	3.2E-04	1.0E-02	1.2E-04		
Total	Base, Recharge	0.0018	0.361	intercept	9.6E+00	4.9E-03	3.0E+00	18.8 (17.8-19.8)	21.5 (20.7-22.3)
				bs_flow					
				date	7.3E-04	1.8E-03	2.0E-04		

Nitrate/Nitrite as N

Dissolved nitrate/nitrite was measured by the USGS, although total nitrate/nitrite was measured by both the USGS and ERM. Dissolved nitrate/nitrite yields no statistically significant temporal trends. To account for variation in collecting entity for total nitrate/nitrite, a quantized collector variable (0=USGS,1=ERM) was included in the model. Total nitrate/nitrite is increasing over time in non-recharge and recharge conditions, with a maximum increase in predicted mean value of 34% in recharge from 1978-2005 (Table 22). No statistically significant temporal trends were evident from 1978-2000 in previous analyses (COA 2000).

Table 21. Summary of nitrate data.

FILTER	COLLECTOR	NOBS	FIRST	LAST
Dissolved	USGS	98	1990	2005
Total	ERM	314	1986	2005
Total	USGS	58	1978	1992

Prior to backward elimination, the full model for nitrate/nitrite is:

NO3+NO2 (diss) = discharge + date;
*NO3+NO2 (tot) = collector + collector*date + discharge + date;*

Table 22. Results for total nitrate/nitrite (mg/L as N). Predicted change in values presented with 95% confidence limits in parenthesis from first to last observation.

Condition	**Model**		**Regression Coefficients**				**Pred. Change**	
	Pr > F	Adj. r^2	Type	Estimate	Pr > F	StdErr	C_0	C_1
Base, NonRecharge	<0.0001	0.173	intercept	1.4E+00	8.6E-46	6.9E-02	1.36 (1.29-1.43)	1.49 (1.46-1.53)
			collector_group	.	.	.		
			coll_date	.	.	.		
			bs_flow	-2.3E-03	1.3E-08	3.9E-04		
			date	1.5E-05	4.8E-03	5.1E-06		
Base, Recharge	<0.0001	0.169	intercept	2.9E-01	1.6E-01	2.0E-01	0.89 (0.73-1.05)	1.35 (1.28-1.41)
			collector_group	.	.	.		
			coll_date	-2.0E-05	2.5E-02	8.9E-06		
			bs_flow	.	.	.		
			date	8.4E-05	9.0E-05	2.1E-05		

The predicted increase in mean nitrate/nitrite will not exceed 2.5 mg/L in recharge conditions until 2054. If nitrate/nitrite from recharging creeks became the dominant nitrate/nitrite inputs to the aquifer, non-recharge and recharge conditions in the future could be expected to increase at similar rates.

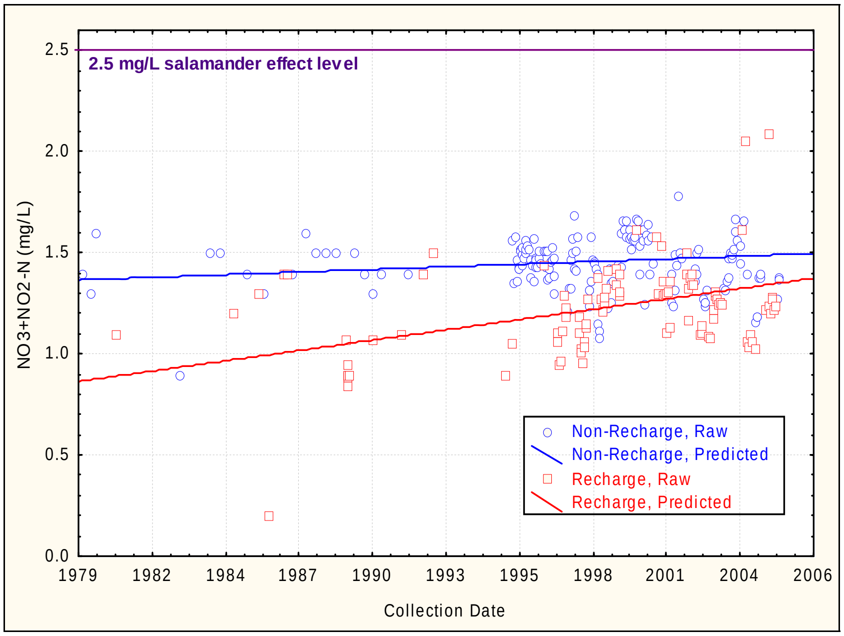

Figure 6. Total nitrate/nitrite predicted values over time with 2.5 mg/L effect level (Rouse et al 1999).

Non-Carbonate Hardness

Dissolved non-carbonate hardness is measured by the USGS (Table 23). Dissolved non-carbonate hardness is increasing over time in recharge (Table 24), and potentially increasing over time in storm conditions (p=0.06). In recharge conditions, the predicted increase in mean non-carbonate hardness is 62.5% from 1990-2005 at average discharge (50 ft^3/s). There is no statistically significant trend over time for dissolved non-carbonate hardness in non-recharge conditions.

Table 23. Summary of dissolved non-carbonate hardness data.

FILTER	COLLECTOR	NOBS	FIRST	LAST
Dissolved	USGS	85	1990	2005

Prior to backward elimination, the full model for dissolved non-carbonate hardness is:

Non-Carb Hard (diss) = bs_flow + date;

Table 24. Results for dissolved non-carbonate hardness (mg/L as $CaCO_3$). Predicted change in values presented with 95% confidence limits in parenthesis from first to last observation.

	Model		Regression Coefficients				Predicted Change	
Condition	Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C_0	C_1
Base, Recharge	0.0003	0.512	Intercept	-6.4E+01	1.8E-02	2.5E+01	18.7 (0.7-36.6)	49.9 (36.3-63.5)
			bs_flow	2.6E-01	7.9E-02	1.4E-01		
			date	6.1E-03	8.7E-05	1.2E-03		
Storm	0.061	0.071	Intercept	1.6E+01	4.0E-01	1.9E+01	45.9 (36.1-55.7)	59.1 (51.2-67.1)
			bs_flow	.	.	.		
			date	2.6E-03	6.1E-02	1.3E-03		

pH

Both the USGS and ERM measure instantaneous pH in Barton Springs in the field (Table 25). ERM staff switched from the Horiba Water Quality Meter to the Quanta Probe in 2001. USGS methods are unknown and assumed to be unchanging over time. To account for variation in collection entity and field instrument, a quantized method variable was included in the full model (0=Unknown,1=Horiba,2=Hydrolab,3=Quanta). Varying the assignment of numerical values to the method variable did not change the regression results. Values for pH yield a statistically significant decreasing (more acidic) trend over time in Barton Springs in recharge (Table 26), with a predicted decrease in mean of 5.3% from 1980-2005. There is no statistically significant trend over time for pH in non-recharge or storm conditions. At present rates of decrease, mean pH in recharge condition is not predicted to drop below the 6.5 TCEQ surface water quality standard for Barton Creek until 2048 (Figure 7).

Prior to backward elimination, the full model for pH is:

*pH= method +method*date + discharge + date;*

Table 25. Summary of pH data.

COLLECTOR	METHOD	LAB	NOBS	FIRST	LAST
ERM	HORIBA WATER QUALITY METER	Field	184	1995	2001
ERM	HYDROLAB	Field	13	2000	2004
ERM	Quanta Probe	Field	71	2001	2005
USGS	UNKNOWN	Field	169	1978	2005

Table 26. Results for pH. Predicted change in values presented with 95% confidence limits in parenthesis from first to last observation.

	Model		Regression Coefficients				Pred. Change	
Condition	Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C_0	C_1
Base, Recharge	0.0002	0.129	Intercept	7.48E+00	1.47E-72	1.70E-01	7.29 (7.12-7.45)	6.92 (6.85-6.99)
			method_code	-4.23E-02	1.87E-02	1.77E-02		
			method_date	.	.	.		
			bs_flow	.	.	.		
			date	-2.63E-05	3.18E-02	1.21E-05		

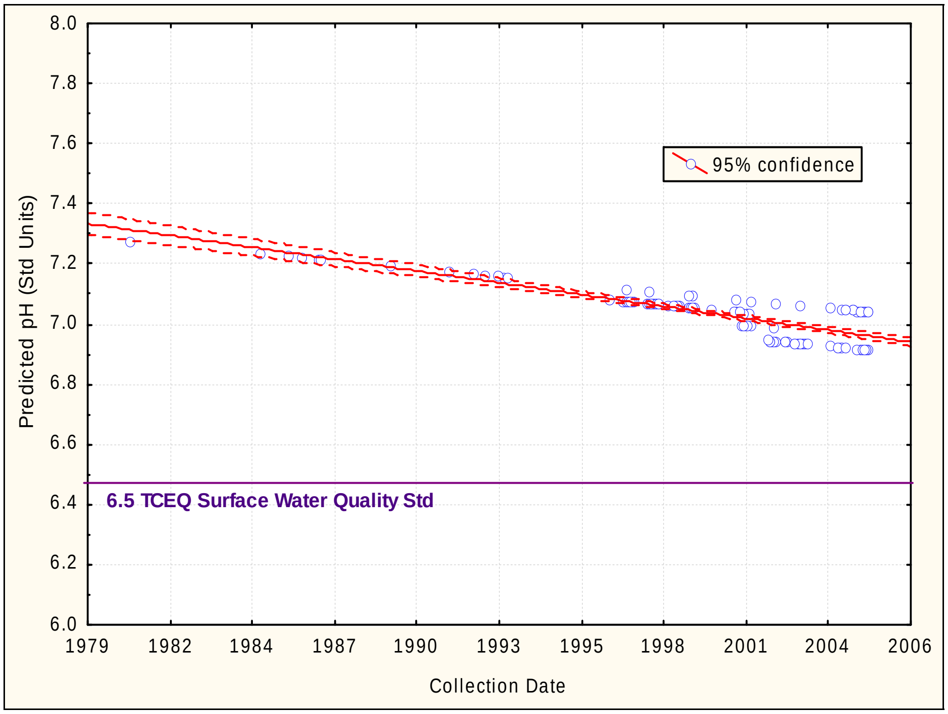

Figure 7. Model-predicted pH values over time during recharge conditions with the 6.5 standard unit TCEQ surface water quality standard.

Potassium

The USGS measures dissolved potassium, and ERM measures total potassium (Table 27). Dissolved potassium is increasing over time in non-recharge and recharge (Table 28), with a maximum predicted increase of 14.5% from 1985-2005 in recharge at average flow (50 ft^3/s). Note that at low discharge (26 ft^3/s), the predicted 2005 dissolved potassium mean concentration in recharge increases to 1.74 mg/L. There is no statistically significant temporal trend for dissolved potassium in storm conditions. There are no statistically significant trends over time for total potassium in any condition.

To assess the difference in observed trends for total and dissolved potassium, temporal trends for dissolved potassium were assessed using only data collected after 1995 (to represent the bulk of total potassium data). A statistically significant increase in dissolved potassium from 1995 to 2005 was again observed in recharge and also storm conditions, although there was no statistically significant trend in non-recharge. A general data gap from 2000 to 2003 in dissolved potassium data may influence the observed trends. Combination of total and dissolved potassium in the specified regression model using a quantized filter variable (0=dissolved,1=total) yields a statistically significant increasing trend over time in recharge conditions only (model Pr>F = 0.0028, model r^2=0.23, date coefficient Pr>F=0.05).

Table 27. Summary of potassium data.

FILTER	COLLECTOR	NOBS	FIRST	LAST
Dissolved	USGS	124	1978	2005
Total	ERM	92	1991	2005

Prior to backward elimination, the full model for dissolved potassium is:

K (diss) = low_flow discharge date;

Table 28. Results for dissolved potassium (mg/L). Predicted change in values at average discharge (50 ft^3/s) presented with 95% confidence limits in parenthesis from first to last observation.

Condition	**Model**		**Regression Coefficients**				**Pred. Change**	
	Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C0	C1
Base, NonRecharge	<0.0001	0.736	Intercept	1.6E+00	2.1E-22	6.9E-02	1.27 (1.17 -1.37	1.46 (1.38-1.54)
			flow_group	-1.7E-01	7.9E-03	6.0E-02		
			bs_flow	-4.8E-03	6.3E-04	1.3E-03		
			date	1.9E-05	6.0E-03	6.4E-06		
Base, Recharge	0.0043	0.301	Intercept	1.4E+00	1.7E-06	2.2E-01	1.36 (1.17 - 1.56)	1.59 (1.40-1.77)
			flow_group	.	.	.		
			bs_flow	-5.8E-03	4.4E-03	1.9E-03		
			date	3.0E-05	2.0E-02	1.2E-05		

Silica

Only the USGS measures dissolved silica in Barton Springs (Table 29). There is a potential change in method precision in 2003 evident from examination of plots of dissolved silica over time, although specific USGS laboratory analysis methods are unknown. A data gap from 1999 to 2003 further complicates analysis interpretation. Dissolved silica yields statistically significant increasing trends over time in all conditions, with a maximum predicted increase in mean dissolved silica of 16.8% in recharge conditions from 1985-2005.

Table 29. Summary of silica data.

COLLECTOR	FILTER	NOBS	FIRST	LAST
USGS	Dissolved	121	1978	2005

Prior to backward elimination, the full model for dissolved silica is:

Silica (diss) = discharge + date;

Table 30. Results for dissolved silica (mg/L). Predicted change in values presented with 95% confidence limits in parenthesis from first to last observation.

	Model		**Regression Coefficients**				**Pred. Change**	
Condition	Pr>F	Adj. r^2	Type	Estimate	Pr > F	StdErr	C_0	C_1
Base, NonRecharge	0.0003	0.295	intercept	9.7E+00	9.6E-23	4.2E-01	10.57 (10.12-11.03)	11.83 (11.53-12.13)
			bs_flow	.	.	.		
			date	1.3E-04	3.1E-04	3.2E-05		
Base, Recharge	<0.0001	0.643	intercept	7.4E+00	1.7E-12	5.8E-01	9.92 (9.45-10.39)	11.93 (11.65-12.22)
			bs_flow	.	.	.		
			date	2.8E-04	3.0E-07	4.0E-05		
Storm	0.0003	0.225	intercept	9.4E+00	1.1E-28	4.3E-01	10.40 (9.97-10.83)	11.72 (11.39-12.05)
			bs_flow	.	.	.		
			date	1.4E-04	1.2E-04	3.3E-05		

Sodium

The USGS measures dissolved sodium, and ERM measures total sodium (Table 31). Dissolved sodium is increasing over time in non-recharge and storm conditions (Table 32), with a maximum predicted increase in mean dissolved sodium concentration of 20.6% in non-recharge from 1978-2005 at average discharge (50 ft^3/s). In low discharge conditions (26 ft^3/s), the predicted mean dissolved sodium in non-recharge in 2005 increases to 30.39 mg/L. There is no statistically significant trend over time for total sodium in any condition. To assess the lack of observed temporal trend in total sodium, the analysis for dissolved sodium was repeated with only data collected after 1995. For dissolved sodium collected after 1995, there is no statistically significant temporal trend in any condition.

Table 31. Summary of sodium data.

COLLECTOR	FILTER	NOBS	FIRST	LAST
ERM	Total	93	1991	2005
USGS	Dissolved	121	1978	2005

Prior to backward elimination, the full model for sodium is:

Sodium (diss) = low_flow + discharge + date;

Table 32. Results for dissolved sodium (mg/L). Predicted change in values at average discharge (50 ft^3/s) presented with 95% confidence limits in parenthesis from first to last observation.

	Model		**Regression Coefficients**				**Pred.Change**	
Condition	Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C_0	C_1
Base, NonRecharge	<0.0001	0.746	intercept	2.8E+01	1.3E-13	2.3E+00	16.98 (13.62 - 20.34)	21.39 (18.70 - 24.08)
			flow_group	-4.3E+00	4.2E-02	2.1E+00		
			bs_flow	-1.9E-01	2.1E-04	4.5E-02		
			date	4.5E-04	4.8E-02	2.2E-04		
Storm	<0.0001	0.507	intercept	2.1E+01	3.6E-15	1.9E+00	12.09 (10.01 - 14.16)	15.08 (13.68 - 16.48)
			flow_group	-1.1E+01	3.3E-10	1.4E+00		
			bs_flow					
			date	3.2E-04	4.3E-02	1.5E-04		

Strontium

The USGS measures dissolved strontium (Table 33). There is no total strontium data after 1996. Dissolved strontium is increasing in storm flow conditions, with a predicted increase in mean value at average discharge (50 ft^3/s) of 32.3% during storm conditions from 1990-2005. There is no statistically significant trend evident in non-recharge or recharge conditions over time.

Table 33. Summary of strontium data.

COLLECTOR	FILTER	NOBS	FIRST	LAST
ERM	Total	5	1995	1996
USGS	Dissolved	87	1990	2005

Prior to backward elimination, the full model for dissolved strontium is:

Strontium (diss) = low_flow + discharge + date;

Table 34. Results for dissolved strontium (mg/L). Predicted change in values at average discharge (50 ft^3/s) presented with 95% confidence limits in parenthesis from first to last observation.

Condition	Model		Regression Coefficients				Predicted Change	
	Pr>F	Adj. r^2	Type	Estimate	Pr > F	StdErr	C_{1990}	C_{2005}
Storm	<0.0001	0.59	intercept	1341.28	0.00	351.27	798 (546-1049)	1178 (1016-1339)
			flow_group	-975.16	0.00	230.41		
			bs_flow	-6.56	0.02	2.59		
			date	0.07	0.00	0.02		

Sulfate

The USGS and ERM collect total sulfate data in Barton Springs (Table 35) by consistent methods. To account for change in collection entity and method, a quantized collector variable (0=USGS,1=ERM) was added to the model. Sulfate is increasing over time in recharge conditions (Table 36), with a predicted increase in mean sulfate concentration at average discharge (50 ft^3/s) of 21.5% from 1985-2005. No statistically significant temporal trend in sulfate was observed in non-recharge or storm conditions. An increasing temporal trend for sulfate in recharge was observed in previous analyses (COA 2000).

Table 35. Summary of sulfate data.

COLLECTOR	FILTER	NOBS	FIRST	LAST
ERM	Total	92	1991	2005
USGS	Total	123	1978	2005

Prior to backward elimination, the full model for sulfate is:

*Sulfate = collector + collector*date + low_flow + discharge + date;*

Table 36. Results for sulfate (mg/L). Predicted change in values presented with 95% confidence limits in parenthesis from first to last observation.

Condition	**Model**		**Regression Coefficients**				**Pred. Change**	
	Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C_{1985}	C_{2005}
Base, Recharge	<0.0001	0.134	intercept	2.0E+01	4.3E-05	4.5E+00	25.96 (22.3-29.6)	33.08 (30.8-35.8)
			collector_group	2.6E+00	6.5E-02	1.4E+00		
			coll_date	.	.	.		
			flow_group	.	.	.		
			bs_flow	.	.	.		
			date	6.2E-04	5.1E-02	3.1E-04		

The predicted increase in mean sulfate is below the 50 mg/L TCEQ surface water quality standard. Predicted mean sulfate in Barton Springs is not projected to exceed the 50 mg/L TCEQ surface water quality standard until 2082 (Figure 8). Only 3 measured values (out of 216 considered) of sulfate have exceeded 50 mg/L, with the last sulfate value exceedance recorded in 1999.

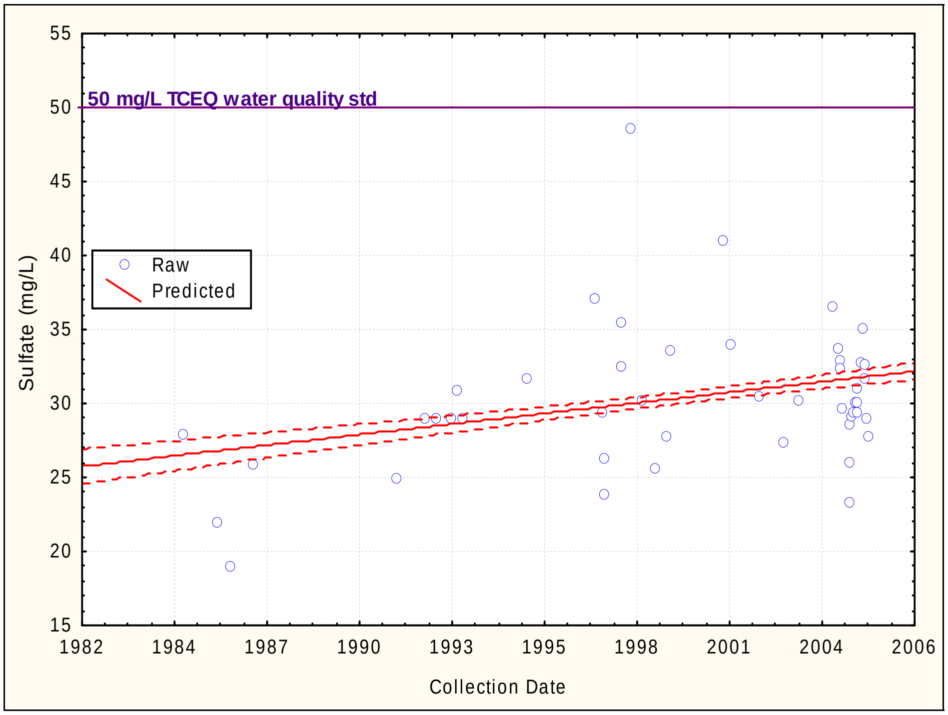

Figure 8. Raw and predicted sulfate in recharge over time with 50 mg/L TCEQ surface water quality standard.

Total Dissolved Solids

The USGS measures total dissolved solids (TDS) in Barton Springs (Table 37). TDS yields statistically significant increasing trends over time in all conditions (Table 38), with a maximum predicted increase in mean TDS of 14.7% in non-recharge from 1978-2005 at average discharge. The predicted mean TDS in non-recharge increases to 426 mg/L in 2005 at low flow (26 ft^3/s).

Prior to backward elimination, the full model for TDS is:

TDS = low_flow + discharge + date;

Table 37. Summary of TDS data.

COLLECTOR	FILTER	NOBS	FIRST	LAST
USGS	Dissolved	119	1978	2005

Table 38. Results for TDS (mg/L). Predicted change in values presented with 95% confidence limits at average discharge (50 ft^3/s) in parenthesis from first to last observation.

	Model		Regression Coefficients				Predicted Change	
Condition	Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C$_0$	C$_1$
Base, NonRecharge	<0.0001	0.621	intercept	3.6E+02	1.2E-25	1.1E+01	326 (306-347)	382 (366-398)
			flow_group	-2.0E+01	5.0E-02	9.9E+00		
			bs_flow	-7.4E-01	1.8E-03	2.2E-01		
			date	5.3E-03	2.7E-05	1.1E-03		
Base, Recharge	0.0047	0.307	intercept	2.3E+02	1.4E-07	3.2E+01	295 (260-329)	324 (292-357)
			flow_group	.	.	.		
			bs_flow	7.2E-01	1.3E-02	2.7E-01		
			date	3.5E-03	5.9E-02	1.7E-03		
Storm	<0.0001	0.275	intercept	3.3E+02	9.9E-32	1.3E+01	321 (306-335)	352 (342-362)
			flow_group	-4.1E+01	7.8E-05	9.5E+00		
			bs_flow	.	.	.		
			date	3.6E-03	9.2E-04	1.0E-03		

The predicted mean TDS values in all conditions in 2005 are below the 500 mg/L TCEQ surface water quality standard for Barton Creek. At present rates of increase, mean TDS in Barton Springs will exceed 500 mg/L at average discharge in non-release by 2064. At low flow, non-recharge predicted mean TDS will exceed 500 mg/L by 2044 (Figure 9). TDS in Barton Springs has never exceeded 500 mg/L.

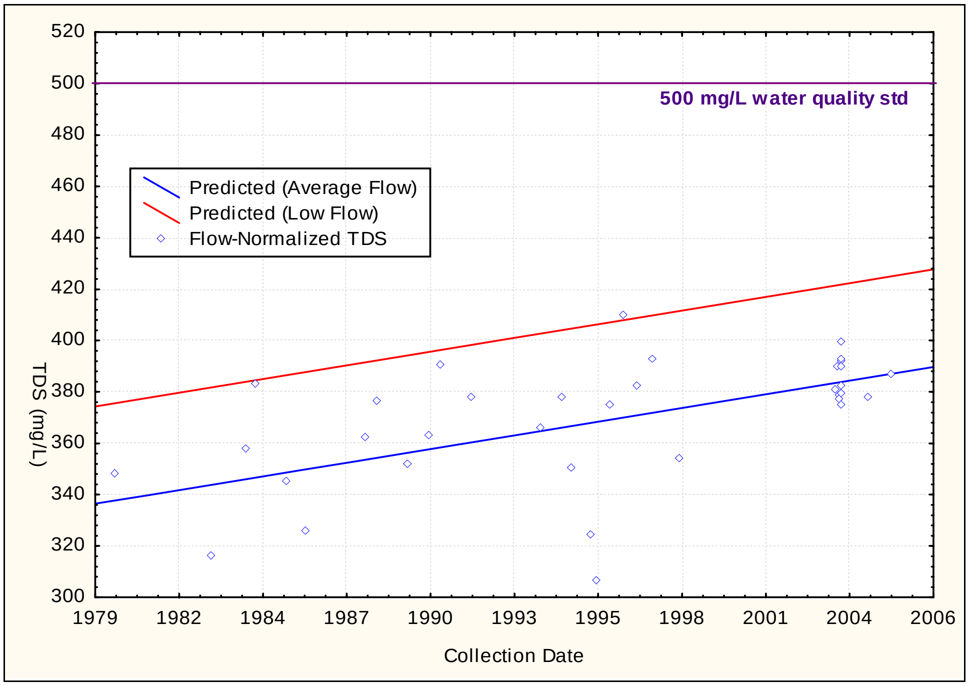

Figure 9. Flow-adjusted TDS and model predictions in non-recharge over time at average (50 ft^3/s) and low (26 ft^3/s) discharge with 500 mg/L TCEQ surface water quality standard.

Total Kjeldahl Nitrogen

The USGS and ERM measure total Kjeldahl nitrogen (TKN) by consistent methods (Table 39). To account for variation in collection agency, a quantized collector variable (0=USGS,1=ERM) was included in the model. TKN is decreasing over time in all conditions (Table 40), with a maximum predicted decrease in mean TKN of more than 260% in storms from 1979-2005. Due to the presence of censored observations, the observed trends were confirmed by proportional hazards regression. The same variables in a PHREG model also yielded positive and statistically significant trends in TKN for all conditions. The lack of observed trends in ammonia suggest that the decrease in TKN is driven by a decrease in organic nitrogen in Barton Springs.

Table 39. Summary of TKN data.

COLLECTOR	FILTER	NOBS	FIRST	LAST
ERM	Total	281	1986	2004
USGS	Total	123	1978	2005

Prior to backward elimination, the full model for TKN is:

*TKN = collector + collector*date + discharge + date;*

Table 40. Results for TKN (mg/L). Predicted change in values presented with 95% confidence limits in parenthesis from first to last observation.

	Model		Regression Coefficients				Pred. Change	
Condition	Pr>F	Adj. r2	Type	Estimate	Pr > F	Std Error	C_0	C_1
Base, NonRecharge	0.0002	0.076	intercept	4.0E-01	6.8E-11	5.7E-02	0.29 (0.23-0.35)	0.14 (0.11-0.16)
			collector_group					
			coll_date					
			bs_flow					
			date	-1.6E-05	1.6E-04	4.1E-06		
Base, Recharge	0.0008	0.096	intercept	6.1E-01	2.3E-06	1.2E-01	0.39 (0.27-0.51)	0.12 (0.07-0.17)
			collector_group					
			coll_date					
			bs_flow					
			date	-3.0E-05	8.3E-04	8.7E-06		
Storm	0.0001	0.145	intercept	6.7E-01	4.6E-04	1.9E-01	0.44 (0.26-0.62)	0.12 (0.00-0.27)
			collector_group	1.0E+00	6.5E-03	3.7E-01		
			coll_date	-7.4E-05	1.0E-02	2.8E-05		
			bs_flow					
			date	-3.4E-05	2.4E-02	1.5E-05		

Water Temperature

Water temperature is measured in the field by the USGS and ERM (Table 41) using different field instruments. To account for variation in field instruments, a quantized method variable (0=unknown,1=Horiba,2=Hydrolab,3=Saturometer,4=Quanta) was included in the model. Temperature is increasing (warming) over time in non-recharge and recharge conditions, with a maximum predicted increase in temperature of 1.4% in non-recharge from 1978-2005 at average discharge. The average annual air temperature in Austin from 1978-2005 is significantly increasing over time (from 67.99 to 69.87ºF) as measured at the Austin-Camp Mabry weather gage (http://www.srh.noaa.gov/ewx/html/cli/aus/ausmontemp.htm). Measurement frequency and time of data collection could affect the analyses, and observed trends should be verified by analysis of available continuous monitoring data.

Table 41. Summary of water temperature data.

COLLECTOR	FILTER	NOBS	FIRST	LAST
ERM	N/A	349	1994	2005
USGS	N/A	140	1978	2005

Prior to backward elimination, the full model for water temperature is:

*Temp = method + method*date + discharge + date;*

Table 42. Results for water temperature (ºC). Predicted change in values presented with 95% confidence limits at average discharge in parenthesis from first to last observation.

Condition	Model		Regression Coefficients				Predicted Change	
	Pr>F	Adj. r^2	Type	Estimate	Pr > F	Std Error	C_0	C_1
Base, NonRecharge	0.0359	0.024	intercept	2.1E+01	2.1E-176	1.9E-01	21.10 (20.89-21.32)	21.41 (21.33-21.50)
			method_code	.	.	.		
			method_date	.	.	.		
			bs_flow	-2.3E-03	3.8E-02	1.1E-03		
			date	3.0E-05	3.6E-02	1.4E-05		
Base, Recharge	0.0002	0.107	intercept	2.0E+01	3.0E-64	6.4E-01	20.43 (18.89-21.97)	21.41 (19.87-22.94)
			method_code	.	.	.		
			method_date	.	.	.		
			bs_flow	-1.4E-02	1.3E-04	3.4E-03		
			date	1.1E-04	1.2E-02	4.2E-05		

Conclusions

Water quality is degrading over time in Barton Springs (Table 43). Temporal trends that were not statistically significant in previous analysis (COA 2000) now yield statistically significant degradation over time.

Table 43. Summary of temporal trends in Barton Springs.

Increasing	Decreasing
Alkalinity Hardness, Non-Carbonate Hardness Calcium Fluoride Magnesium Potassium Sodium Sulfate Strontium Silica Conductivity, TDS Fecal coliform bacteria Nitrate/Nitrite as N Water temperature	Total Kjeldahl Nitrogen as N Dissolved Oxygen pH

Using the available effect level concentrations, Barton Springs water quality does not currently appear to be a threat to the endangered Barton Springs Salamanders or unsafe for contact recreation. However, reduction in mean dissolved oxygen in Barton Springs could pose a threat to the salamander by 2011 in low discharge (26 ft^3/s) conditions at the current estimated rate of decrease. As additional toxicity levels are obtained from on-going experimentation, comparison of Barton Springs water quality to effects levels should be repeated.

The changes in mean concentrations predicted over time are at steady-state conditions using long-term average spring discharge. Mean concentrations for some parameters, including dissolved oxygen and TDS, may be of greater concern at low discharge conditions. Changes in spring discharge over time due to increased pumping of groundwater may increase the rate of degradation in Barton Springs water quality.

The value of long-term datasets in ambient water quality monitoring of high-quality sites over time is clear, even if data must be aggregated from multiple sources to provide sufficient period of record. Complications due to changing methods and collecting entities can be overcome by including those effects in multiple linear regression models.

Results of trend analysis must always be interpreted with caution, and do not attempt to explain direct causation. Further analyses and direct experimentation should be undertaken to more fully investigate the causes of the temporal patterns identified by this analysis.

Recommendations

- Conduct similar analysis for other associated springs when enough data is available (Eliza, Old Mill, and Upper Barton).
- Repeat analysis on all springs in five years (2010) to verify trends, changes in trend patterns, and in additional constituents.
- Conduct analysis to determine if trends in some constituents are related to trends in others, such as TSS related to nitrate-nitrogen or total organic carbon related to dissolved oxygen.
- Refine predictions to determine concentrations or impacts during future severe drought conditions.

- Initiate sampling during storm events to establish similar database. Since the aquifer appears most sensitive to impacts during low flow conditions, focus initial effort at sampling rain events during low flow periods.
- Conduct dye tracing to connect storm water pulses discharging from the springs to specific creeks and or creek reaches.
- Recent extensive monitoring by USGS on pesticides was conducted during average to high flow conditions. Fund similar effort to target base flow concentrations and stormwater impacts during low flow conditions.

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Appendix 1. Parameters not included in the analysis due to a lack of sufficient data.

Parameter	Filter	# Obs	# Non-Detect	First Year	Last Year	Reason for exclusion
1_1_1_2-TETRACHLOROETHANE	Total	41	41	1999	2005	All non-detect
1_1_2_2-TETRACHLOROETHANE	Total	71	71	1986	2005	All non-detect
1_1_2_2-TETRACHLOROETHENE	Total	4	4	1995	1996	All non-detect
1_1_2-TRICHLORO-1_2_2-TRIFLUOROETHANE	Total	31	31	2002	2005	All non-detect
1_1_2-TRICHLOROETHANE	Total	75	75	1986	2005	All non-detect
1_1_2-TRICHLOROETHENE	Total	5	5	1994	1996	All non-detect
1_1-DICHLOROETHANE	Total	75	75	1986	2005	All non-detect
1_1-DICHLOROETHYLENE	Total	75	75	1986	2005	All non-detect
1_1-DICHLOROPROPENE	Total	41	41	1999	2005	All non-detect
1_2_3-TRICHLOROBENZENE	Total	41	41	1999	2005	All non-detect
1_2_3-TRICHLOROPROPANE	Total	41	41	1999	2005	All non-detect
1_2_3-TRIMETHYLBENZENE	Total	31	31	2002	2005	All non-detect
1_2_4-TRICHLOROBENZENE	Total	56	56	1994	2005	All non-detect
1_2_4-TRIMETHYLBENZENE	Total	41	41	1999	2005	All non-detect
1_2-DIBROMO-3-CHLOROPROPANE	Total	10	10	1999	2004	All non-detect
1_2-DIBROMOETHANE	Total	42	42	1996	2005	All non-detect
1_2-DIBROMOETHYLENE	Total	8	8	1986	1988	All non-detect
1_2-DICHLOROBENZENE	Total	90	90	1986	2005	All non-detect
1_2-DICHLOROETHANE	Total	75	75	1986	2005	All non-detect
1_2-DICHLOROPROPANE	Total	75	75	1986	2005	All non-detect
1_2-DIPHENYLHYDRAZINE	Total	3	3	1994	1996	All non-detect
1_3_5-TRIMETHYLBENZENE	Total	41	41	1999	2005	All non-detect
1_3-DICHLOROBENZENE	Total	90	90	1986	2005	All non-detect
1_3-DICHLOROPROPANE	Total	41	41	1999	2005	All non-detect
1_3-DICHLOROPROPENE	Total	29	29	1986	1993	All non-detect
1_4-DICHLORO-2-BUTENE	Total	31	31	2002	2005	All non-detect
1_4-DICHLOROBENZENE	Total	95	95	1986	2005	All non-detect
1_4-DIOXANE	Total	1	1	1996	1996	All non-detect
1_7-DIMETHYLXANTHINE	Total	13	12	2000	2000	Less than 3 detected values
1+2-CHLORONAPHTHALENE	Total	1	1	1994	1994	All non-detect
17-ALPHA-ETHYNYL ESTERDIOL	Total	5	5	2002	2002	All non-detect
17B-ESTRADIOL	Total	5	4	2002	2002	Less than 3 detected values
1-METHYL-2-(PHENYLMETHOXY) BENZENE	Total	1	0	2002	2002	Less than 3 dates
1-METHYL-2-CHLOROBENZENE	Total	31	31	2002	2005	All non-detect
1-METHYL-2-ETHYLBENZENE	Total	31	31	2002	2005	All non-detect
1-METHYL-4-CHLOROBENZENE	Total	31	31	2002	2005	All non-detect
1-METHYL-4-ISOPROPYLBENZENE	Total	31	31	2002	2005	All non-detect
1-METHYLNAPHTHALENE	Total	5	5	2002	2002	All non-detect
2_2-DICHLOROPROPANE	Total	41	41	1999	2005	All non-detect
2_4_5-TP (SILVEX)	Total	32	32	1978	2004	All non-detect
2_4_5-TRICHLOROPHENOL	Total	11	11	1995	2004	All non-detect
2_4_5-TRICHLOROPHENOXYACETIC ACID	Total	23	23	1978	1999	All non-detect
2_4_6-TRICHLOROPHENOL	Total	15	15	1994	2004	All non-detect
2_4-DB (BUTOXON)	Dissolved	4	4	2003	2004	All non-detect
2_4-DB (BUTOXON)	Total	6	6	1994	1999	All non-detect
2_4-DICHLOROPHENOL	Total	15	15	1994	2004	All non-detect
2_4-DICHLOROPHENOXYACETIC ACID	Filtered	4	4	2003	2004	All non-detect
2_4-DICHLOROPHENOXYACETIC ACID	Total	32	32	1978	2004	All non-detect

Parameter	Filter	# Obs	# Non-Detect	First Year	Last Year	Reason for exclusion
2_4-DICHLOROPHENOXYACETIC ACID METHYL ESTER	Filtered	4	4	2003	2004	All non-detect
2_4-DIMETHYLPHENOL	Total	15	15	1994	2004	All non-detect
2_4-DINITROPHENOL	Total	15	15	1994	2004	All non-detect
2_4-DINITROTOLUENE	Total	15	15	1994	2004	All non-detect
2_4-DP (DICHLORPROP)	Total	5	5	1994	1996	All non-detect
2_6-DIETHYLANILINE	Filtered	56	56	2000	2005	All non-detect
2_6-DIETHYLANILINE	Total	3	3	2002	2002	All non-detect
2_6-DIMETHYLNAPHTHALENE	Total	5	5	2002	2002	All non-detect
2_6-DINITROTOLUENE	Total	15	15	1994	2004	All non-detect
2-CHLOROETHYL VINYL ETHER	Total	43	43	1986	2004	All non-detect
2-CHLORONAPHTHALENE	Total	15	15	1994	2004	All non-detect
2-CHLOROPHENOL	Total	15	15	1994	2004	All non-detect
2-CHLOROTOLUENE	Total	10	10	1999	2004	All non-detect
2-ETHOXY-2-METHYL-PROPANE	Total	31	31	2002	2005	All non-detect
2-HEXANONE (BUTYLMETHYLKETONE)	Total	35	35	1995	2005	All non-detect
2-METHOXY-2-METHYL-BUTANE	Total	31	31	2002	2005	All non-detect
2-METHOXY-2-METHYL-PROPANE	Total	31	31	2002	2005	All non-detect
2-METHYL 2-PROPENOIC ACID ETHYL ESTER	Total	31	31	2002	2005	All non-detect
2-METHYLNAPHTHALENE	Total	6	6	1995	2002	All non-detect
2-METHYLPHENOL (O-CRESOL)	Total	2	2	1994	1995	All non-detect
2-NITROANILINE	Total	1	1	1995	1995	All non-detect
2-NITROPHENOL	Total	15	15	1994	2004	All non-detect
3(4-CHLOROPHENYL) METHYL UREA	Filtered	4	4	2003	2004	All non-detect
3_3'-DICHLOROBENZIDINE	Total	15	15	1994	2004	All non-detect
3_4-DICHLOROPHENYL ISOCYANATE	Total	5	5	2002	2002	All non-detect
3_5-DICHLOROBENZOIC ACID	Total	1	1	1999	1999	All non-detect
3B-COPROSTANOL (CARNIVORE FECAL INDICATOR)	Total	5	5	2002	2002	All non-detect
3-HYDROXY CARBOFURAN	Filtered	4	4	2003	2004	All non-detect
3-HYDROXY CARBOFURAN	Total	1	1	1991	1991	All non-detect
3-KETOCARBOFURAN	Filtered	4	4	2003	2004	All non-detect
3-NITROANILINE	Total	1	1	1995	1995	All non-detect
4_4'-DDD	Total	6	6	1994	1999	All non-detect
4_4'-DDE	Dissolved	56	56	2000	2005	All non-detect
4_4'-DDE	Total	6	6	1994	1999	All non-detect
4_4'-DDT	Total	6	6	1994	1999	All non-detect
4_6-DINITRO-2-METHYLPHENOL (4_6-DINITRO-O-CRESOL)	Total	15	15	1994	2004	All non-detect
4-BROMOPHENYL PHENYL ETHER	Total	15	15	1994	2004	All non-detect
4-CHLORO-3-METHYLPHENOL (4-CHLORO-M-CRESOL)	Total	15	15	1994	2004	All non-detect
4-CHLOROANILINE	Total	1	1	1995	1995	All non-detect
4-CHLOROPHENYL PHENYL ETHER	Total	15	15	1994	2004	All non-detect
4-CHLOROTOLUENE	Total	10	10	1999	2004	All non-detect
4-CUMYLPHENOL	Total	5	5	2002	2002	All non-detect
4-METHYL-2-PENTANONE (HEXANONE)	Total	35	35	1995	2005	All non-detect
4-METHYLPHENOL (P-CRESOL)	Total	6	6	1995	2002	All non-detect
4-NITROANILINE	Total	1	1	1995	1995	All non-detect
4-NITROPHENOL	Total	16	16	1994	2004	All non-detect
4-N-OCTYLPHENOL	Total	5	5	2002	2002	All non-detect

Parameter	Filter	# Obs	# Non-Detect	First Year	Last Year	Reason for exclusion
4-TERT-OCTYLPHENOL	Total	5	5	2002	2002	All non-detect
5-HYDROXYDICAMBA	Total	1	1	1999	1999	All non-detect
5-METHYL-1H-BENZOTRIAZLE	Total	5	5	2002	2002	All non-detect
ACENAPHTHENE	Total	16	16	1994	2004	All non-detect
ACENAPHTHYLENE	Total	16	16	1994	2004	All non-detect
ACETOCHLOR	Filtered	56	56	2000	2005	All non-detect
ACETOCHLOR	Total	3	3	2002	2002	All non-detect
ACETONE	Total	45	43	1995	2005	Less than 3 detected values
ACETOPHENONE	Total	5	5	2002	2002	All non-detect
ACIFLUORFEN	Filtered	4	4	2003	2004	All non-detect
ACIFLUORFEN	Total	1	1	1999	1999	All non-detect
ACROLEIN	Total	14	14	1995	2004	All non-detect
ACRYLONITRILE	Total	45	45	1995	2005	All non-detect
ALACHLOR (LASSO)	Dissolved	56	56	2000	2005	All non-detect
ALACHLOR (LASSO)	Total	3	3	2002	2002	All non-detect
ALDICARB (TEMIK)	Filtered	4	4	2003	2004	All non-detect
ALDICARB (TEMIK)	Total	1	1	1991	1991	All non-detect
ALDICARB SULFONE (TEMIK)	Filtered	4	4	2003	2004	All non-detect
ALDICARB SULFONE (TEMIK)	Total	1	1	1991	1991	All non-detect
ALDICARB SULFOXIDE (TEMIK)	Filtered	4	4	2003	2004	All non-detect
ALDICARB SULFOXIDE (TEMIK)	Total	1	1	1991	1991	All non-detect
ALDRIN	Total	23	23	1978	1999	All non-detect
ALKALINITY BICARBONATE (AS CACO3)	Total	6	0	1994	1997	No data after 1999
ALKALINITY CARBONATE (AS CACO3)	Total	5	5	1994	1996	All non-detect
ALLYL CHLORIDE	Total	31	31	2002	2005	All non-detect
ALPHA-BHC (BENZENE HEXACHLORIDE)	Dissolved	56	56	2000	2005	All non-detect
ALPHA-BHC (BENZENE HEXACHLORIDE)	Total	9	9	1994	2002	All non-detect
ALUMINUM	Dissolved	1	0	1999	1999	Less than 3 dates
ANILINE	Total	1	1	1995	1995	All non-detect
ANTHRACENE	Total	21	21	1994	2004	All non-detect
ANTHRAQUINONE	Total	5	5	2002	2002	All non-detect
ANTIMONY	Dissolved	1	1	1999	1999	All non-detect
ANTIMONY	Total	6	6	1994	1996	All non-detect
AROCLOR 1016	Total	5	5	1994	1996	All non-detect
AROCLOR 1221	Total	6	6	1994	1999	All non-detect
AROCLOR 1232	Total	6	6	1994	1999	All non-detect
AROCLOR 1242	Total	6	6	1994	1999	All non-detect
AROCLOR 1248	Total	6	6	1994	1999	All non-detect
AROCLOR 1254	Total	6	6	1994	1999	All non-detect
AROCLOR 1260	Total	6	6	1994	1999	All non-detect
AZINPHOS METHYL (GUTHION)	Filtered	56	56	2000	2005	All non-detect
AZINPHOS METHYL (GUTHION)	Total	19	19	1994	2004	All non-detect
AZOBENZENE	Total	10	10	1999	2004	All non-detect
BARIUM	Dissolved	80	7	1978	1999	No data after 1999
BARIUM	Total	6	0	1994	1996	No data after 1999
BENDIOCARB	Filtered	4	4	2003	2004	All non-detect
BENFLURALIN	Filtered	56	56	2000	2005	All non-detect
BENFLURALIN	Total	3	3	2002	2002	All non-detect
BENOMYL	Filtered	4	3	2003	2004	Less than 3 detected values
BENSULFURON METHYL	Filtered	4	4	2003	2004	All non-detect
BENTAZON	Dissolved	4	4	2003	2004	All non-detect

Parameter	Filter	# Obs	# Non-Detect	First Year	Last Year	Reason for exclusion
BENTAZON	Total	1	1	1999	1999	All non-detect
BENZENE	Total	75	74	1986	2005	Less than 3 detected values
BENZIDINE	Total	15	15	1994	2004	All non-detect
BENZO(A)ANTHRACENE	Total	16	16	1994	2004	All non-detect
BENZO(A)PYRENE	Total	21	20	1994	2004	Less than 3 detected values
BENZO(B)FLUORANTHENE	N/A	1	1	2003	2003	All non-detect
BENZO(B)FLUORANTHENE	Total	15	15	1994	2004	All non-detect
BENZO(GHI)PERYLENE	Total	16	16	1994	2004	All non-detect
BENZO(K)FLUORANTHENE	Total	16	16	1994	2004	All non-detect
BENZOIC ACID	Total	1	1	1995	1995	All non-detect
BENZOPHENONE	Total	5	5	2002	2002	All non-detect
BENZYL ALCOHOL	Total	1	1	1995	1995	All non-detect
BERYLLIUM	Dissolved	38	37	1990	1999	No data after 1999
BERYLLIUM	Total	6	6	1994	1996	All non-detect
BETA-BHC (BENZENE HEXACHLORIDE)	Total	6	6	1994	1999	All non-detect
BETA-SITOSTEROL	Total	5	5	2002	2002	All non-detect
BICARBONATE (AS HCO3)	N/A	8	0	1978	1980	No data after 1999
BIOCHEMICAL OXYGEN DEMAND (5 DAY 20 DEG C)	Total	93	11	1969	1999	No data after 1999
BIS(2-CHLOROETHOXY)METHANE	Total	15	15	1994	2004	All non-detect
BIS(2-CHLOROETHYL)ETHER	Total	15	15	1994	2004	All non-detect
BIS(2-CHLOROISOPROPYL)ETHER	Total	15	15	1994	2004	All non-detect
BISPHENOL A	Total	5	5	2002	2002	All non-detect
BOLSTAR (SULPROFOS)	Total	10	10	1999	2004	All non-detect
BORON	Total	15	0	1987	1990	No data after 1999
BROMACIL	Total	25	25	1993	2004	All non-detect
BROMOBENZENE	Total	41	41	1999	2005	All non-detect
BROMOCHLOROMETHANE	Total	41	41	1999	2005	All non-detect
BROMODICHLOROMETHANE	Total	70	70	1986	2005	All non-detect
BROMOETHENE	Total	31	31	2002	2005	All non-detect
BROMOFORM	Total	80	80	1986	2005	All non-detect
BROMOXYNIL	Filtered	4	4	2003	2004	All non-detect
BUTACHLOR (MACHETE)	Total	3	3	1993	1993	All non-detect
BUTYL BENZYL PHTHALATE	Total	15	15	1994	2004	All non-detect
BUTYL HEXADECANOATE	Total	1	0	1994	1994	Less than 3 dates
BUTYLATE (SUTAN)	Dissolved	56	56	2000	2005	All non-detect
BUTYLATE (SUTAN)	Total	6	6	1993	2002	All non-detect
BUTYLATED HYDROXYANISOLE (BHA)	Total	5	5	2002	2002	All non-detect
CAFFEINE	Filtered	4	3	2003	2004	Less than 3 detected values
CAMPHOR	Total	5	5	2002	2002	All non-detect
CARBARYL (SEVIN)	Total	17	17	1982	2002	All non-detect
CARBAZOLE	Total	5	5	2002	2002	All non-detect
CARBOFURAN	Filtered	60	60	2000	2005	All non-detect
CARBOFURAN	Total	4	4	1991	2002	All non-detect
CARBON DISULFIDE	Total	35	34	1995	2005	Less than 3 detected values
CARBON TETRACHLORIDE	Total	75	75	1986	2005	All non-detect
CARBONATE (AS CO3)	Dissolved	25	25	2004	2005	All non-detect
CARBONATE (AS CO3)	N/A	7	3	1978	1980	No data after 1999
CARBOXIN	Total	3	3	1993	1993	All non-detect
CHEMICAL OXYGEN DEMAND (0.025N K2CR207)	N/A	1	1	1995	1995	All non-detect

Parameter	Filter	# Obs	# Non-Detect	First Year	Last Year	Reason for exclusion
CHEMICAL OXYGEN DEMAND (0.025N K2CR207)	Total	2	2	2001	2003	All non-detect
CHLORAMBEN	Total	1	1	1999	1999	All non-detect
CHLORAMBEN METHYL ESTER	Filtered	4	4	2003	2004	All non-detect
CHLORIMURON	Filtered	4	4	2003	2004	All non-detect
CHLOROBENZENE	Total	76	76	1986	2005	All non-detect
CHLOROETHANE	Total	75	75	1986	2005	All non-detect
CHLOROPHYLL-A	N/A	14	14	2002	2002	All non-detect
CHLOROTHALONIL	Filtered	4	4	2003	2004	All non-detect
CHLORPYRIFOS (DURSBAN)	Dissolved	56	56	2000	2005	All non-detect
CHLORPYRIFOS (DURSBAN)	Total	30	29	1991	2004	Less than 3 detected values
CHOLESTEROL	Total	5	5	2002	2002	All non-detect
CHRYSENE	Total	16	16	1994	2004	All non-detect
CIMETIDINE	Total	13	13	2000	2000	All non-detect
CIS-1_2-DICHLOROETHENE	Total	11	11	1994	2004	All non-detect
CIS-1_3-DICHLOROPROPENE	Total	75	75	1986	2005	All non-detect
CIS-PERMETHRIN	Filtered	56	56	2000	2005	All non-detect
CLOPYRALID	Filtered	4	4	2003	2004	All non-detect
COBALT	Dissolved	38	37	1990	1999	No data after 1999
CODEINE	Total	13	13	2000	2000	All non-detect
COTININE	Total	18	17	2000	2002	Less than 3 detected values
COUMAPHOS (CO-RAL)	Total	15	15	1995	2004	All non-detect
CYANAZINE	Dissolved	56	56	2000	2005	All non-detect
CYANAZINE	Total	3	3	2002	2002	All non-detect
CYCLOATE (RO-NEET)	Total	7	7	1993	2004	All non-detect
DACTHAL (DCPA)	Filtered	60	60	2000	2005	All non-detect
DACTHAL (DCPA)	Total	4	4	1999	2002	All non-detect
DALAPON	Total	3	3	1994	1999	All non-detect
DDD	Total	17	17	1978	1993	All non-detect
DDE	Total	20	20	1978	2002	All non-detect
DDT	Total	17	17	1978	1993	All non-detect
DE-ETHYL DE-ISOPROPYL ATRAZINE	Total	4	3	2003	2004	Less than 3 detected values
DE-ETHYL ETHER	Total	31	31	2002	2005	All non-detect
DEHYDRONIFEDIPINE	Total	13	13	2000	2000	All non-detect
DE-ISOPROPYL ATRAZINE	Total	4	4	2003	2004	All non-detect
DELTA-BHC (BENZENE HEXACHLORIDE)	Total	6	6	1994	1999	All non-detect
DEMETON	Total	12	12	1995	2004	All non-detect
DEMETON-O	Total	1	1	1994	1994	All non-detect
DEMETON-O+S	Total	2	2	1995	1996	All non-detect
DEMETON-S	Total	2	2	1994	1995	All non-detect
DESULFINYLFIPRONIL	Filtered	36	36	2002	2005	All non-detect
DIAZINON	Total	40	39	1978	2004	Less than 3 detected values
DIBENZ(AH)ANTHRACENE	Total	16	16	1994	2004	All non-detect
DIBENZOFURAN	Total	1	1	1995	1995	All non-detect
DIBROMOCHLOROMETHANE	Total	75	75	1986	2005	All non-detect
DIBROMOCHLOROPROPANE	Total	31	31	2002	2005	All non-detect
DIBROMOMETHANE	Total	41	41	1999	2005	All non-detect
DICAMBA (BANVEL)	Dissolved	4	4	2003	2004	All non-detect
DICAMBA (BANVEL)	Total	6	6	1994	1999	All non-detect
DICHLOROBROMOETHANE	Total	5	5	1994	1996	All non-detect
DICHLORODIFLUOROMETHANE	Total	71	71	1986	2005	All non-detect

Parameter	Filter	# Obs	# Non-Detect	First Year	Last Year	Reason for exclusion
DICHLOROPROP (2-(2_4-DICHLOROPHENOXY)PROPANOIC ACID)	Filtered	4	4	2003	2004	All non-detect
DICHLOROPROP (2-(2_4-DICHLOROPHENOXY)PROPANOIC ACID)	Total	1	1	1999	1999	All non-detect
DICHLORVOS	Total	20	20	1995	2004	All non-detect
DIELDRIN	Filtered	56	56	2000	2005	All non-detect
DIELDRIN	Total	26	26	1978	2002	All non-detect
DIETHYL PHTHALATE	Total	20	20	1994	2004	All non-detect
DIGOXIGENIN	Total	13	13	2000	2000	All non-detect
DIGOXIN	Total	13	13	2000	2000	All non-detect
DI-ISOPROPYL ETHER	Total	31	31	2002	2005	All non-detect
DILTIAZEM	Total	13	13	2000	2000	All non-detect
DIMETHOATE	Total	15	15	1995	2004	All non-detect
DIMETHYL PHTHALATE	Total	15	15	1994	2004	All non-detect
DI-N-BUTYL PHTHALATE	Total	14	14	1994	2004	All non-detect
DI-N-OCTYL PHTHALATE	Total	15	15	1994	2004	All non-detect
DINOSEB	Filtered	4	4	2003	2004	All non-detect
DINOSEB	Total	6	6	1994	1999	All non-detect
DIPHENAMID	Total	7	7	1993	2004	All non-detect
DISULFOTON (DISYSTON)	Filtered	56	56	2000	2005	All non-detect
DISULFOTON (DISYSTON)	Total	25	25	1991	2004	All non-detect
DIURON	Filtered	4	3	2003	2004	Less than 3 detected values
D-LIMONENE	Total	5	5	2002	2002	All non-detect
ENALAPRILAT	Total	13	13	2000	2000	All non-detect
ENDOSULFAN	Total	17	17	1978	1993	All non-detect
ENDOSULFAN I	Total	6	6	1994	1999	All non-detect
ENDOSULFAN II	Total	6	6	1994	1999	All non-detect
ENDOSULFAN SULFATE	Total	6	6	1994	1999	All non-detect
ENDRIN	Total	23	23	1978	1999	All non-detect
ENDRIN ALDEHYDE	Total	6	6	1994	1999	All non-detect
ENTEROCOCCUS	N/A	2	0	1999	1999	Less than 3 dates
EPN (SANTOX)	Total	10	10	1999	2004	All non-detect
EPTC	Filtered	56	56	2000	2005	All non-detect
EPTC	Total	3	3	2002	2002	All non-detect
EQUILENIN	Total	5	5	2002	2002	All non-detect
ESTRONE	Total	5	5	2002	2002	All non-detect
ETHALFLURALIN	Filtered	56	56	2000	2005	All non-detect
ETHALFLURALIN	Total	3	3	2002	2002	All non-detect
ETHANOL-2-BUTOXY-PHOSPHATE	Total	5	5	2002	2002	All non-detect
ETHION	Total	22	22	1978	1996	All non-detect
ETHOPROPHOS (ETHOPROP)	Filtered	56	56	2000	2005	All non-detect
ETHOPROPHOS (ETHOPROP)	Total	14	14	1995	2004	All non-detect
ETHYL CITRATE	Total	5	5	2002	2002	All non-detect
ETHYL METHACRYLATE	Total	31	31	2002	2005	All non-detect
ETHYLBENZENE	Total	75	75	1986	2005	All non-detect
ETHYLPARABEN	Total	2	0	2002	2002	Less than 3 dates
FENSULFOTHION	Total	15	15	1995	2004	All non-detect
FENTHION (BAYTEX)	Total	15	15	1995	2004	All non-detect
FENURON	Filtered	4	4	2003	2004	All non-detect
FIPRONIL	Filtered	36	36	2002	2005	All non-detect
FIPRONIL DEGRADATE RPA105048	Filtered	36	36	2002	2005	All non-detect

Parameter	Filter	# Obs	# Non-Detect	First Year	Last Year	Reason for exclusion
FIPRONIL SULFIDE	Filtered	36	36	2002	2005	All non-detect
FIPRONIL SULFONE	Filtered	36	36	2002	2005	All non-detect
FLUMETSULAM	Filtered	4	4	2003	2004	All non-detect
FLUOMETURON	Dissolved	4	4	2003	2004	All non-detect
FLUORANTHENE	Total	21	21	1994	2004	All non-detect
FLUORENE (9H-FLUORENE)	Total	16	16	1994	2004	All non-detect
FLUOXETINE	Total	13	13	2000	2000	All non-detect
FONOFOS (DYFONATE)	Dissolved	56	56	2000	2005	All non-detect
FONOFOS (DYFONATE)	Total	10	10	1991	2002	All non-detect
GALAXOLIDE (HHCB)	Total	5	5	2002	2002	All non-detect
GAMMA-BHC (LINDANE)	Dissolved	56	56	2000	2005	All non-detect
GAMMA-BHC (LINDANE)	Total	26	26	1978	2002	All non-detect
GEMFIBROZIL	Total	13	13	2000	2000	All non-detect
GROSS ALPHA AS NATURAL URANIUM	Dissolved	2	2	1980	1980	All non-detect
GROSS ALPHA AS NATURAL URANIUM	Suspended	2	1	1980	1980	Less than 3 dates
GROSS BETA AS CS-137	Dissolved	2	2	1980	1980	All non-detect
GROSS BETA AS CS-137	Suspended	2	1	1980	1980	Less than 3 dates
HEPTACHLOR	Total	23	23	1978	1999	All non-detect
HEPTACHLOR EPOXIDE	Total	23	23	1978	1999	All non-detect
HEXACHLOROBENZENE (HCB)	Total	15	15	1994	2004	All non-detect
HEXACHLOROBUTADIENE	Total	56	56	1994	2005	All non-detect
HEXACHLOROCYCLOPENTADIENE	Total	12	12	1994	2004	All non-detect
HEXACHLOROETHANE	Total	46	46	1994	2005	All non-detect
HEXAZINONE (VELPAR)	Total	3	3	1993	1993	All non-detect
IBUPROFEN	Total	13	13	2000	2000	All non-detect
IMAZAQUIN (SCEPTER)	Filtered	4	4	2003	2004	All non-detect
IMAZETHAPYR	Filtered	4	4	2003	2004	All non-detect
IMIDACLOPRID	Filtered	4	4	2003	2004	All non-detect
INDENO(1_2_3-CD)PYRENE	Total	16	16	1994	2004	All non-detect
INDOLE	Total	5	5	2002	2002	All non-detect
IODOMETHANE	Total	31	31	2002	2005	All non-detect
ISOBORNEOL	Total	5	5	2002	2002	All non-detect
ISODURENE	Total	31	31	2002	2005	All non-detect
ISOPHORONE	Total	20	20	1994	2004	All non-detect
ISOPROPYLBENZENE (CUMENE)	Total	46	46	1999	2005	All non-detect
ISOQUINOLINE	Total	5	5	2002	2002	All non-detect
LINURON	Dissolved	4	4	2003	2004	All non-detect
LINURON	Filtered	56	56	2000	2005	All non-detect
LINURON	Total	3	3	2002	2002	All non-detect
LITHIUM	Dissolved	37	3	1990	1999	No data after 1999
M+P(META+PARA)XYLENE	Total	33	33	2002	2005	All non-detect
MALATHION	Filtered	56	56	2000	2005	All non-detect
MALATHION	Total	36	36	1978	2004	All non-detect
MANGANESE	Dissolved	97	82	1978	1999	No data after 1999
MANGANESE	Total	6	2	1994	1996	No data after 1999
MBAS (METHYLENE BLUE ACTIVE)	Total	7	7	1979	1996	All non-detect
MCPA (2-METHYL-4-CHLOROPHENOXYACETIC ACID)	Dissolved	4	4	2003	2004	All non-detect
MCPA (2-METHYL-4-CHLOROPHENOXYACETIC ACID)	Total	6	6	1994	1999	All non-detect
MCPB	Dissolved	4	4	2003	2004	All non-detect

Parameter	Filter	# Obs	# Non-Detect	First Year	Last Year	Reason for exclusion
MCPP (MECOPROP)	Total	6	6	1994	1999	All non-detect
MENTHOL	Total	5	5	2002	2002	All non-detect
METALAXYL (APRON)	Filtered	4	4	2003	2004	All non-detect
METALAXYL (APRON)	Total	5	4	2002	2002	Less than 3 detected values
METFORMIN	Total	13	13	2000	2000	All non-detect
METHACRYLONITRILE	Total	31	31	2002	2005	All non-detect
METHIOCARB	Dissolved	4	4	2003	2004	All non-detect
METHOMYL	Filtered	4	4	2003	2004	All non-detect
METHOMYL	Total	10	10	1982	1991	All non-detect
METHOXYCHLOR	Total	19	19	1980	1999	All non-detect
METHYL BROMIDE (BROMOMETHANE)	Total	75	75	1986	2005	All non-detect
METHYL CHLORIDE (CHLOROMETHANE)	Total	75	75	1986	2005	All non-detect
METHYL ETHYL KETONE (BUTANONE)	Total	45	44	1995	2005	Less than 3 detected values
METHYL INDOLE (SKATOL)	Total	5	5	2002	2002	All non-detect
METHYL ISOBUTYL KETONE	Total	10	10	1999	2004	All non-detect
METHYL METHACRYLATE	Total	31	31	2002	2005	All non-detect
METHYL PARATHION	Filtered	56	56	2000	2005	All non-detect
METHYL PARATHION	Total	33	33	1978	2004	All non-detect
METHYL SALICYLATE	Total	5	5	2002	2002	All non-detect
METHYL TERT-BUTYL ETHER (MTBE)	Total	8	8	2000	2004	All non-detect
METHYL TRITHION	Total	10	10	1978	1981	All non-detect
METHYLENE CHLORIDE	Total	72	71	1986	2005	Less than 3 detected values
METHYL-METSULFURON	Filtered	4	4	2003	2004	All non-detect
METHYLPARABEN	Total	2	0	2002	2002	Less than 3 dates
METHYL-SULFOMETRURON	Filtered	4	3	2003	2004	Less than 3 detected values
METOLACHLOR (DUAL)	Dissolved	56	55	2000	2005	Less than 3 detected values
METOLACHLOR (DUAL)	Total	17	16	1987	2002	Less than 3 detected values
METRIBUZIN (SENCOR)	Dissolved	56	56	2000	2005	All non-detect
METRIBUZIN (SENCOR)	Total	13	13	1987	2002	All non-detect
MEVINPHOS (PHOSDRIN)	Total	15	15	1995	2004	All non-detect
MIREX	Total	16	16	1978	1993	All non-detect
MOLINATE	Filtered	56	56	2000	2005	All non-detect
MOLINATE	Total	3	3	2002	2002	All non-detect
MOLYBDENUM	Dissolved	38	35	1990	1999	No data after 1999
MOLYBDENUM	Total	6	6	1994	1996	All non-detect
MONOCROTOPHOS	Total	10	10	1999	2004	All non-detect
N_N-DIETHYLTOLUAMIDE (DEET)	Total	5	4	2002	2002	Less than 3 detected values
NALED (DIBROM)	Total	11	11	1995	2004	All non-detect
NAPHTHALENE	Total	62	62	1994	2005	All non-detect
NAPROPAMIDE	Filtered	56	56	2000	2005	All non-detect
NAPROPAMIDE	Total	3	3	2002	2002	All non-detect
N-BUTYLBENZENE	Total	41	41	1999	2005	All non-detect
NEBURON	Filtered	4	4	2003	2004	All non-detect
NICOSULFURON (ACCENT)	Filtered	4	4	2003	2004	All non-detect
NITROBENZENE	Total	15	15	1994	2004	All non-detect
N-NITROSODIMETHYLAMINE	Total	15	15	1994	2004	All non-detect
N-NITROSO-DI-N-PROPYLAMINE	Total	15	15	1994	2004	All non-detect
N-NITROSODIPHENYLAMINE	Total	15	15	1994	2004	All non-detect
NON-CARBONATE HARDNESS	Total	10	0	1978	1983	No data after 1999
NONYLPHENOL DIETHOXYLATE (NPEO2)	Total	5	4	2002	2002	Less than 3 detected values
NONYLPHENOL MONOETHOXYLATE	Total	5	5	2002	2002	All non-detect

Parameter	Filter	# Obs	# Non-Detect	First Year	Last Year	Reason for exclusion
(NPEO1)						
NORFLURAZON	Filtered	4	4	2003	2004	All non-detect
N-PROPYLBENZENE	Total	41	41	1999	2005	All non-detect
OCTYLPHENOL DIETHOXYLATE (OPEO2)	Total	5	5	2002	2002	All non-detect
OCTYLPHENOL MONOETHOXYLATE (OPEO1)	Total	5	4	2002	2002	Less than 3 detected values
OIL AND GREASE	Total	13	11	1999	2005	Less than 3 detected values
ORGANIC NITROGEN	Total	89	1	1978	1999	No data after 1999
ORYZALIN	Filtered	4	4	2003	2004	All non-detect
OXYAMYL (THIOXAMYL)	Dissolved	4	4	2003	2004	All non-detect
OXYAMYL (THIOXAMYL)	Total	1	1	1991	1991	All non-detect
O-XYLENE	Total	33	33	2002	2005	All non-detect
PARA-NONYLPHENOL (P-NONYLPHENOL)	Total	5	5	2002	2002	All non-detect
PARATHION (PARATHION ETHYL)	Filtered	56	56	2000	2005	All non-detect
PARATHION (PARATHION ETHYL)	Total	39	39	1978	2004	All non-detect
PEBULATE	Filtered	56	56	2000	2005	All non-detect
PEBULATE	Total	3	3	2002	2002	All non-detect
PENDIMETHALIN	Filtered	56	56	2000	2005	All non-detect
PENDIMETHALIN	Total	3	3	2002	2002	All non-detect
PENTACHLOROPHENOL	Total	21	21	1994	2004	All non-detect
PERMETHRIN	Total	3	3	2002	2002	All non-detect
PERTHANE (ETHYLAN)	Total	16	16	1978	1993	All non-detect
PHENANTHRENE	Total	21	21	1994	2004	All non-detect
PHENOL	Total	21	19	1994	2004	Less than 3 detected values
PHEOPHYTIN	N/A	1	1	2002	2002	All non-detect
PHORATE (THIMET)	Filtered	56	56	2000	2005	All non-detect
PHORATE (THIMET)	Total	25	25	1991	2004	All non-detect
PHYTOPLANKTON CHLOROPHYLL A	N/A	10	10	1999	2003	All non-detect
PHYTOPLANKTON CHLOROPHYLL B	N/A	9	9	1999	2003	All non-detect
PICLORAM	Filtered	4	4	2003	2004	All non-detect
PICLORAM	Total	1	1	1999	1999	All non-detect
P-ISOPROPYL TOLUENE	Total	10	10	1999	2004	All non-detect
POLYCHLORINATED BIPHENYL (PCB)	Total	17	17	1978	1993	All non-detect
POLYCHLORINATED NAPHTHALENES	Total	16	16	1978	1993	All non-detect
PREHNITENE	Total	31	31	2002	2005	All non-detect
PROMETON (PRAMITOL)	Total	20	18	1982	2002	Less than 3 detected values
PROMETRYN	Total	13	13	1982	1993	All non-detect
PRONAMIDE (KERB)	Filtered	56	56	2000	2005	All non-detect
PRONAMIDE (KERB)	Total	3	3	2002	2002	All non-detect
PROPACHLOR (RAMROD)	Dissolved	56	56	2000	2005	All non-detect
PROPACHLOR (RAMROD)	Total	6	6	1993	2002	All non-detect
PROPANIL	Filtered	56	56	2000	2005	All non-detect
PROPANIL	Total	3	3	2002	2002	All non-detect
PROPARGITE	Filtered	56	56	2000	2005	All non-detect
PROPARGITE	Total	3	3	2002	2002	All non-detect
PROPAZINE	Total	13	13	1982	1993	All non-detect
PROPHAM	Filtered	4	4	2003	2004	All non-detect
PROPHAM	Total	10	10	1982	1991	All non-detect
PROPICONAZOLE	Filtered	4	4	2003	2004	All non-detect
PROPOXUR	Dissolved	4	4	2003	2004	All non-detect
PROPYLPARABEN	Total	2	0	2002	2002	Less than 3 dates

Parameter	Filter	# Obs	# Non-Detect	First Year	Last Year	Reason for exclusion
PYRENE	Total	21	21	1994	2004	All non-detect
RADIUM 226	Dissolved	2	0	1980	1980	Less than 3 dates
RANITIDINE	Total	13	13	2000	2000	All non-detect
RESIDUE FIXED NONFILTRABLE	Suspended	34	10	1979	1999	No data after 1999
RONNEL (FENCHLORPHOS)	Total	15	15	1995	2004	All non-detect
S_S_S-TRIBUTYL PHOSPHOROTRITHIOATE (DEF)	Total	7	7	1991	1993	All non-detect
SALBUTAMOL	Total	13	13	2000	2000	All non-detect
SEC-BUTYLBENZENE	Total	41	41	1999	2005	All non-detect
SELENIUM	Dissolved	82	74	1978	1999	No data after 1999
SELENIUM	Total	6	6	1994	1996	All non-detect
SIDURON	Dissolved	4	4	2003	2004	All non-detect
SIMAZINE	Total	16	16	1982	2002	All non-detect
SIMETRYNE	Total	13	13	1982	1993	All non-detect
STIGMASTANOL	Total	5	5	2002	2002	All non-detect
STRONTIUM	Total	5	0	1995	1996	No data after 1999
STYRENE	Total	45	45	1995	2005	All non-detect
SULFAMETHOXAZOLE	Total	13	11	2000	2000	Less than 3 detected values
SULFATE TURBIDIMETRIC	Total	3	0	1995	1995	No data after 1999
SULFOTEPP (BLADAFUME)	Total	10	10	1999	2004	All non-detect
TEBUTHIURON	Filtered	56	56	2000	2005	All non-detect
TEBUTHIURON	Total	3	3	2002	2002	All non-detect
TECHNICAL CHLORDANE (ALL ISOMERS)	Total	17	17	1978	1993	All non-detect
TEPP (TETRAETHYLPYROPHOSPHATE)	Total	10	10	1999	2004	All non-detect
TERBACIL (SINBAR)	Filtered	56	56	2000	2005	All non-detect
TERBACIL (SINBAR)	Total	10	10	1993	2004	All non-detect
TERBUFOS	Filtered	56	56	2000	2005	All non-detect
TERBUFOS	Total	3	3	2002	2002	All non-detect
TERBUTHYLAZINE	Total	3	3	2002	2002	All non-detect
TERT-BUTYLBENZENE	Total	41	41	1999	2005	All non-detect
TETRACHLOROVINPHOS (STIROPHOS)	Total	15	15	1995	2004	All non-detect
TETRAHYDROFURAN	Total	31	31	2002	2005	All non-detect
THALLIUM	Total	6	5	1994	1996	No data after 1999
THIOBENCARB	Filtered	56	56	2000	2005	All non-detect
THIOBENCARB	Total	3	3	2002	2002	All non-detect
TOKUTHION (PROTOTHIOFOS)	Total	10	10	1999	2004	All non-detect
TOLUENE	Total	75	74	1986	2005	Less than 3 detected values
TONALIDE (AHTN)	Total	5	5	2002	2002	All non-detect
TOTAL CHLORDANE	Total	6	6	1994	1999	All non-detect
TOTAL COLIFORM BACTERIA	N/A	43	0	1969	1991	No data after 1999
TOTAL SOLIDS	Total	2	0	1991	1999	Less than 3 dates
TOTAL TRIAZINES	Total	3	2	2002	2002	Less than 3 detected values
TOXAPHENE	Total	23	23	1978	1999	All non-detect
TPH-DIESEL	Total	4	4	1995	1996	All non-detect
TPH-MOTOR OIL	Total	4	4	1995	1996	All non-detect
TRANS-1_2-DICHLOROETHENE (TRANS-1_2-DICHLOROETHYLENE)	Total	75	75	1986	2005	All non-detect
TRANS-1_3-DICHLOROPROPENE	Total	74	74	1986	2005	All non-detect
TRI(2-CHLOROETHYL)PHOSPHATE	Total	5	4	2002	2002	Less than 3 detected values
TRI(DI-CHLORISOPROPYL)PHOSPHATE	Total	5	5	2002	2002	All non-detect
TRIALLATE	Filtered	56	56	2000	2005	All non-detect

Parameter	Filter	# Obs	# Non-Detect	First Year	Last Year	Reason for exclusion
TRIALLATE	Total	3	3	2002	2002	All non-detect
TRIBUTYLPHOSPHATE	Total	5	4	2002	2002	Less than 3 detected values
TRICHLOROFLUOROMETHANE	Total	72	72	1986	2005	All non-detect
TRICHLORONATE	Total	10	10	1999	2004	All non-detect
TRICLOPYR	Filtered	4	4	2003	2004	All non-detect
TRICLOSAN	Total	5	5	2002	2002	All non-detect
TRIFLURALINE	Filtered	56	56	2000	2005	All non-detect
TRIFLURALINE	Total	13	13	1987	2002	All non-detect
TRIMETHOPRIM	Total	13	13	2000	2000	All non-detect
TRIPHENYL PHOSPHATE	Total	5	5	2002	2002	All non-detect
TRITHION (CARBOPHENOTHION)	Total	17	17	1978	1993	All non-detect
TRITIUM	N/A	1	0	1978	1978	Less than 3 dates
URANIUM	Dissolved	2	1	1980	1999	Less than 3 dates
VANADIUM	Dissolved	37	37	1990	1999	All non-detect
VERNOLATE (VERNAM)	Total	3	3	1993	1993	All non-detect
VINYL ACETATE	Total	4	4	1995	1996	All non-detect
VINYL CHLORIDE	Total	75	75	1986	2005	All non-detect
WARFARIN	Total	13	13	2000	2000	All non-detect
XYLENES	Total	13	12	1994	2003	Less than 3 detected values

Appendix 2. Parameters with no statistically significant trends over time in any condition.

Parameter	Full Model	Comments
Alkalinity as $CaCO_3$, Dissolved	*Alkalinity (diss) = lab + lab*date + discharge + date*	*lab* to account for field/lab switch in 2000
Ammonia as N, Dissolved	*Ammonia (diss) = discharge + date*	Only measured by USGS
Ammonia as N, Total	*Ammonia (tot) = collector + collector*date + discharge + date*	Total ammonia collected by ATCHD, USGS and ERM, but only ERM data after 1995. No values of ammonia > 0.17 (TCEQ screening level for freshwater streams) in Barton Springs. Only 1 value in 1998 > 0.106 (TCEQ screening level for freshwater reservoirs).
Arsenic, Dissolved or Total	*Arsenic (diss or total) = discharge + date*	(Analysis by PHREG for non-detects) USGS measures dissolved, ERM measures total
Cadmium, Dissolved or Total	*Cadmium (diss or total) = discharge + date*	(Analysis by PHREG for non-detects) USGS measures dissolved, ERM measures total
Chemical Oxygen Demand	*COD = discharge + date*	Analysis by PHREG for non-detects
Chloride, Total	*Chloride (tot) = collector + collector*date + low_flow + discharge + date*	Chloride collected by ATCHD, USGS and ERM and is currently monitored by USGS and ERM. Comparison of chloride concentrations in Barton Springs to the TCEQ surface water quality standard of 50 mg/L for Barton Creek (segment 1430) indicate that although chloride has exceeded 50 mg/L in Barton Springs in 8 of the 260 observations considered, there is no trend in number of exceedances and the most recent exceedance was in 1996.
Chromium, Dissolved or Total	*Chromium (diss or total) = discharge + date*	Analysis by PHREG to account for non-detects
Copper, Dissolved or Total	*Copper (diss or total) = discharge + date*	Analysis by PHREG to account for non-detects
E coli bacteria	*EColi = method + method*date + discharge + date*	E coli collected by ATCHD and USGS, with consistent methods for each collector
Mercury, Dissolved or Total	*Mercury (diss or total) = discharge + date*	Analysis by PHREG to account for non-detects
Organic carbon, Total	*TOC = collector + collector*date + bs_flow + date*	(Analysis by PHREG for non-detects) TOC measured by USGS and ERM with generally consistent methods and overlapping period of record

Parameter	**Full Model**	**Comments**
Orthophosphorus, Dissolved or Total	*OP (diss or total) = collector + collector*date + bs_flow + date*	(Analysis by PHREG for non-detect) Dissolved and total OP measured by ERM and USGS by consistent methods, analyzed individually
Phosphorus, Dissolved or Total	*TP (diss or total) = collector + collector*date + bs_flow + date*	(Analysis by PHREG for non-detect) Dissolved phosphorus measured by ERM and USGS; total phosphorus measured by USGS, ERM and ATCHD
Potassium, Total	*K (tot) = low_flow + discharge + date*	Total potassium measured by ERM
Silver, Dissolved or Total	*Silver (diss or total) = discharge + date*	Analysis by PHREG to account for non-detects
Sodium, Total	*Na (tot) = low_flow + discharge + date*	Dissolved sodium (USGS) decreasing over time; total sodium (ERM) with shorter period of record not changing
Total Suspended Solids	*TSS = collector + collector*date + bs_flow + date*	(Analysis by PHREG for non-detect) TSS measured by ERM and USGS with generally consistent methods and overlapping periods of record.
Turbidity, NTU	*Turb = method + method*date + discharge + date*	Analysis on ERM and USGS turbidity measured in the field. Method code to account for difference in collector differences and change in equipment by ERM.
Volatile Suspended Solids	*VSS = collector + collector*date + bs_flow + date*	(Analysis by PHREG for non-detect) TSS measured by ERM and USGS with consistent methods but no overlap in period of record.