Brush Creek Water Quality Study

Presented by:

Roaring Fork Conservancy

January 31, 2007

Introduction

Brush Creek is located in the south central part of the Roaring Fork Watershed. It is between the drainages of Maroon Creek and Snowmass Creek and is the major creek flowing below the Snowmass Ski Area and the Town of Snowmass Village. The Brush Creek watershed is 16.24 square miles and Brush Creek is 7.28 miles in length. Brush Creek starts at an elevation of 8,661 feet in the Mid-Elevation Forests Ecoregion and then flows through the Foothill Shrublands Ecoregion to join the Roaring Fork River at 7,355 feet.

In its 2006 Water Quality Report, Roaring Fork Conservancy placed Brush Creek on its impacted list. Several factors led to this designation: consistently high pH and phosphorous levels, and continued construction and development along the creek and riparian zone. Brush Creek also had a Family Biotic Index (FBI) of *good*. This is a rating system for measuring the biological health of a river, and a *good* rating indicates organic pollution is probable. By comparison, Snowmass Creek (another nearby creek), lacks the high pH levels, has a FBI rating of *excellent*, and does not have the large scale development seen on Brush Creek. During the course of this study, a new rating system called the Multimetric Index (MMI) provided additional and more in-depth information on Brush Creek. In 2006 Roaring Fork Conservancy initiated a targeted water quality study to further investigate these concerns on Brush Creek. Partners for this study included: Aspen Skiing Company, Colorado Department of Public Health and Environment, Colorado Watershed Network, and Pitkin County.

The overall purpose of the Brush Creek Study was threefold. The first goal was to establish an accurate baseline for Brush Creek. Baseline data will be helpful for comparing with data collected in the future as development and construction continue along the creek. The second was to determine the magnitude, duration, and location of high pH and phosphorus levels found in Brush Creek. (There were 11 pH tests above the state limit of 9.0 over three years, and 60% of phosphorous samples exceeded recommended levels.) The third and final goal of the study was to provide a better understanding of appropriate management of open space parcels with regard to riparian habitat.

Methods

Sample Stations:

Sampling was conducted at four sites, including a reference site above all development (*Divide*), one site in the Town of Snowmass Village (*Chapel*), one site below Snowmass Club Golf Course (*Y*), and lastly one at Roaring Fork Conservancy's River Watch Station on Brush Creek near Highway 82 (*Historic*). This last site was a good reference site because of the five years of historic data compiled by Roaring Fork Conservancy. See Figure 4 in the Appendix for detailed site locations and descriptions.

Sample Parameters:

The following categories list the parameters sampled in this study:
Chemical Parameters: Dissolved oxygen (DO), hardness, pH, temperature, and total alkalinity. (Analysis conducted by RFC staff and contracted consultant)
Macro-invertebrates: Samples of small aquatic insects taken to identify species and quantities and used to determine the FBI Index and Multimetric Index. (Analysis conducted by Colorado Division of Public Health and Environment)
Nutrient Parameters: Ammonia, conductivity, nitrate, and phosphate. (Analysis conducted by Aspen Water and Sanitation District).
pH Samples: Most pH samples included chemical parameters as well. On October 23rd half of the samples included chemical parameters and the other half focused on pH and temperature. (Analysis conducted by RFC Staff and contracted consultant)

Chemical parameters were determined for up to 46 samples on 12 different dates from April 2006 through January 2007. Macro-invertebrates were collected at two sites, Chapel and Y, in September. Nutrient parameters were determined on four different dates: April, May, August, and September. For a detailed list of all sample dates and parameters see Figure 5 in the Appendix.

A segment of the study was heavily focused on pH as well. This segment was conducted to determine the magnitude, frequency, and duration of some high pH events found at the Historic site in the past five years. It consisted of weekly sampling during a six week period in September and October. At the end of this period, on October 23rd, real time sampling was conducted throughout the day with four samples taken at each site.

Protocol:

Field protocol: Temperature was recorded in degrees Celsius using a standard thermometer that was submerged in the creek for a minimum of one minute. Temperature was recorded on the field data sheet. Dissolved oxygen (DO) samples were taken at each site with a 500 ml DO bottle that was rinsed three times with creek water and then placed in the creek and angled at 45 degrees for three minutes. The bottle was then capped underwater and *fixed* with magnesium sulfate and alkaline iodide-azide solutions. The sample and solutions were thoroughly mixed together twice (the second time after settling 50%). In order to complete the procedure for stabilizing the amount of DO in solution, sulfamic acid was introduced. For pH, alkalinity and hardness, a standard 500 ml plastic container was rinsed three times with creek water and then the sample was collected. Macro-invertebrates were collected according to the CDPHE protocols using kick nets. Samples for nutrient parameters were taken at each site using a standard 1000 ml plastic container after rinsing three times with creek water.

Lab Protocol: Dissolved Oxygen was measured in milligrams per liter (mg/l) with the standard *Winkler Titration Method* utilizing sodium thiosulfate as the chemical titrant. Percent saturation of DO was determined by the water temperature cross referenced with the dissolved oxygen value in mg/l. pH was analyzed using a Beckman pH meter that was standardized, utilizing pH 7 and pH 10 buffer solutions, before the creek sample was measured. Alkalinity was determined in mg/l via a titration method utilizing sulfuric acid as the titrant. Hardness was determined in mg/l via a titration method utilizing ethylenediaminetetraacetic acid (EDTA). All results were

recorded on the appropriate field data sheets. Macro-invertebrates were analyzed through the CDPHE. Nutrient parameters were measured at the Aspen Water and Sanitation District laboratory.

Results

Ammonia in its unionized form is toxic to aquatic organisms. Temperature and pH can affect the levels of unionized ammonia in a stream and in-stream concentrations may be reduced with dilution. Low ammonia concentrations are better for aquatic organisms. The state standards for acute ammonia concentrations are currently being reevaluated by the State and were not available at this time. Ammonia levels at the Divide site were N/A, <0.05, <0.05, and 0.06 mg/l respectively during each of the sampling periods. Ammonia levels at the Chapel site were <0.05, <0.05. 0.05, and <0.05 mg/l respectively. Ammonia levels at the Y site were <0.05, <0.05, 0.06, and 0.07 mg/l respectively. Ammonia levels at the Historic site were N/A, <0.05, <0.05, and <0.05 mg/l respectively. (The detection limit (for Ammonia) of the Aspen Water and Sanitation District is 0.05.)

Conductivity is the ability of a substance to conduct an electrical current. Pure liquid water has a very low conductivity. The presence of charged ions in the water makes the solution more conductive. As ion concentration increases, conductance of the solution increases. Therefore, the conductance measurement provides an indication of ion concentration. There is no state standard for conductivity. Conductivity levels at the Divide site were N/A, 194, 260 and 135 ohms/cm respectively during each of the sampling periods. Conductivity levels at the Chapel site were 332, 91, 233, and 199 ohms/cm respectively. Conductivity levels at the Y site were 390, 126, 322, and 257 ohms/cm respectively. Conductivity levels at the Historic site were N/A, 137, 403, and 294 ohms/cm respectively. For a detailed graph of Conductivity levels see Figure 5 in the Appendix.

Dissolved Oxygen concentrations in water determine which organisms can survive in a particular environment. The state standard for dissolved oxygen is a minimum of 6.0 milligrams per liter (mg/l). Dissolved oxygen ranged from 7.6 to 9.2 mg/l at the Divide site, 8.1 to 10.7 mg/l at the Chapel site, 8.3 to 11.0 mg/l at the Y site, and 8.4 to 11.2 mg/l at the Historic site. For a detailed graph of Dissolved Oxygen measurements see Figures 11-14 in the Appendix.

Hardness is the measure of minerals (specifically calcium and magnesium) that are in the water. There is no state standard for hardness. Hardness ranged from 102 to 220 mg/l at the Divide site, 66 to 200 mg/l at the Chapel site, 88 to 228 mg/l at the Y site, and 86 to 214 mg/l at the Historic site**.** For a detailed graph of Hardness levels see Figures 7-10 in the Appendix.

Macro-invertebrates are organisms that have no internal skeleton of cartilage or bone, and are large enough to see without magnification. In freshwater environments, these organisms (e.g. stoneflies, mayflies, and caddisflies) are the primary food for fish and other riparian animals, and are responsible for the breakdown of organic material and nutrients. Some macros are pollution sensitive while others are pollution tolerant. The absence of pollution sensitive species coupled with the presence of pollution tolerant species may indicate organic pollution. This was the basis for the FBI Index. During the past year the CDPHE adopted new criteria for analyzing Macro-

invertebrate samples. It is called the Multimetric Index and uses the above criteria along with additional parameters to give a more accurate idea of the biological health of streams. According to this new index the Chapel Site had an average MMI score of 70.725 and the Y Site had an average MMI score of 76.066. Both of these scores carry a rating of *least disturbed* indicating a lack of organic pollution and a biologically healthy stream.

Nitrate is a reduced form of nitrogen. Excessive concentrations of nitrate in water can cause harm to aquatic organisms. The state standard for nitrate in creeks such as Brush Creek is 10 mg/l. Nitrate levels at the Divide site were N/A, 2.0, 2.6, and 1.4 mg/l respectively during each of the sampling periods. Nitrate levels at the Chapel site were 1.9, 1.7, 0.7, and 1.0 mg/l respectively. Nitrate levels at the Y site were 4.0, 2.1, 4.1, and 3.4 mg/l respectively. Nitrate levels at the Historic site were N/A, 0.3, 2.3, and 1.7 mg/l respectively. For a detailed graph of Nitrate Levels see Figure 1 in the Discussion section.

pH is the measurement of the acidity of water, with acidic (as low as 1) on one end of the pH scale and basic (as high as 14) on the other end of the scale. Aquatic organisms each have an optimal pH range for functioning, and extremes on either end of the pH scale can be toxic. The state standard for pH is between 6.5 and 9.0. pH ranged from 7.83 to 8.24 at the Divide site, 8.12 to 8.50 at the Chapel site, 8.16 to 8.49 at the Y site, and 8.16 to 8.63 at the Historic site. For a detailed graph of pH levels see Figure 2 in the Discussion section.

Phosphate is a constituent of total phosphorus in water. High phosphate concentrations in a water body may decrease productivity of aquatic organisms. Phosphate does not have a state standard. Phosphate levels at the Divide site were N/A, 0.12, 0.15, and 1.78 mg/l respectively during each of the sampling periods. Phosphate levels at the Chapel site were 1.39, 0.13, 0.44, and 0.99 mg/l respectively. Phosphate levels at the Y site were 0.51, 0.23, 2.72 and 1.26 mg/l respectively. Phosphate levels at the Historic site were N/A, 0.19, 1.45 and 0.29, mg/l respectively. For a detailed graph of phosphate levels see Figure 3 in the Discussion section.

Temperature helps determine which kind of organisms can survive in water. Species such as trout and mayflies prefer lower temperatures because cold water holds greater levels of dissolved oxygen. The state standard for temperature in creeks such as Brush Creek is a maximum of 20° Celsius. Temperature at the Divide site ranged from a minimum of 2°C to a maximum of 11°C. Chapel site temperature ranged from 0°C to 13°C. Y site temperature ranged from 2°C to 15°C. Historic site temperature ranged from 1°C to 11°C. The lower temperatures reflected January sampling as opposed to August sampling. For a detailed graph of Temperature measurements see Figures 11-18 in the Appendix.

Total alkalinity concentrations in water represent the total amount of bicarbonate and carbonate in a body of water. Alkalinity measures the ability of water to resist change in pH when either an acid or base is added to the water. There is no state standard for alkalinity. Total Alkalinity ranged from 82 to 174 mg/l at the Divide site, 58 to 166 mg/l at the Chapel site, 70 to 174 mg/l at the Y site, and 74 to 166 mg/l at the Historic site. For a detailed graph of Total Alkalinity levels see Figures 7-10 in the Appendix.

Discussion

Most parameters in this study seemed to reflect normal and relatively healthy conditions for Brush Creek. Although there are no state standards for alkalinity and hardness, the values seem to fall within reasonable ranges and follow expected trends. The state standards for acute ammonia concentrations are currently being reevaluated by the State and were not available at this time. In terms of state standards for temperature and dissolved oxygen, all four sites fell within acceptable ranges and followed expected trends. MMI scores for Macro-invertebrates carry a rating of *least disturbed* indicating a lack of organic pollution and a biologically healthy stream.

Nitrate

The nitrate levels found at all the sites on Brush Creek were well below the state standards. There was, however, a marked increase in nitrate levels between the Chapel and Y sites during every sample event. The Y site also posted the highest nitrate levels of all the sites. This data may indicate that the Snowmass Club Golf Course may be contributing to the rise in nitrate levels. Interestingly, the levels usually dropped again between the Y and Historic sites indicating the possibility of some mitigating factor between those sites.

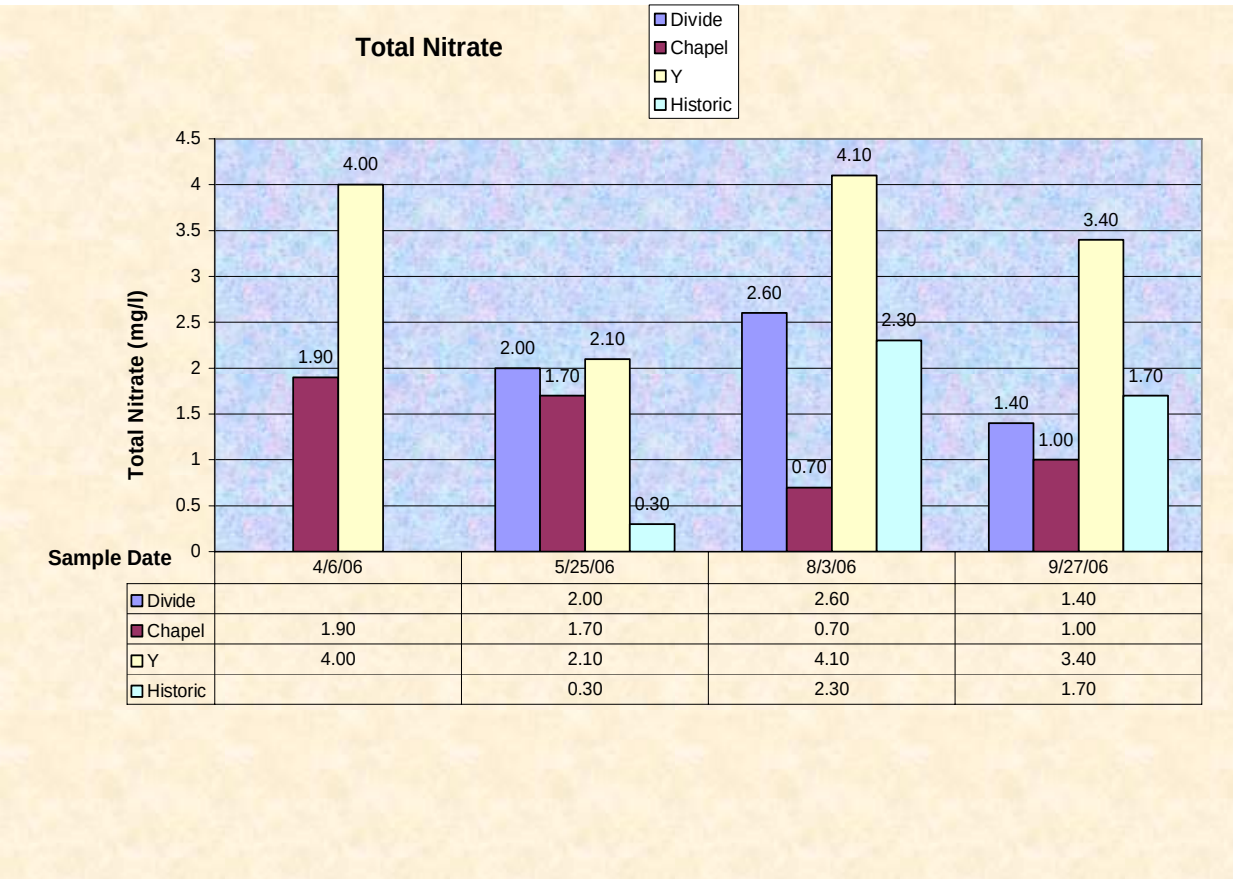
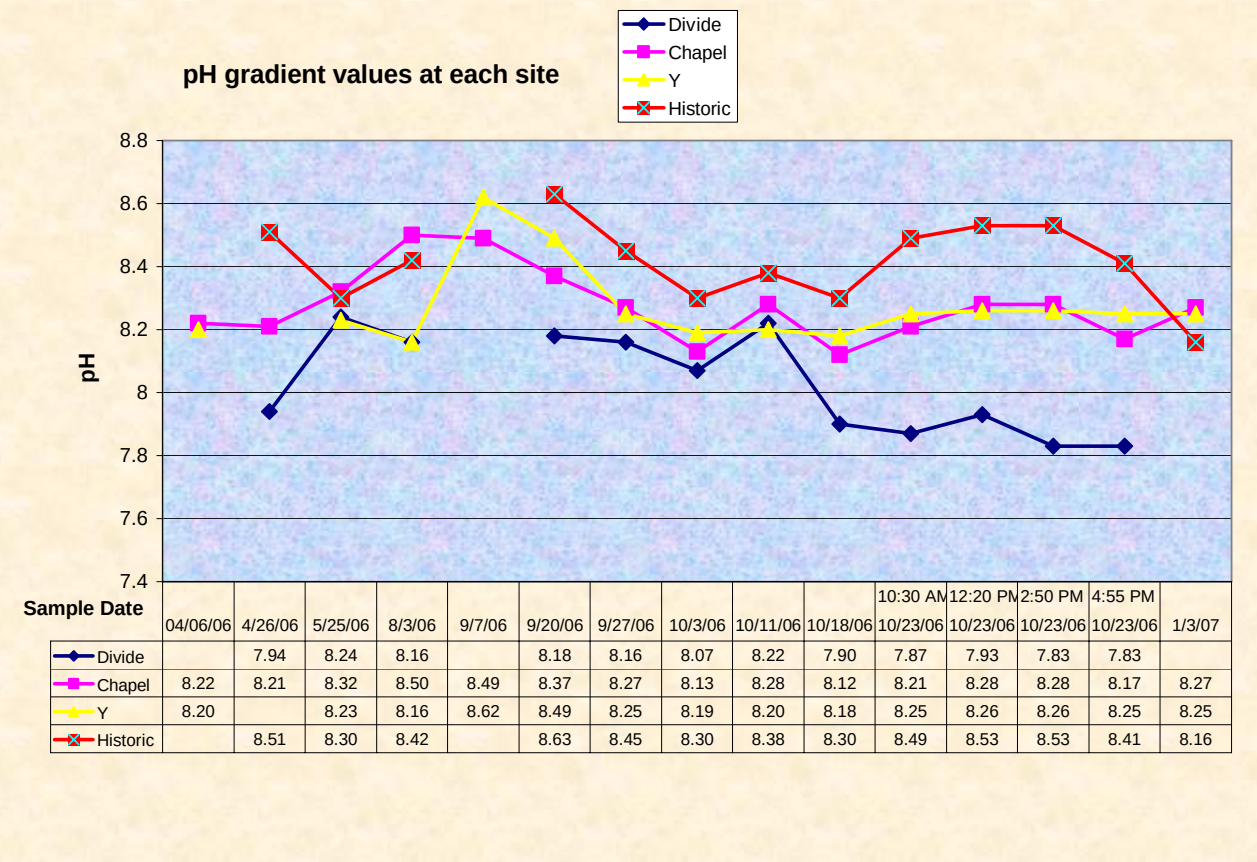


Figure 1 (Total Nitrate levels at each site)

pH

One major focus of this study was to determine the magnitude, duration, and location of high pH levels found in Brush Creek. Over a three-year period, 11 pH tests were above the state limit of 9.0. Data shows that all pH samples collected for this study were within the state standard. Data from the Divide site shows the lowest pH levels, indicative of a headwater sampling point. The pH rose at the Chapel and Y sites, but still at acceptable levels. Yet it was the rise in pH between the Y site and the Historic site that is of note where pH minimums were 8.16 and 8.30 respectively and where pH maximums were 8.49 and 8.63 respectively. This data may suggest that there are factors which slightly influence the rise in pH between the Chapel site which is located below the Town of Snowmass Village, and the Y site which is below Snowmass Club Golf Course. This data also suggests that factors of greater influence to the pH rise exist between the Y site and the Historic site which is near Brush Creek's confluence with the Roaring Fork River at Highway 82.



Sample Date	04/06/06	4/26/06	5/25/06	8/3/06	9/7/06	9/20/06	9/27/06	10/3/06	10/11/06	10/18/06	10:30 AM 10/23/06	12:20 PM 10/23/06	2:50 PM 10/23/06	4:55 PM 10/23/06	1/3/07
Divide		7.94	8.24	8.16		8.18	8.16	8.07	8.22	7.90	7.87	7.93	7.83	7.83	
Chapel	8.22	8.21	8.32	8.50	8.49	8.37	8.27	8.13	8.28	8.12	8.21	8.28	8.28	8.17	8.27
Y	8.20		8.23	8.16	8.62	8.49	8.25	8.19	8.20	8.18	8.25	8.26	8.26	8.25	8.25
Historic		8.51	8.30	8.42		8.63	8.45	8.30	8.38	8.30	8.49	8.53	8.53	8.41	8.16

Figure 2 (pH levels at each site)

The fact that no pH levels exceeded the state standard is of particular interest. This result, although unexpected, is good news for the health of Brush Creek, especially considering the construction and development in progress during the study period. Closer examination of data from previous years shows an interesting trend emerging. It would appear that pH levels are higher during years of lower water levels/flows and lower during years of average water levels/flows. Also, in previous years the pH spike occurred most often in the fall, a time of the year usually associated with lower water levels/flows. These trends seem to indicate the possibility of a relationship between pH levels and water/flow levels.

Phosphate

Although phosphate does not have a state standard, past levels in Brush Creek were high, with values reaching 1.1 mg/l at the Historic sample site near Highway 82. This pattern was recognized during this study as well with each sampling station recording phosphate values that exceeded even those historic values. The highest phosphate value was 1.78 at Divide, 1.39 at Chapel, 2.72 at Y, and 1.45 at Historic. In three out of four samples the largest increase in Phosphate was noted between the Chapel and Y sites. This data may indicate that the Town of Snowmass Village and the Snowmass Club Golf Course may both be contributing to these higher phosphate values, with the larger increased occurring around the Snowmass Club Golf Course.

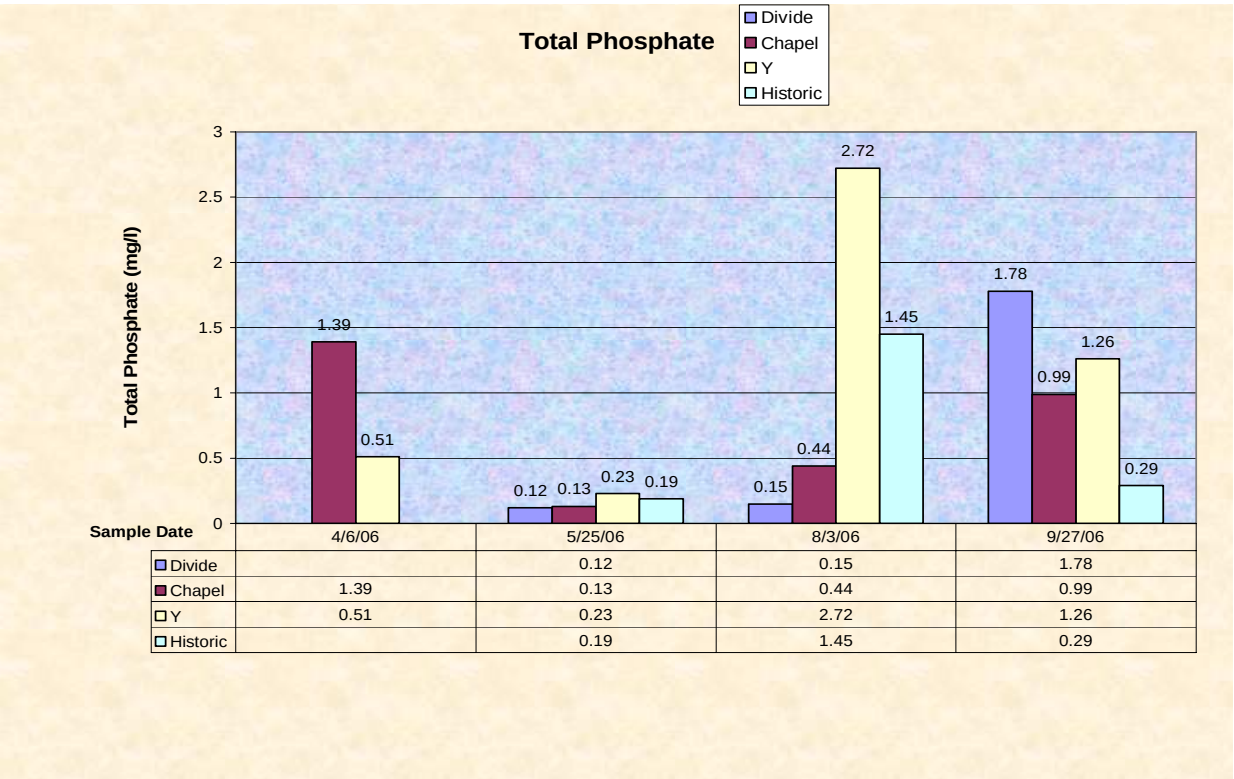


Figure 3 (Total Phosphate levels at each site)

Conclusion

The overall purpose of the Brush Creek Study was threefold. The first goal was to establish an accurate baseline for Brush Creek. This was completed and the data collected will be useful for future comparison to the seven years of historic data Roaring Fork Conservancy has collected on Brush Creek. Looking towards the future, Roaring Fork Conservancy will continue monitoring three of the four sites established during study, and work toward incorporating the fourth site in 2007.

The second goal was determining the magnitude, duration, and location of high pH and phosphorus levels found in Brush Creek. As stated in the discussion, no exceedences of the state limit for pH were recorded during the Brush Creek Study. One possible theory points toward a link between pH and stream flows. This theory could be the basis for the need of a gauging

station on Brush Creek in order to better study the relationship between flows and pH. It could also point towards a need for a minimum in-stream flow to be established on Brush Creek during low flow years. Roaring Fork Conservancy will continue to monitor at least three sites on Brush Creek in hopes to learn more regarding pH. Regarding phosphorus levels, the Roaring Fork Conservancy will share this report with the Snowmass Golf Club, and the Town of Snowmass Village and will provide consultation if requested.

The third and final goal of the study was to provide a better understanding of appropriate management of open space parcels with regard to riparian habitat. Roaring Fork Conservancy will distribute this report to the Aspen Skiing Company, Pitkin County Open Space and Trails, Pitkin County Department of Environmental Health, Snowmass Club Golf Course, and the Town of Snowmass Village, and continue to assist with management decisions in regards to Brush Creek water quality, water quantity, and riparian habitat. This report will also be made available to other interested parties upon request.

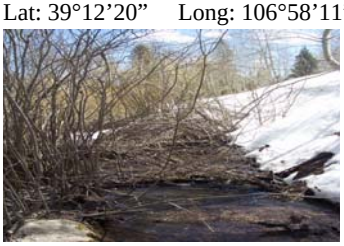
Appendix

Sampling locations:

Divide

Near divide of Brush and Snowmass Creeks. Follow Brush Creek Road up to Krabloonik and park in lot. Sample site is just downstream from divide across the creek from the large house across from Krabloonik parking lot.

Lat: 39°12'20" Long: 106°58'11" Elevation: 8933'



Chapel

Downstream of Base Village. From the Divide site turn right on Highline Road and take an immediate left into the Chapel/Anderson Ranch parking lot. Site is ~10m upstream of culvert at obvious spot among big boulders.

Lat: 39°12'51" Long: 106°56'15" Elevation: 8158'

Y

Just downstream from Snowmass Club outflow and bridge at obvious 90° turn in Creek. Approximately 100m upstream from *Y* intersection (now a round-about) of Brush Creek Road and Highline Road.

Lat: 39°13'28" Long: 106°55'15" Elevation: 8158'

Historic

Historic RW site located in median of Hwy 82, just upstream from culvert underneath southbound Hwy. 82.

Lat: 39°15'41" Long: 106°53'14" Elevation: 7468'

Figure 4 (Sample Site Locations)

Sample Schedule for Brush Creek Study

April 2006 through January 2007

Site	4/6/06	4/26/06	5/25/06	8/3/06	9/7/06	9/20/06	9/27/06	10/3/06
Divide		C	C, N	C, N		C	C, N	C
Chapel	C, N	C	C, N	C, N	C, M	C	C, N	C
Y	C, N		C, N	C, N	C, M	C	C, N	C
Historic		C	C, N	C, N		C	C, N	C

Site	10/11/06	10/18/06	10/23/06 10:30am	10/23/06 12:20pm	10/23/06 2:50pm	10/23/06 4:55pm	1/3/07
Divide	C	C	C	pH	C	pH	
Chapel	C	C	C	pH	C	pH	C
Y	C	C	C	pH	C	pH	C
Historic	C	C	C	pH	C	pH	C

Key

C	Chemistry Parameters = Alkalinity, Dissolved Oxygen, Hardness, pH, and Temperature
N	Nutrient Parameters = Ammonia, Conductivity, Nitrate, and Phosphate
M	Macroinvertebrates
pH	pH and temperature only

Figure 5 (Sample Schedule)

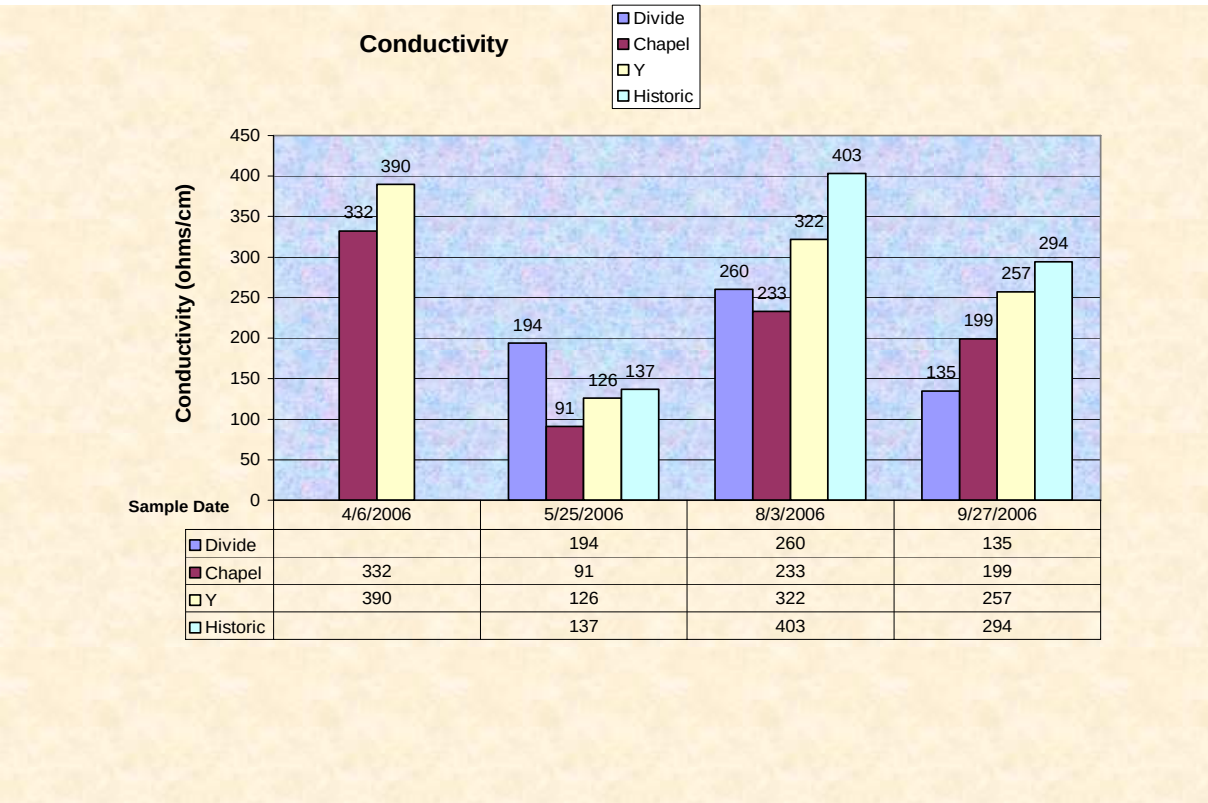
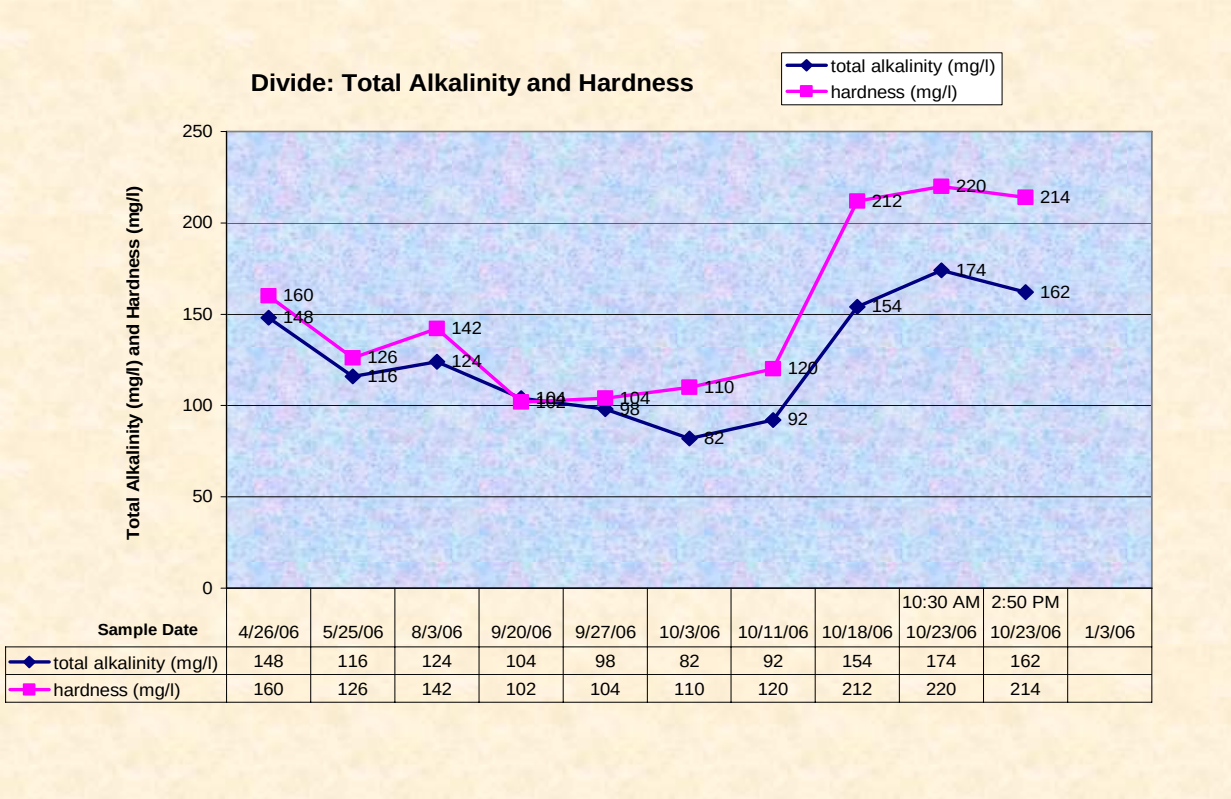
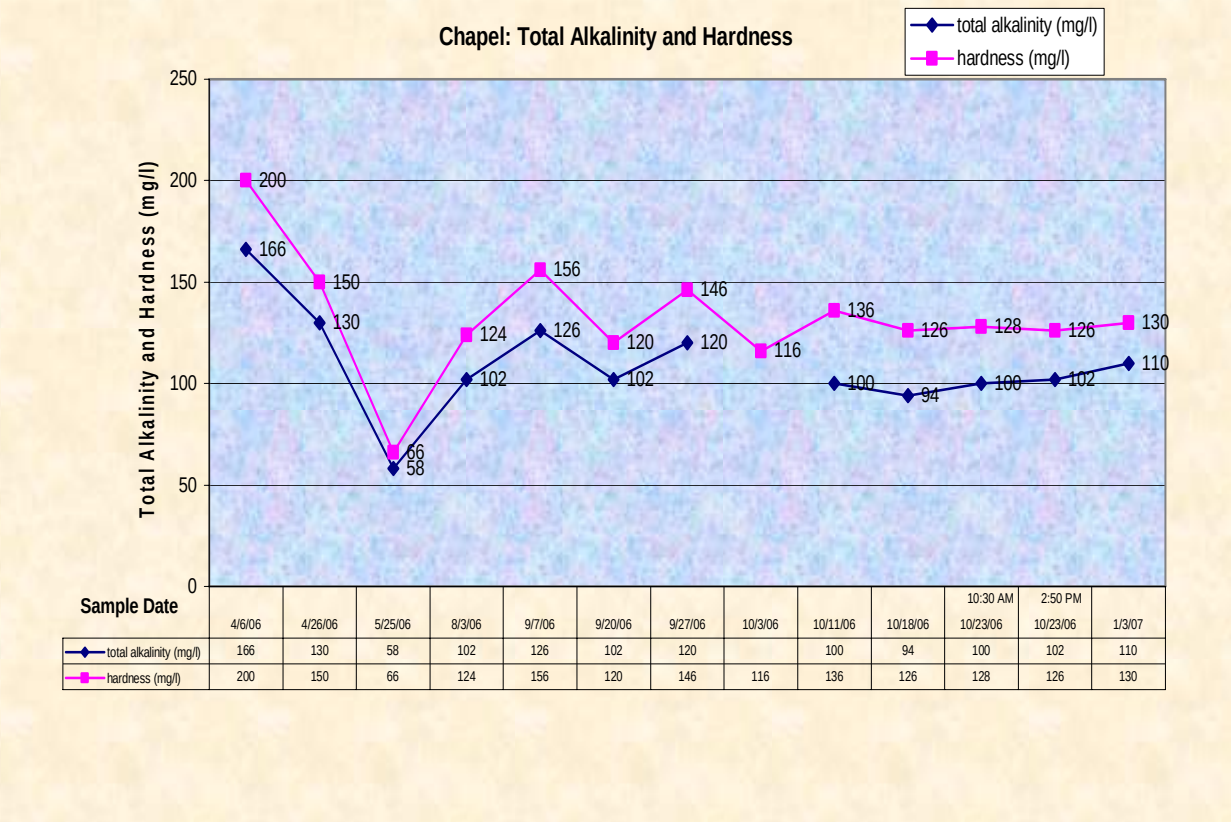


Figure 6 (Conductivity levels at each site)



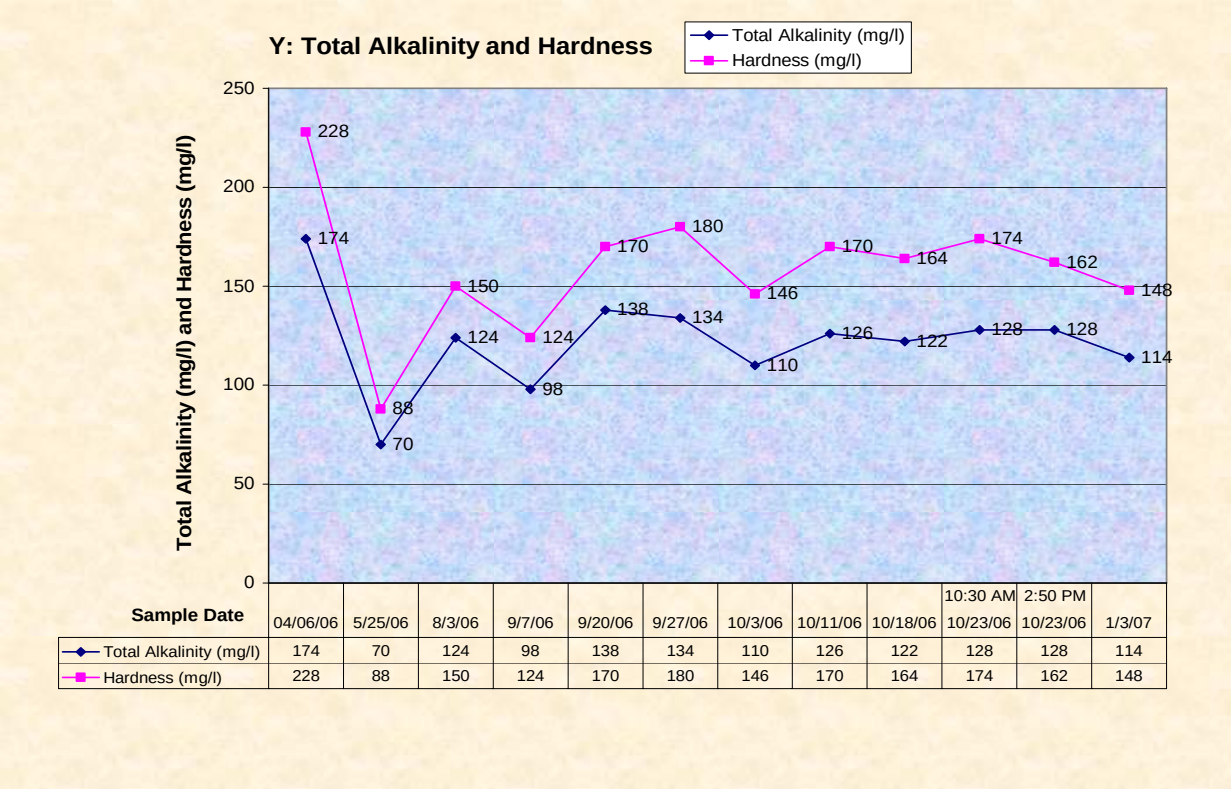
Sample Date	4/26/06	5/25/06	8/3/06	9/20/06	9/27/06	10/3/06	10/11/06	10/18/06	10:30 AM 10/23/06	2:50 PM 10/23/06	1/3/06
total alkalinity (mg/l)	148	116	124	104	98	82	92	154	174	162	
hardness (mg/l)	160	126	142	102	104	110	120	212	220	214	

Figure 7 (Total Alkalinity and Hardness levels at the Divide Site)



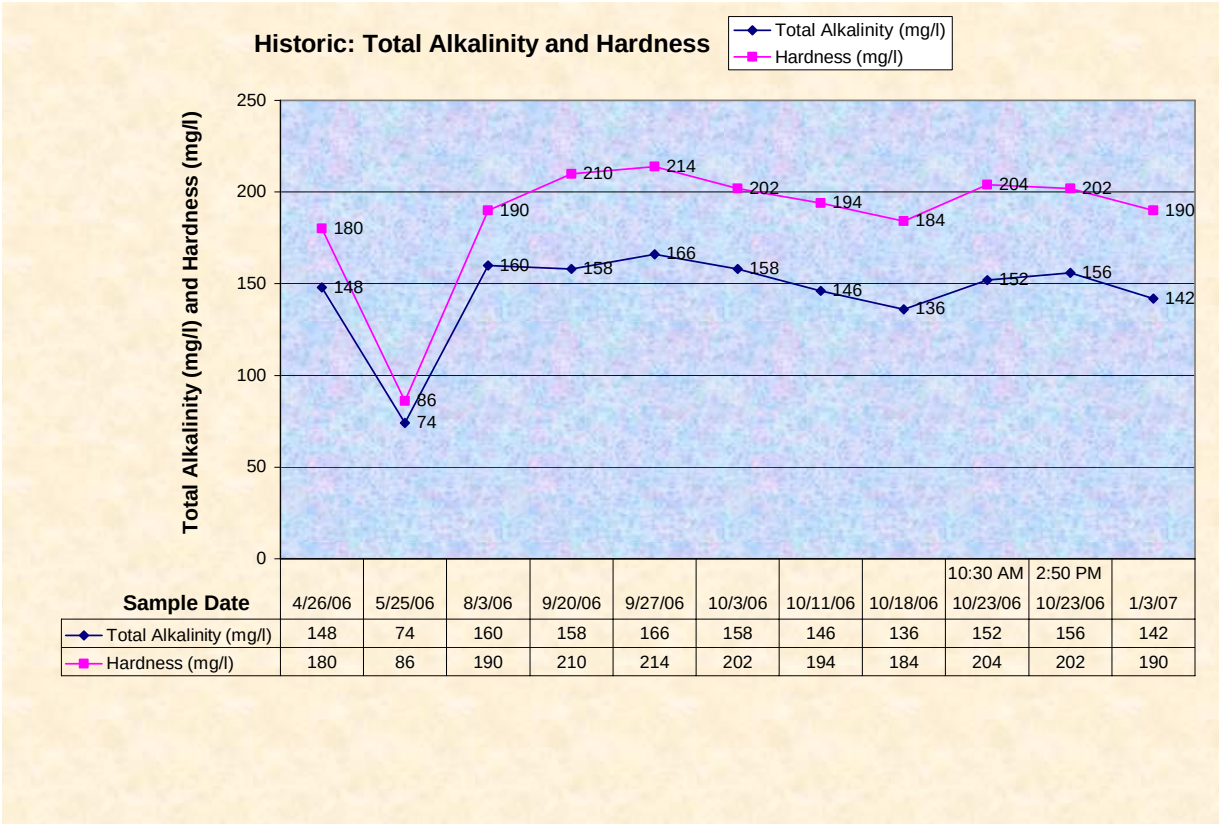
Sample Date	4/6/06	4/26/06	5/25/06	8/3/06	9/7/06	9/20/06	9/27/06	10/3/06	10/11/06	10/18/06	10:30 AM 10/23/06	2:50 PM 10/23/06	1/3/07
total alkalinity (mg/l)	166	130	58	102	126	102	120		100	94	100	102	110
hardness (mg/l)	200	150	66	124	156	120	146	116	136	126	128	126	130

Figure 8 (Total Alkalinity and Hardness levels at the Chapel Site)



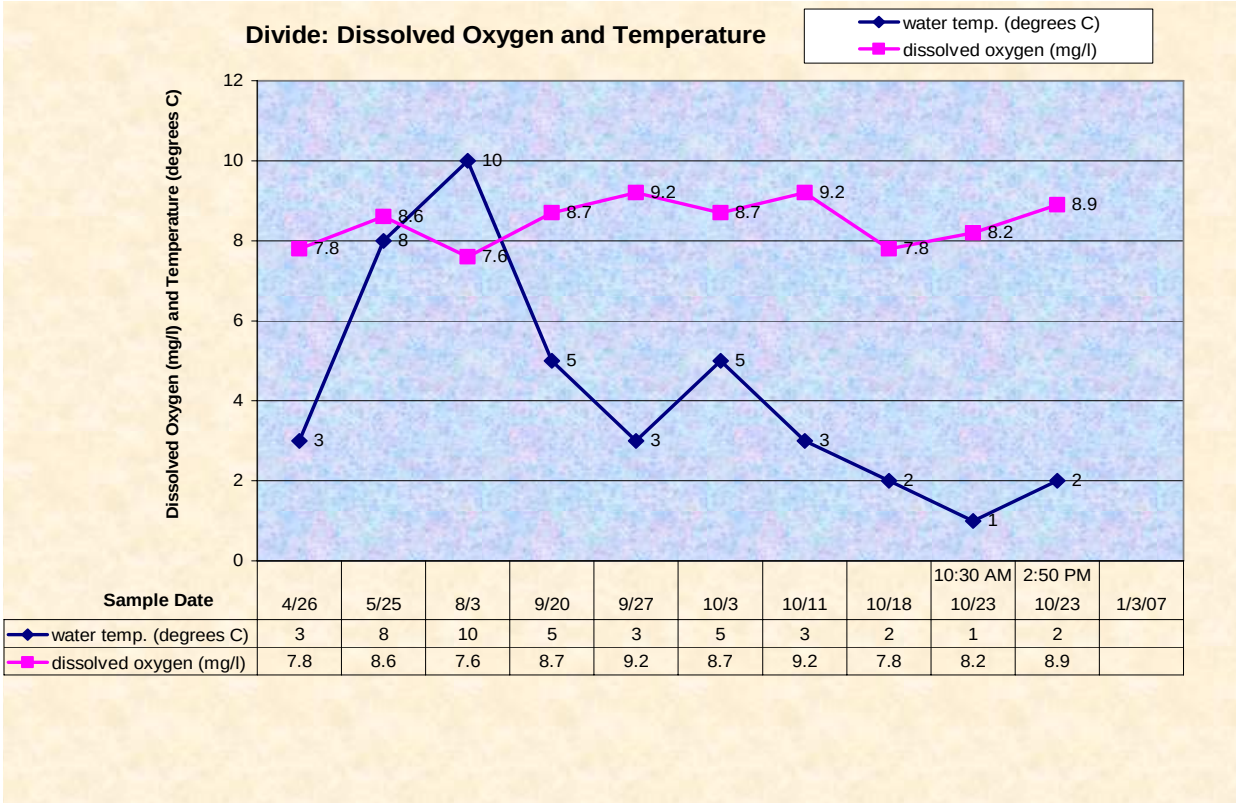
Sample Date	04/06/06	5/25/06	8/3/06	9/7/06	9/20/06	9/27/06	10/3/06	10/11/06	10/18/06	10:30 AM 10/23/06	2:50 PM 10/23/06	1/3/07
Total Alkalinity (mg/l)	174	70	124	98	138	134	110	126	122	128	128	114
Hardness (mg/l)	228	88	150	124	170	180	146	170	164	174	162	148

Figure 9 (Total Alkalinity and Hardness levels at the Y Site)



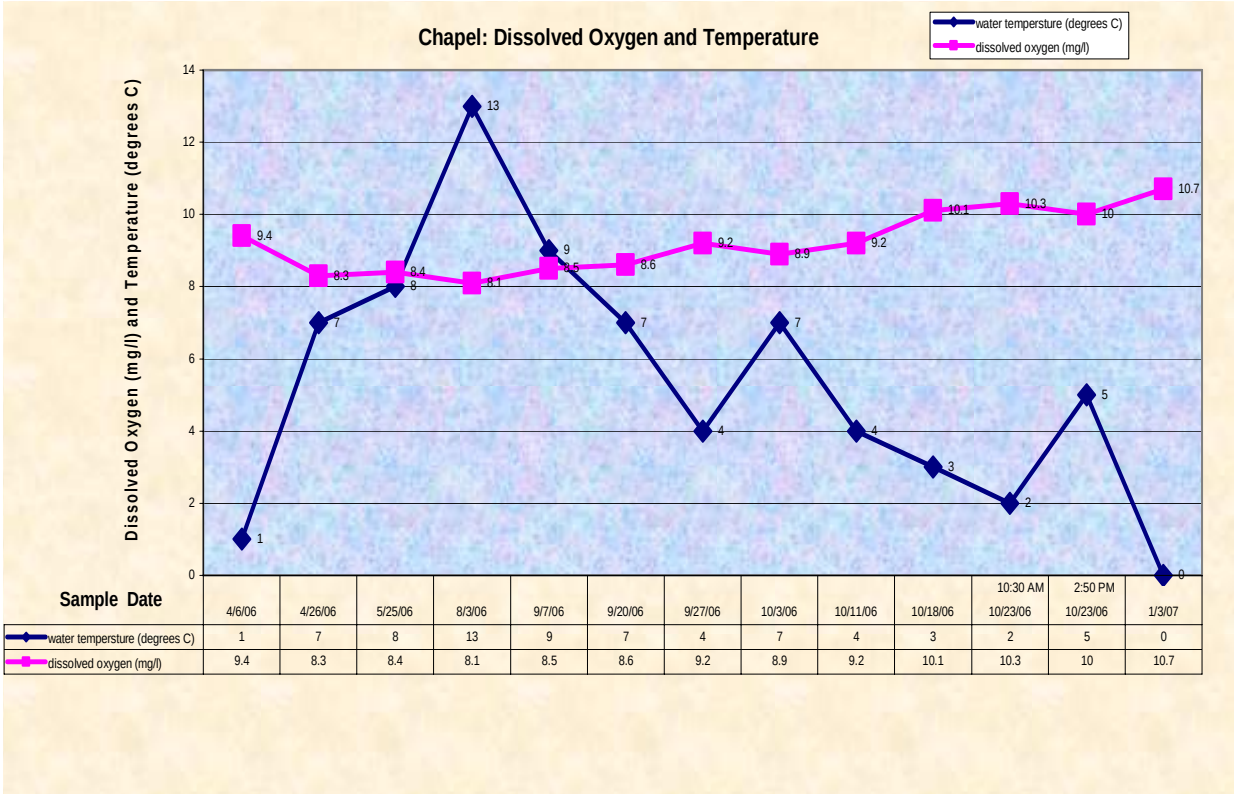
Sample Date	4/26/06	5/25/06	8/3/06	9/20/06	9/27/06	10/3/06	10/11/06	10/18/06	10:30 AM 10/23/06	2:50 PM 10/23/06	1/3/07
Total Alkalinity (mg/l)	148	74	160	158	166	158	146	136	152	156	142
Hardness (mg/l)	180	86	190	210	214	202	194	184	204	202	190

Figure 10 (Total Alkalinity and Hardness levels at the Historic Site)



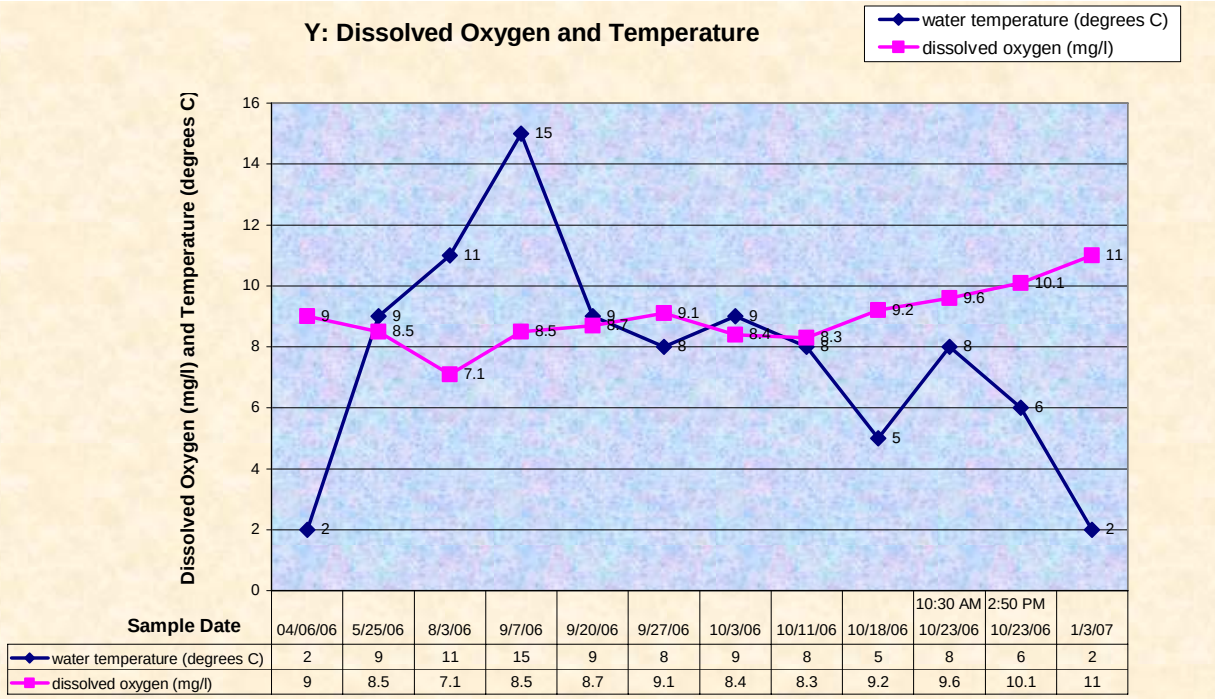
Sample Date	4/26	5/25	8/3	9/20	9/27	10/3	10/11	10/18	10:30 AM 10/23	2:50 PM 10/23	1/3/07
water temp. (degrees C)	3	8	10	5	3	5	3	2	1	2	
dissolved oxygen (mg/l)	7.8	8.6	7.6	8.7	9.2	8.7	9.2	7.8	8.2	8.9	

Figure 11 (Dissolved Oxygen and Temperature measurements at the Divide Site)



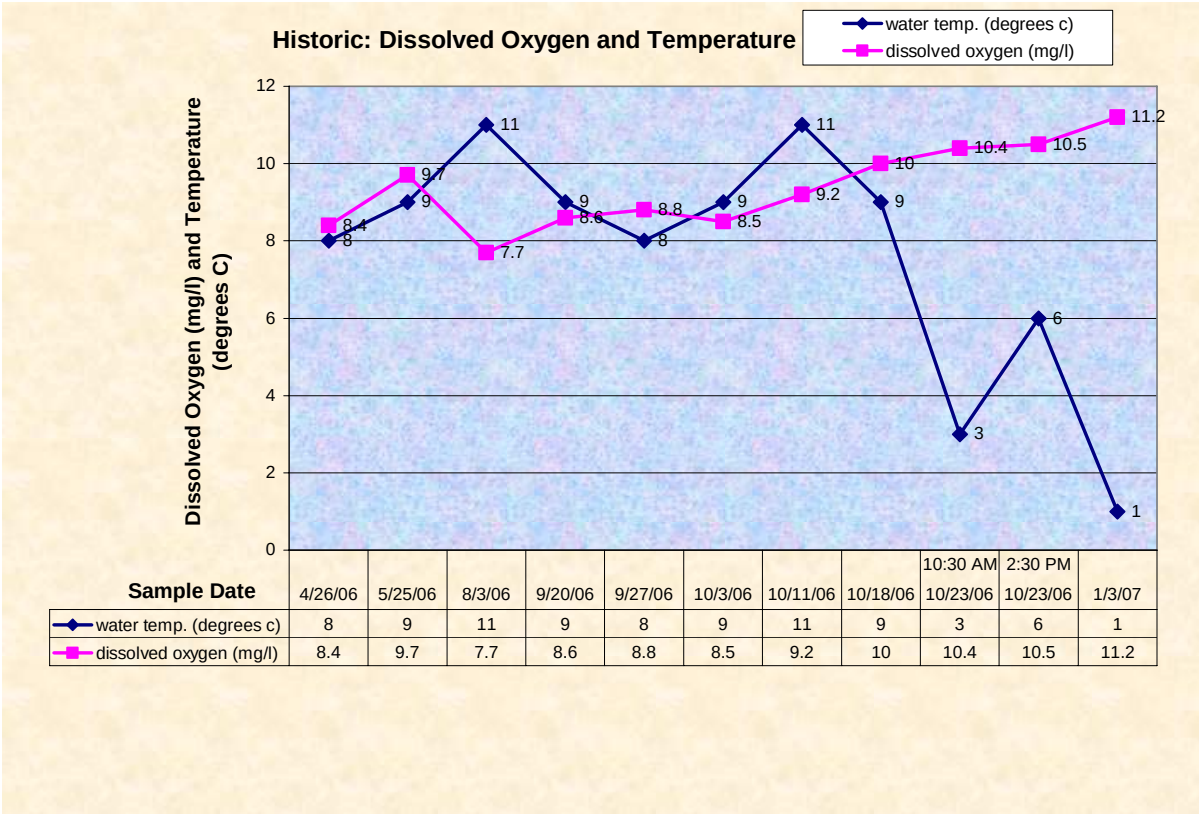
Sample Date	4/6/06	4/26/06	5/25/06	8/3/06	9/7/06	9/20/06	9/27/06	10/3/06	10/11/06	10/18/06	10:30 AM 10/23/06	2:50 PM 10/23/06	1/3/07
water temperature (degrees C)	1	7	8	13	9	7	4	7	4	3	2	5	0
dissolved oxygen (mg/l)	9.4	8.3	8.4	8.1	8.5	8.6	9.2	8.9	9.2	10.1	10.3	10	10.7

Figure 12 (Dissolved Oxygen and Temperature measurements at the Chapel Site)



Sample Date	04/06/06	5/25/06	8/3/06	9/7/06	9/20/06	9/27/06	10/3/06	10/11/06	10/18/06	10:30 AM 10/23/06	2:50 PM 10/23/06	1/3/07
water temperature (degrees C)	2	9	11	15	9	8	9	8	5	8	6	2
dissolved oxygen (mg/l)	9	8.5	7.1	8.5	8.7	9.1	8.4	8.3	9.2	9.6	10.1	11

Figure 13 (Dissolved Oxygen and Temperature measurements at the Y Site)



Sample Date	4/26/06	5/25/06	8/3/06	9/20/06	9/27/06	10/3/06	10/11/06	10/18/06	10:30 AM 10/23/06	2:30 PM 10/23/06	1/3/07
water temp. (degrees c)	8	9	11	9	8	9	11	9	3	6	1
dissolved oxygen (mg/l)	8.4	9.7	7.7	8.6	8.8	8.5	9.2	10	10.4	10.5	11.2

Figure 14 (Dissolved Oxygen and Temperature measurements at the Historic Site)

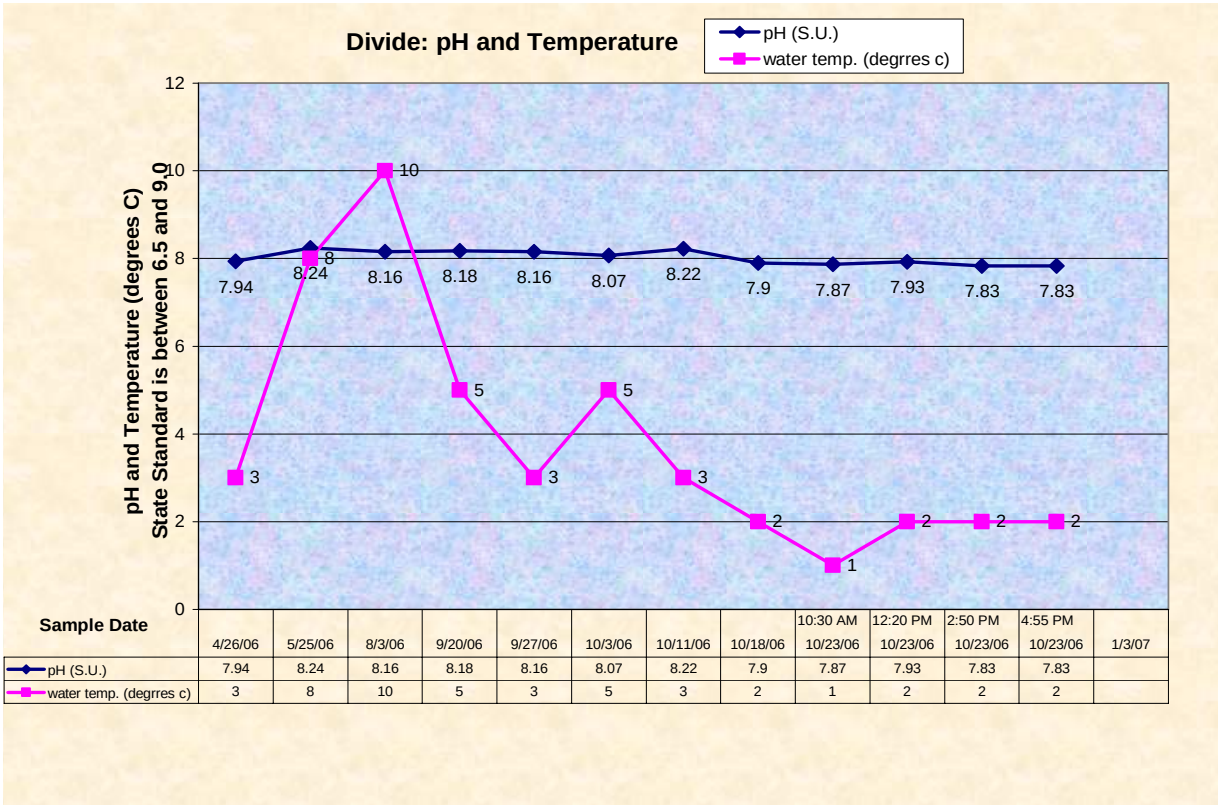


Figure 15 (pH and Temperature measurements taken at the Divide Site)

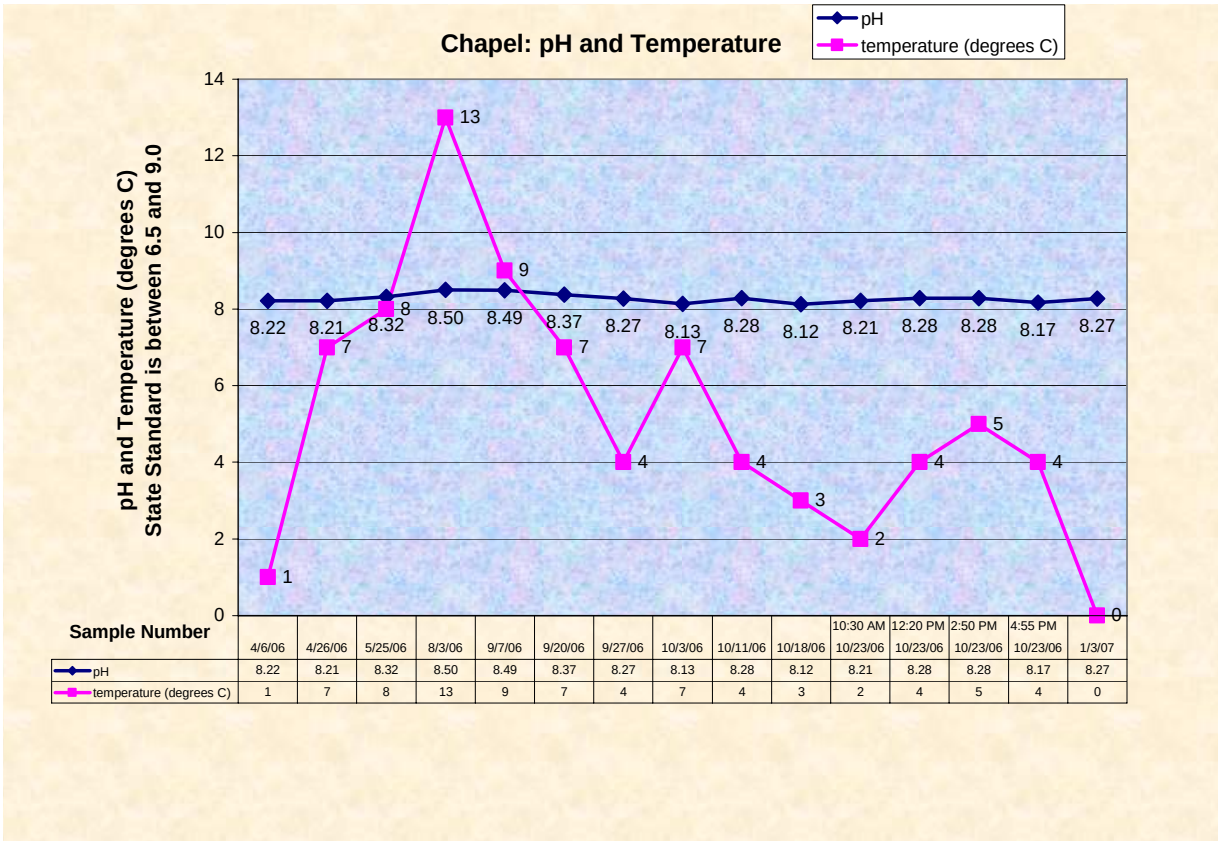


Figure 16 (pH and Temperature measurements taken at the Divide Site)

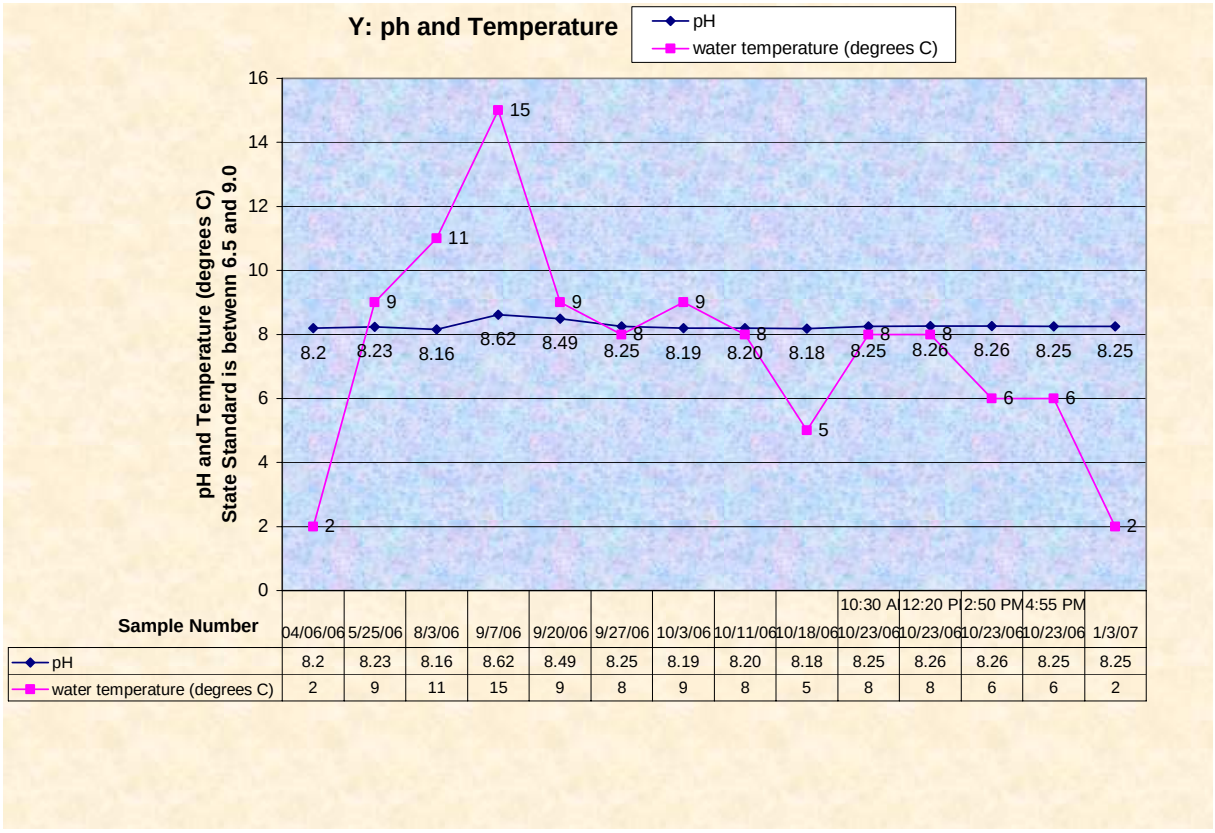


Figure 17 (pH and Temperature measurements taken at the Y Site)

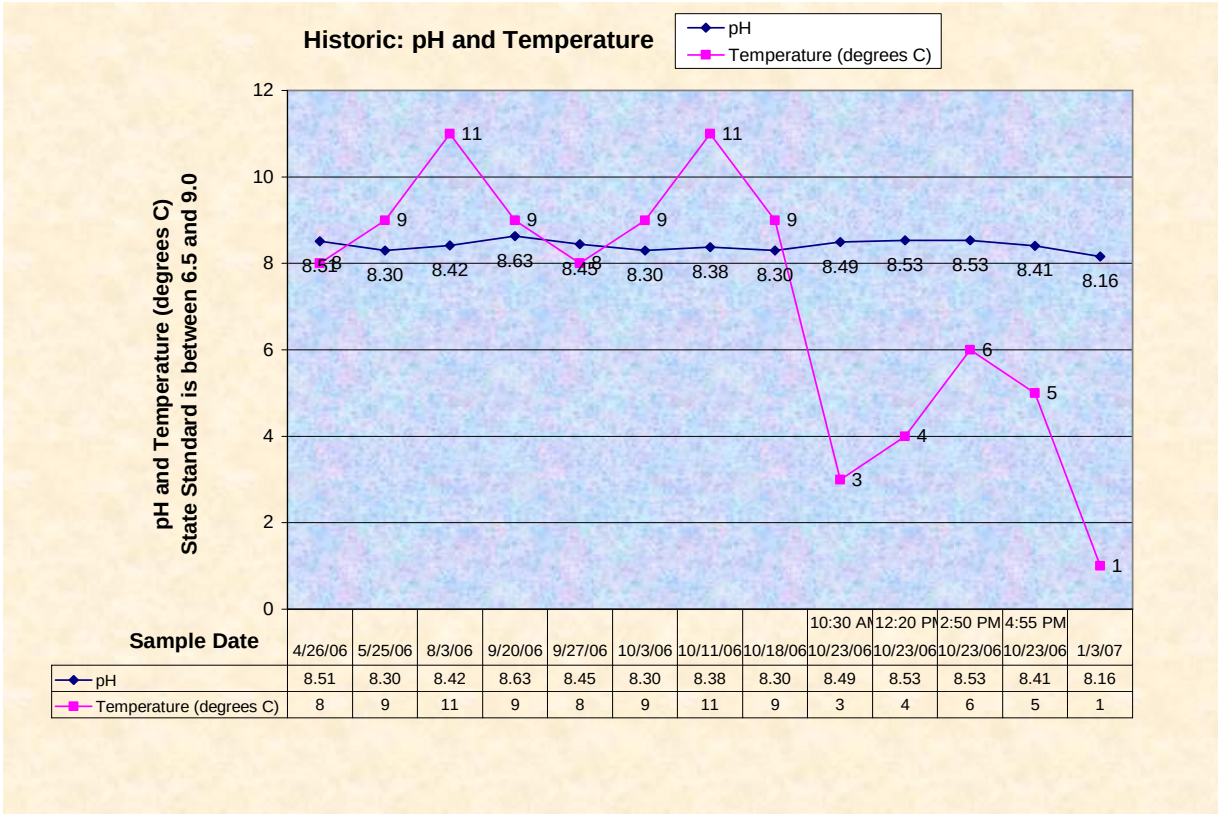


Figure 18 (pH and Temperature measurements taken at the Historic Site)