

Natural Background Levels of Boron in the Clear Lake - Cache Creek Watershed: A Data Analysis and Literature Review

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FLOOD CONTROL &
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Introduction

The Yolo County Flood Control and Water Conservation District (the District) maintains a 1,800 volume report archive regarding issues in the watershed, both published and unpublished. A review of these archives was conducted for data on background boron concentration in both ground and surface water. Ten reports, published from 1955 to 2006, were found with boron data from the Clear Lake – Cache Creek watershed. More than 2,400 water samples were analyzed for boron in these reports. (Additional reports on boron are probably available in other archives and libraries, but only the District archive was researched for this report.)

Boron in Lake and Yolo Counties

Boron is a naturally occurring element in the Clear Lake - Cache Creek watershed. Large Borax deposits were mined here in the 1800s and natural hot and cold springs expel water with extremely high concentrations of boron (215 ppm in Table 1), more than 300 times greater than interpreted narrative water quality objectives for boron (0.7 ppm).

The high boron water in the Cache Creek system has long been a management problem for local farmers. Some crops are sensitive to boron and special considerations must be made when irrigating these crops in Yolo County. In general, the boron does not adversely affect drinking water quality.

Boron is an essential plant micronutrient and some areas of California are deficient in boron. In these cases boron is applied to crops as a fertilizer. However, in Yolo County boron fertilizer is generally not needed. In fact, the boron levels can be high enough to cause crop damage, especially to boron sensitive crops.

In recognition of the high boron levels Cache Creek, monthly monitoring of boron concentration began in 1930 (YCFCWCD, 2006). The District continues this monitoring today. Currently, the District samples eight sites in the Cache Creek watershed once each month for boron. Additionally, 30 wells are sampled for boron concentration on an annual basis. Requests for boron information are, by far, the most popular requested water quality data from the District.

A short history of borax mining is presented. Afterwards, an analysis of Bear Creek boron contributions to the Cache Creek system are analyzed. Then a table with boron meta-data, summarizing the maximum and average concentration of boron in surface and groundwater, is discussed (Table 1).

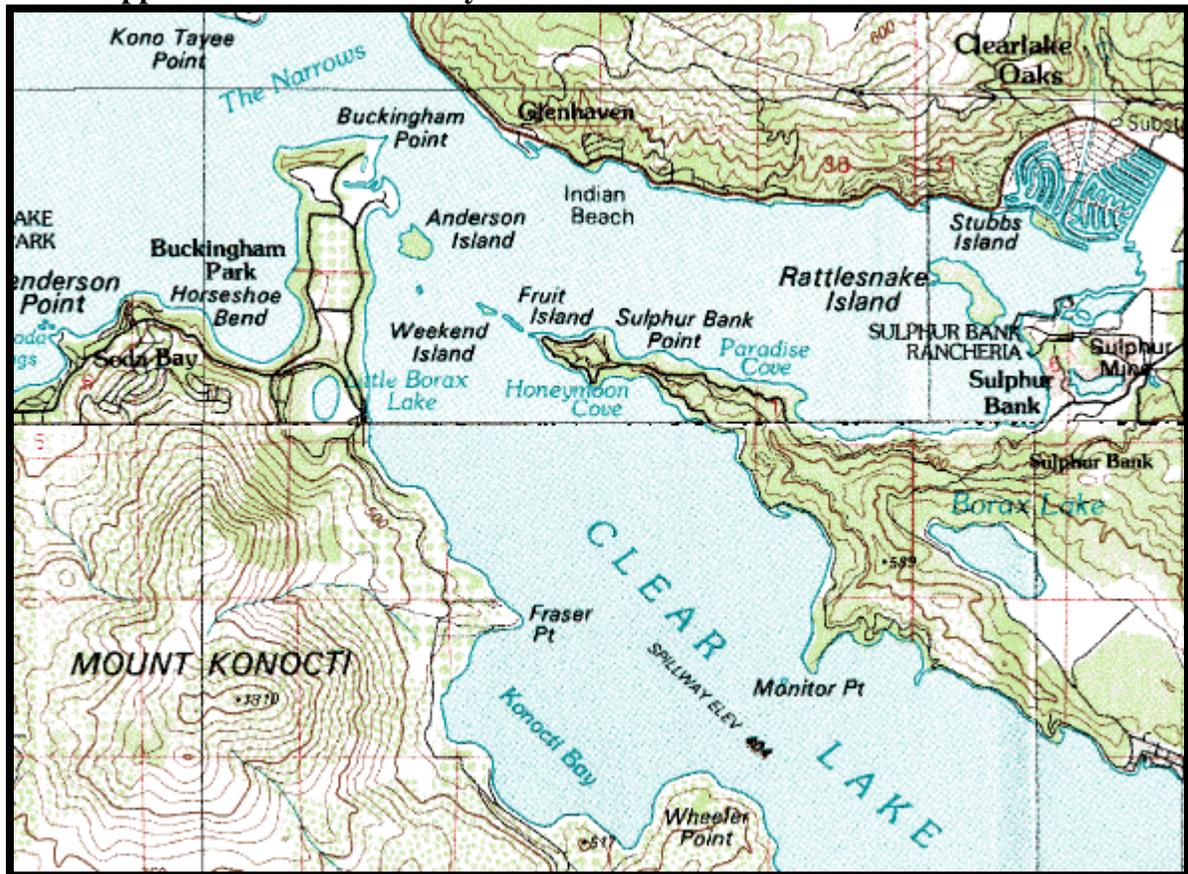
History of Borax Mining

Borax is a commercially valuable, naturally occurring compound that contains boron. (The chemical formula for anhydrous borax is $\text{Na}_2\text{B}_4\text{O}_7$.) Boron compounds are so common in the watershed that they can be mined from certain surface lake deposits. The first discovery of borax in the USA occurred in the Clear Lake – Cache Creek watershed.

“Borax was first discovered in Borax Lake in Lake County in 1856, by Dr. John Veatch. Four years later, he found borax in Little Borax Lake, four miles to the west. The California Borax Company operated at the big lake between 1864 and 1868, extracting 590 tons of borax...

In 1868, the company moved all of its operations to Little Borax Lake. This small lake supplied the entire borax needs of the country from 1868 to 1873, the last year of operation, producing 140 tons valued at \$89,600. The discovery of enormous beds of the mineral in the deserts of California and Nevada ended all production in Lake County. (Mauldin, 1968)

Figure 1 shows the location of Borax Lake, near the Sulphur Bank mine, and Little Borax Lake, at the base of Mt. Konocti. Clear Lake supplies ~2/3 of the irrigation water supplies for the Yolo County Flood Control and Water Conservation District.



After 1873, the borax operations were abandoned in the Clear Lake area, due to more economical deposits elsewhere. Yet large amounts of boron containing borax remain in these lakes, in Clear Lake, and in the watershed as a whole.

Boron concentration data and a review from the literature – the Bear Creek story

More than fifty years ago, the State Water Resources Control Board stated, “The quality of water in the Clear Lake-Cache Creek Basin, particularly with reference to boron, has long been the subject of much interest and speculation.” (SWRCB, 1955). The authors noted that boron levels were higher during low flow times in Cache Creek, but did not specifically call out the Bear Creek tributary as the main source of boron.

In YCFCWCD (1963) Boron is given a section in the “Special Problems” chapter, summarizing the sources, problems with high boron, historical mitigation, and new strategies for amelioration. A multi-color fold out map is also included showing level of boron in groundwater throughout the County. In this document, Bear Creek is identified as a major source of boron in the watershed. Ideas for an impoundment of the boron rich Bear Creek water are discussed. This impounded water would be released during high flows in Cache Creek, so that the boron would become diluted. This strategy was never implemented.

Although Clear Lake, and Cache Creek itself, have high levels of boron, since the 1980’s District staff have informally concluded that most of the boron in Cache Creek comes from the Bear Creek tributary. In a review of the District data archives, 32 dates were found with boron concentration and flow data from Bear Creek and Cache Creek at Capay Dam. The effect of Bear Creek boron entering Cache Creek, and increasing boron concentration downstream at Capay, was analyzed (figure 2).

Figure two shows the boron concentration in Cache Creek at Capay Dam, verses boron from Bear Creek. Since the boron from Bear Creek becomes diluted in the main flow of Cache Creek, a “dilution factor” was calculated for this analysis. The relationship shows that as dilution of Bear Creek boron increases, the concentration of boron at Capay Dam decreases. The flattening of the line at high dilutions shows the baseline boron concentration in Cache Creek of 0.6-0.8 ppm. Inputs from Bear Creek elevate the boron concentration above baseline. Dilution factor is calculated as in equation (1).

$$\text{Dilution factor} = a / (b * c) \quad (1)$$

Where:

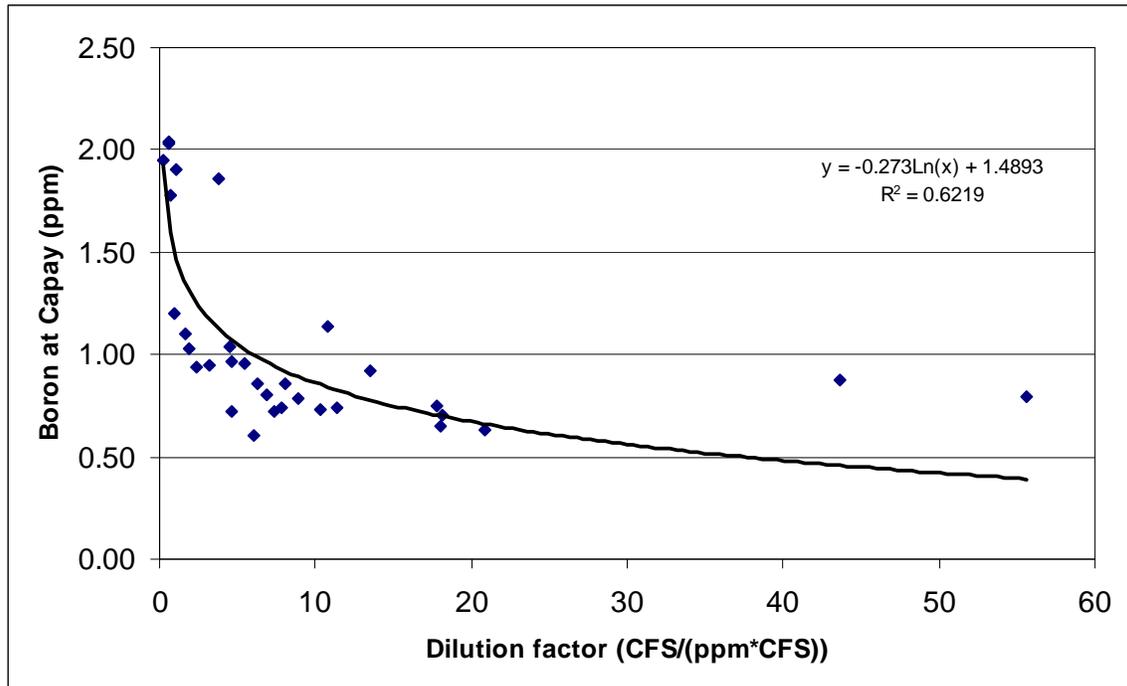
a=water flow in Cache Creek at Rumsey (CFS)

b=water flow in Bear Creek (CFS)

c=boron concentration in Bear Creek (ppm)

No probability analysis for statistical significance was completed for figure 2, as it is outside the scope of this report. However, an R-squared of 0.62 means that the correlation is strong, but 38% of the variation in boron concentration at Cache Creek dam is still unexplained. Other sources of high boron, besides Bear Creek, probably exist in the watershed. These other sources (the “springs”) are alluded to in EIP Associates, et al. (1995).

Figure 2. Graph of boron concentration in Cache Creek at Capay Dam, verses diluted boron from Bear Creek. When increased flows in Cache Creek dilute the flows from Bear Creek, the concentration of boron in Cache Creek decreases. Flow and concentration data are from 32 dates during 1998-2000.



Past reports

Table 1 below is a summary of boron data from ten reports stored in the District archives. These reports, describing data since 1930, show that both surface and groundwater, in the Cache Creek watershed, on average, are almost always above the interpreted narrative water quality objectives for boron (0.7 ppm). Over more than 75 years, 2400 water samples have been taken and analyzed for boron and it is quite clear that farmers, local watershed managers, and State-level water planners all consider the Cache Creek watershed to be highly enriched in boron.

Of note in Table 1 are two “hot spot” locations that can be identified. Bear Creek, as discussed earlier, has consistently high levels of boron. The other location, “springs in the

Cache Creek area” appear to have extremely high levels of boron. These springs probably deserve further investigation in the upcoming Bear Creek Watershed Assessment, described in the next section.

Table 1. Data summary of boron concentration in ground and surface water.

Reference	Location	Period of Record	Ground or Surface Water?	Max [B] (ppm)	Avg. [B] (ppm)*	Approx. Number of Samples
YCFCWCD (2006)	Capay Dam, Cache Creek	1930-1940, 1969-2006	surface	6.4	1.7	539
YCFCWCD (unpub)	Bear Creek	1988-2006	surface	34	13.9	250
YCFCWCD (2004)	All regions of Yolo County	2000-2004	ground	9.5	0.6-6.6 (avg. by region)	267
YCFCWCD (1963)	Map showing groundwater [B] in the entire Yolo County area	~1950-1960	ground	6.4	1.8	Not reported, reference to USACE (1950)
EIP Associates, et al. (1995) p. 4.3-10	Springs in the Cache Creek area	1930-1956	springs flowing to surface	215	130	-
EIP Associates, et al. (1995) p. 4.3-11	Near Madison, Woodland, and Knights Landing	1950-1970s	ground	-	4	-
Scott and Scalmanini (1975)	Yolo County	1950-1972	ground	>3	>1	1200
Yolo County (2006)	Cache Creek	2000-2005	surface	2.4	~1.3	21
SWRCB (1955)	Cache Creek at Capay Dam	1930-1939	surface	3.9	2.3	90
Ca DWR (1961)	Bear Creek	1938-1939	surface	34	21	17
Ca DWR (1961)	North Fork Cache Creek	1938-1941	surface	7.2	3.3	41
Ca DWR (1961)	Clear Lake near Lower Lake	not reported	surface	1.4	1.0	-
Ca DWR (1961)	Cache Creek at Capay Dam	1930-1956	surface	6.4	1.8	-

*"Avg." is either the true average, median of the range, or other approximation of average, depending on the data source.

Current watershed planning effort for Bear Creek

The US Bureau of Land Management is currently preparing a stakeholder based watershed assessment for the Bear Creek drainage. Mercury and Boron are of a particular concern. As of 6/6/07 the effort has just begun. Please contact the project manager for more information on the assessment.

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Data Appendix

Date	Boron (ppm) in Bear Creek	Boron (ppm) in Cache Creek at Capay Dam	Flow in Cache Creek (cfs) at Rumsey	Flow in Bear Creek (cfs) near Cache Creek
1/26/1988	4.46	2.46	139	
3/1/1988	6.30	1.80	91	
4/7/1988	10.00	0.94	430	
5/9/1988	14.00	1.40	108	
5/26/1988	12.00	1.20	626	
6/2/1988	14.00	1.00	507	
6/6/1988	14.00	1.00	470	
6/9/1988	15.00	1.20	297	
6/13/1988	15.00		372	
6/16/1988	15.00	1.10	518	
6/20/1988	16.00	1.10	551	
6/23/1988	16.00	0.89	598	
6/27/1988	15.00	0.96	524	
6/30/1988	17.00	0.96	602	
7/5/1988	18.00	0.98	590	
7/7/1988	17.00	0.95	620	
7/11/1988	19.00	1.00	523	
7/14/1988	19.00	0.97	620	
7/18/1988	20.00	1.00	478	
7/21/1988	20.00	0.93	641	
7/25/1988	19.00	0.97	436	
7/28/1988	20.00	0.97	448	
8/1/1988	21.00	0.97	426	
8/4/1988	21.00	1.10	373	
8/11/1988	22.00	1.20	331	
8/15/1988	24.00	1.10	282	
8/18/1988	22.00	1.10	272	
8/22/1988	22.00	1.10	261	
8/25/1988	24.00	1.10	308	
8/29/1988	24.00	1.10	313	
9/1/1988	25.00	1.10	334	
9/6/1988	26.00	1.20	202	
9/8/1988	24.00	1.10	205	
9/13/1988	25.00	1.20	211	
9/15/1988	23.00	1.10	119	
9/19/1988	25.00	1.20	77	
9/22/1988	28.00	1.20	56	
9/26/1988	28.00	1.20	37	

Date	Boron (ppm) in Bear Creek	Boron (ppm) in Cache Creek at Capay Dam	Flow in Cache Creek (cfs) at Rumsey	Flow in Bear Creek (cfs) near Cache Creek
9/29/1988	30.00	1.30	16	
10/3/1988	30.00	1.40	25	
10/31/1988	30.00	1.50	27	
12/5/1988	24.00	2.40	24	
1/3/1989	25.00	3.30	8	
2/6/1989	25.00	2.80	27	
2/27/1989	24.00	3.00	18	
3/6/1989	20.00	3.30	125	
3/13/1989	4.90	1.20	235	
3/20/1989	3.70	0.95	396	
3/27/1989	4.10	1.10	235	
4/3/1989	5.60	1.60	52	
4/10/1989	7.70	1.60	192	
4/17/1989	8.50	1.40	476	
4/24/1989	10.00	1.50	588	
5/8/1989	11.00	1.40	326	
5/15/1989	12.00	1.60	243	
5/22/1989	12.00	1.40	321	
5/30/1989	13.00	1.40	298	
6/5/1989	13.00	1.30	298	
6/12/1989	16.00	1.40	286	
6/19/1989	16.00	1.40	304	
6/26/1989	18.00	1.30	398	
7/3/1989	18.00	1.40	312	
7/10/1989	21.00	1.40	329	
7/17/1989	21.00	1.20	302	
7/24/1989	21.00	1.20	252	
7/31/1989	22.00	1.10	286	
8/7/1989	24.00	1.10	315	
8/14/1989	26.00	1.20	286	
8/21/1989	28.00	1.40	204	
8/28/1989	32.00	1.50	169	
9/5/1989	33.00	1.50	224	
9/11/1989	31.00	1.50	206	
9/18/1989	24.00	1.60	19	
10/2/1989	24.00	2.20	23	
11/6/1989	22.00	2.40	23	
12/1/1989	25.00	3.00	24	
1/2/1990	26.00	3.00	23	
2/5/1990	8.40	3.90	38	
3/5/1990	12.00	2.90	27	
4/2/1990	17.00	3.20	21	

Date	Boron (ppm) in Bear Creek	Boron (ppm) in Cache Creek at Capay Dam	Flow in Cache Creek (cfs) at Rumsey	Flow in Bear Creek (cfs) near Cache Creek
5/7/1990	18.00	3.10	24	
6/4/1990	19.00	3.50	22	
7/2/1990	22.00	2.40	22	
8/6/1990	34.00	2.80	21	
9/4/1990	34.00	2.70	23	
10/1/1990	33.00	2.70	23	
11/5/1990	31.00	2.40	26	
12/3/1990	26.00	2.20	22	
1/7/1991	27.00	2.20	21	
2/4/1991	32.00	4.60	23	
3/7/1991	6.10	2.40	25	
4/1/1991	4.50	1.80	24	
5/21/1991	11.00	1.80	471	
6/3/1991	11.00	1.70	465	
7/1/1991	17.00	2.00	279	
8/5/1991	22.00	1.90	250	
9/3/1991	28.00	2.10	51	
10/7/1991	32.00	2.40	37	
11/4/1991	29.00	2.60	36	
12/2/1991	30.00	3.40	35	
1/6/1992	26.00	3.90	34	
2/3/1992	32.00	3.90	21	
3/2/1992	8.60	2.90	21	
4/6/1992	7.20	2.30	27	
5/4/1992	11.00	2.40	459	
6/1/1992	10.00	1.60	316	
7/6/1992	13.00	2.00	310	
8/3/1992	16.00	2.00	284	
9/8/1992	1.90	2.40	134	
10/5/1992	7.90	2.60	31	
11/2/1992	9.00	2.50	44	
12/7/1992	9.90	2.70	24	
1/3/1995	4.60	2.70	199	
2/6/1995	1.90	1.40	3789	
3/6/1995	3.10	1.40	366	
4/3/1995	2.00	1.10	6151	
5/1/1995	3.10	0.94	3023	
6/5/1995	4.60	1.10	1352	
7/5/1995	9.00	1.10	830	
8/7/1995	12.00	1.00	984	
9/5/1995	15.00	1.00	420	
10/2/1995	16.00	1.20	432	

Date	Boron (ppm) in Bear Creek	Boron (ppm) in Cache Creek at Capay Dam	Flow in Cache Creek (cfs) at Rumsey	Flow in Bear Creek (cfs) near Cache Creek
10/31/1995	30.00	1.50	24	
11/6/1995	19.00	2.00	24	
12/5/1995	21.00	2.60	21	
1/2/1996	8.40	2.20	248	
2/5/1996	0.87	0.45	6718	
3/4/1996	1.60	0.86	5918	
3/27/1996	3.20	1.60	1173	
4/1/1996	3.00	1.60	812	
4/8/1996	3.70	1.70	221	
4/15/1996	4.20	1.50	332	
4/29/1996	5.10	1.30	587	
5/6/1996	5.90	1.30	680	
6/3/1996	7.30	1.20	682	
7/1/1996	9.60	1.00	614	
8/5/1996	12.00	0.82	605	
9/3/1996	15.00	0.69	488	
10/7/1996	16.00	1.20	214	
1/6/1997	2.30	0.72	7681	
2/3/1997	2.20	0.82	5496	
3/3/1997	4.00	1.20	663	
4/7/1997	5.70	1.00	352	
5/5/1997	8.40	0.93	527	
6/2/1997	10.00	0.84	504	
7/7/1997	12.00	0.76	934	
8/4/1997	16.00	0.78	406	
9/2/1997	20.00	0.92	302	
10/6/1997	21.00	0.97	91	
11/3/1997	16.00	0.88	140	
12/1/1997	3.60	1.90	175	44
1/5/1998	3.20	1.10	308	58
2/2/1998	2.30	1.20	4958	2380
3/2/1998	1.40	0.65	6782	269
5/4/1998	2.63	0.95	708	83
6/1/1998	2.19	0.73	2616	116
7/6/1998	4.64	0.86	790	21
8/3/1998	9.15	0.74	790	7.6
9/8/1998	12.30	0.72	477	5.3
10/5/1998	12.90	0.96	301	4.3
11/2/1998	11.80	1.86	277	6.1
12/7/1998	5.96	0.72	467	17
1/4/1999	8.18	1.78	45	7.4
2/1/1999	6.43	1.03	344	28

Date	Boron (ppm) in Bear Creek	Boron (ppm) in Cache Creek at Capay Dam	Flow in Cache Creek (cfs) at Rumsey	Flow in Bear Creek (cfs) near Cache Creek
3/1/1999	2.59	0.70	4080	87
4/5/1999	2.61	0.94	323	52
5/3/1999	3.72	0.86	684	29
6/7/1999	6.32	0.74	493	10
7/6/1999	7.50	0.63	769	4.9
8/2/1999	9.43	0.75	536	3.2
9/8/1999	10.90	0.79	242	2.5
10/11/1999	12.40	0.96	138	2.4
12/6/1999	16.20	2.03	38	3.9
1/3/2000	15.70	2.04	32	3.7
2/7/2000	5.90	1.95	41	34
3/6/2000	1.46	0.61	2003	227
4/3/2000	4.09	1.04	706	38
5/1/2000	5.45	0.81	712	19
6/5/2000	0.84	0.91	1287	5.7
7/5/2000	9.10	0.79	1214	2.4
8/7/2000	13.80	0.87	963	1.6
9/5/2000	18.00	0.92	414	1.7
10/2/2000	19.40	1.14	335	1.6