

## **A Review of Lake Austin Sediment Quality, 1987-2009**

Mary Gilroy and Martha Turner  
Environmental Resource Management, Watershed Protection Department  
City of Austin

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*Sediment samples were collected on Lake Austin from 1987 through 2009, with site location and frequency varying considerably until 2001, when four sites were sampled annually through 2009. The only lake-wide temporal trend seen in this more recent period of record (2001-2009) was a decreasing trend for chlordane, although there was limited detected chlordane data (21%, or 6 out of 29 samples). Site specific trends include increasing trends in copper and zinc at Tom Miller, the most downstream site, but data was all well below the TEC (Threshold Effects Concentration). Spatial analyses indicated that only Tom Miller was significantly different (always higher) from other sites for any parameter, except for total PAHs, where Bull Creek was higher and significantly different from all others. Only four parameters, arsenic, DDD, DDE and TPAH had values exceeding the TEC, and only DDE, with four exceedances, had more than one exceedance since 2001. Future monitoring should include only the most downstream site, and parameters with no detected data should be dropped from the analysis list.*

### **Introduction**

In addition to causing increased turbidity, smothering of benthic habitat and eventually volume reduction in reservoirs, sediments are an important storage mechanism for many chemicals in surface water. Because of their ability to sequester toxic compounds, sediments can reflect and record the effects of anthropogenic influences on water bodies. Brought into the water from both point and non-point sources, toxins can move throughout the water column, adhering to sediments where long term exposure to aquatic organisms is possible, from both suspended and benthic particles.

Lake Austin is a 1600 acre run-of-the-river reservoir on the Colorado River just upstream of the urban center of the City of Austin in Travis County, Texas. While less intensely developed than the downstream reservoir, Lady Bird Lake, increasing urbanization of the Lake Austin watershed can be expected to impact sediment quality. This report reviews spatial and temporal trends to establish a baseline of current conditions for future comparisons as well as to direct future sampling efforts.

### **Methods**

The period of record for this report is 1987- 2009. Through 1995, site location and sampling frequency varied from year to year. No sediment was collected from 1996 to 2001, when sampling was initiated at four sites intended to characterize the condition of sediment throughout the lake, and this has continued annually through 2009. Samples were collected by City of Austin, Lower Colorado River Authority and USGS in different years, but labs used by all agencies were accredited by the EPA National Environmental Laboratory Accreditation Program.

#### Site location and sampling frequency

All but two data points were collected at four sites, distributed from upstream to downstream (Figure 1, Table 1). These two data points were from single sampling events at two sites, #512, the most upstream site and #218, a

midstream site. Two other sites (# 510 and 511) also had single data points that were combined with data from other more commonly sampled sites (#573 and 561, respectively) in very close proximity.

The most upstream of the four more consistently sampled sites is Lake Austin @ Selma Hughes # 559 located approximately 3 miles downstream from Mansfield Dam, and at the upper end of one segment of a persistent hydrilla infestation. Fine sediment is at times limited in availability here. The next downstream site is Lake Austin @ Emma Long Metro Park, # 573, located approximately mid-lake and near a highly-used recreational park downstream of the most persistent hydrilla infestation. All of the upper and mid-lake sites are characterized by a sandy substrate and often limited sediment availability due to periodic scouring floods. Lake Austin @ Bull Creek, # 562, is located in the lake at the confluence of Bull Creek, and chosen to characterize the influence of this major tributary on lake sediment quality. The most downstream site, Lake Austin @ Tom Miller Dam, #561, has the longest period of record in this report.

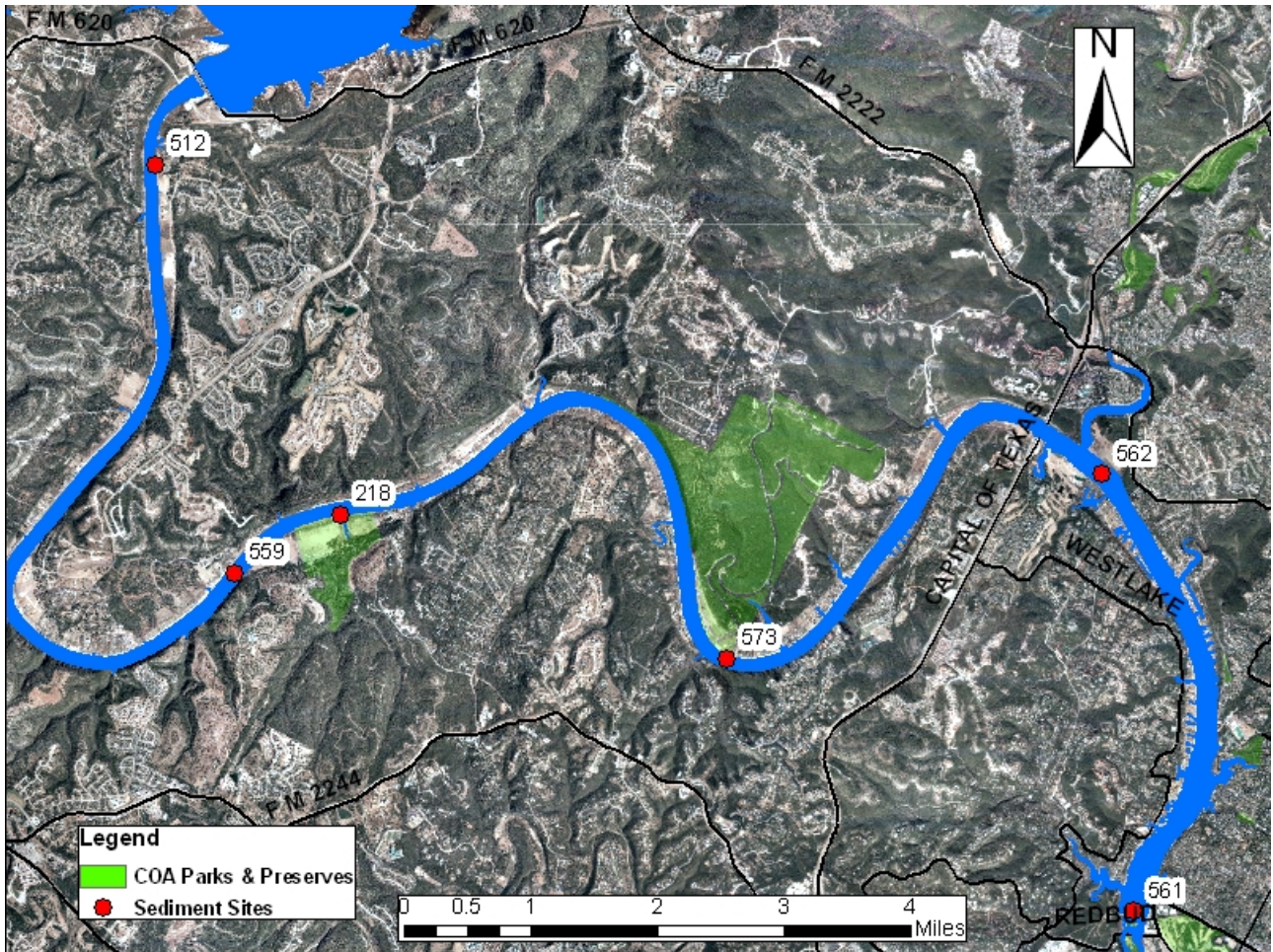


Figure 1 Lake Austin sediment sampling sites, with associated database numbers and City of Austin parks.

Table 1. Site names and sample dates for Lake Austin sediment, 1987-2009. Sites are ordered from upstream (left) to downstream (right).

Date	#512 Lake Austin @ Fritz Hughes Park	#599 Lake Austin @ Selma Hughes Park	#218 Lake Austin @ Commons Ford Preserve	#573 Lake Austin @ Emma Long Park	#562 Lake Austin @ Bull Creek	#561 Lake Austin @ Tom Miller Dam
Mar-87						X
May-87						X
Aug-87						X
Jan-88						X
Apr-88						X
Jul-88						X
Jan-89					X	
Mar-89					X	
Apr-89					X	
May-89					X	
Aug-89					X	
Mar-90					X	
May-90					X	
May-90					X	
Aug-90					X	
Sep-91			X			
Jan-95	X			X		X
Jun-01		X		X	X	X
Jul-02		X		X	X	X
Jul-03		X		X	X	X
Aug-04				X	X	X
Feb-05						X
Aug-05		X		X	X	
Aug-05						X
Jul-06		X		X	X	X
Dec-07		X		X		X
May-09		X		X	X	X

Sampling methods and analysis

Sediment was collected and analyzed (Table 2) according to standard lake sediment sampling procedures (WRE SOP, 2009), using a Ponar dredge to take at least three sub-littoral sediment grabs composited into a single sample for each site.

Spatial patterns were evaluated using Analysis of Variance with the Ryan-Einot-Gabriel-Welsch (REGW) multiple-range test used to tell which site means were different. Temporal trends were evaluated using linear regression (SAS 9.1.3). An alpha level of 0.05 was used to assess significance but p values were generally provided to evaluate the range of test results. Values below detection limits were not used in most analyses since detection limits varied widely and some were very high. In some cases, non-detect values were set to the detection limit and used in the analysis if the detection limit was less than the median of the dataset. While not the optimal method for dealing with non-detect values in data analysis, substitution of censored values at the detection limit was reasonable in this analysis given the observed differences in detected values and the lower (below the median) non-detect results.

Table 2. Parameters and analysis methods for sediment samples on Lake Austin.

<b>Parameter</b>	<b>Method (2009)</b>
Ammonia	EPA 350.1
Percent Moisture (%)	ASTM D2216
TOC (%)	EPA 9060
TPH	Tx 1005
Arsenic	
Cadmium	
Chromium	
Copper	
Iron	
Lead	
Zinc	
Silver	
Nickel	
Mercury	
PAHs	EPA 8270C
PCB	EPA 8080
Organochlorine pesticides	EPA 8081
Chlorophenoxy acid herbicides	EPA 8151
Organophosphate pesticides	EPA 8141
Texture	Hydrometer

## Results

Sediment texture relationships (%) and organic carbon concentrations from all sites and sample dates are shown in Table 3. Both of these constituents show a similar spatial pattern, with the two upper to mid lake sites (Emma Long, Selma Hughes) tracking together while the lower sites (Bull Creek and Tom Miller Dam) share similar values, as shown in Figure 2. The upper sites have much higher percentage sand (means greater than 82%) and very limited silt and clay (means less than 15%) while the lower sites Bull Creek and Tom Miller have a more even distribution of sediment particle size. Organic carbon content showed a similar pattern, with Emma Long and Selma Hughes typically very low (1.5-5.5 mg/kg) and Bull Creek and Tom Miller much higher (34.6-105 mg/kg).

Table 3. Sediment texture and organic carbon shown by site on Lake Austin, 1995-2009, including mean values where multiple samples were taken. Sites are listed top to bottom , upstream to downstream, respectively.

SITE	DATE	Percent										Carbon (mg/kg)		
		BED MATERIAL SIEVE %<.125MM	BED MATERIAL SIEVE %<.250MM	BED MATERIAL SIEVE %<.500MM	BED MATERIAL SIEVE %<1.00MM	SEDIMENT FINER THAN .062MM	TEXTURE CLAY (<0.002MM)	TEXTURE GRAVEL (>0.0787")	TEXTURE SAND (0.05-2.0MM)	TEXTURE SILT (0.002-0.05MM)	VOLATILE SOLIDS	ORGANIC CARBON (mg/kg)	ORGANIC+INORGANIC IC CARBON (mg/kg)	
Lake Austin @ Fritz Hughes Park	30-Jan-95												44.0	
Lake Austin @ Selma Hughes Park	21-Jun-01	32	51	95	100	26								25
	24-Jul-02	100	100	100	100	100								22
	17-Jul-03	58	81	100	100	11								36
	11-Aug-05						2.1	0.4	95.4	2.0		2.1		
	18-Jul-06							0.9	96.4	2.7		1.5		
	05-Dec-07								98.0	2.0				
	11-Mar-09								0.8	97.2	2.0			
Selma Hughes Mean							2.1	0.7	96.8	2.2		1.8		
Lake Austin @ Commons Ford Park	27-Sep-91						42.6		10.6	46.8	9.0	0.0		
Lake Austin @ Emma Long Metro Park	30-Jan-95											20.0		
	21-Jun-01	46	75	100	100	37							25	
	24-Jul-02	100	100	100	100	100							41	
	17-Jul-03	39	68	100	100	10							27	
	09-Aug-04											3.3		
	11-Aug-05						3.7	2.1	88.2	6.0		5.5		
	18-Jul-06							0.3	95.1	4.7		3.2		
	05-Dec-07						9.2	11.0	51.7	28.0		27.9		
11-Mar-09						2	0.3	93.7	4.0					
Emma Long Mean							3.7	3.4	82.2	10.7		15.0		
Lake Austin @ Bull Creek	21-Jun-01	98	100	100	100	93							87	
	24-Jul-02	100	100	100	100	100							81	
	17-Jul-03	73	88	100	100	6							81	
	09-Aug-04						19.6	0.0	30.4	50.0		50.3		
	11-Aug-05						8.1	0.0	39.9	52.0		26.5		
	18-Jul-06						27.4	0.6	35.3	36.7		40.4		
	11-Mar-09						15.3	1.8	41.0	42.0				
Bull Creek Mean							17.6	0.6	36.7	45.2		39.0		
Lake Austin @ Tom Miller	30-Jan-95											54.0		
	21-Jun-01	98	100	100	100	95							70	
	24-Jul-02	100	100	100	100	94							87	
	17-Jul-03	83	93	100	100	14							81	
	09-Aug-04						41.6	0.0	28.4	30.0		40.6		
	16-Feb-05						42.0	0.0	32.0	26.0		38.6		
	17-Aug-05						34.1	0.0	33.9	32.0		105		
	18-Jul-06						37.4	1.0	38.9	22.7		34.6		
	05-Dec-07						45.4		24.5	30.1		69.5		
11-Mar-09						40.0		25.6	34.4					
Tom Miller Mean							40.0	.25	30.6	29.2		57.7		

Figure 2. Percent texture and organic carbon in sediment on the four most consistently sampled sites on Lake Austin, 1995-2009

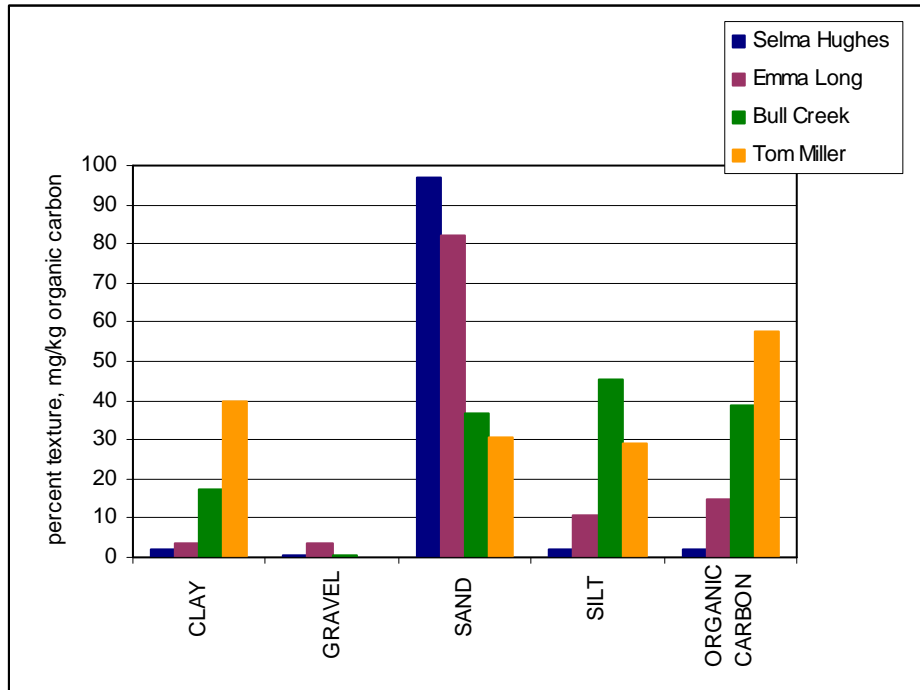


Table 4 provides summary statistics for detection limits and detected values for all analysis parameters for the period of record. Constituents with no detected values throughout the study period include silver, aldrin, three species of chlordane and diazinon. Most metals had a fairly high percentage of detected values, with mercury having the least (48%) and nickel being the only parameter with 100% detected values.

Additional data is presented in Appendix A, with detected values for all pesticides and herbicides in Table 5, semi-volatile and polychlorinated biphenyls (PCBs) in Table 6 and 7, respectively, and the sum of polycyclic aromatic hydrocarbons (TPAH) values (both detects and non-detects) in Table 8. TPAH data includes non-detects, as one laboratory had particularly high detection limits, and only one detected value (1650 µg/kg) which was the maximum value recorded for that parameter in the study.

### Temporal Trends

When data from all sites are combined, sediment quality on Lake Austin generally shows improvement over the entire period of record, with only decreasing temporal trends in seven parameters shown in Table 9. For six of the seven parameters, there was no trend when the analysis was limited to more recent data from 2001-2009. Chlordane was not analyzed for samples prior to 2001, and is the only parameter showing any significant trend with this more recent data set. Three of the seven (chromium, mercury, chlordane) parameters had detection limits that were less than the median of the detected values, so all non-detect data was set to the detection limit and included in the analyses. Substitution is not the optimal method for dealing with censored observations, but since all non-detect values were less than the median of the dataset the application in temporal trend analysis may affect magnitude but not the direction of the predicted slope. Detection limits for the other parameters did not meet this criteria, so non-detect values were not included. Temporal graphs of each parameter are presented in Appendix C, with only detected values.

Table 4. Percent detection of sediment parameters, associated detection limits, and range of detected values among all study sites on Lake Austin, 1987-2009. Gray cells indicate no data, either because no sample values

were above detection limits (0% detected) or because all sample values were above detection limits (100% detected).

Parameter type	UNITS	PARAMETER	% detected	# of non-detect values	Sample Detection Limits		Sample Detected Values				
					Median	Min	Max	Median	Min	N	
Metals	MG/KG	ARSENIC	97	1	6.150	6.150	11.400	4.530	0.830	37	
Metals	MG/KG	CADMIUM	80	10	0.058	0.050	3.000	0.246	0.057	39	
Metals	MG/KG	CHROMIUM	90	5	0.400	0.400	230.000	9.430	1.740	45	
Metals	MG/KG	COPPER	96	2	10.000	10.000	18.000	10.000	0.498	48	
Metals	MG/KG	LEAD	96	2	100.000	100.000	60.000	15.300	1.070	44	
Metals	MG/KG	MERCURY	48	27	0.010	0.000	0.700	0.039	0.013	25	
Metals	MG/KG	NICKEL	100	0			19.400	7.500	0.913	19	
Metals	MG/KG	SILVER	0	19	0.080	0.052					
Metals	MG/KG	ZINC	98	1	16.000	16.000	92.000	32.500	2.960	46	
Organochlorines	UG/KG	ALDRIN	0	40	1.525	0.500					
Organochlorines	UG/KG	ALPHA-CHLORDANE	0	17	2.080	1.200					
Organochlorines	UG/KG	DDD	20	32	1.540	0.500	9.590	2.650	0.380	8	
Organochlorines	UG/KG	DDE	45	22	2.695	1.200	11.000	2.235	0.100	18	
Organochlorines	UG/KG	DDT	5	35	1.540	0.500	2.900	2.050	1.200	2	
Organochlorines	UG/KG	DIELDRIN	3	39	1.540	0.500	2.200	2.200	2.200	1	
Organochlorines	UG/KG	GAMMA-CHLORDANE	0	20	1.955	1.200					
Organochlorines	UG/KG	TECHNICAL CHLORDANE (ALL ISOMERS)	0	3	101.000	21.800					
Organochlorines	UG/KG	TOTAL CHLORDANE	21	23	5.000	1.240	4.800	2.800	2.000	6	
Organophosphates	UG/KG	DIAZINON	0	18	10.900	6.000					
TPAH	UG/KG	PAH	63	14	315.900	131.260	1650.000	359.900	42.960	24	
PCBs	UG/KG	PCB	17	15	22.000	9.470	19.800	10.000	8.800	3	

Table 9. Lake Austin sediment parameters with significant temporal trends, 1987-2009. Yellow cells indicate analysis that includes non-detect values set to the detection limit where the detection limit is less than the median detected value.

Parameter	Slope	Std Error	Prob>  t	Direction	Period of record
ARSENIC	-0.0004	0.00014	0.0207	decreasing	1987-2009
CADMIUM	-0.0003	0.00003	<0.0001	decreasing	1987-2009
LEAD	-0.0032	0.00060	<0.0001	decreasing	1987-2009
DDE	-0.0014	0.00042	0.0042	decreasing	1987-2009
CHROMIUM	-0.0034	0.00165	0.0439	decreasing	1987-2009
MERCURY	-0.00001	0.00001	0.0205	decreasing	1987-2009
CHLORDANE	-0.0006	0.00024	0.0371	decreasing	2001-2009

When data is analyzed on a site by site basis, only Lake Austin @ Bull Creek and Lake Austin @ Tom Miller Dam show any significant temporal trends (Table 10). Only Tom Miller showed increasing trends in any parameters, specifically in copper and zinc. Both sites show decreasing trends for cadmium and lead, while copper decreased only at Bull Creek and mercury only decreased at Tom Miller. As is shown with lake-wide data, many of these decreasing trends are driven by a very few high values from samples collected prior to 1986. In particular, mercury had a single high value in 1985 that resulted in the decreasing trend (see Figure C6, Appendix C). Including all non-detect data (as described above) did not result in additional parameters showing significant temporal trends when analyzed on a site-by-site basis. No trend in recent years can be analyzed for

site-specific data, as the number of data points is too small. Observed temporal trends in chromium and mercury may be influenced by the improvement of analytical methods (decrease in detection limits) over time.

Table 10. Lake Austin sediment parameters (with values over the detection limit) which show significant temporal trends broken out by site, 1987-2009. Yellow cells indicate parameters with increasing trends.

PARAMETER	SITE	Slope	Prob>  t	Direction
CADMIUM	Lake Austin @ Bull Creek (BC)	-0.0003	<0.0001	decreasing
CADMIUM	Lake Austin @ Tom Miller Dam (AC)	-0.0002	0.0002	decreasing
COPPER	Lake Austin @ Bull Creek (BC)	-0.0005	0.0250	decreasing
COPPER	Lake Austin @ Tom Miller Dam (AC)	0.0007	0.0135	increasing
LEAD	Lake Austin @ Bull Creek (BC)	-0.0027	0.0136	decreasing
LEAD	Lake Austin @ Tom Miller Dam (AC)	-0.0024	0.0348	decreasing
MERCURY	Lake Austin @ Tom Miller Dam (AC)	-0.0001	0.0241	decreasing
ZINC	Lake Austin @ Tom Miller Dam (AC)	0.0036	0.0134	increasing

### Spatial Differences

Since routine sampling at the four representative sites was initiated in 2001, spatial analysis focused on this more recent period of record (2001-2009). Using this data, the most downstream site, Tom Miller, was significantly higher for metals, DDD and DDE than the other three sites. Bull Creek site means were not significantly different from Tom Miller site means for cadmium, lead and TPAH values.

Table 11 shows the degree of difference between each site, with means of all parameters but TPAHs increasing longitudinally from up to downstream. While Tom Miller had significantly higher means than all other sites for most parameters, the two more upstream sites (Emma Long and Selma Hughes) had means that were always similar to each other. Bull Creek's location between these upper and lower sites is evident in this analysis, where it groups with the upper sites only for arsenic (Fig 3), chromium and DDE, then with Tom Miller only for lead (Fig 3) and TPAHs, and then shares similarity with both upper and lower sites for cadmium. Bull Creek means for copper (Fig 4), nickel, zinc and DDD are significantly different from all other sites. Unique among all parameters, TPAH shows a slightly different spatial pattern, with Bull Creek having the significantly highest mean, Tom Miller the next significantly highest, and then Selma Hughes with a higher, but not significantly different, mean from Emma Long. This pattern is graphed in Figure 5. Spatial plots of all other sediment parameters are presented in Appendix B.

Table 11. Significantly different site means for sediment parameters using data above detection limits, Lake Austin, 2001-2009. Grouping letters indicate degree of significance among/between sites. Bold indicates site(s) with significantly highest means.

<b>Parameter</b>	<b>Grouping</b>	<b>Mean</b> (mg/kg metals, ug/kg DDD, DDE, PAHs)	<b>N</b>	<b>Site</b>
<b>Arsenic</b>	A	7.0	6	<b>Tom Miller</b>
	B	3.7	4	Bull Creek
	B	1.8	5	Emma Long
	B	1.2	4	Selma Hughes
<b>Cadmium</b>	A	0.37	7	<b>Tom Miller</b>
	AB	0.25	7	<b>Bull Creek</b>
	B	0.12	6	Emma Long
	B	0.08	4	Selma Hughes
<b>Chromium</b>	A	17.0	8	<b>Tom Miller</b>
	B	9.1	6	Bull Creek
	BC	4.7	7	Emma Long
	C	4.1	6	Selma Hughes
<b>Copper</b>	A	15.4	9	<b>Tom Miller</b>
	B	9.3	7	Bull Creek
	C	4.0	7	Emma Long
	C	3.5	6	Selma Hughes
<b>Lead</b>	A	19.1	8	<b>Tom Miller</b>
	A	14.3	6	<b>Bull Creek</b>
	B	4.1	7	Emma Long
	B	3.4	6	Selma Hughes
<b>Nickel</b>	A	15.9	4	<b>Tom Miller</b>
	B	9.9	5	Bull Creek
	C	3.7	3	Emma Long
	C	1.7	4	Selma Hughes
<b>Zinc</b>	A	62.5	8	<b>Tom Miller</b>
	B	36.1	7	Bull Creek
	C	13.1	7	Emma Long
	C	12.3	5	Selma Hughes
<b>DDD</b>	A	4.7	5	<b>Tom Miller</b>
	B	0.5	3	Bull Creek
<b>DDE</b>	A	6.6	5	<b>Tom Miller</b>
	B	2.3	6	Bull Creek
	B	0.5	3	Emma Long
	B	0.2	4	Selma Hughes
<b>PAH</b>	A	736	9	<b>Bull Creek</b>
	AB	398	7	<b>Tom Miller</b>
	B	159	4	Selma Hughes
	B	100	4	Emma Long

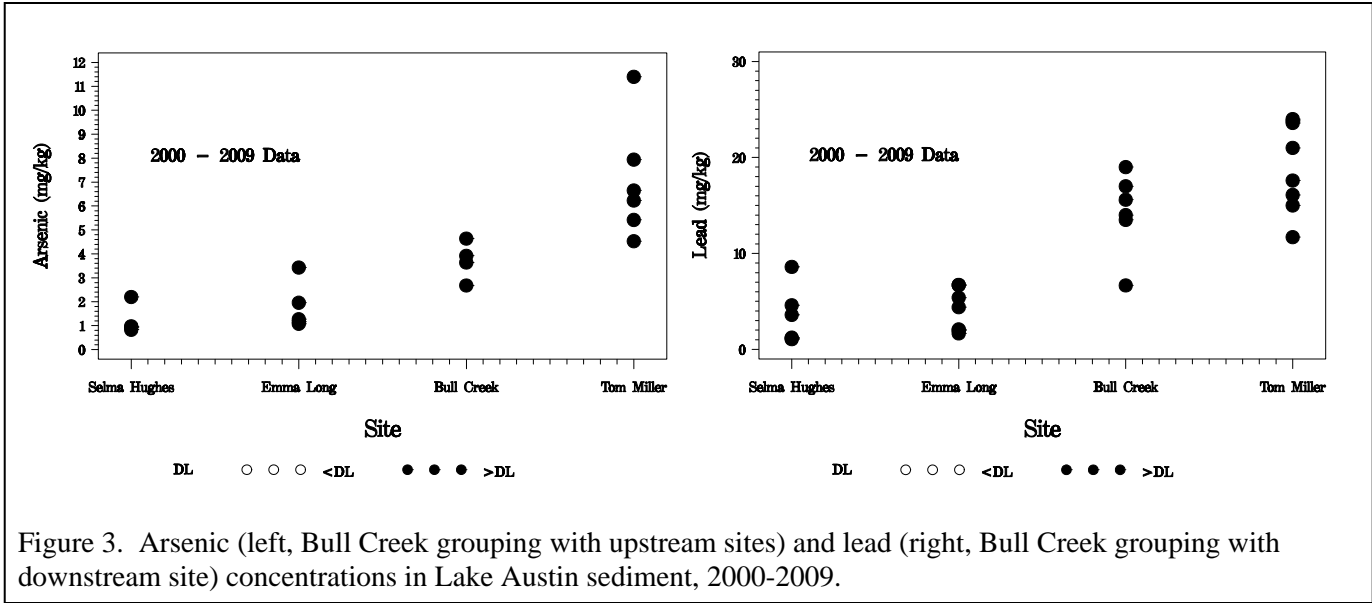


Figure 3. Arsenic (left, Bull Creek grouping with upstream sites) and lead (right, Bull Creek grouping with downstream site) concentrations in Lake Austin sediment, 2000-2009.

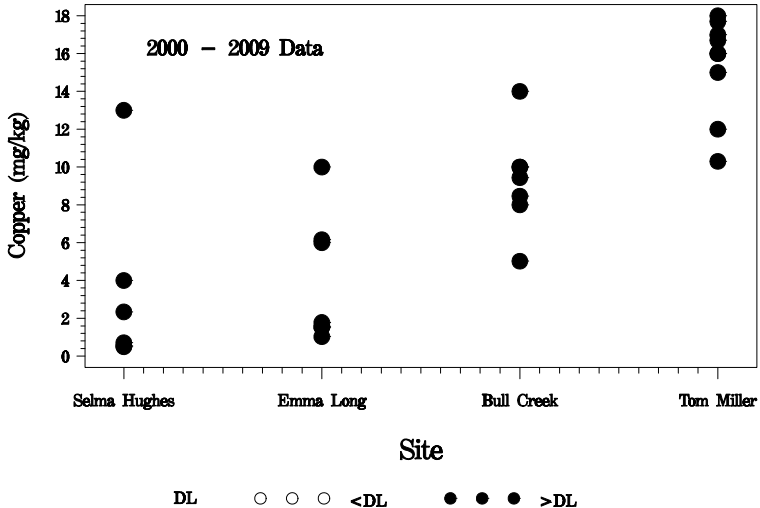


Figure 4. Copper concentrations in Lake Austin sediment, 2000-2009. Bull Creek is not similar to either up or downstream sites.

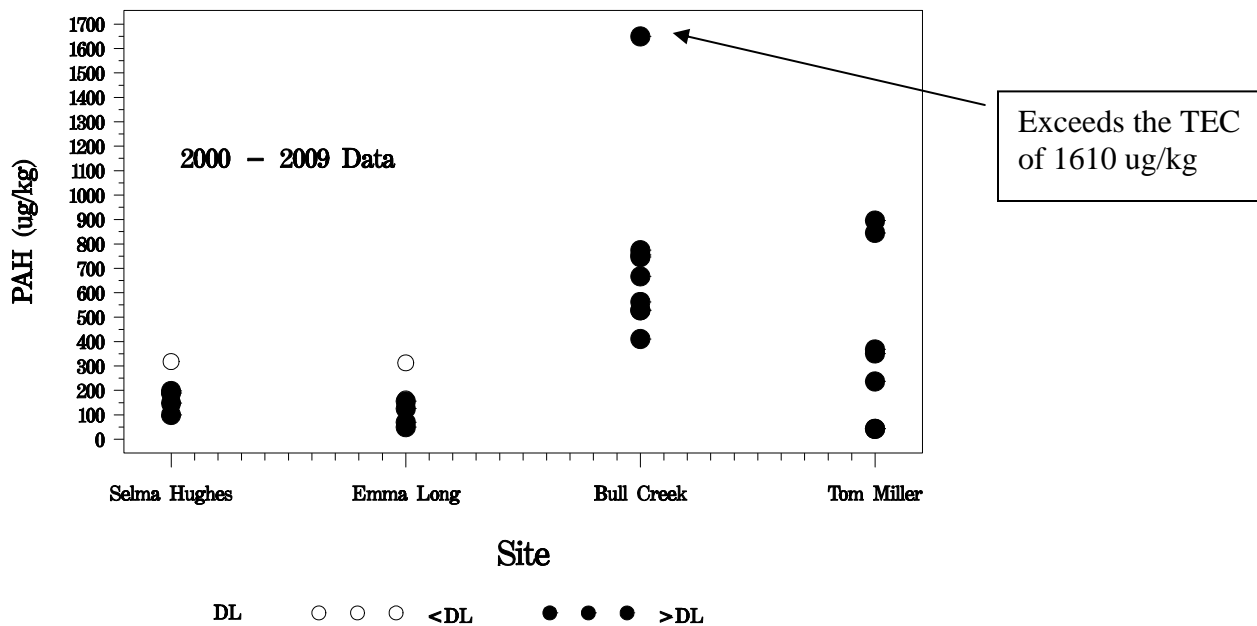


Figure 5. Total PAH concentrations in Lake Austin sediment, 2000-2009. PAH has a TEC of 1610 ug/kg.

### Sediment Toxicity

In order to focus on the most recent conditions, assessment of sediment toxicity was performed using data since 2001, when sampling was initiated at the four most representative sites. The standard used to define toxicity in this analysis is the Threshold Effects Concentration (TEC), below which adverse effects to aquatic life are not expected to occur (MacDonald et. al., 2000). During this period, Lake Austin sediment was not characterized by highly toxic components, as there were only four parameters (and seven values) exceeding any TEC, shown in Table 13. Three of those four (arsenic, DDD, DDE) occurred at Tom Miller, while the fourth, TPAH, was at Bull Creek, where the July 2004 TPAH value was only slightly above the TEC of 1610 ug/kg.

Table 13. Lake Austin sediment parameters with values over the TEC from 2001-2009.

Parameter	# exceedances	Location	TEC
Arsenic	1	Tom Miller	9.79 mg/kg
DDD	1	Tom Miller	4.88 ug/kg
DDE	4	Tom Miller	3.16 ug/kg
TPAH	1	Bull Creek	1610 ug/kg
Chlordane	1	Tom Miller	3.24 ug/kg

Graphs of these four parameters are shown in Figures 6-9 (arsenic, DDD, DDE, TPAH respectively) with all data since 1985 included for historic comparison purposes. Additional temporal graphs of all parameters are provided in Appendix C, where TEC values are also included for all parameters.

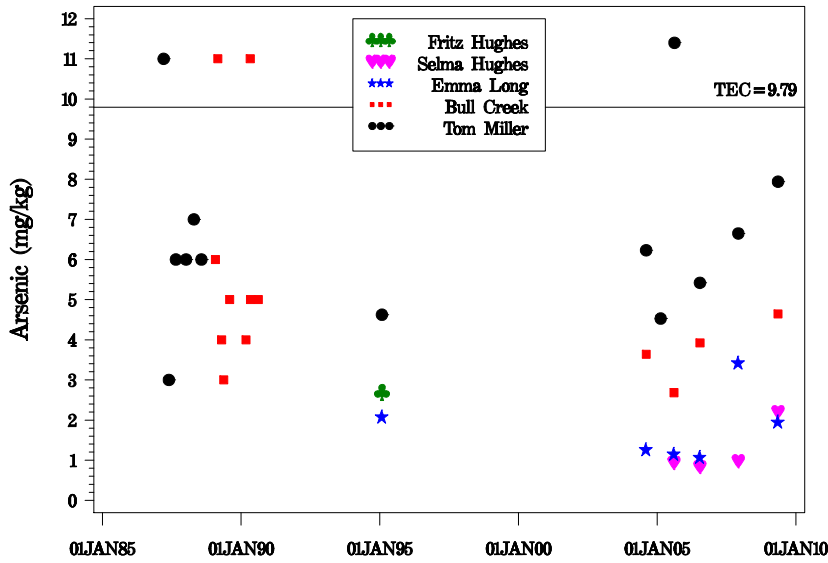


Figure 6. Arsenic concentrations in Lake Austin sediment, 1987-2009. Horizontal line represents TEC value for arsenic of 9.79 mg/kg.

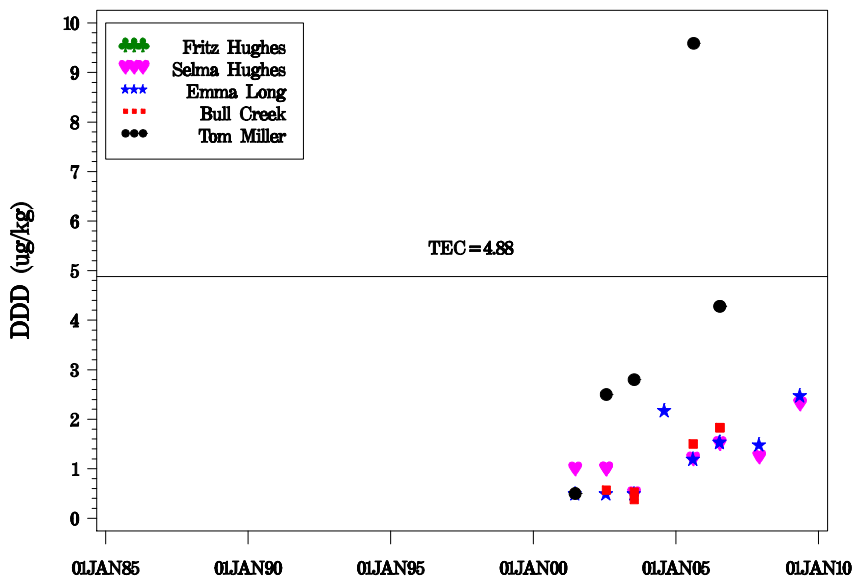


Figure 7. DDD concentrations in Lake Austin sediment, 1987-2009. Horizontal line represents TEC value for DDD of 4.88 ug/kg.

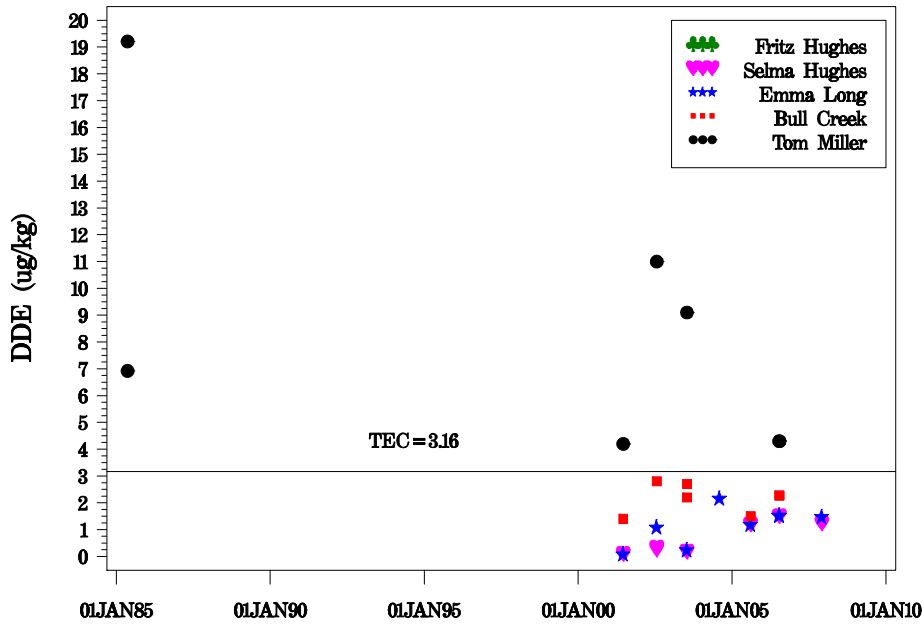


Figure 8. DDE concentrations in Lake Austin sediment, 1985-2009. Horizontal line represents TEC value for DDE of 3.16 ug/kg.

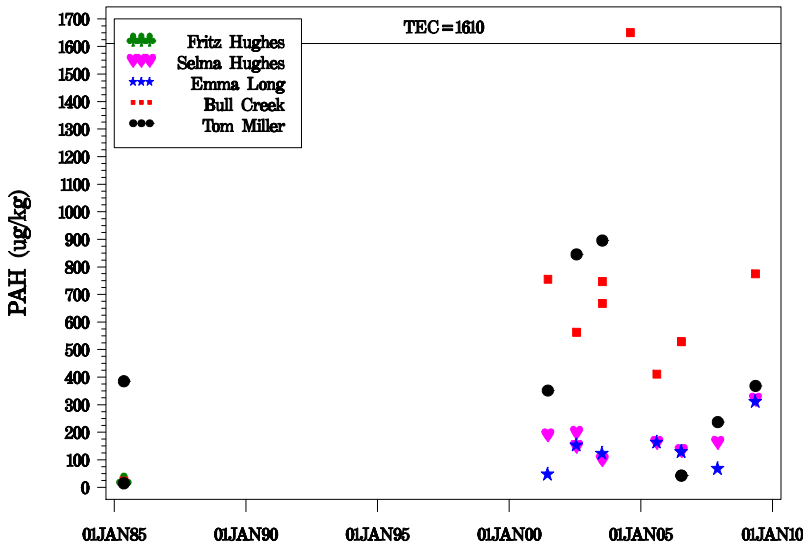


Figure 9. Total PAH concentrations in Lake Austin sediment, 1985-2009. Horizontal line represents TEC value for PAH of 1610 ug/kg.

## Conclusions

The following conclusions were derived from the analyses of Lake Austin sediment data:

- Sediment quality on Lake Austin does not show significant degradation over the entire period of record, with many parameters showing no change, and some metals and herbicides significantly decreasing over time. While many pesticides, herbicides, and PCBs had detectable values during the study, only seven parameters showed any lake-wide significant temporal trend. All lake-wide trends were decreasing, and all but chlordane produced this trend as a result of data collected prior to 1990. At least in the case of chromium and mercury, this may indicate an improvement in analysis techniques in the past 20 years, as

non-detects were set to one-half the detection limit, and detection limits have improved (decreased) over time.

- Since 2001, no parameters have shown any lake-wide change except for chlordane. Chlordane was detected in 2003 and 2004 and has been below detection from 2005-2009. This most recent period of non-detects may be due to scouring floods (two significant floods have occurred since 2001) removing sediment from the lake.
- Site specific analysis shows a similar pattern, with only five metals showing any temporal trend. Of these, only copper and zinc trends are a result of more recent data, other trends appear to be from data collected prior to 1990. Copper and zinc are both increasing over time, and only at Tom Miller. The reasons for this increase are not clear, although copper could be a result of a possible (but not documented) increase in copper-based herbicide use since 1999, when hydrilla was first documented in the lake. It is important to note that even with this increase the maximum value reported is well below the TEC for both parameters.
- Spatially, concentrations of parameters generally increased with downstream location, as the most downstream site, Tom Miller had the significantly highest mean for most parameters showing spatial differences. This is to be expected, as there is increasing, and more long-established, residential development towards the downstream end of the lake. In addition, sediment (and associated contaminants) is transported downstream during high flow events and deposited in deeper, slower water near the dam, so the most downstream site becomes the repository for contaminants.
- The Bull Creek site, located between the upper and the lower sites, was often a ‘transition’ site, either sharing significant means with the upper sites or with Tom Miller, except for PAHs. This fits with the pattern of longitudinal increase noted above.
- The upper sites, Selma Hughes and Emma Long, were not significantly different from each other, and always had means well below the other two more downstream sites. This could be in part due to their location in the upper, less developed portion of the watershed, but also a function of the sediment characteristics. Both these sites were dominated by sand, with very little clay or silt, providing little substrate for contaminant adherence. In addition, the upper end of the watershed typically experiences more scouring flows during flood events, as extremely high velocity water moves in from the upstream dam, and less sediment was available at these sites during many sampling events.
- PAHs show a unique pattern from other parameters, with Bull Creek having a significantly higher mean than all other sites, and a single exceedance of the TEC. The site is located at the confluence with the lake’s only major tributary (Bull Creek), which has a large drainage area with ongoing urban development, possibly a contributing factor in these higher PAH values.
- Sediment toxicity is generally low on Lake Austin, with only four parameters (arsenic, DDD, DDE, and PAH) showing any exceedances of TEC. None of these parameters were shown to be increasing over time.

## Recommendations

- Drop parameters that have no detectable data during the study:
  - All data from silver, aldrin, alpha-chlordane, gamma chlordane and technical chlordane and diazinon were below detection limits during the period of record, and should be considered for deletion from future parameter lists, unless detection limits improve or conditions change that may increase these parameters.
  - Consider dropping other parameters with detected, but very low values (i.e., DDT, PCBs)
- Drop sites that show no significant trends or provide limited information
  - Upper sites (Selma Hughes, Emma Long) show no significant difference from each other and were always lower in value than the lower end sites. Bull Creek only showed a significant difference from all other sites for PAHs, while Tom Miller Dam consistently showed higher levels of detected constituents, and was significantly different from all other sites. It is recommended that only Tom Miller Dam be included in future monitoring efforts. Any changes in Bull Creek sediment quality can be addressed by the Environmental Integrity Index creek

- sampling program, which includes sediment sampling at a creek mouth site that has also shown significantly high levels of PAHs.
- Continue annual sampling at Tom Miller Dam, with a limited parameter set, based on need to maintain continuity with long history of sampling even with non-detects and very low values for some detected parameters.

## **References**

MacDonald, D. D., and C.G. Ingersoll, T. A. Berger. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. *Archives of Environmental Contamination and Toxicology* 39: 20-31.

**Appendix A Tables of detected values for pesticides, herbicides, semi-volatiles, PCBs and TPAHs**

Table A1. Pesticide and herbicide constituents with values above detection limits for all study sites on Lake Austin, 1987-2009. Red text indicates values over the TEC for that parameter.

		Organochlorines (µg/kg)								Organo phosphates (µg/kg)		Chlorinated Herbicides (µg/kg)			
SITE	Date	ALPHA-BHC (BENZENE HEXACHLORIDE)	DDD	DDE	DDT	DIELDRIN	GAMMA-BHC (LINDANE)	HEPTACHLOR	TOTAL CHLORDANE	DEMETON	DEMETON-S	2,4,5-TRICHLOROPHENOXYACETIC ACID	2,4-DICHLOROPHENOXYACETIC ACID	DICAMBA (BANVEL)	DINOSEB
Lake Austin @ Bull Creek	21-Jun-01			1.40											
	24-Jul-02		0.57	2.80					2.3						
	17-Jul-03		0.46	2.45					2.4						
	18-Jul-06			2.27						13.9	13.9				
Lake Austin @ Common Ford Metro Park	27-Sep-91	2305					1821								
Lake Austin @ Emma Long Park (CC)	21-Jun-01			0.10											
	24-Jul-02			1.10											
	17-Jul-03			0.25		2.2								4.4	1.2
	05-Dec-07														
Lake Austin @ Emma Long Park Boat Dock	30-Jan-95							41.7							
Lake Austin @ Fritz Hughes Park	30-Jan-95							39.8							
Lake Austin @ Selma Hughes Park (DC)	21-Jun-01			0.10											
	24-Jul-02			0.31											
	17-Jul-03			0.19					2.8						
	05-Dec-07											1.9	2.5	0.8	1.5
Lake Austin @ Tom Miller Dam	30-Jan-95							154.0							
Lake Austin @ Tom Miller Dam (AC)	21-Jun-01			4.20											
	24-Jul-02		2.50	11.00	2.9				4.8						
	17-Jul-03		2.80	9.10	1.2				2.9						
	17-Aug-05		9.59												
	18-Jul-06		4.28	4.30											
	05-Dec-07													7.9	5.5
TEC, where available		4.88	3.16	4.16					3.24						

Table A2 Semi-Volatiles with values above detection limit for all study sites, Lake Austin, 1987-2009.

		Semi-Volatiles (µg/Kg)						
SITE	DATE	1_2-DIMETHYL NAPHTHALENE	1_6-DIMETHYL NAPHTHALENE	2_3_6-TRIMETHYL NAPHTHALENE	2-ETHYL NAPHTHALENE	4-METHYL PHENOL (P-CRESOL)	PENTACHLOROPHENOL	PHENOL
Lake Austin @ Bull Creek (BC)	21-Jun-01		2.4			40.0		7.2
	24-Jul-02		2.9	1.2	0.7	20.7		5.9
	17-Jul-03		6.3	1.6				
Lake Austin @ Emma Long Park (CC)	21-Jun-01		1.5			19.0		3.7
	24-Jul-02		2.2	1.0	0.6	5.9		2.2
	17-Jul-03		4.2	1.0				
Lake Austin @ Selma Hughes Park (DC)	21-Jun-01	3.1	4.8			183.0		11.6
	24-Jul-02		4.6			22.4		6.1
	17-Jul-03		6.6	1.3				
	05-Dec-07						5.1	
Lake Austin @ Tom Miller Dam (AC)	21-Jun-01	2.2	2.6	0.7		11.2		3.8
	24-Jul-02			1.7		16.2		5.4
	17-Jul-03		11.7	2.2				

Table A3 Polychlorinated biphenyls (PCBs) with values above detection limit on all study sites, Lake Austin, 1987-2009.

SITE	DATE	AROCLOR 1254	AROCLOR 1260	POLYCHLORINATED BIPHENYL (PCB)
Lake Austin @ Bull Creek (BC)	21-Jun-01	7.0	1.8	8.8
	24-Jul-02	16.0	3.8	19.8
	17-Jul-03	5.8		
Lake Austin @ Emma Long Park (CC)	21-Jun-01			10.0

Table A4 TPAH (COA method combining 16 parent PAHs), including data below detection limits, all study sites, Lake Austin, 1991-2009. Yellow shaded results indicate high detection limits of LCRA laboratory, with only one value above detection limit. (in red, Bull Creek, 8/9/2004)

Site #	Site Name	Lab	Qual	Result	Units	Date Sampled
512	Lake Austin @ Fritz Hughes Park	LCRA	<	41600	UG/KG	1/30/1995
559	Lake Austin @ Selma Hughes Park (DC)	USGS		190	UG/KG	6/21/2001
559	Lake Austin @ Selma Hughes Park (DC)	USGS		198	UG/KG	7/24/2002
559	Lake Austin @ Selma Hughes Park (DC)	USGS		148	UG/KG	7/24/2002
559	Lake Austin @ Selma Hughes Park (DC)	USGS		100	UG/KG	7/17/2003
559	Lake Austin @ Selma Hughes Park (DC)	DHL	<	162	UG/KG	8/11/2005
559	Lake Austin @ Selma Hughes Park (DC)	DHL	<	133	UG/KG	7/18/2006
559	Lake Austin @ Selma Hughes Park (DC)	DHL	<	162	UG/KG	12/5/2007
559	Lake Austin @ Selma Hughes Park (DC)	DHL	<	319	UG/KG	5/11/2009
218	Lake Austin @ Common Ford Metro Park	LCRA	<	73600	UG/KG	9/27/1991
573	Lake Austin @ Emma Long Park (CC)	LCRA	<	16240	UG/KG	1/30/1995
573	Lake Austin @ Emma Long Park (CC)	USGS		50	UG/KG	6/21/2001
573	Lake Austin @ Emma Long Park (CC)	USGS		156	UG/KG	7/24/2002
573	Lake Austin @ Emma Long Park (CC)	USGS		125	UG/KG	7/17/2003
573	Lake Austin @ Emma Long Park (CC)	LCRA	<	3488	UG/KG	8/9/2004
573	Lake Austin @ Emma Long Park (CC)	DHL	<	165	UG/KG	8/11/2005
573	Lake Austin @ Emma Long Park (CC)	DHL	<	131	UG/KG	7/18/2006
573	Lake Austin @ Emma Long Park (CC)	DHL		70	UG/KG	12/5/2007
573	Lake Austin @ Emma Long Park (CC)	DHL	<	313	UG/KG	5/11/2009
562	Lake Austin @ Bull Creek (BC)	USGS		755	UG/KG	6/21/2001
562	Lake Austin @ Bull Creek (BC)	USGS		563	UG/KG	7/24/2002
562	Lake Austin @ Bull Creek (BC)	USGS		667	UG/KG	7/17/2003
562	Lake Austin @ Bull Creek (BC)	USGS		747	UG/KG	7/17/2003
562	Lake Austin @ Bull Creek (BC)	LCRA		1650	UG/KG	8/9/2004
562	Lake Austin @ Bull Creek (BC)	DHL		411	UG/KG	8/11/2005
562	Lake Austin @ Bull Creek (BC)	DHL		529	UG/KG	7/18/2006
562	Lake Austin @ Bull Creek (BC)	DHL		775	UG/KG	5/11/2009
561	Lake Austin @ Tom Miller Dam	LCRA	<	18640	UG/KG	1/30/1995
561	Lake Austin @ Tom Miller Dam (AC)	USGS		352	UG/KG	6/21/2001
561	Lake Austin @ Tom Miller Dam (AC)	USGS		846	UG/KG	7/24/2002
561	Lake Austin @ Tom Miller Dam (AC)	USGS		896	UG/KG	7/17/2003
561	Lake Austin @ Tom Miller Dam (AC)	LCRA	<	8528	UG/KG	8/9/2004
561	Lake Austin @ Tom Miller Dam (AC)	DHL		43	UG/KG	7/18/2006
561	Lake Austin @ Tom Miller Dam (AC)	DHL		237	UG/KG	12/5/2007
561	Lake Austin @ Tom Miller Dam (AC)	DHL		368	UG/KG	5/11/2009

Appendix B

Spatial graphs for all parameters including both detected and non-detected data from 2000-2009.

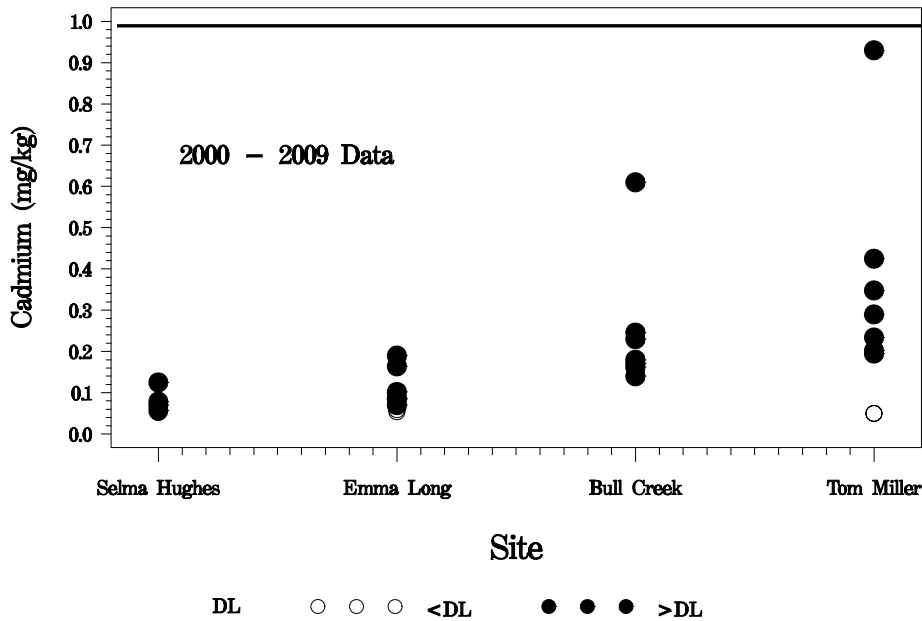


Figure B1. Cadmium sediment concentrations at Lake Austin Sites: 2000-2009. horizontal line indicates TEC for Cadmium, 0.99 mg/kg

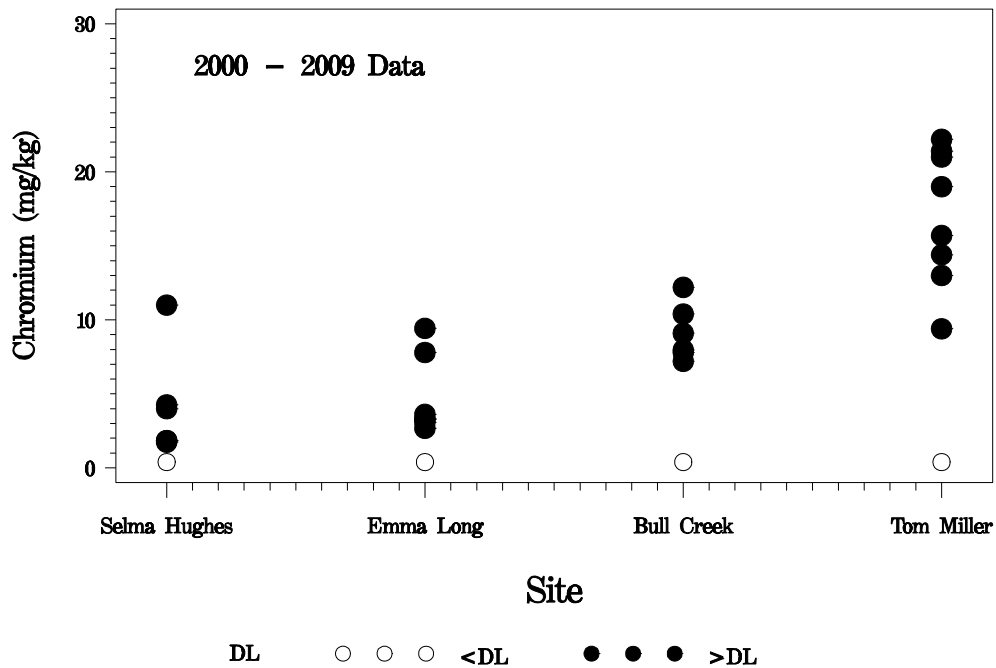


Figure B2. Chromium sediment concentrations at Lake Austin Sites: 2000-2009. TEC for Chromium is 43.4 mg/kg, beyond the graph's scale.

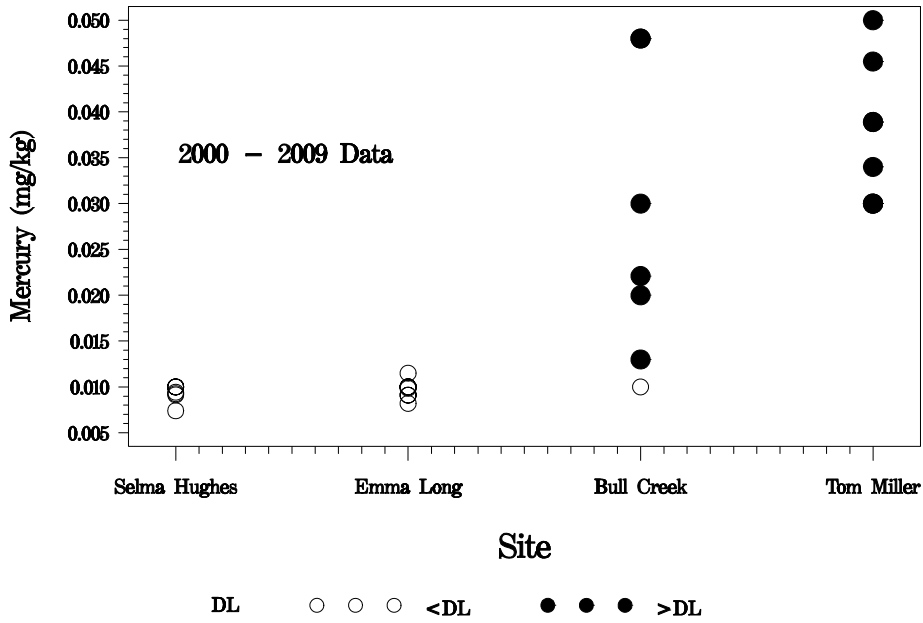


Figure B3. Mercury sediment concentrations at Lake Austin Sites: 2000-2009. TEC for mercury is 0.18 mg/kg, beyond the graph's scale.

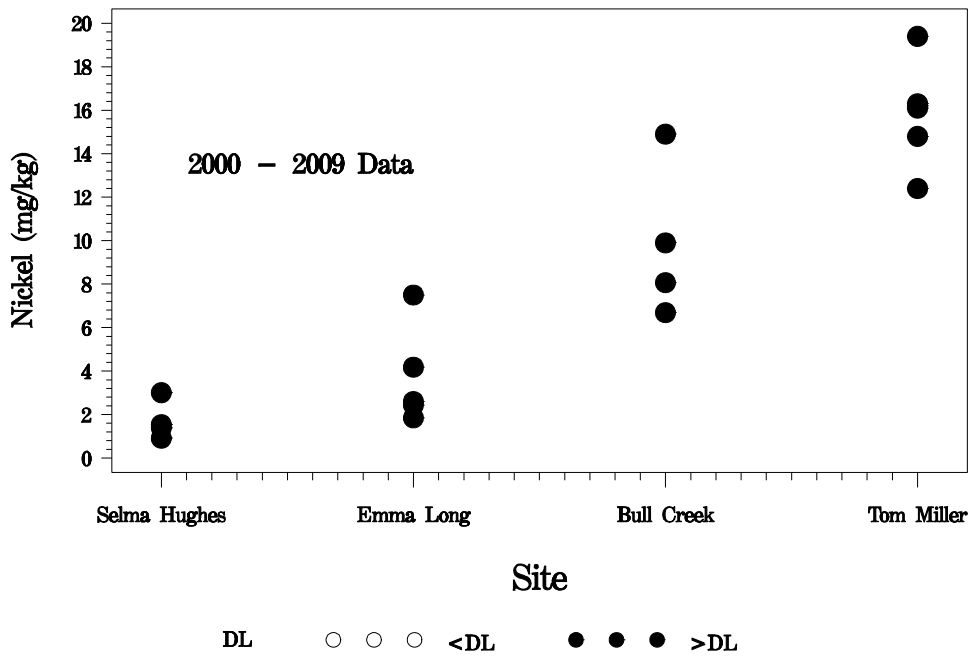


Figure B4. Nickel sediment concentrations at Lake Austin Sites: 2000-2009. TEC for nickel is 22.7 mg/kg, beyond the graph's scale.

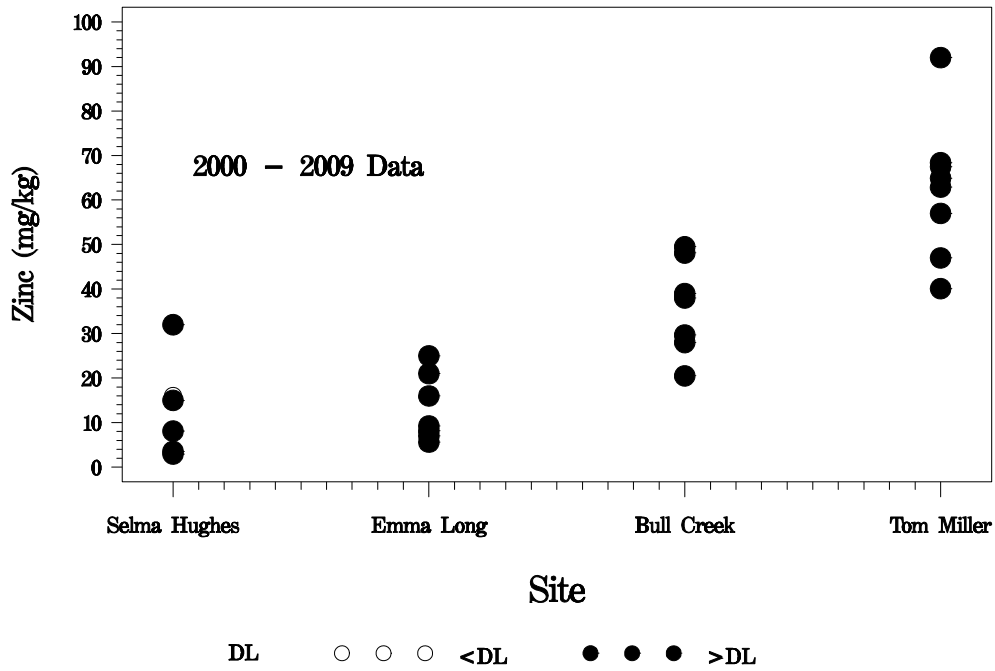


Figure B5. Zinc sediment concentrations at Lake Austin Sites: 2000-2009. TEC for zinc is 121 mg/kg, beyond the graph's scale.

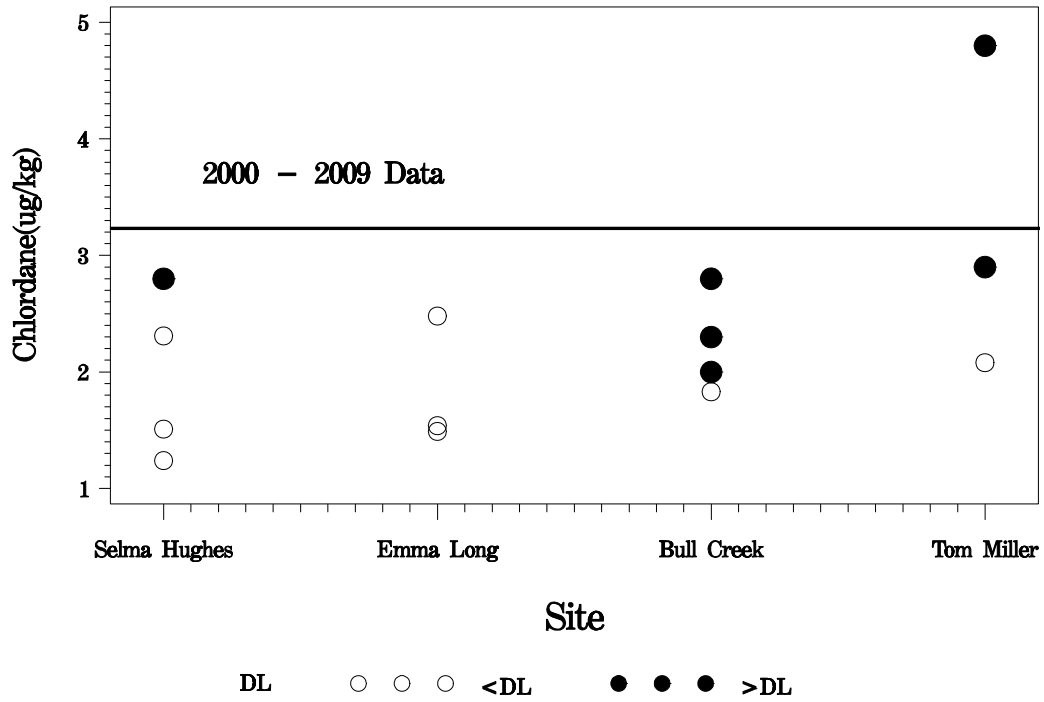


Figure B6. Chlordane sediment concentrations at Lake Austin Sites: 2000-2009. Horizontal line indicates TEC for Chlordane, 3.24 ug/kg.

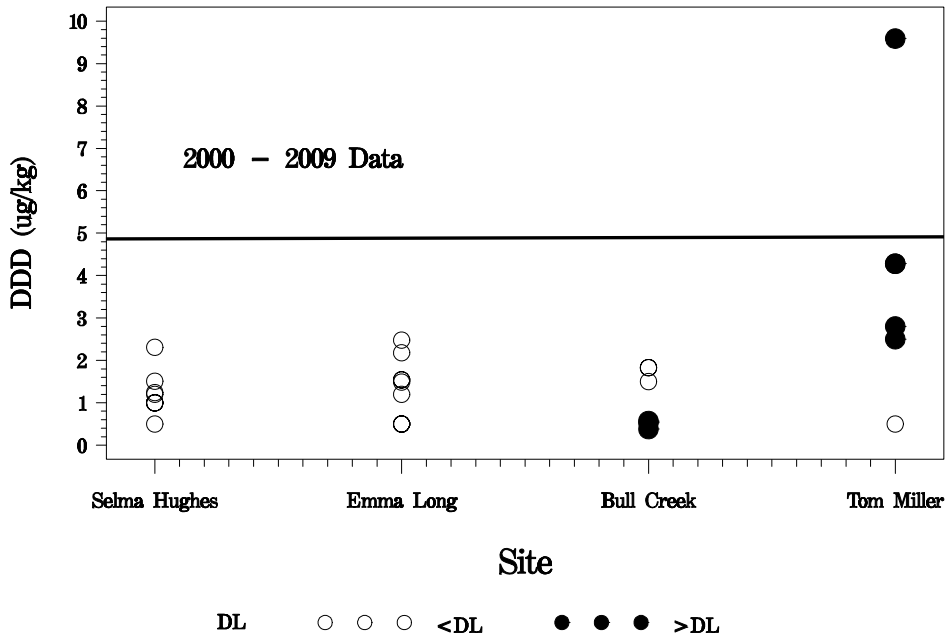


Figure B6. DDD sediment concentrations at Lake Austin Sites: 2000-2009. The horizontal line indicates the TEC for DDD, 4.88 ug/kg.

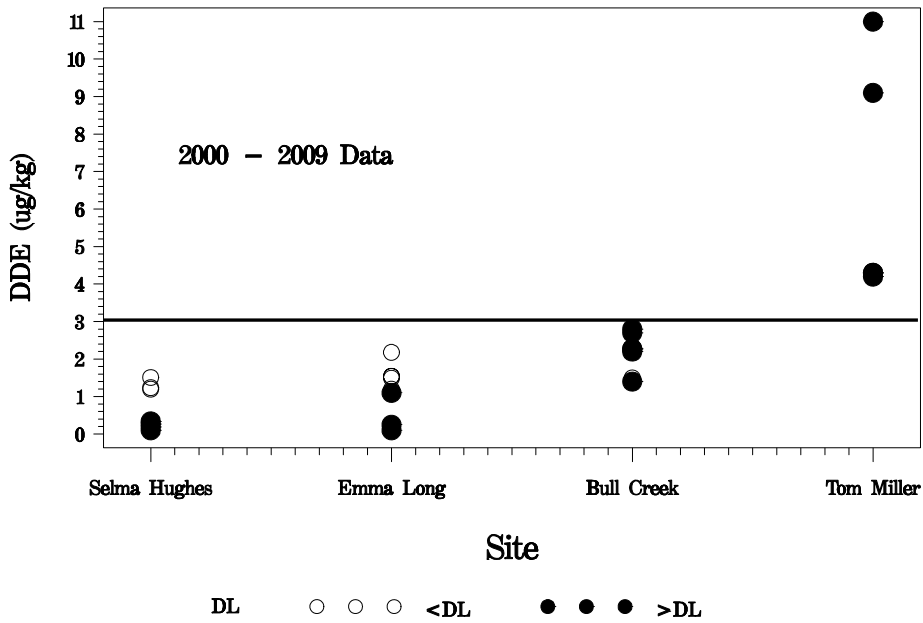


Figure B6. DDE sediment concentrations at Lake Austin Sites: 2000-2009. The horizontal line indicates the TEC for DDE, 3.16 ug/kg.

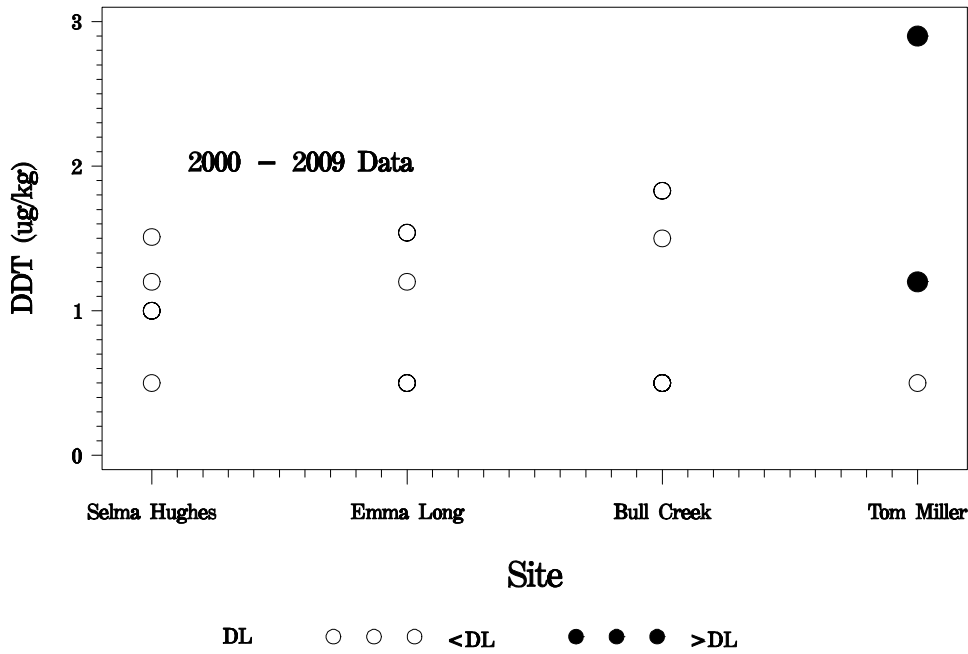


Figure B7. DDT sediment concentrations at Lake Austin Sites: 2000-2009. TEC for DDT is 4.16 ug/kg, beyond the graph's scale.

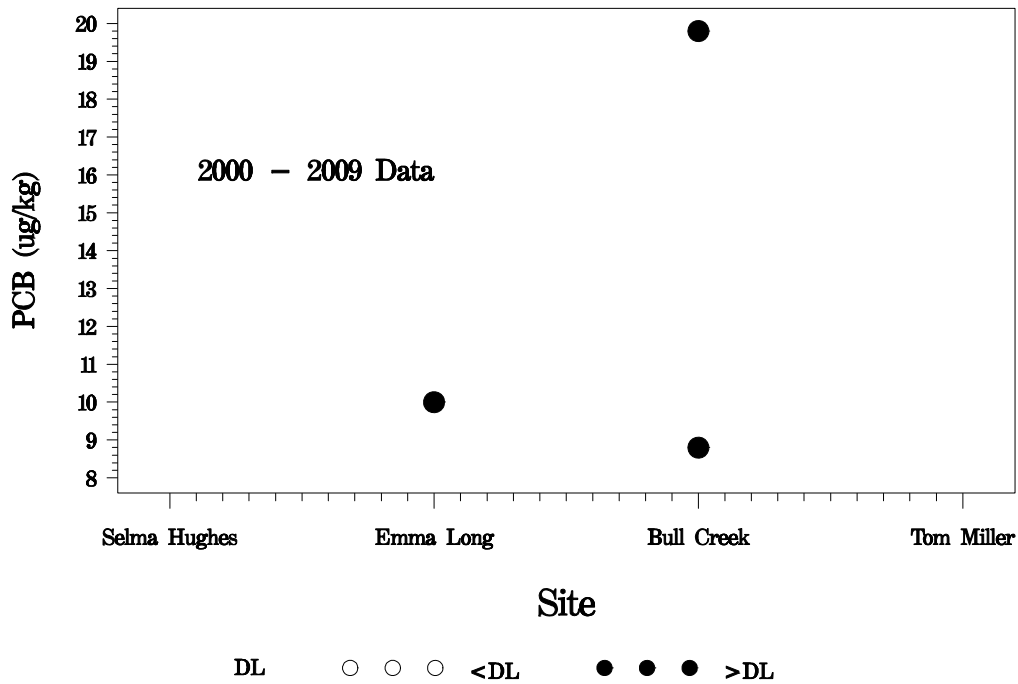


Figure B8. PCB sediment concentrations at Lake Austin Sites: 2000-2009. TEC for PCBs is 59.8 ug/kg, beyond the graph's scale.



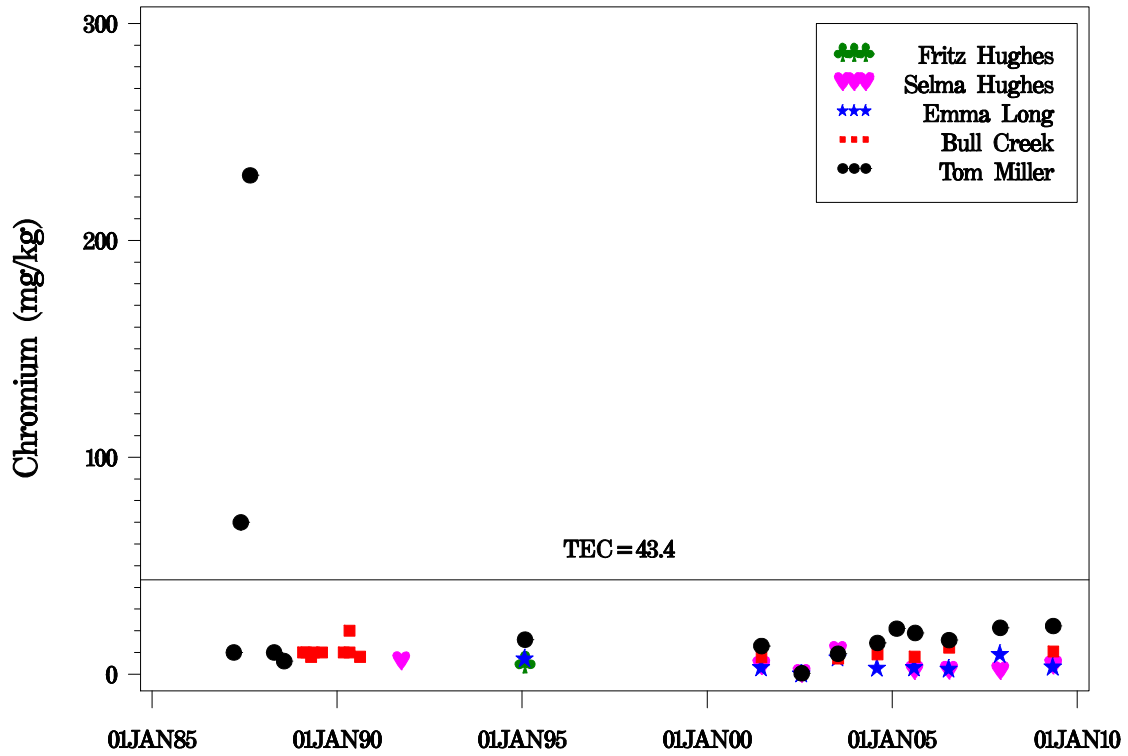


Figure C3. Chromium sediment concentrations in Lake Austin. Horizontal line indicates TEC value.

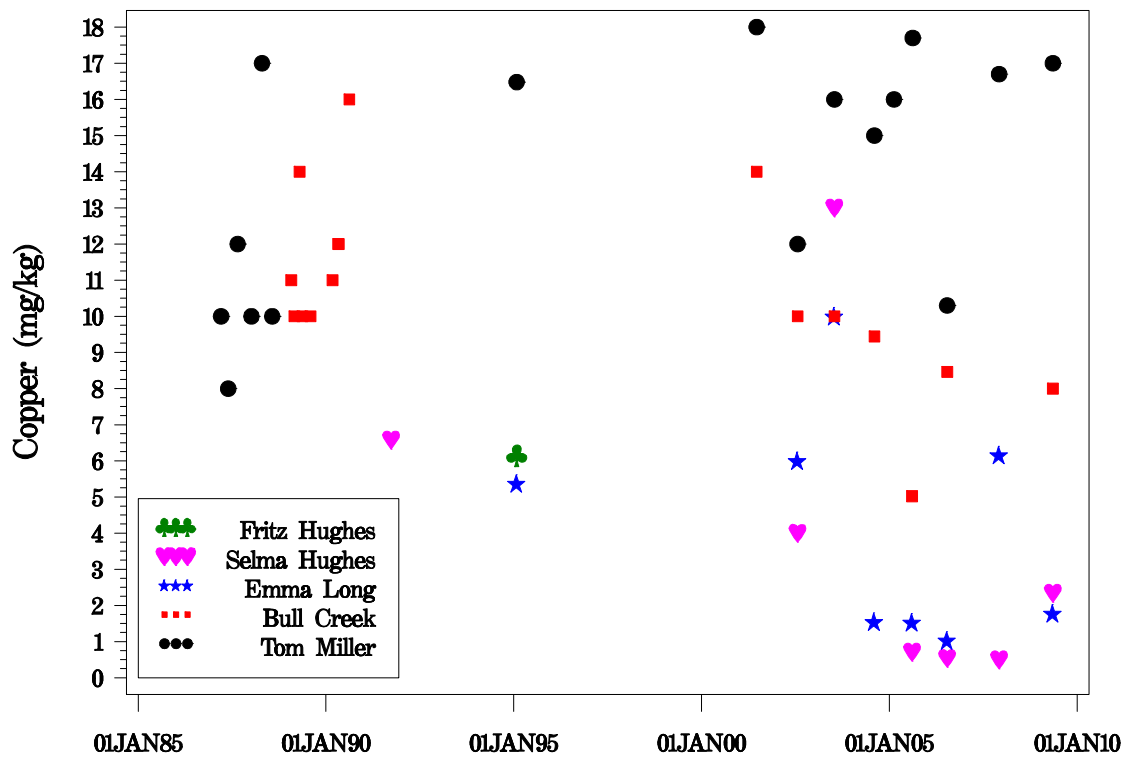


Figure C4. Copper sediment concentrations in Lake Austin. TEC for copper is 31.6 mg/kg, beyond scale of graph.

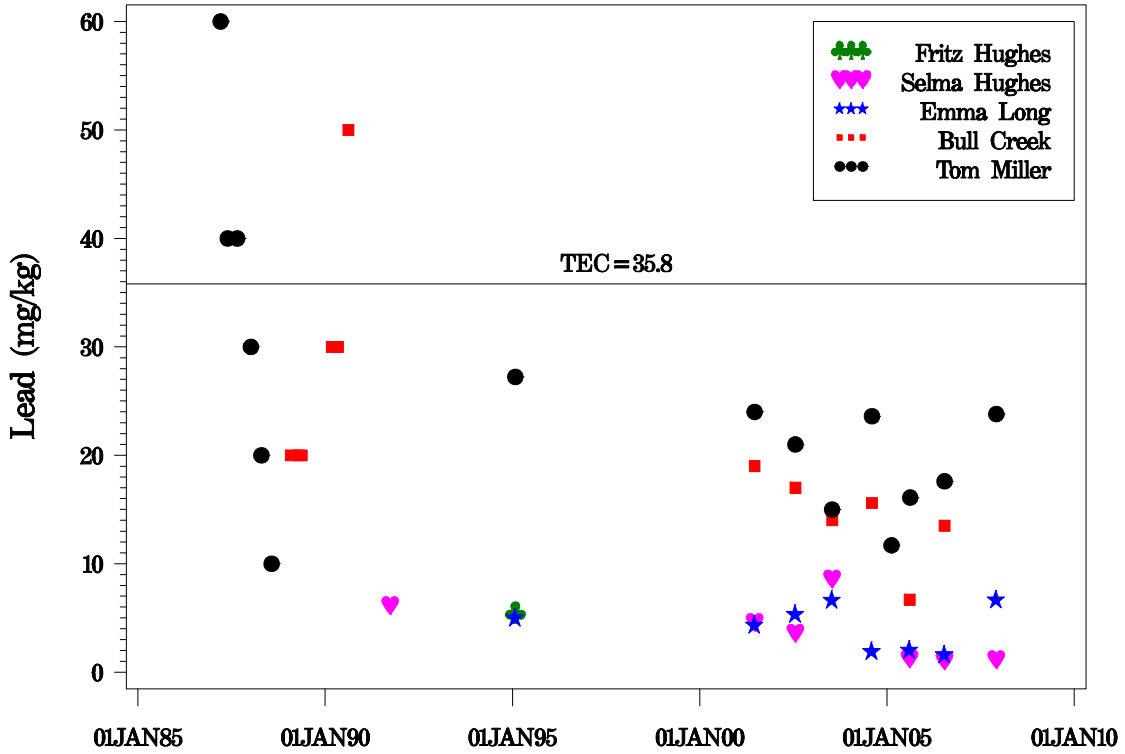


Figure C5. Lead sediment concentrations in Lake Austin. Horizontal line indicates TEC value.

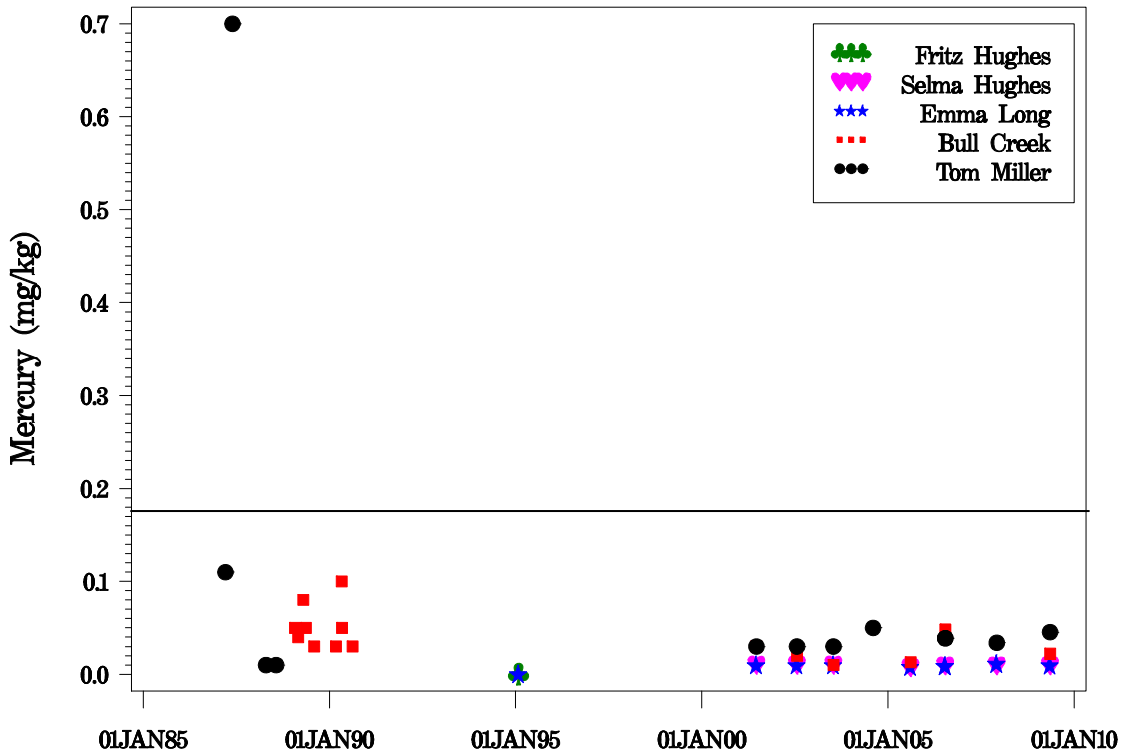


Figure C6. Mercury sediment concentrations in Lake Austin. Horizontal line indicates TEC for mercury, 0.18 mg/kg.

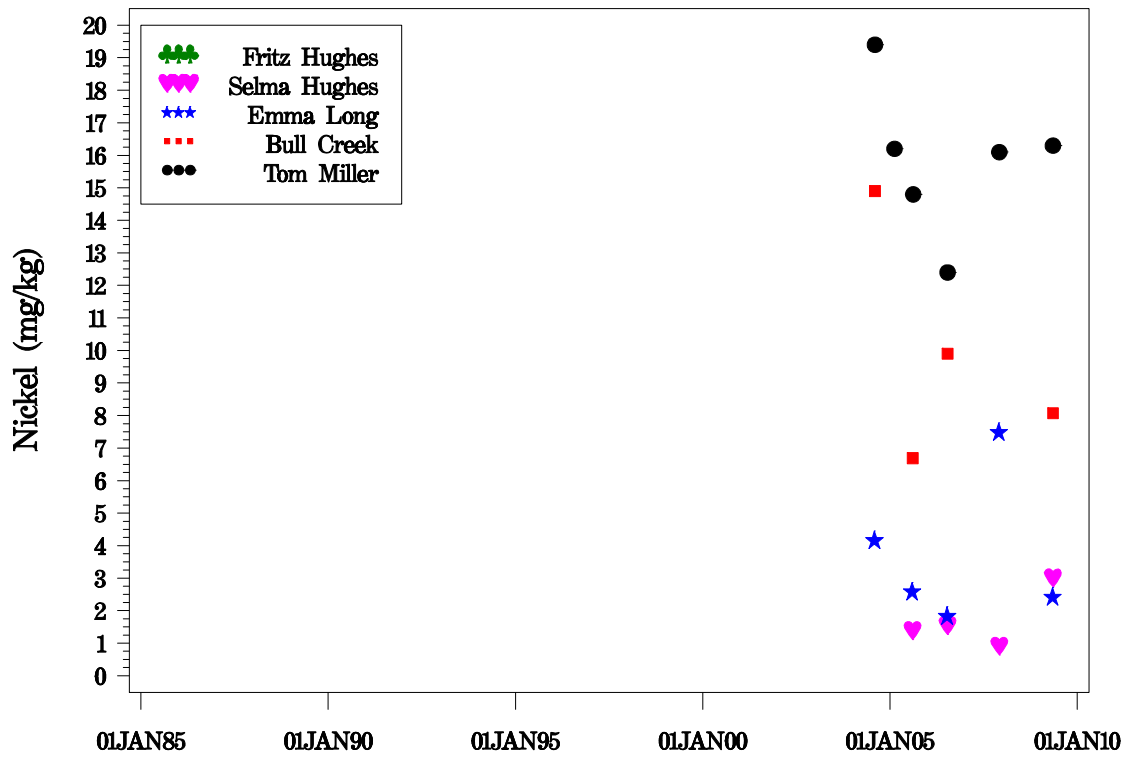


Figure C7. Nickel sediment concentrations in Lake Austin. TEC for nickel is 22.7 mg/kg, beyond the scale of the graph.

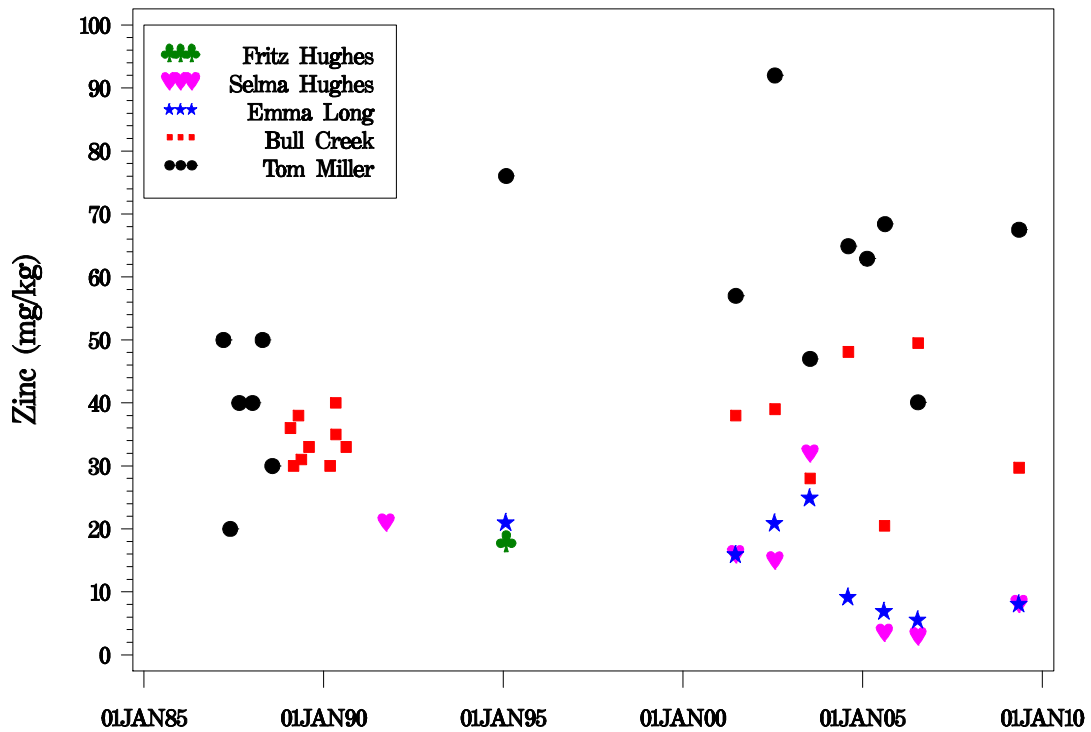


Figure C8. Zinc sediment concentrations in Lake Austin. TEC for zinc is 121 mg/kg, beyond the scale of the graph.

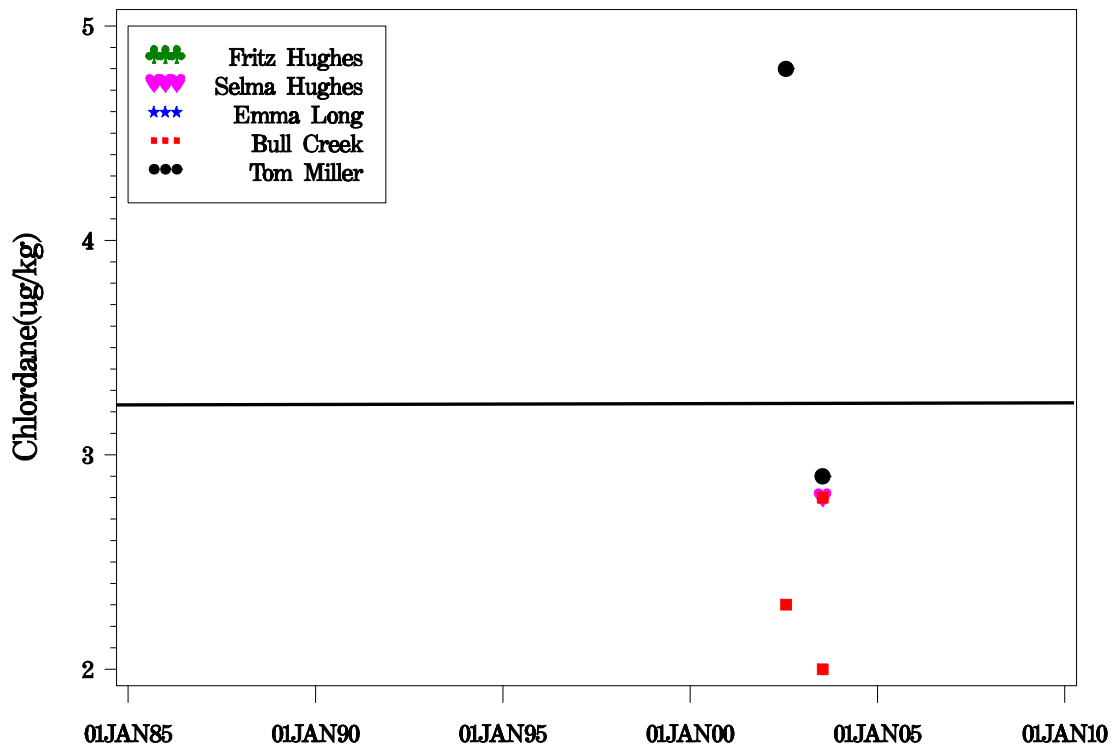


Figure C9. Chlordane sediment concentrations in Lake Austin. Horizontal line indicates TEC for chlordane, 3.24 ug/kg.

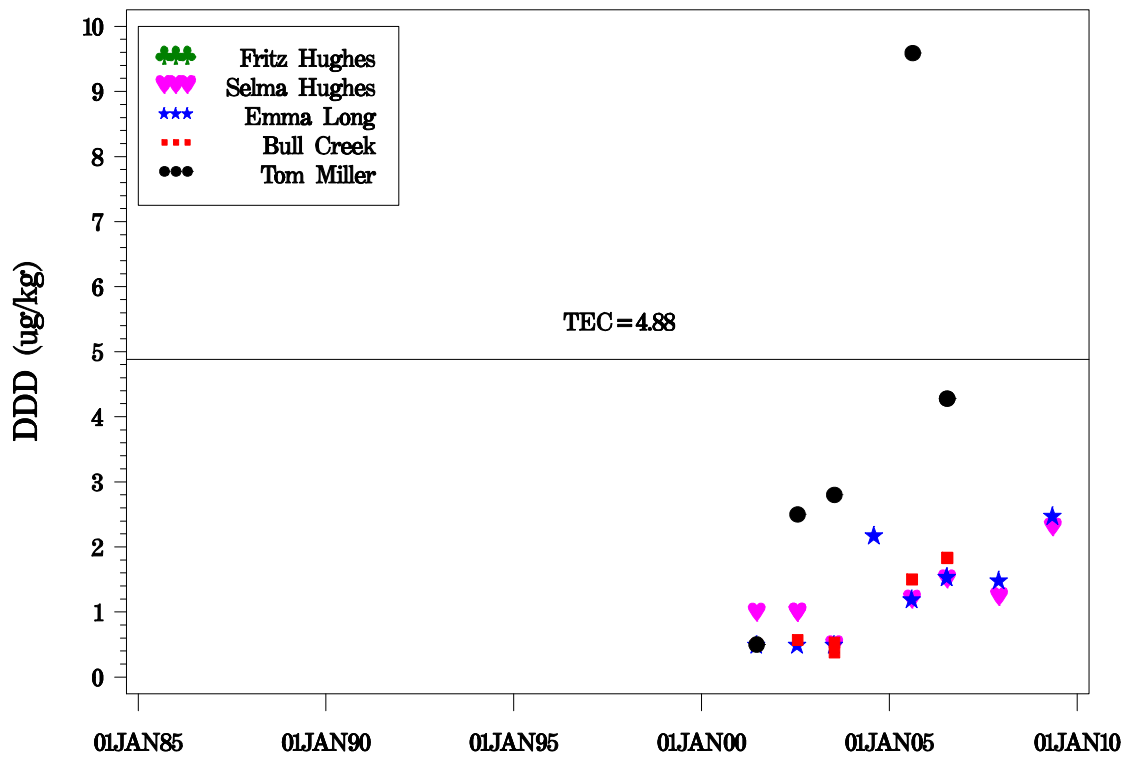


Figure C10. DDD sediment concentrations in Lake Austin. Horizontal line indicates TEC value.



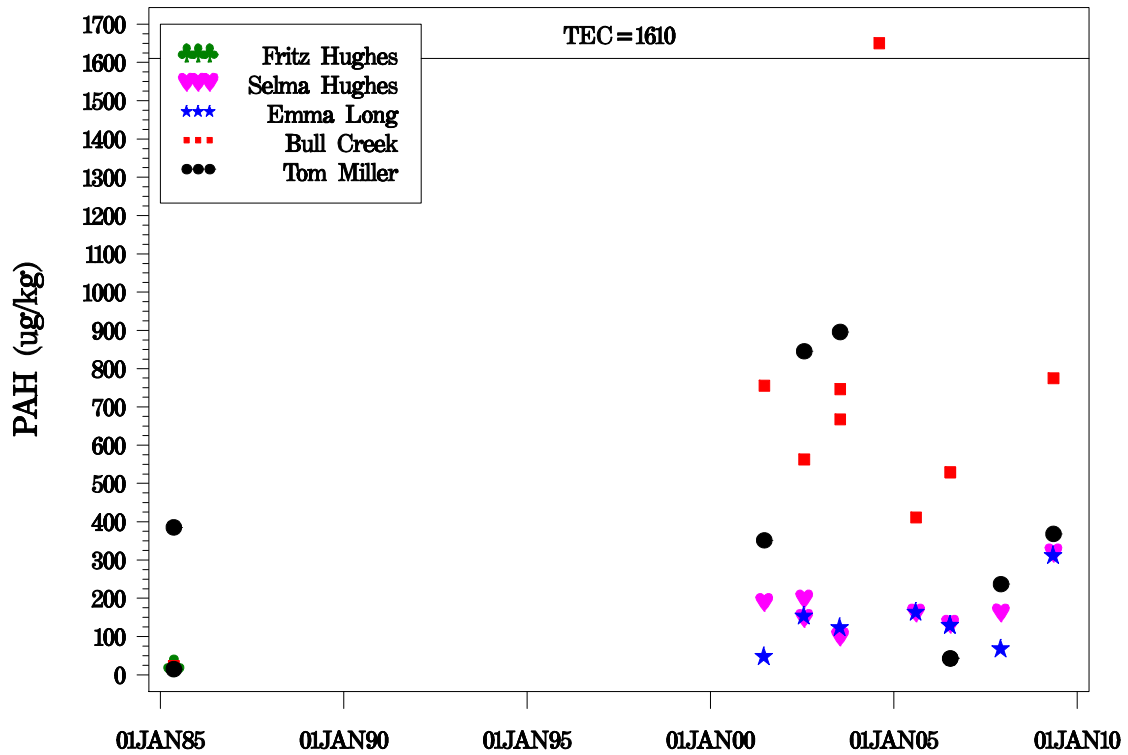


Figure C13. Total PAH sediment concentrations in Lake Austin. The horizontal line indicates TEC value.

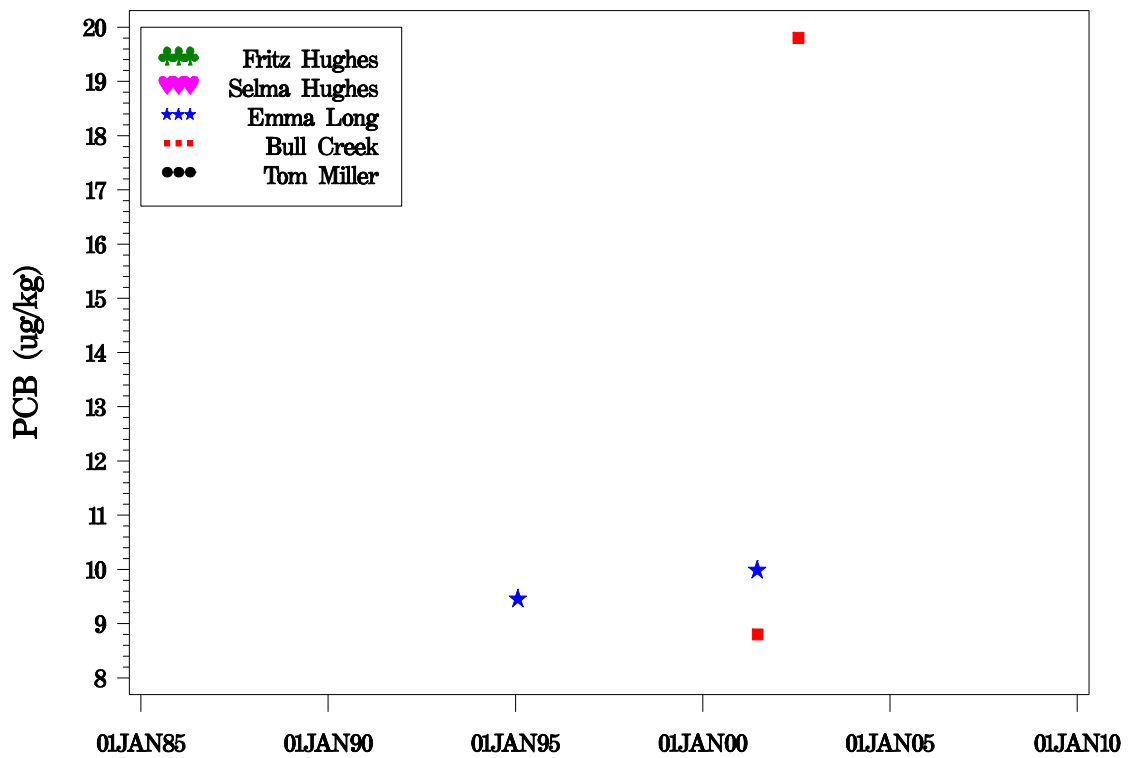


Figure C14. PCB sediment concentrations in Lake Austin. The TEC value for PCBs is 59.8 ug/kg, beyond the scale of the graph.