6. Upper Chorro Watershed

6.1 Introduction

Chorro Creek Dam (CHD) and Chorro Valley Culvert (CVC) are the upper and lower sampling stations of a total cattle exclusion area on Camp San Luis Obispo. In 1994, fencing was installed along the riparian corridor of upper Chorro Creek. These sampling stations were established to examine changes in water quality as result of BMP implementation.

Chorro Reservoir, located just upstream of the riparian fencing, is a major influence in Chorro Creek. Chorro Reservoir acts as a settling basin, reducing turbidity and suspended sediment during high flows. However, on occasion, high wind or dredging activity in the reservoir can increase levels above downstream stream levels. The reservoir also results in increased water temperature due to its shallow depth and large surface area exposed to sunlight. Surface water released from Chorro Reservoir is warmer than the subsurface water and even warmer than the creek flowing into the reservoir. After leaving the dam into Chorro Creek, the water shaded and cooled by overhanging riparian trees such as western sycamores, coast live oaks, and California bay. CHD is just below the spillway, and may also influence dissolved oxygen levels at this site.

6.2 Methods

CHD is located just downstream of Chorro Creek Reservoir in an area that has not been heavily grazed in the past and serves as a "positive" control. CVC is located further downstream at a culvert crossing. A total cattle exclusion between CHD and CVC was constructed in 1995. Sampling for CHD was conducted initially at the spillway of the reservoir and later just down stream to allow for safer access. CHD and CVC are within a 1.0 km of each other and were consistently sampled with 0.5 hour of each other, between 8:00 and 9:00 a.m. Water quality (physical parameters) and flow data were collected as part of NMP project.

Rapid bioassessment was performed at Chorro Creek sampling stations CHD and CVC to understand benthic macro-invertebrate dynamics as an indication of water quality following BMP implementation. Samples were taken pre-BMP and post-BMPs. Regional Board staff and volunteers collected benthic macro invertebrates and sent them to the California Fish and Game laboratory for identification. Habitat Assessments were also performed. The Rapid Bioassessment methods are described in Chapter 3. Paired Watershed. Five cross-sectional profiles were measured at the implementation project between 1993 and 2000. Stream Profile methods are described in Chapter 4 Dairy Creek. Photo documentation was also conducted each year.

6.3 Results and Discussion

6.3.1 Water quality even-interval sampling

Water temperature

Regional Board Project staff has found that water temperature has improved at CVC as a result of BMP implementation. Prior to BMP implementation, CHD, the control site, had a mean water temperature of 15.47 °C, which was significantly higher than CVC (Table 6.1). After the implementation of the cattle exclusion fencing, both CHD and CVC mean water temperature increased. The mean increase was greater at CHD (Δ=0.75°C) than CVC (Δ=0.18°C) and again a significant difference occurred.

Table 6.1. Statistical results for water temperature °C between CVC and CHD.

Time Period	CHD - control	CVC - treatment	P-value
Pre-BMPs mean	15.47	14.85	0.001***
Post-BMPs mean	16.22	15.03	0.010*

*<α=0.05, ***<α=0.001

The difference in water temperature between CHD and CVC takes place in the summer months. Figure 6.1 displays even-interval water temperature at CHD and CVC during the 1996 and 1997 water year. Water temperature is similar at both sites in the winter and spring months, but differs during the late spring, summer, and fall months during low flow periods.

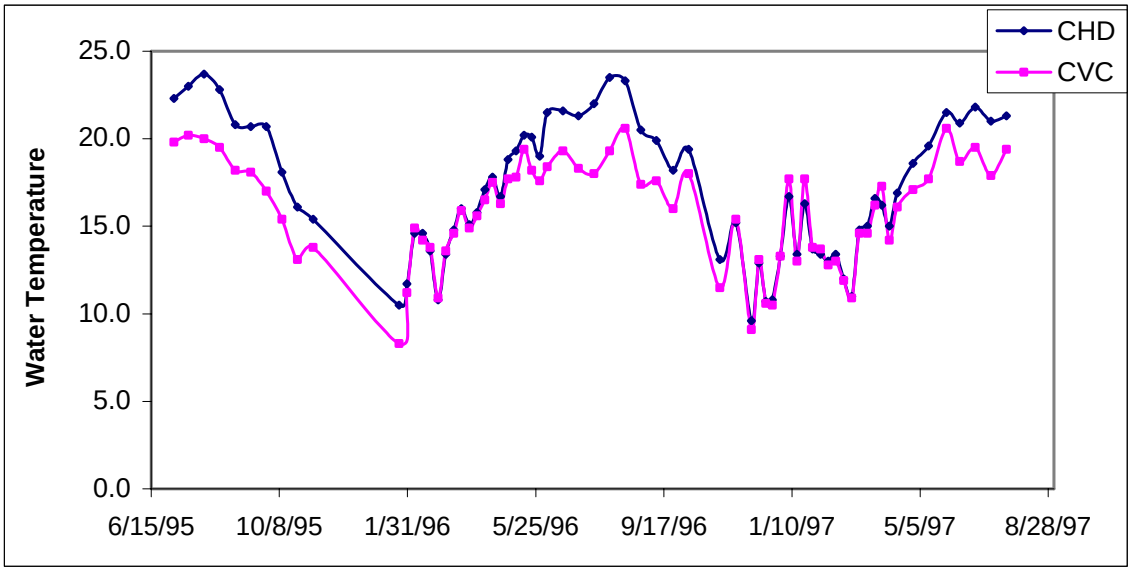


Figure 6.1. Even-interval water temperature at CHD and CVC for the water year 1995 and 1996. Water temperature is in C.

Air temperature

Air temperature is very similar between sites and time periods, pre- and post-BMPs. Mean air temperature increased on average 0.358°C at CHD and decreased 0.197°C at CVC during the post-BMP time period. Neither time period was found to be significantly different (Table 6.2). Air temperature is an environmental variable that can influence water temperature results (along with direct solar radiation). Results suggest that changes in air temperature did not effected water temperature (discussed above).

Table 6.2. Statistical results for air temperature °C between CVC and CHD.

Time Period	CHD - control	CVC - treatment	P-value
Pre-BMPs mean	17.029	17.493	0.114
Post-BMPs mean	17.387	17.296	0.129

Dissolved oxygen

Mean dissolved oxygen values decreased slightly from pre-BMPs to post-BMPs at CVC. Mean dissolved oxygen levels were the same at CHD and CVC pre-BMPs, and both means decreased during the post-BMP period. However, CHD experienced a greater decline with mean dissolved oxygen levels of 9.59 PPM to 8.38 PPM (Δ=1.21 PPM), while CVC changed from 9.59PPM to 9.02PPM (Δ=0.57 PPM). The difference in the post-BMPs time period was statistically significant (Table 6.3).

Table 6.3. Repeated Measures linear regression results for dissolved oxygen (PPM) °C between CVC and CHD.

Time Period	CHD	CVC	P-value
Pre-BMPs mean	9.589	9.589	0.441
Post-BMPs mean	8.380	9.024	<0.0001***

***<α=0.001

Figure 6.2 displays weekly dissolved oxygen readings for the 1994-water year, a pre-BMP year. When Figure 6.2 is compared to Figure 6.3 the difference post-BMPs are apparent. During the post-BMP period, CVC has consistently higher oxygen levels than CHD. As a result, Project Staff determined that BMP implementation (the total cattle exclusion fencing) significantly improved dissolved oxygen levels at CVC.

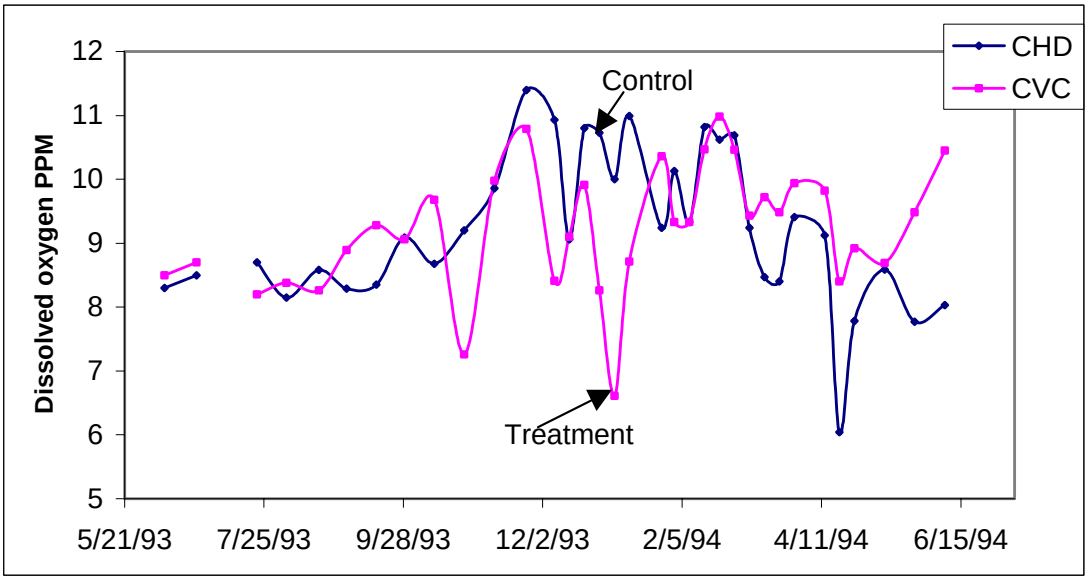


Figure 6.2. Weekly dissolved oxygen (PPM) values for CHD and CVC during the pre-BMP time period.

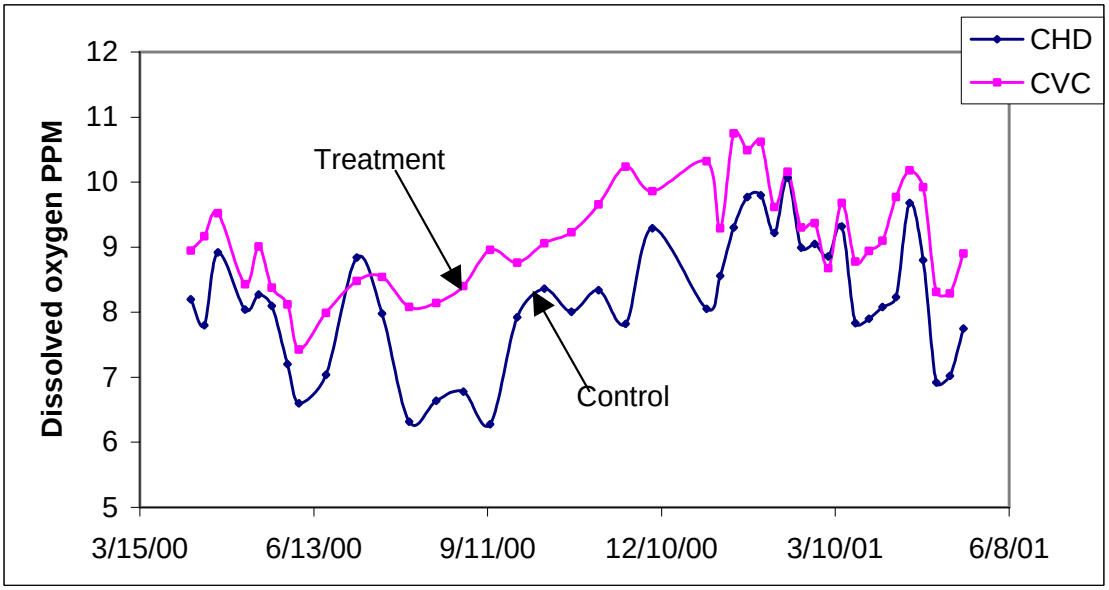


Figure 6.3. Weekly dissolved oxygen (PPM) data for CHD and CVC during the post-BMP time period.

Fecal coliform bacteria

Regional Board Project Staff found that fecal coliform bacteria levels decreased significantly at CVC after BMP implementation. Before BMPs were implemented, CHD had a mean of 24 MPN/100mL while CVC had an mean of 148 MPN/100mL, almost 7 times that of CHD, and was found to be significantly different (Table 6.4). Following implementation of the cattle exclusion fence, mean fecal concentrations increased at CHD from 24 to 43 MPN/100mL, while CVC experienced a decrease from 148 to 76 MPN/100mL. The reason for the increase in fecal coliform bacteria at CHD, the control, during the post-BMP period may be due to changes in cattle grazing in the upper area of the Chorro Creek watershed.

Table 6.4. Statistical results for Fecal Coliform Bacteria (MPN/100mL) between CVC and CHD.

Time Period	CHD	CVC	P-value
Pre-BMPs mean	24[1]	148	<0.0001***
Post-BMPs mean	43	76	<0.0001***

***<α=0.001 [1]Values are the inverse natural log of test values; Natural log values were used for the statistical analysis.

Figure 6.4 shows pre-BMP conditions at CVC and CHD. In Figure 6.4, 1998 (water year) weekly values for CVC and CHD during the post-BMP time period are displayed. Fecal coliform levels have dropped significantly for CVC and have increased at CHD.

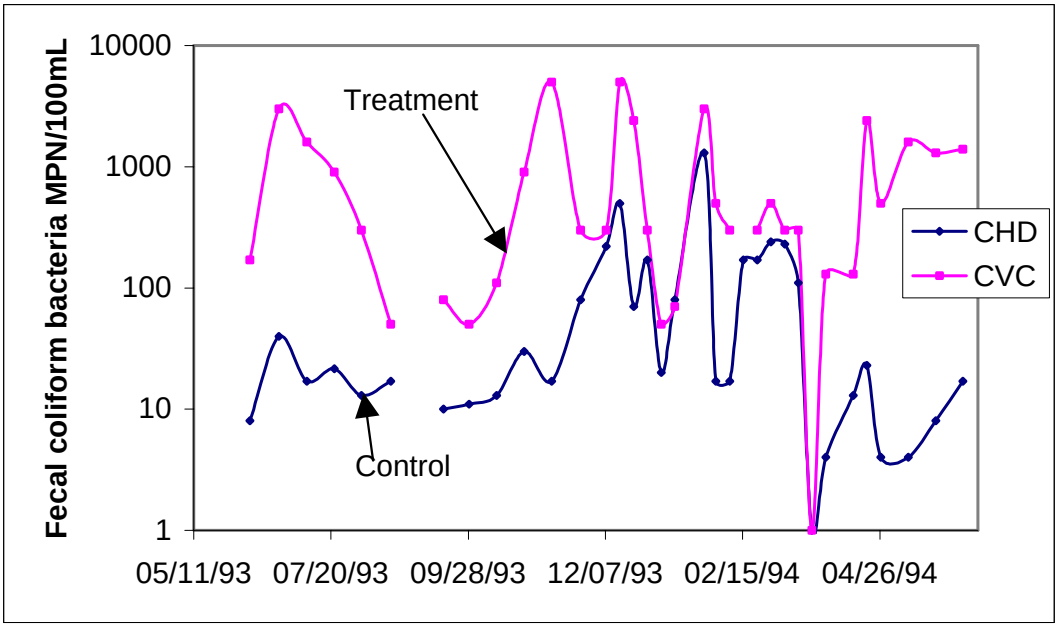


Figure 6.4. CVC and CHD even-interval fecal coliform bacteria values for the 1994 water year, pre-BMP time period. Y-axis scale is Log_{10}.

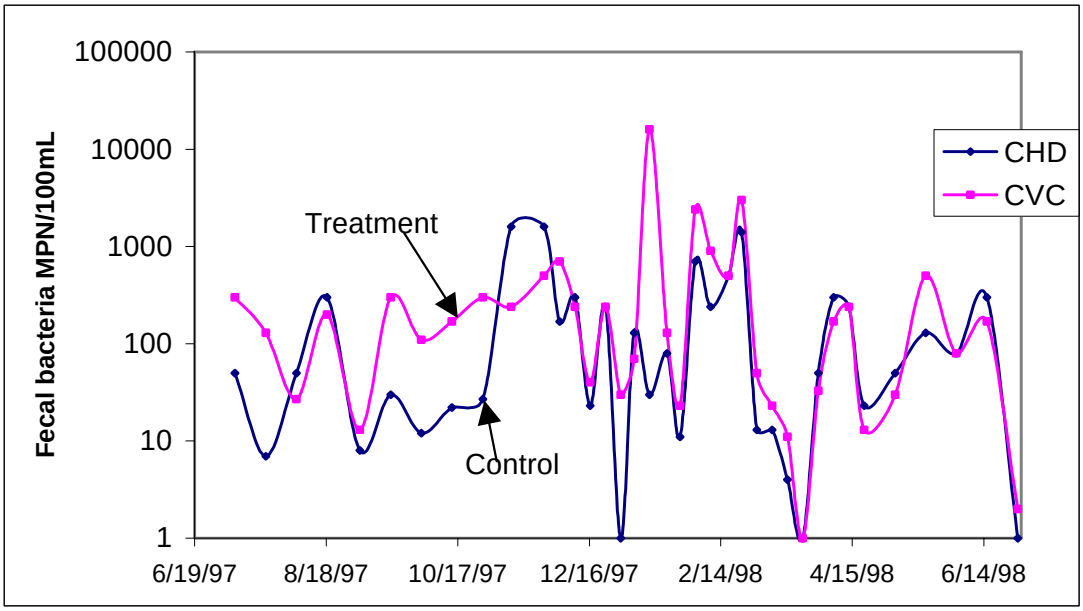


Figure 6.5. CVC and CHD even-interval fecal coliform bacteria values for the 1998 rain year, post-BMP time period. Y-axis scale is Log_{10}.

Fecal coliform bacteria data was also investigated using repeated-measure-binary-logistic-regression. Table 6.5 summarizes statistical results using a threshold of 200 MPN/100mL, the 1994 CCRWQCB fecal coliform bacteria water quality objective for water-contact recreation. Results from the logistic regression are similar to the linear regression (discussed previously). Figure 6.6 shows the percentages of samples over 200 MPN/100mL for CVC and CHD pre- and post-BMPs, and illustrates that CVC improved relative to CHD.

Table 6.5. Contingency table of the number of fecal coliform bacteria samples above and below the threshold for pre- and post-BMP implementation at CVC (threshold value = 200MPN/100mL).
CHD serves as the positive control. Also included is percentage of samples above and below the threshold, total number of samples, and p- values form binary logistic regression analysis. BMP start year is 1995.

		CVC-Treatment		**CHD-Control**	
		number	%	number	%
Pre-BMPs	<200 MPN	52	61	77	91
	≥200 MPN	33	39	8	9
	Total	85	100	85	100
	P value	<.0001***			
Post-BMPs	<200 MPN	95	70	99	73
	≥200 MPN	41	30	37	27
	Total	136	100	136	100
	P value	<.0001***			

***<α=0.001

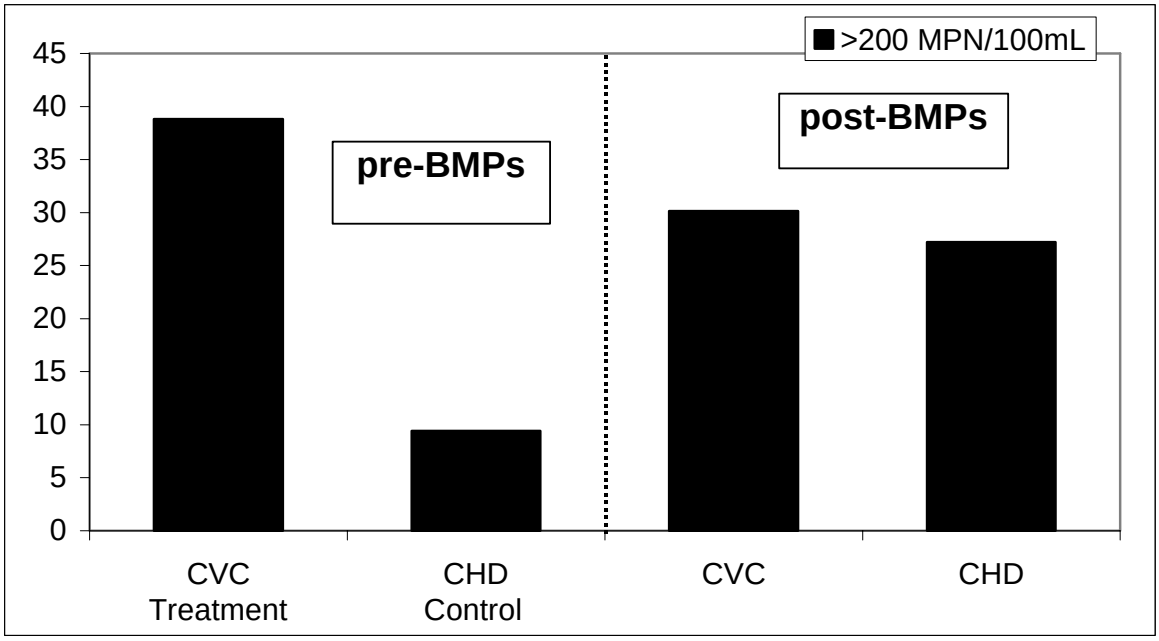


Figure 6.6. Bar graph depicting the percentage of fecal samples at CVC and CHD found to be over 200 MPN/100mL (CCRWQCB 1999 Basin Plan's Contact Recreational limit for fecal coliform bacteria levels) for pre-BMP and post-BMP time periods.
Also included is statistical analysis p-scores. The dotted line separates pre-BMPs (1993-1994, on left) from post-BMPs (1996-2001, on right).

A higher fecal coliform bacteria threshold of 2000 MPN/100mL was used to examine high flow fecal levels at CVC and CHD. Again, water quality at CVC improved while CHD declined. Both time periods were found to be statistically significant.

Table 6.6. Contingency table of the number of fecal coliform bacteria samples above and below the threshold for pre- and post-BMP implementation at CVC (threshold value = 2000MPN/100mL).
CHD serves as the positive control. Also included is percentage of samples above and below the threshold, total number of samples, and p- values form binary logistic regression analysis. BMP start year is 1996.

		CVC-Treatment		**CHD-Control**	
		number	%	number	%
Pre-BMPs	<2000 MPN	81	91	89	100
	≥2000 MPN	8	9	0	0
	Total	89	100	89	100
	P value	0.0003***			
Post-BMPs	<2000 MPN	153	97	153	97
	≥2000 MPN	4	3	4	3
	Total	157	100	157	100
	P value	0.0040**			

<α=0.01, *<α=0.001

Fecal coliform bacteria levels are improving at CVC as a result of implementation of a total cattle exclusion. Both tests, linear and logistic regression, and time series data suggests that CVC has improved from pre- to post-BMP and has experienced even a greater improvement when compared to CHD.

Total coliform bacteria

The percentage of total coliform bacteria greater than the threshold has not changed at CVC between pre- and post-BMP periods. A greater number of total coliform bacteria samples over the threshold (490 MPN/100mL) were found at CVC than at CHD (Table 6.7). Both time periods were found to be significantly different.

Table 6.7. Contingency table displaying the number of total coliform bacteria samples above and below the threshold for pre- and post-BMP implementation at CVC (threshold value = 490 MPN/100mL).
CHD serves as the positive control. Also included is percentage of samples above and below the threshold, total number of samples, and p- values form binary logistic regression analysis. BMP start year is 1996.

		CVC-Treatment		**CHD-Control**	
		number	%	number	%
Pre-BMPs	<490 MPN	39	44	61	69
	≥490 MPN	50	56	28	31
	Total	89	100	89	100
	P value	<0.0001***			
Post-BMPs	<490 MPN	68	43	93	59
	≥490 MPN	89	57	64	41
	Total	157	100	157	100
	P value	0.0497*			

*<α=0.05, ***<α=0.001

Turbidity

Using a binary logistic regression with a threshold of 10 NTU, NMP Project Staff did not find significant differences between turbidity samples at CVC and CHD. Table 6.8 shows the number and percentage of turbidity values at CVC and CHD below and above the threshold of 10 NTUs.

Table 6.8. Contingency table displaying the number of turbidity samples above and below the threshold for pre- and post-BMP implementation at CVC (threshold value = 10 NTUs). CHD serves as the positive control. Also included is percentage of samples above and below the threshold, total number of samples, and p- values form binary logistic regression analysis. BMP start year is 1996.

		CVC-Treatment		**CHD-Control**	
		number	%	number	%
Pre-BMPs	<8.87 NTUs	66	74	60	67
	≥8.87 NTUs	23	26	29	33
	Total	89	100	89	100
	P value	0.6207			
Post-BMPs	<8.87 NTUs	116	74	104	66
	≥8.87 NTUs	41	26	53	34
	Total	157	100	157	100
	P value	0.2451			

Differences between CVC and CHD can be seen in Figure 6.7. Turbidity varied between CVC and CHD, except during the rainy season, when turbidity levels were similar. Late spring through much of fall, turbidity levels at CHD were exceptional higher than CVC possibly due to algal blooms in the reservoir.

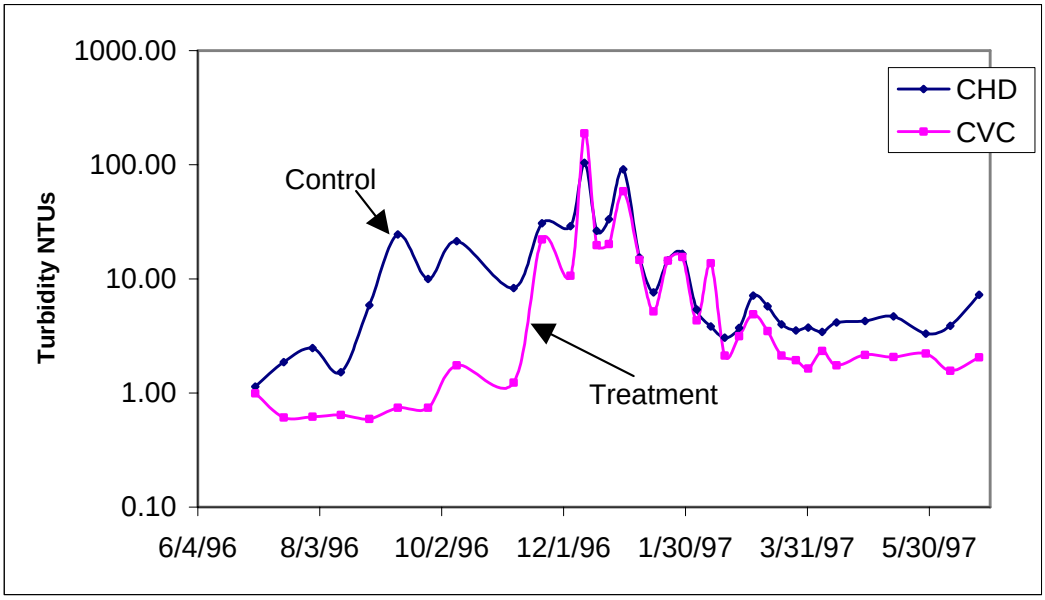


Figure 6.7. Weekly turbidity values for CVC and CHD during water year 1997.

6.3.2 Water Quality Conclusions

BMP implementation on Chorro Creek resulted in significant water quality improvements. Water temperature and dissolved oxygen has significantly improved at CVC, as with the other BMP implementation projects.

Fecal coliform bacteria improved at CVC as a result of the total cattle exclusion (BMP) implementation. Both tests, linear and logistic regression, and time series data suggests that CVC has improved from pre- to post-BMP and has experienced even a greater improvement when compared to CHD.

Other water quality parameters did not experience a significant change. Total coliform bacteria and turbidity remained similar when comparing pre-BMP to post-BMP conditions.

6.4 Rapid Bioassessment

NMP Project Staff evaluated benthic communities using an Index of Biological Integrity (IBI). As shown in Figure 6.8, IBI scores declined following the Highway-41 Fire. The Highway 41 Fire, which burned portions of the Chorro Creek subwatershed, makes it difficult to draw conclusions regarding BMP effectiveness. Overall IBI scores from the Morro Bay watershed are shown in Chapter 8.

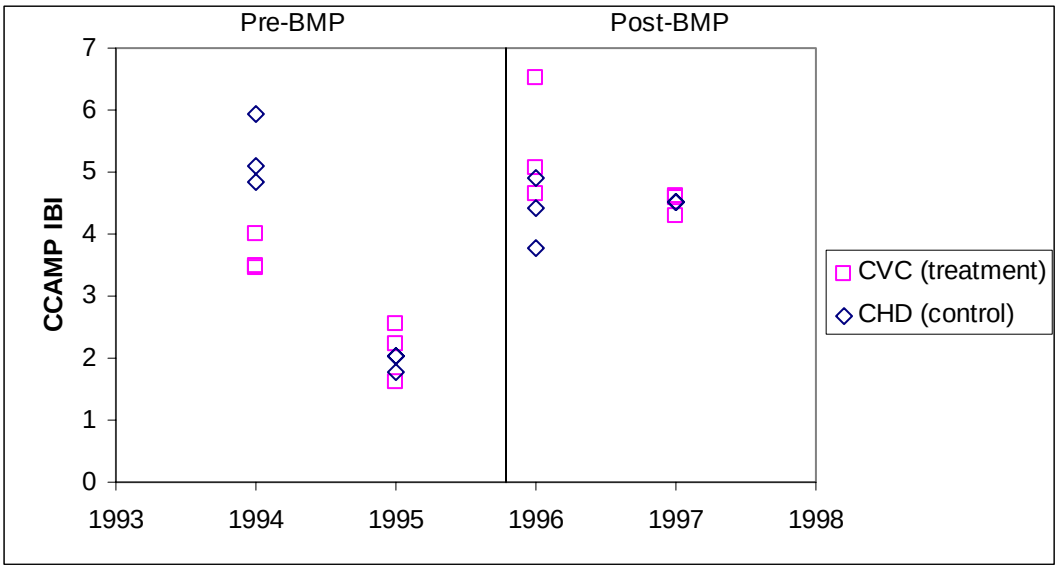


Figure 6.8. IBI scores at rapid bioassessment samples from 1994 to 1997. Pre-BMPs are 1994 and 1995 and post-BMPs are 1996 and 1997.
Cattle exclusion fence was installed in 1995 as indicated by the black line.

Percent Grazers at CVC and CHD were variable, and overall changes as a result of BMP implementation are not apparent. (Figure 6.9).

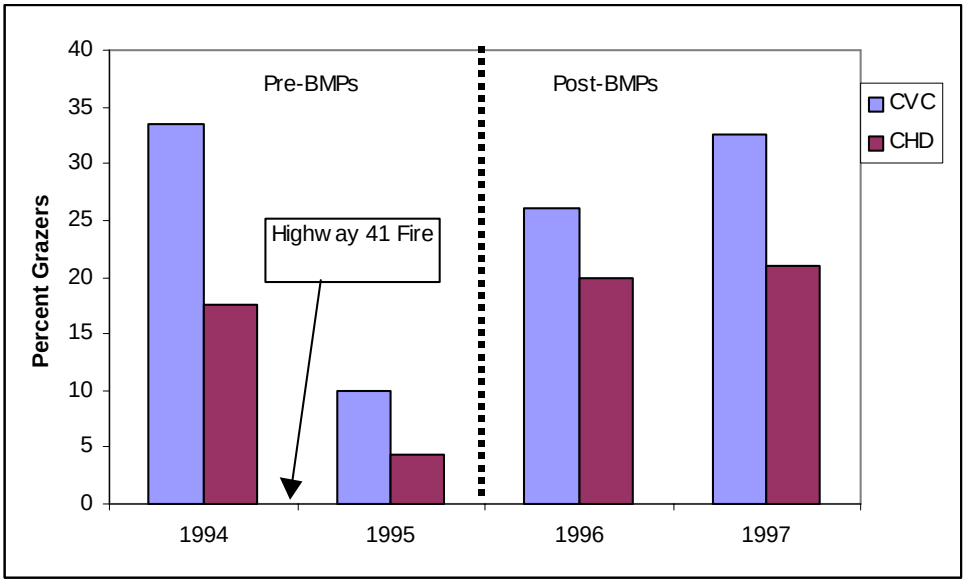


Figure 6.9. The percent of the benthic macro invertebrate feeding strategy Grazers, found at CVC and CHD rapid bioassessment samples from 1994 to 1997.
Pre-BMPs are 1994 and 1995 and post-BMPs are 1996 and 1997. Cattle exclusion fence was installed in 1995 as indicated by the black dotted line.

Two richness metrices were examined for Chorro Creek at CHD and CVC - Taxonomic Richness and EPT Taxa Richness. Following the Highway 41 fire, Taxonomic Richness declined dramatically at both CVC and CHD (Figure 6.10). In the post-BMP time period, Taxonomic Richness was variable and results are inconclusive regarding the effects of BMP implementation.

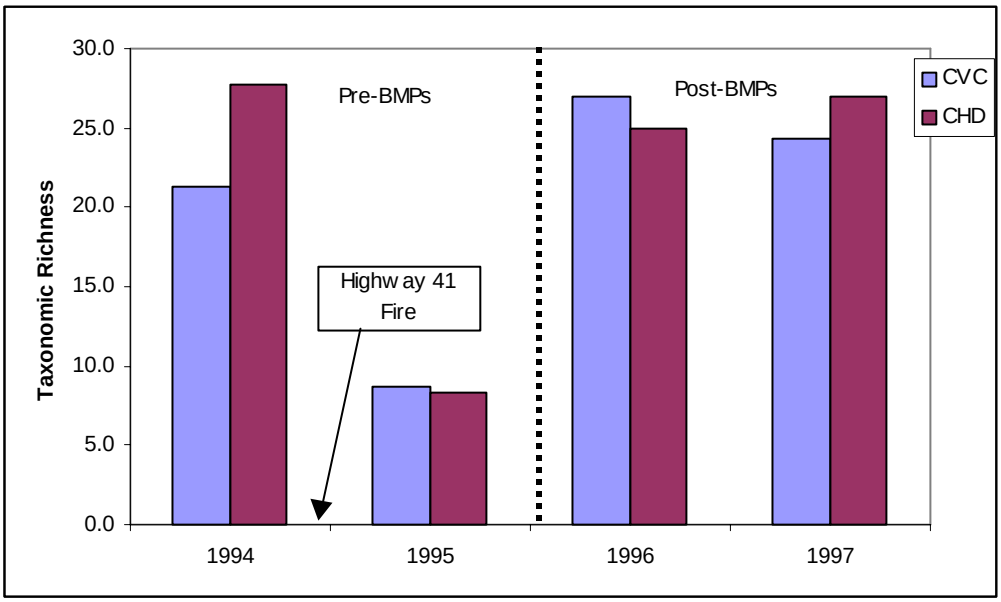


Figure 6.10. Taxonomic richness at CHD and CVC from 1994 through 1997. Pre-BMP time period is 1994, 1995, 1996 and post-BMP time period 1997.

The dash and dot line marks the end of BMP implementation. The dotted line marked the event of the Highway 41 fire. Cattle exclusion fence was installed in 1995 as indicated by the black dotted line.

EPT Taxa Richness was also variable (Figure 6.11). Again, the effectiveness of BMPs is difficult to determine with only two years of pre- and post-BMPs and the Highway 41 Fire.

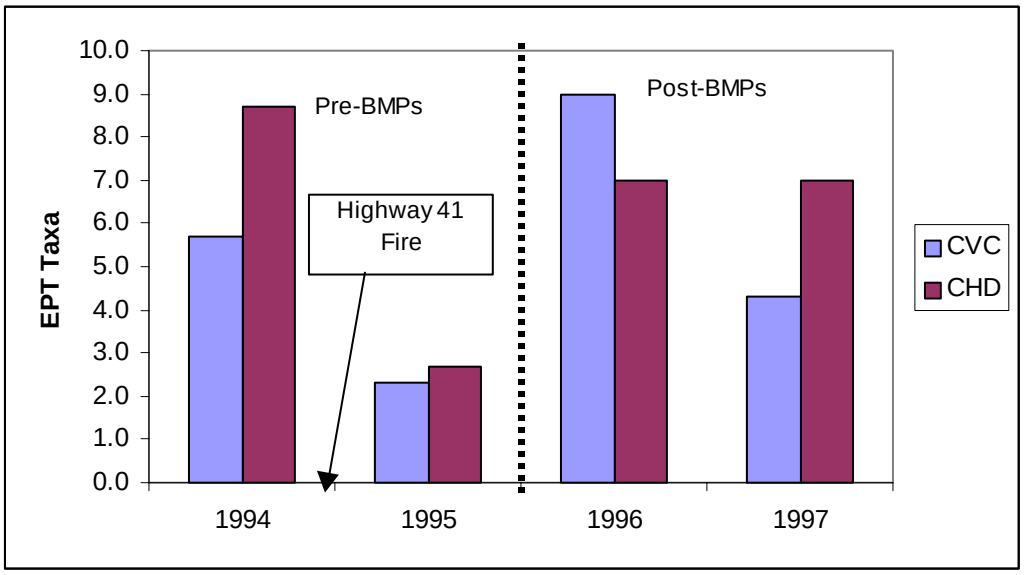


Figure 6.11. Abundance of EPT Taxa represented at CHD & CVC from 1994 - 1997.
Pre-BMP time period is 1994, 1995, and 1996 and post-BMP time period is 1997. The dash and dot line marks the end of BMP implementation. The dotted line marked the event of the Highway 41 fire. Cattle exclusion fence was installed in 1995 as indicated by the black dotted line.

During the pre-BMP period, CVC and CHD were similar (Figure 6.12). Following the implementation of BMPs, CVC improved when compared to CHD. This may imply that benthic invertebrate assemblages have improved, however, as with the other metrics, the effectiveness of BMPs are difficult to determine due to the limited number of samples, and the Highway 41 Fire.

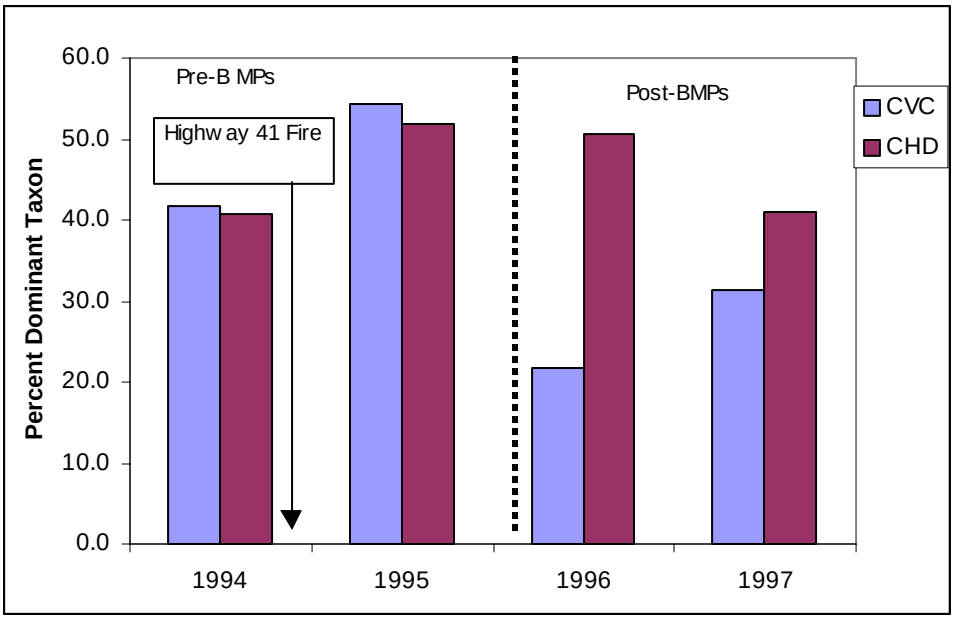


Figure 6.12. Percentage of the dominant macro-invertebrate taxon at CHD and CVC from 1994 to 1997.
A percent dominant taxon is defined as the percent of the sample dominated by the most abundant macro-invertebrate taxon (genera). Cattle exclusion fence was installed in 1995 as indicated by the black dotted line.

Habitat scores at CVC improved when compared to CHD, but due to the qualitative nature of the method, results are not definitive. The scores are shown in Figure 6.13.

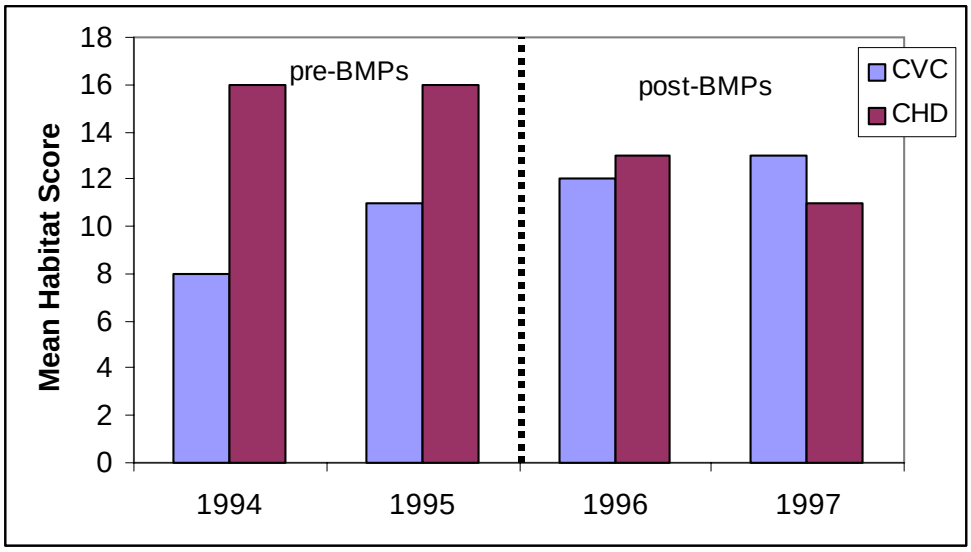


Figure 6.13. Mean Habitat Score for Upper Chorro Creek sites Chorro Dam (CHD) and Chorro Valley Culvert (CVC) between 1994 and 1997.
BMPs implemented in 1995. Post-BMPs is 1996 and 1997. 20 is the highest possible score.

6.4.1 Rapid Bioassessment Conclusions

Results suggesting that the BMPs were effective were apparent, however, trends are difficult to determine due to the limited number of pre-BMP samples, and because of the Highway 41 Fire. More data is necessary to provide a clearer picture of benthic macro-invertebrate community health.

6.5 Stream Profiles

Changes in stream channel shape have occurred in the upper reach of Chorro Creek during the study period (Figures 6.14 – 6.18) Stream bank erosion along Chorro Creek following the Highway 41 Fire and heavy stream flows during the 1994/1995 winter are shown in Figure 6.14.

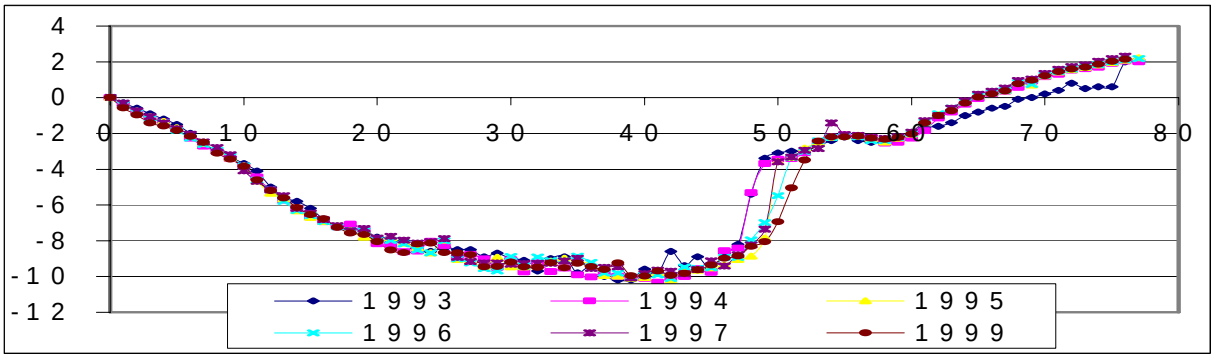
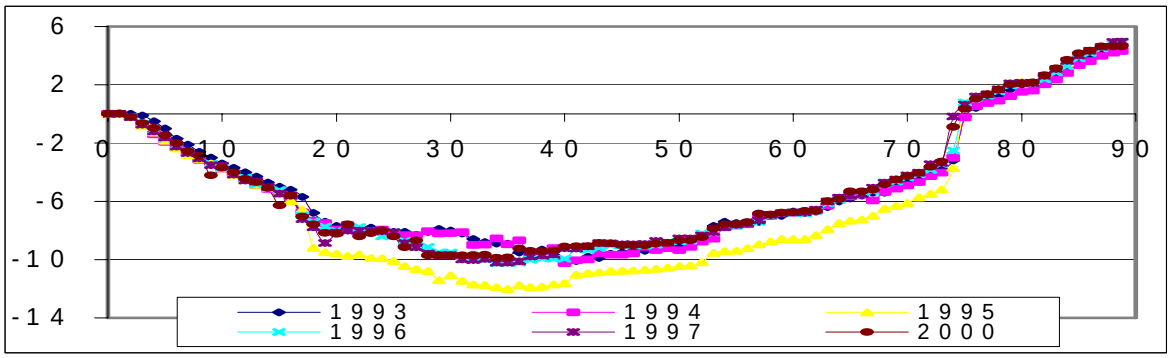


Figure 6.14. Cross sectional profile #0 of Chorro Creek. The X and Y axis are in feet units. The X axis is the height of the permanent reference point. The profile extends from left bank of creek (0 ft) to the right bank of the creek and was sampled in 1 foot increments.

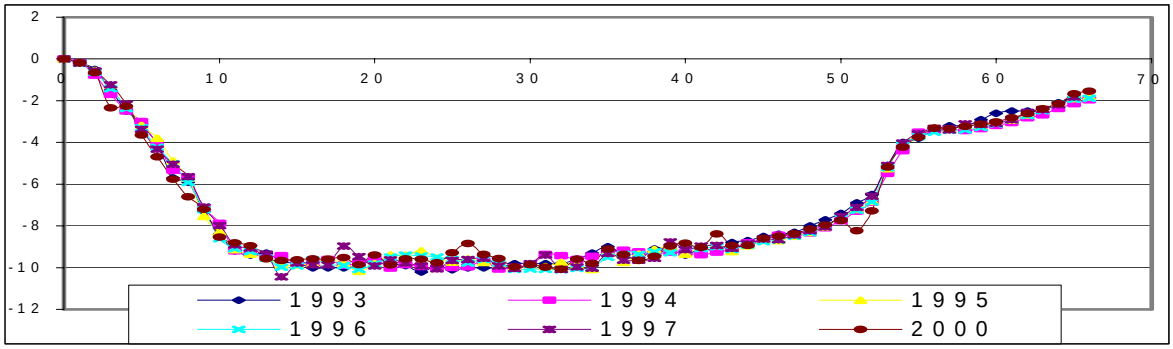
Another broader segment of Chorro Creek experienced substrate degradation between 1994 and 1995 and aggregation between 1995 and 1996 (Figure 6.15). This profile remained stable in subsequent years following BMP implementation..

Figure 6.15. Cross sectional profile #2 of Chorro Creek. The X and Y axis are in feet units. The X axis is the height of the permanent reference point. The profile extends from left bank of creek (0 ft) to the right bank of the creek and was sampled in 1 foot increments.



Stream profile #4 remained stable from 1993 to 2000 (Figure 6.16). Degradation of the Upper Chorro Creek steam profile #5 (Figure 6.18) occurred between 1994 and 1995.In subsequent years, channel changes continued but at a much slower rate.

Figure 6.16. Cross sectional stream profile #4 of Chorro Creek.



The X and Y axis are in feet units. The X axis is the height of the permanent reference point. The profile extends from the left bank (0 ft) to the right bank of the creek and was sampled in 1 foot increments.

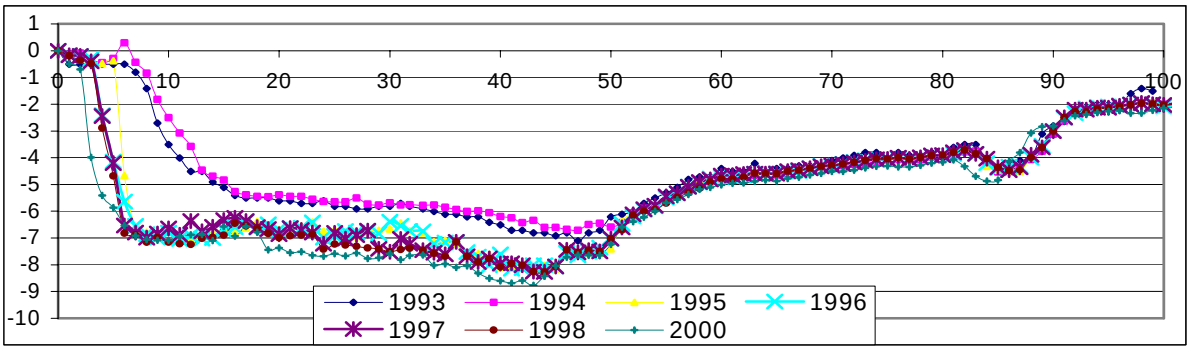


Figure 6.18. Cross sectional stream profile #5 of Chorro Creek.
The X and Y-axis are in feet units. The X-axis is the height of the permanent reference point. The profile extends from the left bank (0 Ft) to the right bank of the creek and was sampled in 1 foot increments.

6.5.1 Stream Profile Conclusions

The stream profiles do not appear to be affected by BMP implementation, but rather provide data for long-term stream morphology. Substrate results and photo documentation are included in the appendix.

6.6 Overall Conclusions

Water quality at CVC has improved after installation of total cattle exclusion fencing. Fecal coliform bacteria experienced the most significant improvement. The fecal coliform geometric mean decreased by half at CVC and fecal coliform levels became indicative of the upstream site CHD. This BMP evaluation project was the only one where significant declines in fecal coliform bacteria were found (see Chapters 3 and 4 for the different suites of BMPs implemented). These results suggest the most effective way to reduce fecal coliform levels in the Morro Bay watershed is to keep cattle from direct access to the creeks.

Water temperature and dissolved oxygen levels also improved due to BMP implementation. This is consistent with effects observed at the other BMP sites. Other water quality parameters such as total coliform bacteria and turbidity did not show improvement.

Rapid bioassessment and macro invertebrate metrices were inconclusive in determining effectiveness at CVC. The most noticeable event was the Highway 41 fire in August of 1994. Stream morphology, as shown in the stream profiles, on Upper Chorro Creek has not changed substantially except during heavy rain years following the Highway 41 Fire.