2016 Annual Report

Horse Creek Stewardship Program

January 2019, Final

Document Information

Prepared for	Mosaic Fertilizer, LLC.
Project Name	2016 Annual Report Horse Creek Stewardship Program
Project Number	E217009520
Project Manager	Sheri A. Huelster
Prepared By	Sheri A. Huelster – Cardno Kristan M.N. Robbins – Brown and Caldwell
Date	January 2019, Final

Prepared for:

Mosaic Fertilizer, LLC.
13830 Circa Crossing Drive, Lithia, FL 33547 USA

Prepared by:

Cardno, Inc.
3905 Crescent Park Drive, Riverview, FL 33578 USA

AND

Brown and Caldwell
5405 Cypress Center Drive Suite 250, Tampa FL 33609 USA

Table of Contents

Executive Summary ... viii
- Introduction ... viii
- Mining and Reclamation ... viii
- Monitoring Program Components ... viii
- Water Quantity Results ... ix
- Water Quality Results ... ix
- Benthic Macroinvertebrate Results ... xi
- Fish Results ... xi
- Conclusions ... xii

1 Introduction ... 1-1

2 Description of the Horse Creek Basin ... 2-4

3 Summary of Mining and Reclamation Activities ... 3-7
- 3.1 Mining ... 3-7
- 3.2 Reclamation ... 3-9

4 Methods ... 4-11
- 4.1 Station Locations and Sampling Schedule ... 4-11
- 4.2 Water Quantity ... 4-12
- 4.3 Water Quality ... 4-12
  - 4.3.1 Changes to Class III Dissolved Oxygen Standard ... 4-16
- 4.4 Benthic Macroinvertebrates ... 4-16
- 4.5 Fish ... 4-18
- 4.6 Initial General Habitat Configuration at Monitoring Stations ... 4-19
- 4.7 Current Habitat Configuration at Monitoring Stations ... 4-19

5 Water Quantity Results and Discussion ... 5-25
- 5.1 Rainfall ... 5-25
- 5.2 Stream Stage ... 5-28
- 5.3 Streamflow ... 5-30
- 5.4 Rainfall-Runoff Relationship ... 5-33
- 5.5 NPDES Discharges ... 5-36
- 5.6 Summary of Water Quantity Results ... 5-39

6 Water Quality Results and Discussion ... 6-40
- 6.1 Data Analysis ... 6-41
- 6.2 Physio-Chemical Parameters ... 6-45
- 6.3 Nutrients ... 6-53
- 6.4 Dissolved Minerals, Mining Reagents, and Radionuclides ... 6-60
- 6.5 Summary of Water Quality Results ... 6-70

7 Biological Results and Discussion ... 7-74
- 7.1 Benthic Macroinvertebrates ... 7-74
  - 7.1.1 Stream Habitat Assessment ... 7-74

7.1.2 Stream Condition Index 7-76
7.1.3 Total Taxa 7-78
7.1.4 Shannon-Wiener Diversity Index 7-79
7.1.5 Summary of Benthic Macroinvertebrate Results 7-82
7.2 Fish 7-83
7.2.1 Taxa Richness and Abundance 7-83
7.2.2 Shannon-Wiener Diversity Index 7-85
7.2.3 Morisita's Index of Similarity 7-89
7.2.4 Summary of Fish Results 7-90

8 Conclusions 8-93
8.1 Water Quantity Results 8-93
8.2 Water Quality Results 8-93
8.3 Benthic Macroinvertebrate Results 8-95
8.4 Fish Results 8-95

9 Recommendations 9-96
9.1 Previous TAG and Annual Report Recommendations 9-96
9.2 Current TAG Recommendations 9-97
9.3 Current Annual Report Recommendations 9-97

10 References 10-98

Appendices

Appendix A	Horse Creek Stewardship Program
Appendix B	Cumulative Chronological List of Procedural Changes to the HCSP
Appendix C	Additional Water Quality Graphs
	C.1 Period of Record HCSP Water Quality Data from 2003 to 2016
	C.2 Historical Water Quality Data Boxplots: Public Sources (1990-2016) and HCSP (2003-2016)
Appendix D	Literature Review of Statistical Trend Analysis Method
Appendix E	Tag Meeting Summary
Appendix F	Summary of Trigger Exceedances from 2003 to 2016
Appendix G	Summary of Impact Assessments from 2003 to 2016
Appendix H	Summary of Trends from the 2008 to 2015 HCSP Annual Reports
Appendix I	Investigation of Statistically Significant Water Quality Trends
Appendix J	Comments on HCSP SCI Data
Appendix K	Summary of Major Events, Lab Changes, and Potentially Erroneous Data Recorded During the HCSP
	K.1 Events Timeline
	K.2 Lab Changes Timeline
	K.3 Major MDL Changes

K.4 Possible Outlier Data Identified but Remaining in Analysis
K.5 Erroneous and Outlier Data Removed from Analysis

Tables

Table 3-1. Total acres mined, reclaimed to final contour, and reconnected by Mosaic in the Horse Creek and Brushy Creek Basins from 2004 to 2016. 3-7
Table 4-1. 2016 schedule of water quality and biological sampling events of the HCSP. 4-11
Table 4-2. HCSP water quality sampling field methods and acceptance limits associate with monthly sampling by Mosaic staff. 4-13
Table 4-3. Parameters analyzed and laboratory methods for HCSP during 2003 to 2016 monthly water quality samples. 4-14
Table 4-4. Parameters, general monitoring protocols, and corrective action trigger values for the HCSP. 4-15
Table 4-5. Equations for calculating SCI metrics for Peninsular Florida (individual metric scores range from zero to ten). 4-18
Table 4-6. Ecological interpretation of SCI scores calculated for benthic macroinvertebrate samples collected for the HCSP. 4-18
Table 5-1. Annual total rainfall in inches at gauges in the Horse Creek watershed from 2003 to 2016. 5-25
Table 5-2. Coefficients of rank correlation (r_s) for Spearman’s rank correlations of monthly gauge height (NGVD) from 2003 to 2016 ($p < 0.0001$). 5-28
Table 5-3. Median, 10th percentile, and 90th percentile streamflow (cfs) at HCSW-1 and HCSW-4 from 2003 to 2016. 5-31
Table 5-4. Coefficients of rank correlation (r_s) for Spearman’s rank correlations of HCSW-1 monthly average streamflow and total monthly rainfall at SWFWMD Flatford Swamp gauge and three Mosaic gauges from 2003 to 2016. 5-34
Table 5-5. 2016 total monthly Mosaic NPDES discharge to Horse Creek (FTG-003 and WIN-004 outfalls). 5-37
Table 5-6. Coefficients of rank correlation (r_s) for Spearman’s rank correlations of monthly average NPDES discharge and USGS daily streamflow, gauge height, and total monthly rainfall at three Mosaic gauges and a SWFWMD gauge from 2003 to 2016. 5-37
Table 6-1. Water quality summary of NPDES discharge into Horse Creek during 2016 at Outfall WIN-004. 6-40
Table 6-2. Summary of Seasonal Kendall-tau with LOESS (F=0.5) for HCSW-1 and HCSW-4 from 2003 to 2016. 6-43
Table 6-3. Summary of results from ANOVA for differences between stations from 2003 to 2016. 6-44
Table 6-4. Spearman’s Rank Correlation between water quality and water quantity at HCSW-1 and HCSW-4, as represented by average daily streamflow, average daily NPDES discharge, and total rainfall for the same month from 2003 to 2016. 6-44
Table 6-5. Instances of trigger level exceedance observed in 2016 HCSP monthly monitoring. 6-72
Table 6-6. Summary of trends over time (2003 to 2016) from Seasonal Kendall-tau analysis. 6-72

Table 7-1. Habitat scores obtained during HCSP biological sampling events in 2016. 7-75
Table 7-2. SCI 2012 metrics calculated for benthic macroinvertebrates collected at four locations in Horse Creek during 2016. 7-77
Table 7-3. Fish collected from Horse Creek during sampling events in 2016. 7-84
Table 7-4. Morisita's Similarity Index matrix comparing sapling dates within stations or within years for 2003 to 2016 samples. 7-89
Table 7-5. Percentage of individual fish captures per year for most abundant fish families/groups in Horse Creek from 2003 to 2016 as part of the HCSP. 7-90
Table 7-6. Number of individual fish captured per year for major native and exotic fish groups in Horse Creek from 2003 to 2016 as part of the HCSP[31]. 7-91

Figures

Figure 1-1. Overview of drainage basins, HCSP sampling locations, and Mosaic property in the Horse Creek Basin. 1-3
Figure 2-1. Aerial photograph of the Horse Creek Basin and the HCSP sampling locations. 2-6
Figure 3-1. Mining and reclamation areas in the Horse Creek Basin. 3-10
Figure 4-1. Panoramic photographs of the HCSP sampling locations. Photos taken on 25 April 2003. 4-22
Figure 4-2. Photographs of HCSP sampling locations on 17 March 2016. 4-23
Figure 4-3. Photographs of HCSP sampling locations on 16 November 2016. 4-24
Figure 5-1. Total monthly rainfall from three Mosaic gauges and one SWFEMD gauge in the Horse Creek watershed in 2016. 5-26
Figure 5-2. Total monthly rainfall from the average of three Mosaic gauges in the Horse Creek watershed from 2003 to 2016. 5-27
Figure 5-3. Stream stage at HCSP monitoring stations in 2016. Individual data points are from Mosaic's monthly monitoring and continuous lines are average daily stage from USGS (Stations 02297155 and 02297310). 5-29
Figure 5-4. Stage duration curves for HCSW-1 and HCSW-4 in 2016 showing percent of year water levels were at or above a given stage. Typical reference points of 10% (P10), 25% (P25), 50% (P50), 75% (P75), and 90% (P90) are indicated on the graph, as well as the minimum gauge heights (MGH) of HCSW-1 (66.3 ft. NGVD) and HCSW-4 (10.96 ft. NGVD). 5-29
Figure 5-5. Average daily streamflow at HCSW-1 and HCSW-4 in 2016. 5-30
Figure 5-6. Median (marker), 10th percentile (lower bar), and 90th percentile (upper bar) streamflow at HCSW-1 and HCSW-4 from 2003 to 2016. 5-32
Figure 5-7. Average daily streamflow at HCSW-1 and average daily rainfall (from three Mosaic gauges) in the Horse Creek watershed in 2016. 5-34
Figure 5-8. Monthly average of average daily streamflow at HCSW-1 and monthly sum of rainfall (average of NOAA 148 and 336 gauges) in the Horse Creek watershed from 1978 to 2016. 5-35
Figure 5-9. Double mass curve of cumulative daily discharge (USGS gauge at SR64) and rainfall (NOAA gauges 148 and 36) at HCSW-1 from 1978 to 2016. 5-36
Figure 5-10. Combined Mosaic NPDES discharge and average daily rainfall in the Horse Creek watershed in 2016. 5-38

Figure 5-11. Daily streamflow at HCSW-1 and combined Mosaic NPDES discharge in 2016. 5-38

Figure 6-1. Values of pH obtained during monthly HCSP water quality sampling and biological sampling events in 2016. 6-46

Figure 6-2. Relationship between daily mean pH (obtained from the continuous recorder at HCSW-1) and daily mean streamflow for 2016. Minimum pH detection limit = 0.1 SU. 6-46

Figure 6-3. Dissolved oxygen concentrations obtained during monthly HCSP water quality sampling and biological sampling events in 2016. 6-48

Figure 6-4. Dissolved oxygen percent saturations obtained during monthly HCSP water quality sampling and biological sampling events in 2016. 6-48

Figure 6-5. Relationship between daily mean DO concentration (obtained from the continuous recorder at HCSW-1) and daily mean streamflow for 2016. Minimum DO detection limit = 0.5 mg/L. 6-49

Figure 6-6. Relationship between daily mean DO percent saturation (obtained from the continuous recorder at HCSW-1) and daily mean streamflow for 2016. Minimum DO detection limit = 1%. 6-49

Figure 6-7. Turbidity levels obtained during monthly HCSP water quality sampling and biological sampling events in 2016. 6-50

Figure 6-8. Relationship between daily mean turbidity (obtained from the continuous recorder at HCSW-1) and daily mean streamflow for 2016. Minimum detection limit = 0.1 NTU. 6-51

Figure 6-9. Color levels obtained during monthly HCSP water quality sampling in 2016. 6-52

Figure 6-10. Total nitrogen concentrations obtained during monthly HCSP water quality sampling in 2016 (Data from samples where nitrate-nitrite nitrogen was undetected are circled in red.) 6-54

Figure 6-11. TKN concentrations obtained during monthly HCSP quality sampling in 2016. 6-55

Figure 6-12. Nitrate-nitrite nitrogen concentrations obtained during monthly HCSP water quality sampling in 2016. 6-56

Figure 6-13. Total ammonia nitrogen concentrations obtained during monthly HCSP water quality sampling in 2016. 6-57

Figure 6-14. Orthophosphate concentrations obtained during monthly HCSP water quality sampling in 2016. 6-58

Figure 6-15. Chlorophyll-*a* concentrations obtained during monthly HCSP water quality sampling in 2016. 6-59

Figure 6-16. Specific conductivity measurements obtained during monthly HCSP water quality sampling and biological sampling events in 2016. 6-61

Figure 6-17. Relationship between daily mean specific conductivity (obtained from the continuous recorder at HCSW-1) and daily mean streamflow for 2016. Minimum detection limit = 10 µmhos/cm. 6-61

Figure 6-18. Dissolved calcium concentrations obtained during monthly HCSP water quality sampling in 2016. 6-62

Figure 6-19. Dissolved iron concentrations obtained during monthly HCSP water quality sampling in 2016. 6-63

Figure 6-20. Total alkalinity concentrations obtained during monthly HCSP water quality sampling in 2016. 6-64

Figure 6-21. Chloride concentrations obtained during monthly HCSP water quality sampling in 2016. (HCSP trigger value for chloride is 250 mg/L.) 6-65

Figure 6-22. Fluoride concentrations obtained during monthly HCSP water quality sampling in 2016. 6-66

Figure 6-23. Sulfate concentrations obtained during monthly HCSP water quality sampling in 2016. 6-67

Figure 6-25. Total dissolved solids concentrations obtained during monthly HCSP water quality sampling in 2016. 6-68

Figure 6-25. Levels of total radium obtained during monthly HCSP water quality sampling in 2016. (All of the samples were undetected for Radium 228 except for July 2016 at HCSW-3 and March 2016 at HCSW-4.) 6-69

Figure 6-26. HCSP water quality correlations with average monthly NPDES discharge, average monthly streamflow, and total monthly rainfall at HCSW-1 from 2003 to 2016. 6-73

Figure 7-1. Total habitat scores obtained during HCSP biological sampling events at all locations from 2003 to 2016. 7-76

Figure 7-2. SCI scores for samples collected at all HCSP locations from 2003 to 2016. 7-78

Figure 7-3. Number of invertebrate taxa collected at all locations for the HCSP from 2003 to 2016. 7-79

Figure 7-4. Shannon-Wiener diversity indices for benthic macroinvertebrate genera from all HCSP locations from 2003 to 2016. 7-80

Figure 7-5. Shannon-Wiener diversity indices for benthic macroinvertebrate genera per year from Horse Creek for Combined sample dates and stations. 7-81

Figure 7-6. Shannon-Wiener diversity indices for benthic macroinvertebrate genera per station at Horse Creek for combined sample dates. 7-81

Figure 7-7. Species richness for fish at all HCSP locations from 2003 to 2016. 7-85

Figure 7-8. Shannon-Wiener diversity indices for fish samples from all HCSP locations from 2003 to 2016[31]. 7-86

Figure 7-9. Shannon-Wiener diversity indices and 95% confidence limits for fish samples from four stations in Horse Creek, summarized over sampling events within each year[31]. 7-87

Figure 7-10. Shannon-Wiener diversity indices and 95% confidence limits for fish samples from Horse Creek summarized over all stations per sampling event[31]. 7-87

Figure 7-11. Shannon-Wiener diversity indices and 95% confidence limits for fish samples from four stations in Horse Creek summarized over all sampling dates[31]. 7-88

Figure 7-12. Shannon-Wiener diversity indices and 95% confidence limits for fish samples from fourteen years at Horse Creek summarized over all stations combined[31]. 7-88

Figure 7-13. Species accumulation curve for each HCSP station and at all stations combined from 2003 to 2016. 7-92

Executive Summary

Introduction

This is the fourteenth annual report summarizing the status of the Horse Creek Stewardship Program (HCSP). After a series of legal challenges to the required permits, Mosaic Fertilizer, LLC (Mosaic) and the Peace River Manasota Regional Water Supply Authority (PRMRWSA) executed a settlement agreement to ensure that mining would not have negative impacts on Horse Creek, a major tributary of the Peace River, as a result of proposed mining activities by Mosaic in eastern Manatee and western Hardee Counties, Florida. A principal component of the agreement was the creation of the HCSP. The overall goals of the HCSP are to ensure that Mosaic's mining activities do not interfere with the ability of the PRMRWSA to withdraw water from the Peace River for potable use nor adversely affect Horse Creek, the Peace River, or Charlotte Harbor. The program, which is funded and managed by Mosaic, has two purposes: 1) in order to detect any adverse conditions or significant trends that may occur as a result of mining, the HCSP provides a protocol for the collection of information on the physical, chemical, and biological characteristics of Horse Creek during Mosaic's mining activities in the watershed, and 2) if detrimental changes or trends caused by Mosaic's activities are found, the HCSP provides mechanisms for corrective action. The program is limited to the investigation of the potential impacts of Mosaic mining activities on the Horse Creek Basin and is not intended to investigate the potential impacts of other land uses or mining activities by other entities.

This program has three basic components: 1) monitoring and reporting on stream quality, 2) investigating adverse conditions or significant trends that are identified through monitoring, and 3) implementing corrective action for adverse changes to Horse Creek caused by Mosaic's mining activities. The HCSP is unique in that it does not rely solely upon the exceedance of a standard or threshold to bring about further investigation and corrective action, where appropriate. The presence of a significant temporal trend alone will be sufficient to initiate such steps. This program offers additional protection to Horse Creek; this protection is not usually present in the vast majority of regulatory scenarios.

Monitoring for the HCSP began in April 2003, and this report, which is the fourteenth in a series of Annual Reports, presents the results of the first 14 years of monitoring, including historical data since 1990.

Mining and Reclamation

At the time the HCSP was initiated, some 12,000 acres of land in the Upper Horse Creek Basin had already been mined. From 2003 to 2015, about 3,701 additional acres were mined in the Horse Creek Basin upstream of the northernmost monitoring location, and an additional 1,409 acres were mined in the Brushy Creek basin upstream of BCSW-1 and HCSW-2. In 2016, 219 additional acres were mined in the Horse Creek Basin upstream of the northernmost monitoring location, and an additional 222 acres were mined in the Brushy Creek basin upstream of BCSW-1 and HCSW-2. Reclamation in 2016 included 162 acres reclaimed to final contour (zero acres in Brushy Creek basin) and 138 acres reconnected (zero acres in Brushy Creek basin).

Monitoring Program Components

Four locations on Horse Creek were monitored for physical, chemical, and biological parameters; two of these sites are also long-term US Geological Survey (USGS) gauging stations. Water quantity data were collected continuously from the USGS gauging stations at HCSP stations HCSW-1 and HCSW-4. Rainfall data were collected daily from three Mosaic rain gauges located in the Horse Creek Basin. Water quality data were collected during monthly sampling events at HCSP stations HCSW-1 to HCSW-4, continuously from one Horse Creek station (HCSW-1), and at all four stations during biological sampling events. Biological (fish and benthic macroinvertebrates) sampling events are scheduled to occur three times each year.

Water Quantity Results

The annual average daily streamflow at Horse Creek in 2016 at both HCSW-1 (67 cfs) and HCSW-4 (229 cfs) was above the long-term annual averages[1] of 32 and 189 cfs, respectively. Annual rainfall of 63 inches in 2016 was above the long-term average annual rainfall of 53 inches (1908-2016)[2]. In 2016, there was a period of slightly higher flow during the dry season that corresponded to heavy rain events (mid-January to mid-February). Then, flows were generally low from March to early-June before increasing rapidly; flows were then variable for the remainder of the wet season, responding to high rainfall events. Additionally, a final large increase in streamflow occurred in early-October before water levels decreased through the end of the year, similar to historical patterns (Durbin and Raymond 2006). At the beginning of the wet season, the lag effect between rainfall and streamflow is more apparent as the surrounding wetlands or small creeks either need to fill or resume flow. However, later in the wet season when the wetlands and small creeks are full, the lag is much shorter.

NPDES discharge accounted for 73 percent of streamflow on average at HCSW-1 during the period of NPDES discharge (ranging from 12 percent to 100 percent over the 283 days of discharge). NPDES discharge from March to December was a lagged response to larger rainfall events that occurred from late-January through February and multiple moderate (greater than one inch) rainfall events that continued through the wet season; NPDES discharge from the Horse Creek outfalls usually does not occur until sufficient water storage accumulates in the mining circulation system, resulting in a lag. In general, the above average rainfall in 2016 coupled with multiple moderate rain events during the wet season led to a steady volume of NPDES discharge to Horse Creek.

There is no evidence that mining and reclamation activities in the basin caused any statistically significant decrease in total streamflow in 2016, according to the double mass curve analysis. In a previous study (Robbins and Durbin 2011) that compared streamflow during dry years in reference and potentially impacted streams before and during phosphate mining, there was no evidence that phosphate mining practices caused lower monthly flows in the potentially impacted streams (including Horse Creek) than what would be expected given the conditions in a reference stream (Charlie Creek).

Water Quality Results

Water quality parameters in 2016 were almost always within the desirable range relative to trigger levels and water quality standards at the station with the highest percent of upstream mined lands (HCSW-1). Alkalinity was the only parameter above the trigger level at HCSW-1 during 2016, but the exceedance was only 16 mg/L above the trigger and did not occur during a time of NPDES discharge. The dissolved oxygen trigger level was exceeded during most of the year at HCSW-2 (February through December 2016). Based upon historical conditions in Horse Creek (Durbin and Raymond 2006), the reported values for dissolved oxygen at HCSW-2 are the result of natural conditions (proximity to hypoxic segment of stream – Horse Creek Prairie) and are not related to mining activities. Total nitrogen was above the trigger level in February 2016 at HCSW-3; this sample was also comprised mainly of nitrate-nitrite. There did not appear to be a lab error for this sampling event, but the sample was collected following a few days of high rainfall totals. Dissolved iron concentrations consistently exceeded the trigger value set at HCSW-4 (July to September 2016), but Mosaic and the PRMRWSA agree that the trigger value at that station has been set too low given historical and upstream concentrations of dissolved iron. Based on impact

---

[1] Long-term annual average of daily streamflow calculated for 1978 to 2016 for HCSW-1 and 1951 to 2016 for HCSW-4 using USGS gauging stations.

[2] Historical rainfall information came from the following stations and years: 1908 to 1943 NOAA station 148, 1944 to 2016 average of NOAA station 148 and 336.

assessments already completed, none of the observed exceedances pose a significant adverse ecological impact to Horse Creek that would be attributable to mining.

Twelve water quality parameters showed statistically significant increasing or decreasing trends in 2016 at HCSW-1 or HCSW-4. Several of the trends detected during the statistical analysis either have an estimated slope that 1) was not in the direction of an adverse trend (dissolved oxygen concentration, dissolved oxygen saturation, color, ammonia, and dissolved iron) or 2) was very small compared to the observed differences between primary and duplicate field samples (pH and fluoride). Specific conductivity, TDS, and various dissolved ions had reported trends with higher estimated rates of change. The potential trends for pH and specific conductivity (with reference to TDS and other ions) are discussed in Appendix I. The apparent change in pH since 2003 is not a strong trend when compared to SWFWMD data collected at the same place, and the observation of similar change-point increases at HCSW-1 and upstream stations around the drought period lead to the conclusion that pH is not having an ecologically significant increase at HCSW-1 over the course of the HCSP program and is not of concern at this time.

For specific conductivity, a significant increasing trend was detected at HCSW-1 even when the period of record was expanded, but an analysis of other stations shows the influence of climatic and upstream conditions. At least part of the increase may be caused by regional influences, as Charlie Creek (an unmined stream) and Horse Creek closely mirror each other; Charlie Creek and Horse Creek show a step-change increase in conductivity around 2006 to 2007, followed by stable or decreasing levels through 2016. Specific conductivity at Horse Creek and West Fork Horse Creek stations upstream of the NPDES outfalls show similar trends and step-change increases. In addition, the trends at the upstream stations begin well before the beginning of the HCSP program. Specific conductivity at HCSW-1 began to rise during a very dry period in 2006 to 2008 (from 100–400 µmhos/cm to 200–500 µmhos/cm) when Mosaic had very little NPDES discharge into Horse Creek, and the stream was dominated by baseflow (surficial aquifer) contributions. Water resulting from Wingate dredge mining activities began to discharge from the two Horse Creek NPDES outfalls in late 2008; dredge mining is more influenced by groundwater than conventional mining. Although HCSW-1 specific conductivity remained at higher levels (200–600 µmhos/cm) after 2008, concentrations at three of the four Horse Creek stations upstream of the NPDES outfalls were also higher during that time period.

When compared to another upstream station on West Fork Horse Creek or station on Charlie Creek, the majority of HCSW-1 observations fall within the 95% prediction interval of the other stations. Thus, while some isolated conductivity values at HCSW-1 may be related to increased groundwater influence at NPDES discharges, the majority of the increasing trend at HCSW-1 can be explained by other factors. The trend for specific conductivity and other ions may have been influenced by regional factors unrelated to mining, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities, but the current concentrations are stable and not biologically harmful. Any small portion of the change in specific conductivity (and other related ions) that may have been affected by changes in NPDES water quality is likely to stay relatively constant at HCSW-1 in the near future given planned mining practices and the stable range of concentrations shown since Wingate mine began discharging to Horse Creek in 2008.

Dissolved ion concentrations at HCSW-1 in recent years still meet all applicable state drinking water and Class III surface water standards, except where otherwise noted in previous monthly impact assessments. In addition, the current specific conductivity concentrations at HCSW-1 are within the preferred range of Horse Creek freshwater fish species, and the diversity and composition of fish populations have remained steady over the HCSP study period with no correlation with specific conductivity. SCI scores, an indicator of benthic macroinvertebrate community health, have also remained steady over the HCSP study period and show no relationship with specific conductivity.

Significant differences between stations were evident for several parameters. When stations were compared, HCSW-2 was the most dissimilar from the other three stations, especially in pH, dissolved oxygen, color, chlorophyll-*a*, and some dissolved ions. Some nutrients (nitrate-nitrite) and dissolved ions (specific conductivity, calcium, chloride, and sulfate) had higher concentrations downstream in Horse Creek (at HCSW-3 and HCSW-4), probably because of increased groundwater seepage and agricultural irrigation runoff in the lower Horse Creek basin. Differences in topography, geology, and land use that could account for these station differences in Horse Creek are examined in the Horse Creek Stewardship Program Historical Report (Durbin and Raymond 2006).

Water quality parameters were compared with water quantity variables recorded during the same month: average daily streamflow for the month, average daily NPDES discharge for the month, and total monthly rainfall. In general, pH, dissolved oxygen, and most dissolved ions are higher when the overall quantity of water in the Horse Creek system is low. (In this report, chlorophyll-a, specific conductivity, calcium, alkalinity, sulfate, and TDS showed the opposite pattern with NPDES discharge at HCSW-1.) Conversely, turbidity, color, iron, and nitrogen are high when the water quantity is also high. When water quantity in Horse Creek is low, the stream is often pooled or slow-moving, leading to algal blooms that may increase pH and chlorophyll-a. In addition, the majority of water in the stream during low quantity periods may be from groundwater (seepage or agricultural runoff); groundwater has a higher concentration of dissolved ions than surface water. When water quantity is high because of rainfall or streamflow, an increased amount of sediment and organic debris is washed into the stream, leading to increases in turbidity, color, iron, and nitrogen.

Benthic Macroinvertebrate Results

The general quality of the macroinvertebrate community at the Horse Creek stations was within the range commonly observed by Cardno in similarly-sized natural streams in this region of Florida. Habitat scores ranged from 105 to 131 at all stations in 2016, which is typical of previous scores for the HCSP. Recent SCI scores at three of the four stations are consistently above 35; in 2016 station HCSW-2 had one SCI score above 35 and one below 35 similar to past scores because of unique, natural upstream conditions (Horse Creek Prairie).

Benthic invertebrate taxa diversity and SCI metrics in Horse Creek exhibited both seasonal and year-to-year variation. Overall, taxa diversity indices and SCI metrics show few monotonic trends over time and are very similar between sampling events and stations. However, HCSW-2 has lower SCI scores (long term average of 32 compared to 61-64) than other stations because of natural conditions. Natural habitat conditions at HCSW-2 include lower streamflow, dissolved oxygen, and pH than other Horse Creek stations; these conditions are related to the lower than average streamflow and rainfall of the previous few years and the presence of Horse Creek Prairie, the large marsh located upstream of the biological sampling station.

Fish Results

During 2016, 23 species of fish were collected from the four Horse Creek sampling stations. Abnormally cold winters in 2009 to 2010 and 2010 to 2011 may have led to decreased fish diversity at some stations in 2010 and 2011, with evidence of recovery and recruitment in 2012 and 2013. Over the period of record, fish richness and diversity was lowest at HCSW-2, but there were no increasing or decreasing trends in richness over time at any station. Fish communities were similar by sampling date when data were combined by station, but diversity was lower in 2010 and higher in 2013 when stations were combined by year. Additionally, there was a slight decreasing trend in diversity during the spring sampling events when HCSW-1, HCSW-3 and HCSW-4 were combined. No consistent patterns over time were evident in the abundance of fish from exotic and native fish groups.

Conclusions

This report covers the fourteenth year of an ongoing monitoring program, where some general conclusions can be drawn. Expected relationships between rainfall, runoff and streamflow were observed in the 2003 to 2016 water quantity data. Program trigger levels were exceeded for four (4) parameters in 2016 and 12 parameters had statistically significant trends from 2003 to 2016, but the exceedances and trends are not of immediate concern (Appendix I). The benthic macroinvertebrate and fish communities found in Horse Creek in 2003 to 2016 were typical of those found in a Southwest Florida stream.

1 Introduction

As a result of proposed mining operations by Mosaic Fertilizer, LLC (Mosaic) in eastern Manatee and western Hardee Counties, Florida, and a series of legal challenges to the permits required for such mining, Mosaic and the Peace River Manasota Regional Water Supply Authority (PRMRWSA) executed a settlement agreement structured to ensure that mining would not have negative impacts on Horse Creek, a major tributary of the Peace River. A principal component of that agreement was the creation of the Horse Creek Stewardship Program (HCSP), which is funded and managed by Mosaic. The program document, as referenced in the settlement agreement, is provided as Appendix A.

There are two purposes for the HCSP. First, it provides a protocol for the collection of information on the physical, chemical, and biological characteristics of Horse Creek during Mosaic's mining activities in the watershed (Figure 1-1). This information would then allow the ability to detect any adverse conditions or significant trends that may occur as a result of mining. Second, it provides mechanisms for corrective action with regard to detrimental changes or trends caused by Mosaic's activities, if any are found. The program is limited to the investigation of the potential impact of Mosaic mining activities on the Horse Creek Basin and is not intended to investigate the potential impacts of other land uses or mining activities by other entities.

The overall goals of the program are to ensure that Mosaic's mining activities do not interfere with the ability of the PRMRWSA to withdraw water from the Peace River for potable use nor adversely affect Horse Creek, the Peace River, or Charlotte Harbor. There are three basic components to the HCSP: 1) monitoring and reporting on stream quality, 2) investigating adverse conditions or significant trends identified through monitoring, and 3) implementing corrective action for adverse stream quality changes attributable to Mosaic's activities. An important aspect of this program is that it does not rely solely upon the exceedance of a standard or threshold to bring about further investigation and, where appropriate, corrective action. The presence of a significant temporal trend alone is sufficient to initiate such steps. This protection mechanism is not present in the vast majority of regulatory scenarios.

In brief, the HCSP provides for the following data collection:

- Continuous recording (via USGS facilities) of stage and discharge at two locations on the main stem of Horse Creek
- Daily recording of rainfall via Mosaic and USGS rain gauges in the upper Horse Creek basin
- Continuous recording of temperature, dissolved oxygen, conductivity, turbidity and pH at HCSW-1, the Horse Creek station nearest to Mosaic's active mining operations
- Monthly water quality monitoring of 21 parameters at four stations on the main stem of Horse Creek[3]
- Sampling of fish, benthic macroinvertebrates and field water quality parameters (temperature, dissolved oxygen, conductivity, turbidity and pH) three times annually at the same four stations on the main stem of Horse Creek

HCSP monitoring began in April 2003. At the time the HCSP was initiated, some 12,000 acres of land in the Upper Horse Creek Basin had been previously mined. From 2003 to 2015, about 3,701 acres were mined (by Mosaic or legacy CF Industries operations) in the Horse Creek Basin upstream of the northernmost monitoring location, and an additional 1,409 acres were mined (by legacy CF Industries operations) in the Brushy Creek basin upstream of BCSW-1 and HCSW-2. In 2016, 219 acres were

---

[3] In 2009, the list of parameters was reduced by three (total amines, total fatty acids, and FL-PRO were removed), and an additional station on Brushy Creek (tributary of Horse Creek) was added.

mined in the Horse Creek Basin upstream of the northernmost monitoring location, and an additional 209 acres were mined in the Brushy Creek basin upstream of BCSW-1 and HCSW-2. Water quantity data are collected essentially continuously, water quality data are collected monthly, and biological data (fish and benthic macroinvertebrates) are collected three times annually (March to April, July to September, and October to December). Specific months when biological sampling occurs may change from year to year to avoid very low or very high flows, which would impede representative sampling.

This report, which is the fourteenth in a series of Annual Reports, presents the results of monitoring conducted from April 2003 through December 2016. All data presented in tables and figures was collected as part of the HCSP unless otherwise noted. Additional sources of data since 1990 have also been included in the box plots to provide a short historical perspective (Appendix C). A separate HCSP historical report (Durbin and Raymond 2006) contains a review and summary of all available historical water quality and biological information for Horse Creek.

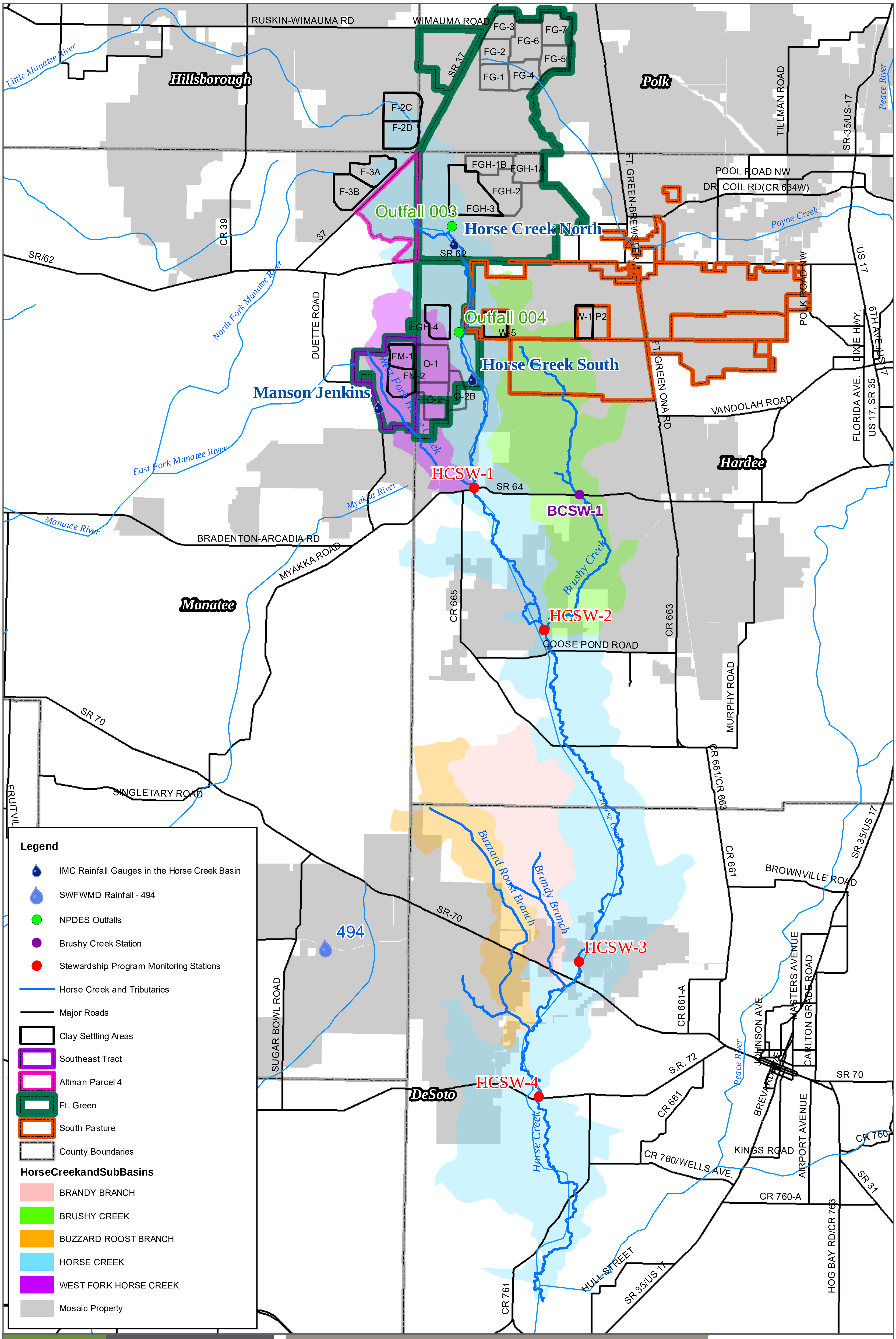


Figure 1-1. Overview of drainage basins, HCSP sampling locations, and Mosaic property in the Horse Creek Basin.

0 15,000 30,000 Feet
0 4,572 9,144 Meters

Cardno
Shaping the Future
3905 Crescent Park Drive, Riverview, FL 33578 USA
Phone (+1) 813-664-4500 Fax (+1) 813-664-0440
www.cardno.com

Date Created: 11/30/2018 Date Revised: 11/30/2018 File Path: Q:\UnitedStates\Florida\Tampa\Mosaic\HorseCreekStewardshipProgram\working\arcmap\Horse_Creek_Overview_2015_working_20181130.mxd
GIS Analyst: James.Bottiger

2 Description of the Horse Creek Basin

The Horse Creek basin is located in five counties of South-Central Florida: Hillsborough, Polk, Manatee, Hardee, and Desoto, with the majority of the watershed spanning portions of western Hardee and DeSoto Counties (Figures 1-1 and 2-1). Horse Creek is a major tributary of the Peace River that drains into the southwestern portion of the Peace River Basin and supplies approximately 15 percent of the surface water runoff to the Peace River (Lewelling 1997).

The basin occupies some 241 square miles, and the length of the channel is approximately 43 miles. Horse Creek has an elongated basin with a north-to-south drainage that is influenced by the general topography of the area. Six sub-basins and five tributaries make up the Horse Creek Basin. West Fork Horse Creek and Brushy Creek, two northern tributaries in the Polk Uplands, are generally straight, at least partially channelized, and have relatively rapid flows (Lewelling 1997). The remaining tributaries, occupying the central to southern Horse Creek Basin, include Buzzard Roost Branch and Brandy Branch. These lower reaches are located in the DeSoto Plains/Gulf Coast Lowlands area and are generally meandering, slower streams. Horse Creek ultimately discharges into the Peace River near Fort Ogden (SWFWMD 2000).

The topography of the Horse Creek basin generally follows the north-to-south drainage flows of the creek. Elevation in the basin ranges from 135 feet in the north to 30 feet in the south near the confluence of Horse Creek and the Peace River. The basin is located in the mid-peninsular physiographic zone of Florida, in three subdivisions: Polk Uplands, DeSoto Plains, and Gulf Coast Lowlands. The Polk Uplands underlie the northern portion of the Horse Creek Basin, where the elevation generally exceeds 100 feet NGVD. In this location, the channel of Horse Creek is generally steep and slightly incised, with swiftly moving water. The central Horse Creek basin is located in the DeSoto Plain. Average elevations in this area range from 30 to 100 feet NGVD. Where Horse Creek enters the Peace River, the Gulf Coast Lowlands range in elevation from about 30 to 40 feet NGVD. The Horse Creek channel in the Desoto Plain and Gulf Coast Lowlands is slower and more sinuous than the northern channel (SWFWMD 2000, Lewelling 1997).

The northern Horse Creek Basin is located in the Polk Uplands, with Pomona-Floridana-Popash soils characterized by nearly level, poorly drained, and very poorly drained sandy soils. Some soils in this association have dark colored subsoil at a depth of less than 30 inches over loamy material, and some are sandy to a depth of 20 to 40 inches and are loamy below. The extreme northern basin of Horse Creek contains isolated areas of the Arents-Hydraquents-Neilhurst soils group, parts of which have been strip-mined for phosphate (Robbins et al. 1984).

The central and southern Horse Creek Basin is located in the DeSoto Plain, which is a very flat, submarine plain probably formed under Pleistocene Wicomico seas, 70 to 100 feet above present sea level (Cowherd et al. 1989). The Smyrna-Myakka-Ona and Smyrna-Myakka-Immokalee soil associations characterize this portion of the Horse Creek Basin with flat, poorly drained soils that are sandy throughout (Lewelling 1997). The soil group Bradenton-Felda-Chobee is also located immediately adjacent to the main channel of Horse Creek, from below State Road 64 to just above the mouth of the creek. These soils are characterized by nearly level, poorly drained and very poorly drained soils that are sandy to a depth of 20 to 40 inches and underlain by loamy material or that are loamy throughout and subject to frequent flooding. The dominant soil groups in the Horse Creek basin are generally poorly drained, reducing the infiltration of rainwater to the water table in the surficial aquifer, thereby limiting the amount of water available to support baseflow (SWFWMD 2000).

The climate of Horse Creek Basin is subtropical and humid with an average temperature of about 72ºF. Summer temperatures average 80ºF, and winter temperatures average 60ºF (Hammett, 1990). The average daily temperatures in Hardee County, in the northern Horse Creek Basin, range from 52ºF to

91ºF (Robbins et al. 1984). The average daily temperatures in DeSoto County, in the southern Horse Creek Basin, range from 49ºF to 92ºF. Average relative humidity in Horse Creek Basin ranges from 57 percent in the mid-afternoon to 87 percent at dawn. The prevailing wind is from the east-northeast, with the highest average wind speed, 7.8 mph, occurring in March (Cowherd et al. 1989).

The average annual rainfall in the Peace River Basin, which includes Horse Creek, is 53.1 inches, with more than half of that falling during localized thundershowers in the wet season (June to September)[4]. Rain during fall, winter, and spring is usually the result of large, broad frontal systems instead of local storms. November is typically the driest month of the year, averaging 1.8 inches over the historical period from 1908 to 2016. The months of December and January are also characteristically dry, averaging 1.8 and 2.2 inches, respectively. Dry conditions coincide with high evaporation rates and generally result in the lowest stream flows, lake stages, and ground-water levels of the year (Hammett, 1990). The wettest months of the year are typically August and June, each averaging 8.50 inches.

Horse Creek flows through a generally rural area. Major land use activities in the basin are primarily agricultural, with extractive mining activities occurring in the northern part of the basin. Agricultural activities include cattle grazing, row crop farming, citrus grove production, sod farming, and conversion of native lands to pasture for both cattle grazing and hay production.

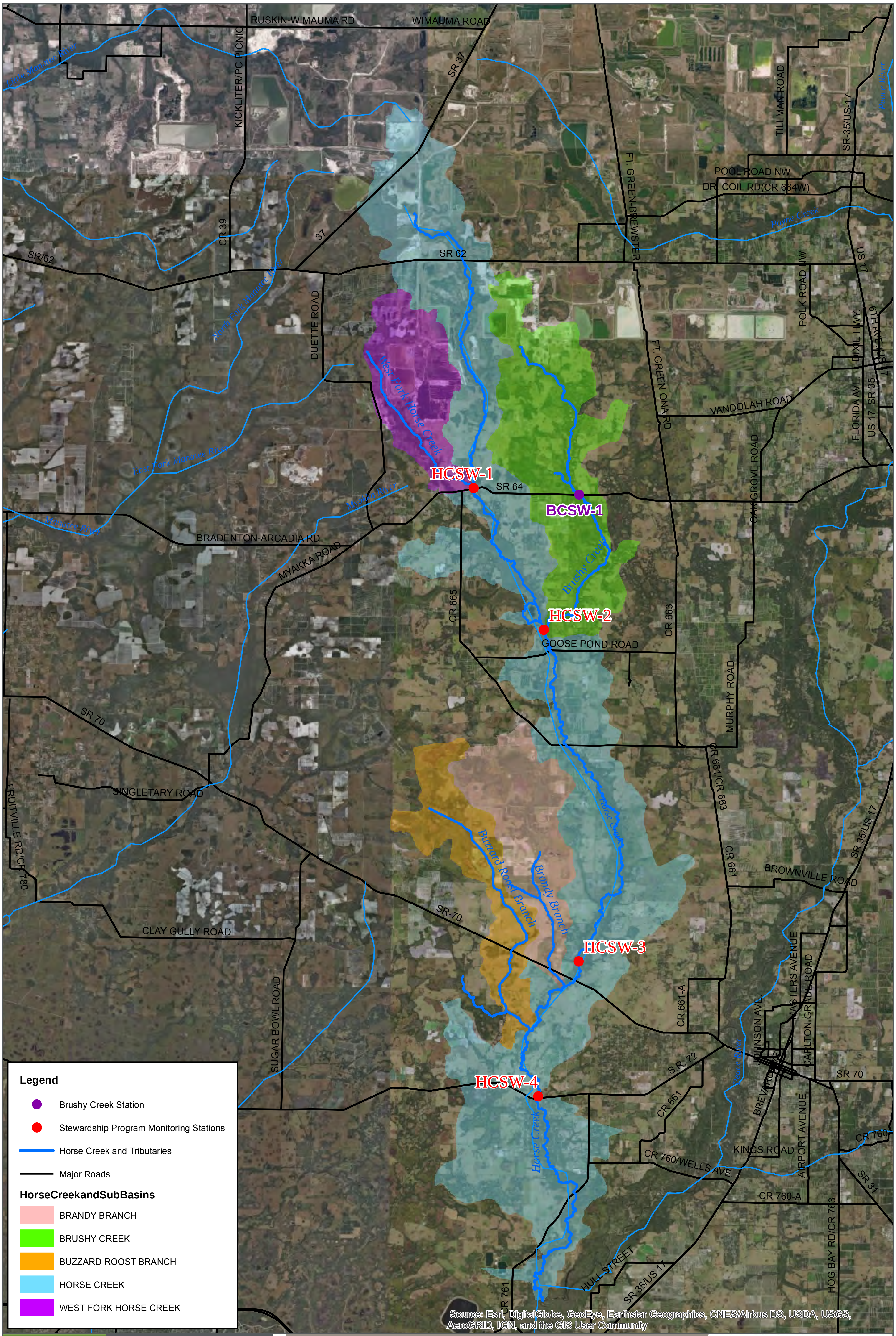
Small rural agricultural communities are located in and near the Horse Creek drainage basin including Fort Green, Ona, and Myakka Head in the northern portion of the basin, Limestone, Lily, and Edgeville in the approximate center of the basin, and Arcadia, Fort Ogden and Nocatee near the southern end of the basin (Post et al. 1999). Generally, the northern Horse Creek basin is covered more by natural vegetation, while the southern basin is covered mostly by pasture and row crops (SWFWMD 2000).

Total acreages in each land cover type and proportions of the various land uses differ between regions of the basin. The percent mining cover has increased between 1988 and 2009, according to SWFWMD land use maps for those years. The majority of land newly identified as mined in 2009 SWFWMD land use was agricultural or rangeland in 1988. Mining is the primary land use above State Road 64, but the percentage of land devoted to mining decreases rapidly downstream. Agricultural land use more than doubles in acreage from above County Road 663 (HCSW-2) to above SR 72 (HCSW-4). Rangeland covers about the same percentage of land in the northern part of the basin and in the southern portion. The percent upland forest and wetland cover also remains relatively constant in upstream and downstream sections of Horse Creek. Land use changes between 2009 and 2011 SWFWMD maps were very minor, with only 2% of the area upstream of State Road 64 or upstream of County Road 663 converted from agricultural or natural land use to mining or reclamation land use.

Water quality sampling on Brushy Creek was added to the HCSP in 2009. Land use in 2009 in the Brushy Creek basin is primarily agricultural (38%), with a relatively small percentage of mining (6%) compared to Horse Creek above State Road 64 or County Road 663. Overall, the Brushy Creek basin has a similar percentage of rangeland (15%), upland forest (13%), and wetland (29%) land use as the Horse Creek Basin. Land use changes between 2009 and 2011 SWFWMD maps were very minor, with only 3% of the area within the Brushy Creek basin converted from agricultural or natural land use to mining or reclamation land use.

---

[4] Historical rainfall information came from the following stations and years: 1908-1943 NOAA station 148, 1944 to 2016 average of NOAA station 148 and 336.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 2-1. Aerial photograph of the Horse Creek Basin and HCSP sampling locations

Cardno
Shaping the Future
3905 Crescent Park Drive, Riverview, FL 33578 USA
Phone (+1) 813-664-4500 Fax (+1) 813-664-0440
www.cardno.com

Date Created: 3/2/2018 Date Revised: 3/2/2018 File Path: Q:\UnitedStates\Florida\Tampa\Mosaic\HorseCreekStewardshipProgram\working\arcmap\Horse_Creek_Aerial_2015_working_20180302.mxd
GIS Analyst: Lauren.Federsel

3 Summary of Mining and Reclamation Activities

3.1 Mining

Mining activities in the Horse Creek basin have occurred on two mines: Fort Green Mine (operated by Mosaic, previously IMC) and South Pasture Mine (operated by Mosaic, previously CF Industries). In 2016, a total of 219 acres was mined at the Mosaic Fort Green/Four Corners/Altman and South Pasture Mines in the West Fork Horse Creek and Horse Creek Basin upstream of HCSW-1, and 209 acres were mined at the South Pasture Mine in Brushy Creek Basin upstream of BCSW-1 and HCSW-2 (Figure 3-1). A summary of all mining and reclamation activities from 2004 to 2016 is provided below in Table 3-1, although the South Pasture Mine information was first included for years beginning in 2015 when legacy CF Industries holdings became part of Mosaic (table updated starting in 2015 with acres mined at South Pasture added to both the Horse Creek and Brushy Creek basins from 2003 to 2015); total acres mined, reclaimed, and reconnected in each basin may be different in earlier reports. Information on pre-mining conditions in the Horse Creek Basin may be found in an Environmental Impact Statement prepared by Environmental Science and Engineering, Inc. (1982) and a Development of Regional Impact statement prepared by Ardaman and Associates and colleagues (1979).

Table 3-1 lists mining and reclamation data for the Horse Creek Basin over the course of the HCSP (omitting the partial year of 2003). The table lists the acres mined, the acres reclaimed to the final contour (but not necessarily vegetated), and the acres released and reconnected to Horse Creek.

Table 3-1. Total acres mined, reclaimed to final contour, and reconnected by Mosaic in the Horse Creek and Brushy Creek Basins from 2004 to 2016.

Year	Acres Mined		Acres Reclaimed to Final Contour		Acres Reconnected	
	Horse Creek	Brushy Creek	Horse Creek	Brushy Creek	Horse Creek	Brushy Creek
2004	637	0	30	0	0	0
2005	645	169	205	0	38	0
2006	370	18	0	0	205	0
2007	22	146	106	42	0	0
2008	150	187	245	0	66	0
2009	137	16	711	95	315	0
2010	287	220	270	91	0	0
2011	306	165	114	12	0	0
2012	111	153	600	63	0	0
2013	201	96	71	85	0	0
2014	112	114	98	96	0	0
2015	379	126	318	81	793	183
2016	219	209	162	0	138	0

There are four clay settling areas (CSAs) in the Horse Creek Basin at the Fort Green Mine (Figure 3-1). The FGH-3 clay settling area is located predominantly in Sections 5, 8, and 9, T33S, R23E. Construction of clay settling area FGH-3 was completed in 1999, and it was immediately put into service. The settling area was designed by Ardaman & Associates with a crest elevation of 151 feet NGVD, and a final pool elevation of 146 feet NGVD. The effective area of the CSA is approximately 933 acres. Clays are introduced into the settling area approximately midway on the east wall. Three decant spillways, two on the west wall and one on the north wall, were designed to return water to the Ft. Green plant. Flow can also be directed to the south to Horse Creek using the FTG-003 outfall through spillways located in the return water ditch near the southwest corner of FGH-3. As of 2012, water from FGH-3 was sent either north to Four Corners to use in the mining process, or northeast out of the FTG-002 outfall to Payne Creek.

The FGH-4 clay settling area is located predominantly in Section 31, T33S, R23E. Construction of the CSA was completed in 2001, and it was put into service shortly thereafter. The settling area was designed by Ardaman & Associates with a crest elevation of 164.0 feet NGVD, and a final pool elevation of 159.0 feet NGVD. The effective area of the CSA is approximately 415 acres. Two decant spillways, one on the north wall, and one on the south wall were designed to return water to the Ft. Green central screening station (the smaller beneficiation plant located on SR39). Decant spillways located in the south return water ditch also have the capability of discharging water to the WIN-004 outfall and Horse Creek. Clay slurry is introduced into the settling area at the southwest corner, and at a point approximately midway on the west wall of the dam. The settling area is also used to store mine pit water, which is pumped in at the northwest corner and at approximately the center of the south wall.

The third settling area, Fort Green Manatee-1 (FM-1) is located predominately in Section 1, T34S, R22E. FM-1 was constructed in 2006 to 2007 and put into service in March 2009. The settling area was designed by Ardaman and Associates with a crest elevation of 164 feet NGVD and a final pool elevation of 159 feet NGVD. The effective area of the CSA is approximately 350 acres. Two decant spillways, both located on the west wall of the dam, are designed to return water to a holding area at the base of the dam, which is then pumped via pipeline back to the Wingate Creek Mine. Water from this dam can also be routed via a series of pumps and surface water conveyance ditches to the WIN-004 outfall; thus discharges from the clay settling area can be routed to either the Myakka or Horse Creek basins.

The fourth settling area, Fort Green Manatee-2 (FM-2) is located predominately in Section 12, T34S, R22E. FM-2 was constructed from 2013 to 2014 and put into service in July 2013 for below grade storage. The settling area was designed by AMEC with a crest elevation of 164 feet NGVD and a final pool elevation of 159 feet NGVD. The effective area of the CSA is approximately 426 acres. Two decant spillways, both located on the west wall of the dam, are designed to return water to a holding area at the base of the dam, which is then pumped via pipeline back to the Wingate Creek Mine. Water from this dam can also be routed via a series of pumps and surface water conveyance ditches to the WIN-004 outfall; thus discharges from the clay settling area can be routed to either the Myakka or Horse Creek basins.

In an electronic submittal, “Proposed Modifications to Monitoring Methodology”, dated October 31, 2013, the previous methodologies utilized to monitor the FM-1 clay settling area were outlined, as a part of the 2003 settlement agreement between Mosaic and PRMRWSA. That submittal described historic issues encountered with the telemetric fluid level monitoring equipment, summarized the findings of Florida Engineering and Design’s (“FED”) letter report dated July 17, 2013, “Breach Discharge Analysis, Clay Settling Area FM-2”, and recommended discontinuing the existing telemetry monitoring in favor of reliance on already existing inspection and notification protocols found in the NPDES permits and FDEP rule criteria.

In response to this submittal, representatives from PRMRWSA indicated that they did not agree with relying solely on inspections. As an alternative, Mosaic then suggested using turbidity monitoring at the existing Horse Creek station (HCSW-1) located at Horse Creek and State Road 64 for the purposes of providing continuous monitoring of a potential dam breach, since this location is downstream of all currently operational clay settling areas in the Horse Creek basin and real time monitoring equipment was already in place at that location. In subsequent discussions, the Authority indicated that this approach might prove acceptable, but requested that Mosaic develop a specific proposal to utilize turbidity monitoring in lieu of the continuous level monitoring before granting approval.

Mosaic presented a monitoring proposal utilizing rolling averages of continuously measured turbidity values at this location, with a set point of 150 NTU. This set point was based on a review of historic data at the station and was selected to be sensitive enough to detect any potential turbidity excursions that might result from an upstream dam breach, but not so sensitive as to result in a number of false positives. Based on that set point, telemetric equipment would send text messages and email alerts in two instances; the first, when the 3-hour rolling average exceeds the set point, and a second when the 6-hour rolling average exceeds the set point, with the 3-hour alert being sent to Mosaic representatives only, and the 6-hour alert sent to both Mosaic and PRMRWSA representatives. Three hour alerts would trigger Mosaic investigation of the source of the high turbidity in the creek, and necessary follow-up with PRMRWSA staff in the event that the cause of the alarm was associated with a dam breach or other significant upset conditions at Mosaic’s operations. A final set of alerts would be sent once the turbidity drops below the 150 NTU set point, on the 3- and 6-hour rolling average basis. This CSA monitoring methodology change was adopted on July 14, 2014 and is listed in Appendix B, change number 12.

3.2 Reclamation

Reclamation of lands that have been mined is an ongoing process at Mosaic’s mined lands in the Horse Creek Basin. The reclamation process consists of backfilling the mined excavations with sand “tailings” produced as a by-product of the phosphate production process or shaping existing deposits of overburden material to bring the ground surface up to rough grade. Overburden material is spread over the backfilled areas and the areas are brought to the required final contours (usually occurs within 18 months after the completion of mining operations). Planting of both upland and wetland communities is done with appropriate species over three phases. Phase A plantings occur no later than six months after final grading and are made up of species that tolerate a wider range of water levels. Following the Phase A plantings, a hydrological assessment will occur for up to two years. Within 12 months of the hydrological assessment, Phase B plantings will occur with species that tolerate a more narrow range of water levels. Finally, at least two years prior to release (forested wetlands) Phase C plantings of shade-adapted groundcover and shrub species along with additional trees and shrubs will occur to meet the objectives of each mines Compensatory Mitigation Plan. Reclaimed areas are monitored and supplemental plantings are done as necessary until the revegetation of the land is successful. In general, reclamation can take up to three years to meet applicable criteria for herbaceous wetlands and up to 15 years to meet applicable criteria for forested wetlands. The number of acres reclaimed to the final contour and the acres reconnected to Horse Creek are summarized in Table 3-1 and Figure 3-1.

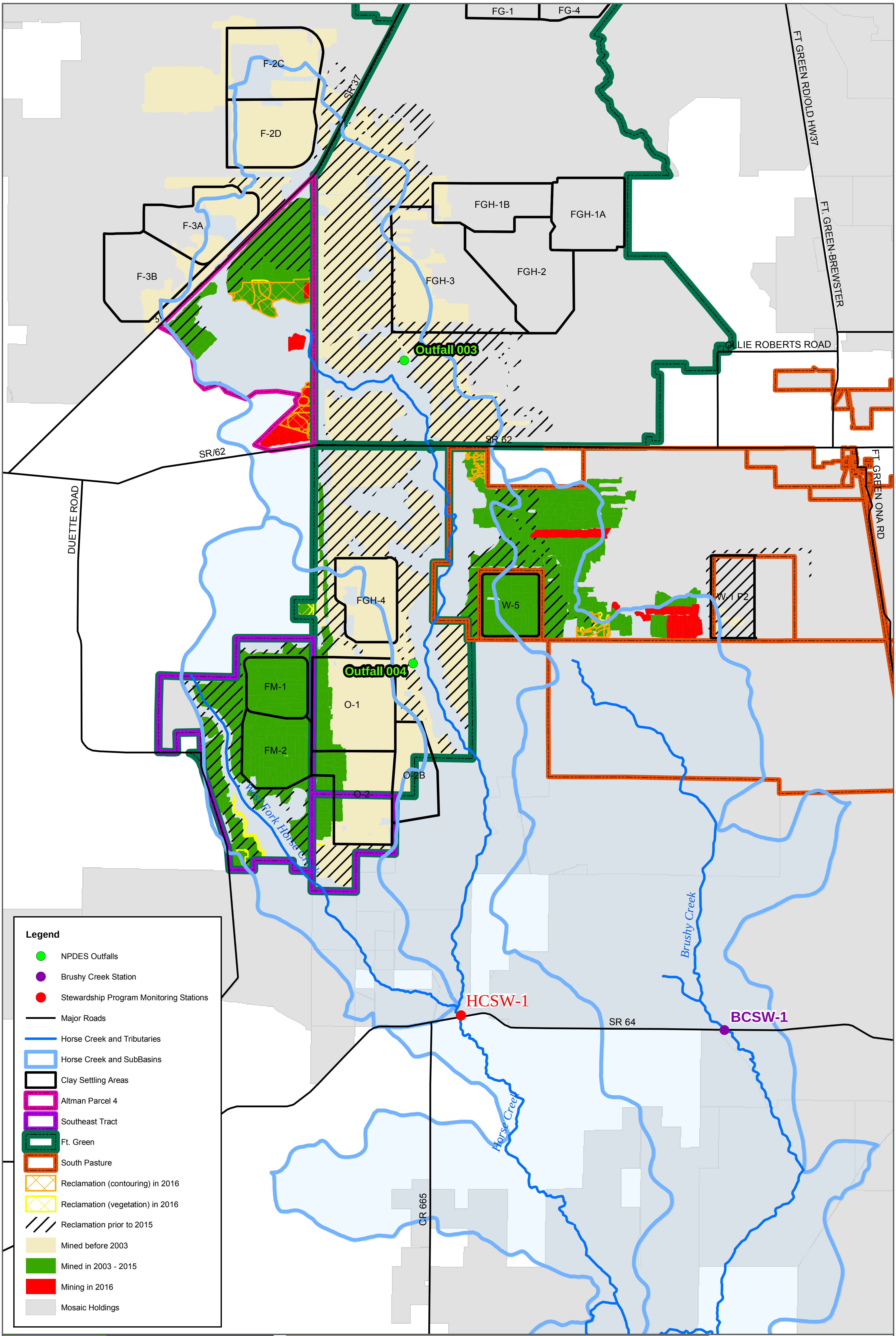


Figure 3-1. Mining and reclamation areas in the Horse Creek Basin.

Cardno
Shaping the Future
3905 Crescent Park Drive, Riverview, FL 33578 USA
Phone (+1) 813-664-4500 Fax (+1) 813-664-0440
www.cardno.com

Date Created: 8/24/2018 Date Revised: 1/30/2019 File Path: Q:\UnitedStates\Florida\Tampa\Mosaic\HorseCreekStewardshipProgram\working\arcmap\Horse_Creek_Mined_2016_working_20180824.mxd
GIS Analyst: Lauren.Federsel

4 Methods

4.1 Station Locations and Sampling Schedule

Four Horse Creek locations are monitored for physical, chemical, and biological parameters (Figure 1-1):

HCSW-1 - Horse Creek at State Road 64 (USGS Station 02297155)
HCSW-2 - Horse Creek at County Road 663A (Goose Pond Road)
HCSW-3 - Horse Creek at State Road 70 (also known as Horse Creek at Wuthrich Road)
HCSW-4 - Horse Creek at State Road 72 (USGS Station 02297310)

As indicated above, HCSW-1 and HCSW-4 are also long-term US Geological Survey (USGS) gauging stations, with essentially continuous stage and discharge records since 1977 and 1950, respectively. Water quality sampling for the HCSP has been conducted monthly beginning in April 2003, while biological sampling events have been conducted typically three times per year (Table 4-1).

In September 2009, based on recommendations of the PRMRWSA and the Technical Advisory Group (TAG), Mosaic began sampling water quality at an additional station on Brushy Creek (BCSW-1 at Post Plant Road). Brushy Creek is a tributary to Horse Creek and flows into Horse Creek between the HCSW-1 and HCSW-2 sampling stations.

This additional station was added for comparison purposes, and will not be evaluated against the HCSP trigger levels and exceedances because Mosaic does not have a NPDES discharge on Brushy Creek. The Brushy Creek location is also not included in the macroinvertebrate or fish sampling components of the program. In September 2009, Mosaic also discontinued water quality analysis for FL-PRO, total fatty acids, and total amines based on recommendations made in previous HCSP annual reports. Mosaic, PRMRWSA, and the TAG agree that the results for these parameters from 2003 to 2009 show that these substances are present only occasionally at very low concentrations, and are not a cause for concern at this time.

Table 4-1. 2016 schedule of water quality and biological sampling events of the HCSP.

Month	Horse Creek Water Quality Sampling Events	Horse Creek Biology Sampling Events	Brushy Creek Water Quality Sampling Events
January	Sampled January 25		Flooded-could not access
February	Sampled February 23		Sampled February 23
March	Sampled March 7	Sampled March 17	Sampled March 7
April	Sampled April 7		Sampled April 7
May	Sampled May 5		Sampled May 5
June	Sampled June 7		Flooded-could not access
July	Sampled July 7		Sampled July 7
August	Sampled August 4		Sampled August 4
September	Sampled September 8		Sampled September 8
October	Sampled October 18		Sampled October 18
November	Sampled November 7	Sampled November 16	No flow
December	Sampled December 13		No access; dry at SR64

4.2 Water Quantity

Approved discharge data were obtained from the USGS (http://waterdata.usgs.gov/fl/nwis/nwis) for HCSW-1 and HCSW-4. Staff gauges were installed and surveyed to NGVD by Mosaic at HCSW-2 and HCSW-3; stage data were obtained at those stations during monthly water quality sampling. Daily flow and gauge data are not recorded in Brushy Creek, so there is no summary or analysis of water quantity for the Brushy Creek sampling location in this report. Discharge data were obtained for Mosaic's National Pollutant Discharge Elimination System (NPDES)-permitted discharges into Horse Creek (FTG-003 and WIN-004 outfalls) for 2003 to 2016 (Figure 1-1). Daily rainfall data were obtained from Mosaic's rain gauges in the Horse Creek Basin (Figure 1-1). New Mosaic rainfall gauges (Pine Level 001 and 002) were installed late July 2011. However, because of the limited data set (only available for five complete years), totals recorded at Pine Level 001 and 002 will not be used in this analysis, but monthly sums will be used to supplement months where data was missing from the two Horse Creek and the Manson Jenkins rain gauges. The general relationship between rainfall and streamflow was graphically evaluated. All rainfall gauges with an extended period of record are located in the upper portion of the Horse Creek basin (new Pine Level gauges are located parallel with HCSW-3 and HCSW-4 but only have a few years' worth of data), so longitudinal comparisons along the basin are not possible. A separate report (Durbin and Raymond 2006) addresses long-term rainfall patterns in the area.

4.3 Water Quality

A continuous monitoring unit is installed at HCSW-1 to record pH, specific conductivity, dissolved oxygen, and turbidity. Beginning in April 2003, data were recorded hourly, and daily mean, maximum, and minimum were downloaded at least monthly. This data provides for the characterization of natural background fluctuations, and allows for the detection of instantaneous conditions or general water quality changes not observed during the collection of monthly grab samples.

Water quality grab samples were obtained monthly, when flow was present, by Mosaic at each of the four HCSP monitoring stations beginning in April 2003. The four locations are sampled the same day, working from downstream to upstream. In September 2009, based on recommendations of the PRMRWSA and the TAG, Mosaic began sampling water quality at an additional station on Brushy Creek (BCSW-1 at State Road 64). Brushy Creek is a tributary to Horse Creek and flows into Horse Creek between the HCSW-1 and HCSW-2 sampling stations. All activities affecting sample collection, sample handling, and field-testing activities were thoroughly documented. Field sample collection logs were completed at each station that include the following information: stream level elevations at the time of sampling (from on-site gauges or from the USGS real-time web site); stream size; a qualitative description of the water color, odor, and clarity; weather conditions; field measurements; sample preservation; and any anomalous or unusual conditions. Individual sample containers were labeled with identification codes, date and time of sampling, sample preservation, and the desired analysis. Sample transmittal chain-of-custody records were filled out during sampling listing locations, times, and required analysis.

Field measurements were taken for pH, dissolved oxygen[5], specific conductivity, and turbidity using meters that were operated and maintained according to manufacturer's instructions. Instruments were calibrated in the field prior to making measurements using the appropriate standards and acceptance limits (Table 4-2). All calibration activities were documented and records checked for completeness and accuracy. Field measurements by Cardno in association with the three biological sampling events employed an YSI 6920 multi-parameter data sonde with the same measuring methods and acceptance limits listed in Table 4-2 Cardno also employed a Hach 2100P unit for turbidity measurement.

---

[5] In May 2013, Mosaic began collecting dissolved oxygen saturation (DO Sat) data in addition to mg/L because of the changes to the dissolved oxygen standard. Cardno began collecting DO Sat data in March 2012. The continuous recorder at HCSW-1 began recording DO Sat in January 2011. For all prior dates, reported DO Sat was calculated using DO (mg/L), temperature, and salinity. See Section 4.3.1 for an explanation of the change in DO standards.

Table 4-2. HCSP water quality sampling field methods and acceptance limits associate with monthly sampling by Mosaic staff.

Analyte	Meter Used	Method	Minimum Detection Limit	Acceptance Limit
pH	Hach HOD	150.1	1 su	+/- 0.2 standards units of the calibration standard
Temperature	Hach HOD	170.1		1 degree Centigrade
Specific Conductivity	Hach HOD	120.1	10 uS/cm	+/- 5% of the calibration standard
Dissolved Oxygen	Hach HOD	360.1	0.5 mg/L	+/- 0.2 mg/L of the correct Dissolved Oxygen - Temperature value
Turbidity	Hach 2100P	180.1	0.1 NTU	+/- 8% of the calibration standard

Surface water samples were collected in a manner that represented the physical and chemical characteristics of Horse Creek without contamination or bias in the sampling process. Water samples for chemical analysis were generally collected from mid-stream and from mid-depth to the upper portion of the water column unless flows were at either extreme (flood stage or nearly dry at the upper stations). Samples were usually obtained by wading into the stream (taking care not to disturb or stir up bottom sediments) and collecting samples upstream from the sampler. When flooded conditions precluded wading to collect samples (principally at HCSW-3), samples were taken from the top of the water column in the main flow path from the bridge. Samples were collected directly into unpreserved sample containers, which were used to fill the other sample containers. Pre-preserved sample containers (with either sulfuric or nitric acid) were filled with sample water and their pH levels checked. The sample containers were stored on ice prior to transport to laboratories for analysis. Sample containers were either taken directly to the laboratory or laboratory personnel picked them up in the field, using appropriate chain-of-custody procedures. The monthly surface water samples were analyzed for the parameters listed in Table 4-3. Table 4-3 also includes the laboratory analysis methods.

In addition to the continuous recorders and monthly water quality sampling, field measurements of temperature, pH, specific conductivity, turbidity and dissolved oxygen were collected during each biological sampling event (Table 4-1) using a YSI 6920 data sonde. All sampling was conducted according to the Florida Department of Environmental Protection’s (FDEP’s) Standard Operating Procedures (SOPs) for field sampling. Laboratory analyses were performed by experienced personnel according to National Environmental Laboratory Accreditation Conference (NELAC) protocols.

Results were tabulated to allow for comparisons among stations and sampling events, through time, and to the “trigger values” established for the HCSP (Table 4-4). In addition, results were compared with applicable Florida surface water quality standards (which in many cases are the same as the trigger values).

While the numeric nutrient criteria (NNC) development has been ongoing since 2009, the adopted criteria did not go into effect until late October 2014. The trigger level and the NNC requires the evaluation of nutrient concentrations over different time scales. Monthly samples are compared to the trigger level and identify acute changes in nutrient concentrations that warrant investigation, while the NNC threshold is based on annual geometric mean concentrations and evaluate longer term trends. Also, the nutrient thresholds are only used in conjunction with biological metrics to determine compliance. A site must first pass the floral components (Rapid Periphyton Survey, Linear Vegetation Survey, and annual geometric mean for chlorophyll-a), then either be within the nutrient thresholds or SCI requirements in order to be in compliance according to 62-302.531(2)(c), F.A.C. Therefore, incorporating the NNC thresholds as standalone trigger levels for the HCSP would be inappropriate and would not accurately reflect the NNC.

Table 4-3. **Parameters analyzed and laboratory methods for HCSP during 2003 to 2016 monthly water quality samples.**

Parameter	Method	Hold Time	Preservation	Minimum Detection Limit Range	Container
Color	110.2	48 hours	Unpreserved	2-5 PCU	Clear HDPE bottle
Total Kjeldahl Nitrogen	351.2	28 days	Sulfuric Acid, pH < 2	0.008-0.24 mg/L	Clear HDPE bottle
Nitrate-Nitrite Nitrogen	353.2	28 days	Sulfuric Acid, pH < 2	0.0001-1.0 mg/L	Clear HDPE bottle
Total Ammonia Nitrogen	350.1	28 days	Sulfuric Acid, pH < 2	0.0008-0.05 mg/L	Clear HDPE bottle
Orthophosphate	365.1	48 hours	Unpreserved	0.002-0.75 mg/L	Clear HDPE bottle
Chlorophyll-*a*	SM 10200H	48 hours	Unpreserved	0.1-2.0 µg/l	Opaque plastic bottle
Specific Conductivity	120.1	28 days	Unpreserved	10 µmhos/cm	Clear HDPE bottle
Total Alkalinity	310.1	14 days	Unpreserved	0.24-3.0 mg/L CaCO3	Clear HDPE bottle
Dissolved Calcium*	200.7	28 days	Unpreserved	0.008-0.8 mg/L	Clear HDPE bottle
Dissolved Iron*	200.7	28 days	Unpreserved	0.003-0.1 mg/L	Clear HDPE bottle
Chloride	300	28 days	Unpreserved	0.005-30 mg/L	Clear HDPE bottle
Fluoride	300	28 days	Unpreserved	0.003-5.0 mg/L	Clear HDPE bottle
Total Radium (Radium 226+228)	903	6 months	Nitric Acid, pH < 2	1 pCi/l	Clear HDPE bottle
Sulfate	300	28 days	Unpreserved	0.0007-100 mg/L	Clear HDPE bottle
Total Dissolved Solids	160.1	7 days	Unpreserved	5-25 mg/L	Clear HDPE bottle

- All water samples were preserved at 4°C while awaiting analysis.
- Orthophosphate samples were initially filtered in the laboratory rather than the field. While Mosaic is cognizant of the FDEP SOP for field sampling, the decision was made to have samples lab filtered (less risk of contamination and the guarantee of lab filtering within hours of lab delivery). Starting in January 2005, samples were field-filtered with a 0.45 micron filter.
- The analytical method for iron and calcium was changed during the 2003–2005 monitoring period.
- Total radium is the arithmetic sum of Radium 226 and Radium 228. Total nitrogen is reported as the arithmetic sum of nitrate-nitrite nitrogen and total Kjeldahl nitrogen. As requested by the PRMRWSA, if either of each pair is undetected, the MDL of the undetected constituent will be used as part of the total. This use of MDL for undetected constituents is contrary to both laboratory and DEP SOPs.
- Petroleum Range Organics, Fatty Amido-amines, and Total Fatty Acid analysis were discontinued in September 2009.

Table 4-4. Parameters, general monitoring protocols, and corrective action trigger values for the HCSP.

Pollutant Category	Analytical Parameters	Analytical Method	Reporting Units	Monitoring Frequency	Trigger Level	Basis for Initiating Corrective Action Process
General Physio-chemical Indicators	pH	Calibrated Meter	Std. Units	Monthly	<6.0->8.5	Excursions beyond range or statistically significant trend line predicting excursions from trigger level minimum or maximum.
	Dissolved Oxygen Saturation(9)	Calibrated Meter	%	Monthly	<38% daily average	Excursions below trigger level or statistically significant trend line predicting concentrations below trigger level.
	Turbidity	Calibrated Meter	NTU(1)	Monthly	>29	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Color	EPA 110-2	PCU	Monthly	<25	Excursions below trigger level or statistically significant trend line predicting concentrations below trigger level.
Nutrients	Total Nitrogen	EPA 351 + 353	mg/L(2)	Monthly	>3.0	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Ammonia	EPA 350.1	mg/L	Monthly	>0.3	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Ortho Phosphate	EPA 365	mg/L	Monthly	>2.5	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Chlorophyll-*a*	EPA 445	mg/L	Monthly	>15	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
Dissolved Minerals	Specific Conductance	Calibrated Meter	µs/cm(3)	Monthly	>1,275	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Alkalinity	EPA 310.1	mg/L	Monthly	>100	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Calcium	EPA 200.7	mg/L	Monthly	>100	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Iron	EPA 200.7	mg/L	Monthly	>0.3 (6); >1.0(7)	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Chloride	EPA 325	mg/L	Monthly	>250	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Fluoride	EPA 300	mg/L	Monthly	>1.5(6); >4(7)	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Radium 226+228	EPA 903	pCi/l(4)	Quarterly	>5	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Sulfate	EPA 375	mg/L	Monthly	>250	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Dissolved Solids	EPA 160	mg/L	Monthly	>500	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
Mining Reagents(5)	Petroleum Range Organics	EPA 8015 (FL-PRO)	mg/L	Monthly	>5.0	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Fatty Acids, Incl.Oleic, Linoleic, and Linolenic Acid	EPA/600/4-91/002	mg/L	Monthly	>NOEL	Statistically significant trend predicting concentrations in excess of the No Observed Effects Level (NOEL to be determined through standard toxicity testing with Mosaic reagents early in monitoring program, NOEL to be expressed as a concentration – e.g., mg/L)
	Fatty Amido-Amines	EPA/600/4-91-002	mg/L	Monthly	>NOEL	Statistically significant upward trend predicting concentrations in excess of No Observed Effects Level (NOEL to be determined through standard toxicity testing with Mosaic reagents early in monitoring program, NOEL expressed as a concentration – e.g., mg/L)
Biological Indices: Macro-invertebrates	Total Taxa	Stream Condition Index (SCI) sampling protocol, taxonomic analysis, calculation of indices according to SOP-002/01 LT 7200 SCI Determination	Units vary based upon metric or index	3 times per year	N/A	Statistically significant declining trend with respect to SCI values, as well as presence, abundance or distribution of native species
	Ephemeropteran Taxa					
	Tricopteran Taxa					
	Percent Collector-Filterer Taxa					
	Long-lived Taxa					
	Clinger Taxa					
	Percent Dominant Taxon					
	Percent Tanytarsini					
	Sensitive Taxa					
	Percent Very Tolerant Taxa					
	Shannon-Wiener Diversity(a)					
Biological Indices: Fish	Total Number of Taxa	Various appropriate standard sampling methods, taxonomic analysis, calculation of indices using published formulas	Units vary based upon metric or index	3 times per year	N/A	Statistically significant declining trend with respect to presence, abundance or distribution of native species
	Abundance					
	Shannon-Wiener Diversity(a)					
	Species Turnover (Morisita Similarity Index(a)					
	Species Accumulation Curves(b)					

Notes:

(1) Nephelometric turbidity units.

(2) Milligrams per liter.

(3) Microsiemens per centimeter.

(4) PicoCuries per liter.

(5) If reagents are not detected after two years, sampling frequency will be reduced to quarterly - if subsequent data indicate the presence of reagents, monthly sampling will be resumed. Parameter sampling removed from program in September 2009 as agreed by TAG.

(6) At Station HCSW-4 only, recognizing that existing levels during low-flow conditions exceed the trigger level.

(7) At Stations HCSW-1, HCSW-2, and HCSW-3.

(8) Some metrics have been revised from original HCSP plan document due to revision of DEP SCI Protocol.

(9) Revised from Dissolved Oxygen trigger of <5.0 mg/L based on changes to FDEP water quality standards,

References:

(a) Brower, J. E., Zar, J. H., von Ende, C. N. Field and Laboratory Methods for General Ecology. 3rd Edition. Wm. C. Brown Co., .Dubuque, IA. pp. 237; 1990

(b) Gotelli, N.J., and G.R. Graves. 1996. Null Models in Ecology. Smithsonian Institution Press, Washington, DC.

4.3.1 Changes to Class III Dissolved Oxygen Standard

The original dissolved oxygen (DO) Class III Standard for Florida freshwater of 5.0 mg/L was adopted more than 30 years ago, and was based on the response of southern warm water species to DO conditions. FDEP conducted a study in 2005-2006 in lakes and streams throughout the state to assess the accuracy of the current criteria and to revise the standard. Using data collected from unimpacted waterways in different regions throughout the state, FDEP determined the minimum DO levels that protect aquatic life (using the SCI) specific to the Florida environment. As a result of the data evaluation, FDEP chose percent saturation over concentration because saturation already accounts for the DO concentration and temperature relationship, and because daily average DO saturation provided the best fit with SCI scores (FDEP 2013).

Separate daily average percent saturation criteria were created for three bioregions (Panhandle West, Peninsula, and Big Bend + Northeast) of 67, 38, and 34 percent, respectively (62-302.533, F.A.C.). To be consistent with the criteria derivation process, application of the bioregion percent saturation criteria should utilize diel monitoring data (at least one measurement per hour over a 24 hour period) to assess against the daily average criteria. However, FDEP recognizes that most monitoring programs do not collect diel monitoring data; therefore, FDEP developed time of day translations of the daily average criterion to apply to grab sample data. The equation (provided in 62-303.320(4)(c), F.A.C.) allows for evaluation of individual grab sample data points against a time of day translation of the daily average criterion based on the time of the sample collection. As Horse Creek is part of the Peninsula bioregion, and the HCSP collects DO data as individual grab samples, the appropriate criterion is the time of day translation of the 38 percent saturation daily average criterion.

The change in criterion can have a significant effect on the DO trigger level used in the HCSP. The previous 5.0 mg/L criterion was found by FDEP to be overprotective for many fresh waterbodies in Florida (FDEP 2013). The revised criterion reflects a Florida specific evaluation of the oxygen needs of important macroinvertebrate species. Based on the application of the revised criterion versus the previous concentration based criterion, the 5.0 mg/L trigger level can result in exceedances for the HCSP that do not violate the Class III water quality criterion. In practice, continuing with the 5.0 mg/L trigger level would result in an overprotective regulation that does not reflect the state of the science or current water quality criteria. On January 21, 2016, a memo was approved and circulated to the TAG changing the DO trigger level from a 5.0 mg/L concentration to the time of day translation of the 38 percent saturation daily average criterion beginning with the 2014 annual report. This change is also noted in Appendix B, change number 13.

4.4 Benthic Macroinvertebrates

Benthic macroinvertebrate sampling was conducted at all four HCSP stations during the 17 March and 16 November 2016 sampling events. Only two sampling events occurred in 2016 because of high water levels and flows that prohibited a summer sampling event. The Brushy Creek location is not included in the macroinvertebrate sampling component of the HCSP.

At each Horse Creek station, a Stream Habitat Assessment (DEP Form FD 9000-5) was performed, and a Physical/Chemical Characterization Field Sheet (DEP Form FD 9000-3) was completed. The habitat assessment is comprised of a variety of physical criteria that are independently evaluated on a numerical scale, and the component values are summed to provide a quantitative rating for a stream segment that is presumed to be proportional to the quality of the stream for native macroinvertebrates. The Physical/Chemical form records a variety of other information and also provides for the delineation of various microhabitats in the stream into categories to allow for sampling of such microhabitats in general proportion to their abundance.

Macroinvertebrate sampling was performed in Horse Creek according to the Stream Condition Index (SCI) protocol developed by the DEP (DEP-SOP-003/11, SCI 1000) by personnel with training and experience in the SCI protocol and who have successfully passed DEP audits for the protocol. The SCI is a standardized macroinvertebrate sampling methodology that accounts for the various microhabitats available (e.g. leaf packs, snags, aquatic vegetation, roots/undercut banks) within a 100-meter segment of stream. Utilizing this methodology, 20 half-meter D-frame dip net sweeps are performed within a 100-meter segment of the stream. The number and quality of benthic macroinvertebrate microhabitats present during the sampling event determines the number of sweeps performed within each microhabitat type. Consistent with DEP protocols, each benthic macroinvertebrate sample was processed and taxonomically analyzed.

Data from each invertebrate sample were used to calculate the various SCI metrics and resulting overall SCI values as per the methodology for the Florida Peninsula (Table 4-5). The general interpretation for SCI score ranges are provided in Table 4-6. The calculation methodology for the SCI was revised by DEP in June 2004, and sampling conducted from 2003 to 2006 uses that methodology. This change required a departure from the specific metrics listed for benthic macroinvertebrates in the HCSP plan; however, the plan contemplated such changes in methodology and the use of the revised protocol is acceptable with the plan. Between the 2004 and 2005 biological sampling events, individuals conducting biological sampling were trained and audited by the DEP in SCI and Stream Habitat Assessment techniques. Because of this improvement, some SCI results from previous years may not be directly comparable with results from 2005 and beyond.

Fortunately, the revisions to the SCI protocol in 2004 were implemented before the previous methodology was used to calculate SCI values for the HCSP, so there was no need to retroactively adjust SCI values from 2003 sampling results. Changes made to the calculation protocol were fairly esoteric, essentially based upon a broad array of statistical analyses with invertebrate samples collected across Florida to determine the best correlates with human disturbance to stream habitats (Fore 2004).

In 2007, the FDEP SCI protocol was again revised, this time to include provisions for the taxonomic analysis of two aliquots for every SCI sample collected to account for variation in sample sorting (DEP-SOP-002/01 LT 7200). Under the new protocol, the SCI score for each sample is the arithmetic average of the SCI scores of the two aliquots. In addition, the recommended number of invertebrates per aliquot was raised from 100 to 120 in 2004 to 140 to 160 in 2007. Table 4-5 provides the 2007 list of metrics used in calculating SCI scores, while the parameter table from the HCSP methodology document (copied as Table 4-4 above) includes the metrics used in the original SCI protocol. In addition to the change in aliquots in 2007, the new protocol also gives a slightly different ecological interpretation of SCI scores (Table 4-6).

In 2012, FDEP again revised the calculations in the SCI scores and altered the bioregions[6] in the state. This revised protocol was finalized in March 2014 and officially went into effect in July 2014. The revised SCI protocol is in a single SOP (DEP-SOP-003/11 SCI 1000) that includes the field, lab, and calculations procedures. The revised calculations for each of the metrics are shown in Table 4-5 alongside the SCI 2007 method. The method of collection and sorting (number of aliquots, recommended number of invertebrates per sample, etc.) and ecological interpretation (Table 4-6) did not change between the 2007 and 2012 SCI protocols, so samples collected under the 2007 protocol can be rescored under the 2012 calculations. Appendix J lists the SCI scores for every sampling date calculated under the 2004 protocol (2003 to 2006) or the 2007 and 2012 protocols (2007 to 2016). The SCI scores reported in Section 5.3 of the 2016 Annual Report were calculated using the 2012 protocol. Scores from the 2004 SCI (2003 to 2006[7]) and the 2007 or 2012 SCI (2007 to 2016) may not be directly comparable, given the differences in how they were collected.

---

[6] The change in bioregions for the 2012 SCI protocol does not affect this project.

[7] The November 2006 sample was collected under the SCI 2007 protocol and rescored under the SCI 2012 calculations. However, statistical analyses do not include that sample because the other two 2006 samples were collected under the old protocol and are not comparable.

The Shannon-Wiener Diversity Index was calculated using Ecological Methodology Software, Version 7.0 (www.exetersoftware.com).

Table 4-5. Equations for calculating SCI metrics for Peninsular Florida (individual metric scores range from zero to ten).

SCI Metric	2004/2007* Peninsula Score	2012 Peninsula Score
Total Taxa	10*(X-16)/25	10*(X-15)/24
Ephemeropteran Taxa	10*X/5	10*X/5
Trichopteran Taxa	10*X/7	10*X/7
Percent Collector-Filterer Taxa	10*(X-1)/39	10*(X-0.7)/43
Long-lived Taxa	10*X/4	10*X/3
Clinger Taxa	10*X/8	10*X/7
Percent Dominant Taxa	10-(10*[(X-10)/44])	10-(10*[(X-14)/50])
Percent Tanytarsini	10*[ln(X+1)/3.3]	10*[ln(X+1)/3.4]
Sensitive Taxa	10*X/9	10*X/7
Percent Very Tolerant Taxa	10-(10*[ln(X+1)/4.1])	10-(10*[(ln(X+1)-0.7)/4.0])

Note: In each equation, “X” equals the number representing the count or percentage listed in the corresponding row of the left column. For calculated values greater than ten, the score is set to ten; for values calculated less than zero, the score is set to zero.

* 2004 and 2007 used the same metric calculations; only the number of individual invertebrates (100-120 for 2004 and 140-160 for 2007) and vial replicates (no replicate in 2004) differ.

Table 4-6. Ecological interpretation of SCI scores calculated for benthic macroinvertebrate samples collected for the HCSP.

SCI Category	Range	Typical Description for Range
Category 3 (Exceptional)	68-100	Higher diversity of taxa than for Category 2, particularly for Ephemeroptera and Trichoptera; several more clinger and sensitive taxa than found in Category 2; high proportion for Tanytarsini; few individuals in the dominant taxon; very tolerant individuals make up a very small percentage of the assemblage.
Category 2 (Healthy)	35-67	Diverse assemblage with 30 different species found on average; several different taxa each of Ephemeroptera, Trichoptera, and long-lived and, on average, 5 unique clinger and 6 sensitive taxa routinely found; small increase in dominance by a single taxon relative to Category 1; very tolerant taxa represent a small percentage of individuals, but noticeably increased from Category 1.
Category 1 (Impaired)	0-34	Notable loss of taxonomic diversity; Ephemeroptera, Trichoptera, long-lived, clinger, and sensitive taxa uncommon or rare; half the number of filterers than expected; assemblage dominated by a tolerant taxon, very tolerant individuals represent a large portion or the individuals collected.

4.5 Fish

Fish sampling was conducted at all four HCSP stations during the 17 March and 16 November 2016 sampling events. Only two sampling events occurred in 2016 because of high water levels and flows that prohibited a summer sampling event. The Brushy Creek location is not included in the fish sampling component of the HCSP.

Fish were collected with a 4-foot by 8-foot seine (3 mm mesh size) and by electrofishing with a Smith-Root, Inc. backpack unit (Model LR-24 Electrofisher). Electrofishing was timed (typically 500 seconds), and the number of seine hauls (typically five) was recorded to standardize the sampling efforts among stations and between events.

Some fish (generally those larger than about 10 cm) were identified, weighed, measured, and released in the field, while some large and most small fish (<10 cm) were preserved in the field for analysis in the laboratory. All fish collected were identified in the field or laboratory according to American Fisheries Society-accepted taxonomic nomenclature (American Fisheries Society 2004). Total length (mm) and weight (g) were recorded for each individual, with the following exceptions: for samples with very large numbers of fish of the same species (a common occurrence with species like eastern mosquitofish [Gambusia holbrooki], least killifish [Heterandria formosa], and sailfin molly [Poecilia latipinna]), a randomly selected subset of individuals (approximately 10) were measured for length and weight, while the remaining individuals were counted and then weighed en masse. All fish retained as voucher specimens were submitted to the Ichthyology Collection at the Florida Museum of Natural History in Gainesville.

Taxa richness (number of species) and abundance were determined by station and for each sampling event, and data were compared among stations and across sampling events. The Shannon-Wiener Diversity Index and Morisita's Community Similarity Index were calculated using the Ecological Methodology Software. Species accumulation curves were plotted to estimate the efficacy of the sampling at producing a complete list of the species present in the sampled portions of the stream.

4.6 Initial General Habitat Configuration at Monitoring Stations

The following descriptions and panoramic photos of the four HCSP sampling sites represent the general habitat conditions at the time of initial sampling, April 2003. Several hurricanes in summer 2004, however, substantially altered the landscape and channel of Horse Creek, which have since continued to change through 2016.

The sampling segment at HCSW-1 is a deeply incised, narrow valley with very steep banks of rock-like outcroppings (Figure 4-1). The substrate is also rocky with little sand accumulation except in deeper holes. There is little woody/herbaceous structure at the water level. There are few undercut banks, but some eroded holes are available for fish and macroinvertebrates in the rocky substrate. Canopy cover in the sampling zone is heavy (>75 percent); thus the area receives a minimal amount of direct sunlight.

At HCSW-2, the sampling segment is essentially an oxbow of the main Horse Creek channel (Figure 4-1). The substrate is generally sandy. There are numerous holes, snags, and undercut banks and roots present. Canopy cover along the sampling zone is moderate (approximately 25 to 50 percent).

The sampling segment at HCSW-3 is more sinuous than the other three stations, with some shallow, sandy areas and several deep holes (Figure 4-1). There are numerous snags, undercut banks/roots, and occasional organic debris. Sand is the primary substrate component. During periods of low flow, portions of the sandy bottom are exposed, creating large sand bars. The canopy cover is low (approximately 25 percent); so, the area receives considerable direct sunlight.

At HCSW-4, the sampling segment is less sinuous (Figure 4-1). Submerged habitats include holes, undercut banks/roots, snags, and small amounts of emergent aquatic vegetation. The substrate is primarily sand, with occasional areas of small gravel. Several sand bars are located in the sampling zone and are exposed during periods of low flow. Canopy cover is moderate (about 50 percent).

4.7 Current Habitat Configuration at Monitoring Stations

At HCSW-1, the channel configuration in the sampling area is essentially fixed by the deeply incised, rock-like banks and has not been altered over the course of monitoring since 2003. Flow and water depth have been the two factors that have varied between monitoring events over time. While this site has the greatest canopy cover, there have been slight reductions since monitoring began, mainly because of land management activities[8]. Roots/undercut banks, snags, and rock-like structures have tended to be the main productive habitats during monitoring events, with the occasional leaf pack/mat or small vegetation patch sampled as minor habitats. Sand and silt deposition was relatively low during the November 2016 event with much rock exposed, but sand smothering was moderate during the March 2016 event. During March 2016, some algae was present within the first 40 m of the sample transect, slightly smothering rock and snag habitat, but it was not present at each of the 10-meter lines or observed during the November event. The updated fencing from 2014 remains, as does the cattle trail crossing the creek between the 0 and 10m mark which continues to be eroded by livestock movements. Numerous fish were observed but not caught during the March 2016 event (largemouth bass, bluegill, and other sunfish). The substrate diversity and availability were consistent between sampling events in 2016, as well as water velocities and levels (Figures 4-2 to 4-3).

At HCSW-2, the size and position of a sand bar on the west side of the stream in the sampling area has changed noticeably, indicating accrual of sediment there (Figures 4-2 to 4-3). The once sandy bottom has become dominated by detritus and muck as flow tends to be minimal at this site for most of the year. Snags and trees make up most of the stream segment from 40-65 meters with minimal flow and large accumulations of vegetation. Very little productive habitats are present upstream of the 70 meter mark as there are steep banks and deeper waters in this area. The Carolina willows (*Salix caroliniana*) once present downstream of the sampling area were blown-out during high flows during the wet season of 2012, which has appeared to help maintain flow for a longer duration of the year. Woody debris and aquatic vegetation were the main productive habitats during 2016 sampling events, similar to 2015. During the March event, many habitats had moderate silt smothering along with minor sand and algae smothering, and the greatest velocity observed (0.20 m/sec) was near the middle of the monitoring transect. There was less aquatic vegetation present in the November event compared to March event in 2016. Small amounts of algae were observed within the monitoring transect, but with less coverage in November 2016. In 2016, water hyacinth (*Eichhornia crassipes*) was trapped in the willows and other snags with higher coverage in March, but there were fairly consistent water velocities around 0.17 m/sec throughout during both sampling events. Buttonbush (*Cephalanthus occidentalis*) in the riparian zone was very healthy and appears to have filled in since 2013. During the 2016 wet season, the water levels overflowed both banks with high water marks clearly visible in the riparian vegetation.

At HCSW-3, the oak tree once present at the start of the transect in 2003 has slowly fallen into the water and has been washed away. The downed tree has acted like a barrier for floating vegetation, and has caught large quantities of water hyacinth after high flows in previous years. However, in 2013, the tree was mostly gone, and there was little vegetation accumulated at the remaining snag. In March 2016, additional trees were found to have fallen either over or into the water between the 60 and 80 meter marks in the transect; these newly felled trees were accessible as water levels were lower than the last 2015 monitoring event. This site still has good sinuosity and varying depths throughout which have been habitats for numerous fish species, including Florida gar. The riparian zone is still mainly treed pasture, with minimal canopy cover over the creek. In 2016, three productive habitats were present during the March 2016 event, while two productive habitats were present during the November 2016 event. In general, the quality of root habitat has declined over the last few years, while the addition of tress in this section has led to an increase in productive snag habitat. The large area of water hyacinth previously sampled was not observed in 2016, only a few small patches of water hyacinth was observed (30 to 40 meters and 90 to 100 meters) during the March event (Figures 4-2 to 4-3). There was a continued canopy cover change in 2016 with more trees in the water instead of on the banks, and minor algae coverage was observed on some of the felled trees during March 2016. Sand and silt smothering were slight to moderate throughout the year, with velocities that varied by season and within the 100-meters

---

[8] A controlled burn between December 2012 and March 2013 initially reduced 30-40 percent of trees and palmetto along the banks, but vegetation has slowly returned over time.

because of deeper pools (0.20-0.33 m/sec). During the wet season, water appeared to overflow the banks, and some bank erosion was present along with vine death on the banks.

At HCSW-4, the stream channel is steep-sided and generally deeper throughout the middle of the sampling area, which continues to complicate sampling efforts. Sampling is easier during times of lower flow and water levels (spring and winter events) as the entire creek bed can be traversed. During sampling events where there are higher water levels and flows, snags and undercut/banks roots have been the primary productive habitats. During low water level/flow sampling events, there has been high cover by aquatic vegetation as this site is generally open and plants can actually remain in place. Sand is still the dominant bottom substrate with slight changes in sandbar locations over time as flows and snags have dictated areas of deposition. The sand and silt smothering at this station was slight to moderate in 2016 with few habitats smothered, but a return of more shifty sand along the streambed. There was more sand deposition in March and more silt smothering in November with similar velocities observed during both events (0.25-0.33 m/sec). During the March 2016 event, there was more aquatic vegetation in the water to sample than in November 2016. Water hyacinth was not observed in 2016; swamp smartweed (*Polygonum hydropiperoides*) was present as the dominant species during both events both along the banks and in the water (Figures 4-2 to 4-3). Snags/woody debris and roots/undercut banks were major productive habitats during both events, while there was only enough aquatic vegetation in March 2016 to be considered a major productive habitat. While some aquatic vegetation habitats were not present during the November event, snags continue to be very productive habitats and can be sampled throughout the year.

HCSW-1 Horse Creek above SR 64

HCSW-2 Horse Creek above CR 663

HCSW-3 Horse Creek above SR 70

HCSW-4 Horse Creek above SR 72

Figure 4-1. Panoramic photographs of the HCSP sampling locations. Photos taken on 25 April 2003.

Figure 4-2. **Photographs of HCSP sampling locations on 17 March 2016.**

Figure 4-3. **Photographs of HCSP sampling locations on 16 November 2016.**

5 Water Quantity Results and Discussion

5.1 Rainfall

Figure 5-1 includes 2016 total monthly rainfall data from the three Mosaic rain gauges located in the Horse Creek watershed[9] (see Figure 1-1 for locations) as well as the nearby SWFWMD Flatford Swamp gauge. Total and median monthly rainfall in 2016 was slightly different at each gauge, but the heaviest rainfall was observed during January and from May to October at all locations (Figure 5-1). Overall rainfall averaged from the three Mosaic gauges for 2016 was less than totals from 2003 to 2005, greater than totals from 2006 to 2012, and similar to totals observed in 2013 to 2015 (Table 5-1, Figure 5-2); rainfall was slightly below the historic range (53 in) for the closest long-term NOAA station[10]. When one of the rainfall gauges was non-functional, average daily rainfall was calculated from the other functional gauges[11], and total monthly or annual rainfall was calculated from these adjusted daily averages.

Table 5-1. Annual total rainfall in inches at gauges in the Horse Creek watershed from 2003 to 2016.

Gauge	Horse Creek North	Horse Creek South	Manson Jenkins	Average of Mosaic Gauges	SWFWMD Flatford
2003	53.4	59.75	30.10*	57.10	49.85*
2004	53.82	60.74	62.15	58.90	59.85
2005	54.52*	64.53	31.34*	66.04	42.40
2006	31.82*	34.17	41.26	37.35	31.11
2007	33.9	31.97	32.49	32.79	38.45
2008	40.49	36.8	37.48	38.26	44.94
2009	36.63	43.7	46.87	42.40	44.23
2010	32.53	37.47	41.84	37.28	41.11
2011	24.54*	31.73*	39.85	37.11	40.25
2012	19.99*	36.06*	37.96*	44.49	51.99
2013	38.54*	54.69	34.33*	48.63	47.39
2014	47.93	39.22*	40.37*	49.06	52.69
2015	37.20*	35.64*	45.38*	44.13	59.89
2016	46.76*	50.72	48.09	51.43	53.99

* - Gauge was non-functional during portion of year.

---

[9] Continuous rainfall data collected by the SWFWMD at HCSW-3 (SWFWMD Station 494) ended in November 2011. Previous HCSP Annual reports used the USGS gauge at HCSW-1, which has been discontinued. At the end of July 2011, two new rainfall gauges (Pine Level 001 and 002) were installed by Mosaic in the lower basin west of stations HCSW-3 and HCSW-4, but they will not be used for general analysis purposes because there is only one complete year of data; these gauges may be used if the three upper basin gauges are all offline at the same time.

[10] Historical rainfall information came from the following stations and years: 1908 to 1943 NOAA station 148, 1944 to 2016 average of NOAA station 148 and 336

[11] Horse Creek North rain gauge was not functioning from January 5 to February 7 2016, the Horse Creek South and Manson Jenkins gauges were used during this period.

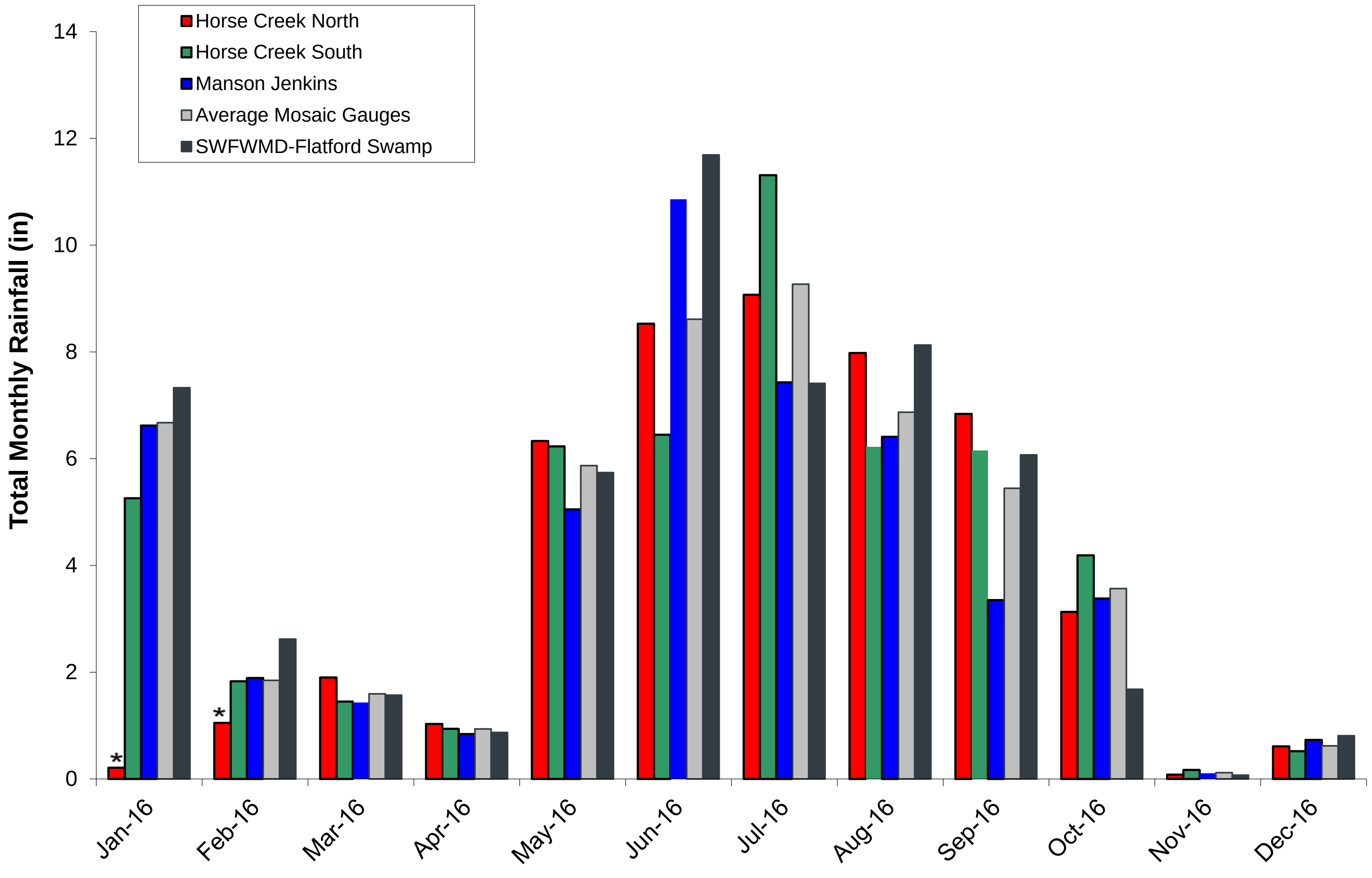


Figure 5-1. Total monthly rainfall from three Mosaic gauges and one SWFEMD gauge in the Horse Creek watershed in 2016.

* - Gauge was non-functional during portion or all of month.

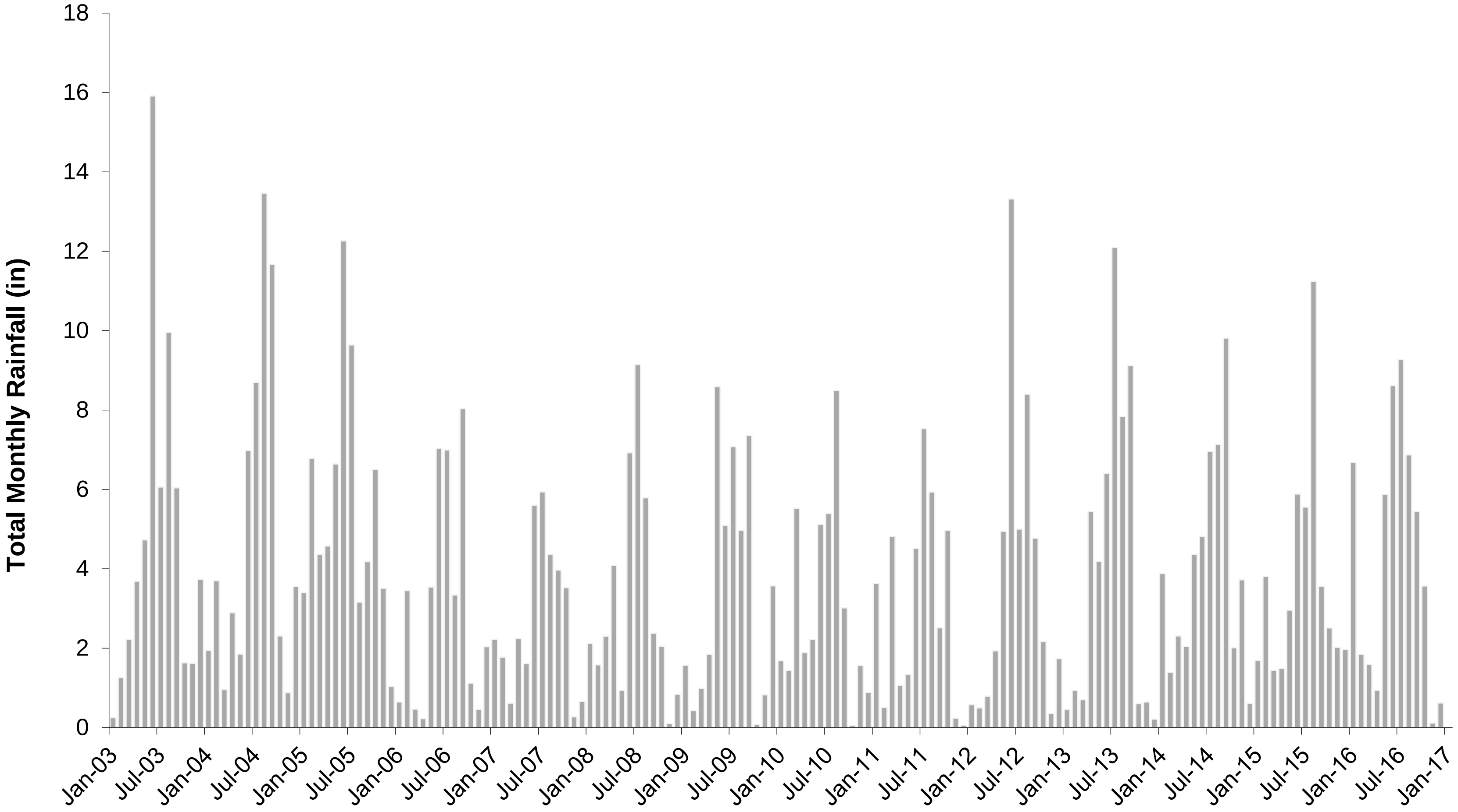


Figure 5-2. Total monthly rainfall from the average of three Mosaic gauges in the Horse Creek watershed from 2003 to 2016[12].

---

[12] All three Mosaic upper basin gauges were out of service from August 7, 2012, to September 11, 2012. Average of two Pine Level rain gauges were used for this period. Horse Creek North and Manson Jenkins rain gauges were not functioning properly from September 5 to September 30, 2013. Only the Horse Creek South gauge was used for this period. During May 2015 the Horse Creek North and Manson Jenkins gauges were not functioning, only the Horse Creek South gauge was used during this period; in September 2015 only the Manson Jenkins gauge was functional. Horse Creek North rain gauge was not functioning from January 5 to February 7 2016, the Horse Creek South and Manson Jenkins gauges were used during this period.

5.2 Stream Stage

Figure 5-3 illustrates the relationship between the four Mosaic staff gauge readings made during each Mosaic monthly water-quality sampling event. It also provides the average daily stage as recorded at the USGS gauging stations at HCSW-1[13] and HCSW-4 (after adjustment to NGVD datum). Patterns of daily stage levels were clearly temporally correlated among the four Mosaic stations (Figure 5-3). Stage height (feet NGVD) collected monthly by Mosaic at four sites and continuously by the USGS at two sites was examined using Spearman's rank correlations (Zar 1999) because the gauge heights are not distributed normally (Shapiro-Wilk test for normality, $p < 0.05$). Gauge heights showed a strong and significant correlation between all Mosaic stations and USGS stations (Table 5-2). Such close correspondence is expected for a fairly small watershed in a low gradient setting like peninsular Florida.

Mean daily USGS stage levels in 2016 were fairly high during mid-January through mid-February before decreasing through the remainder of the dry season. Water elevations increased again in early-June and remained there through mid-October at both HCSW-1[14] and HCSW-4 (Figure 5-3). Stage duration curves for 2016 were developed for HCSW-1 and HCSW-4 (Figure 5-4) to indicate the percentage of time stream stage was above particular elevations. Stage at HCSW-1 varied by 2.64 feet between the curve's P10 (70.41 feet NGVD) and P90 (67.77 feet NGVD) in 2016 (P10 and P90 are commonly used to bracket the 'typical' fluctuation of a water body, thus omitting the highest and lowest 10 percent of the flows). The difference in height between the maximum and the P10 shows that the highest rainfall events were enough to raise the stream at HCSW-1 3.56 feet in 2016. Stream stage at HCSW-4 is more variable than at HCSW-1 between the P10 (20.85 feet NGVD) and P90 (13.33 feet NGVD) (7.52 foot difference), but it also showed an additional rise in stage beyond the P10 level (2.39 feet) during high rainfall events. Stage levels in 2016 were relatively consistent for most of the year at both locations, with a brief increases in January/February and during the wet season (Figure 5-3).

Table 5-2. Coefficients of rank correlation (r_s) for Spearman's rank correlations of monthly gauge height (NGVD) from 2003 to 2016 ($p < 0.0001$).

	HCSW-1 (USGS)	HCSW-4 (USGS)	HCSW-1 (Mosaic)	HCSW-2 (Mosaic)	HCSW-3 (Mosaic)	HCSW-4 (Mosaic)
HCSW-1 (USGS)	1	0.91	0.99	0.83	0.81	0.90
HCSW-4 (USGS)		1	0.91	0.86	0.86	0.99
HCSW-1 (Mosaic)			1	0.81	0.79	0.90
HCSW-2 (Mosaic)				1	0.86	0.85
HCSW-3 (Mosaic)					1	0.85
HCSW-4 (Mosaic)						1

---

[13] The USGS censors gauge height at HCSW-1 in no flow or extremely low flow conditions, which leaves a broken line in Figure 5-3.

[14] USGS stage data was not available at HCSW-1 on September 1 (day following a heavy rainfall event causing rapid rise in water level) and from December 7 through the remainder of 2016.

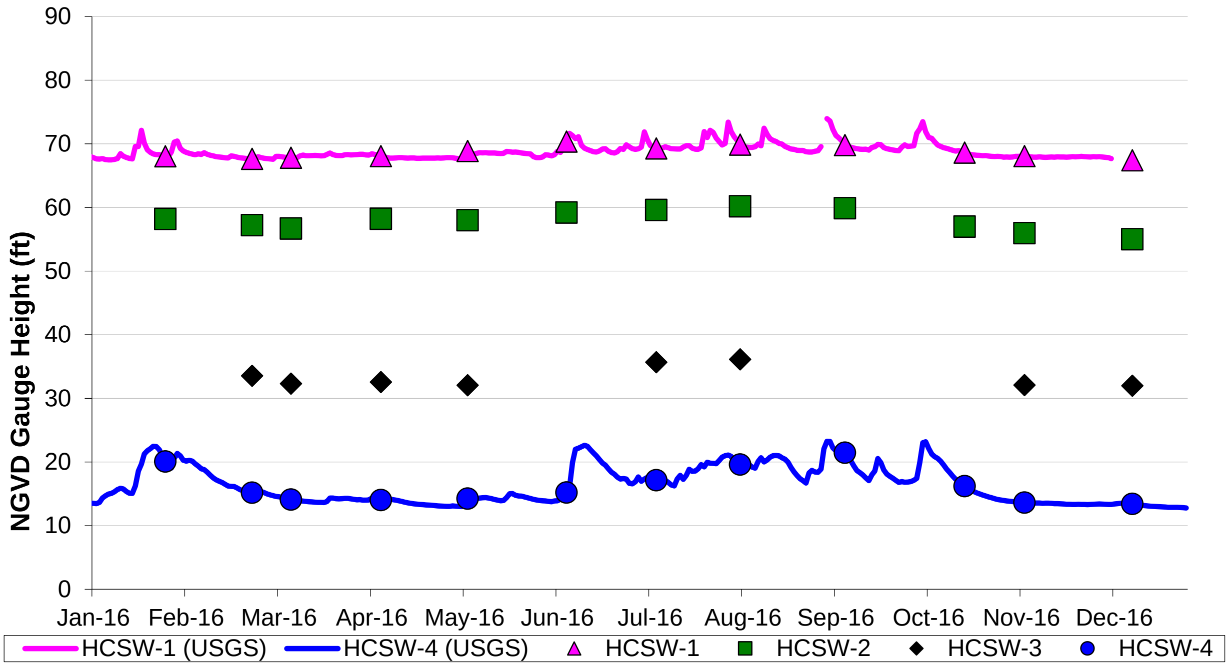


Figure 5-3. **Stream stage at HCSP monitoring stations in 2016. Individual data points are from Mosaic's monthly monitoring and continuous lines are average daily stage from USGS (Stations 02297155 and 02297310).**

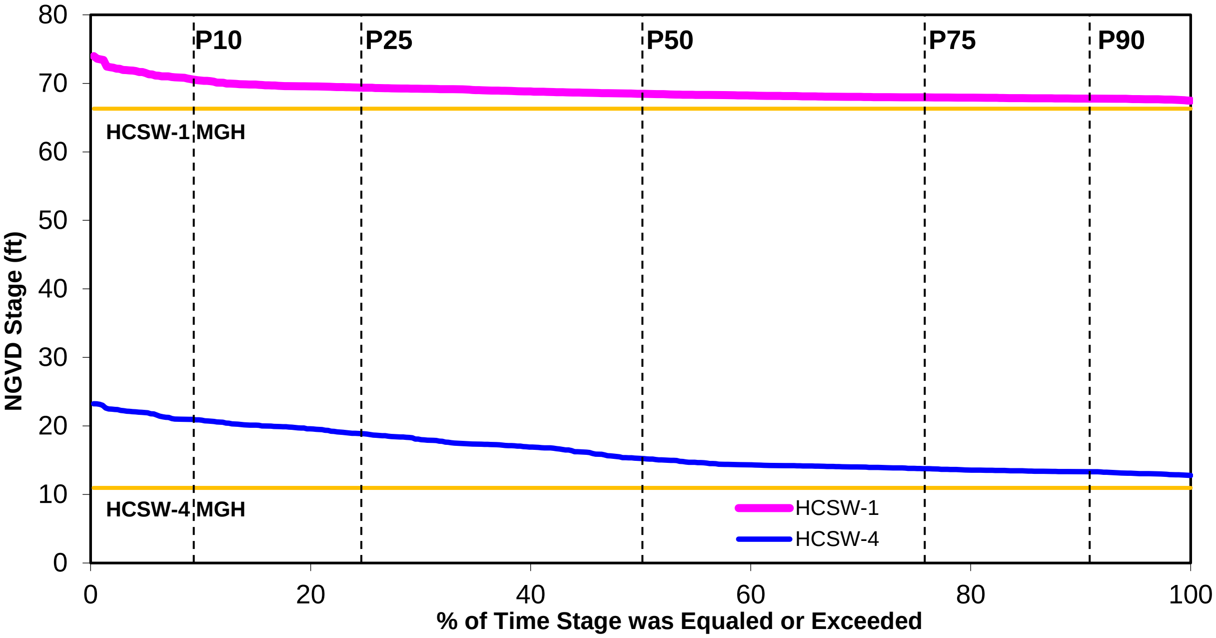


Figure 5-4. **Stage duration curves for HCSW-1 and HCSW-4 in 2016 showing percent of year water levels were at or above a given stage. Typical reference points of 10% (P10), 25% (P25), 50% (P50), 75% (P75), and 90% (P90) are indicated on the graph, as well as the minimum gauge heights (MGH) of HCSW-1 (66.3 ft. NGVD) and HCSW-4 (10.96 ft. NGVD).**

5.3 Streamflow

The average daily streamflow for 2016, obtained from the USGS continuous recorder data for HCSW-1 and HCSW-4, is presented in Figure 5-5 and Table 5-3. In 2016, there was a period of slightly higher flow during the dry season that corresponded to heavy rain events (mid-January to mid-February). Then, flows were generally low from March to early-June before increasing rapidly; flows were then variable for the remainder of the wet season, responding to high rainfall events (Figure 5-5). Additionally, a final large increase in streamflow occurred in early-October before water levels decreased through the end of the year, similar to historical patterns (Durbin and Raymond 2006). Average daily stream flows exhibited a similar pattern at both HCSW-1 and HCSW-4, with higher flows at HCSW-4 beginning earlier and ending later than HCSW-1 for the winter rain event and summer wet season (Figure 5-5). Streamflow magnitude was much higher at HCSW-4 than at HCSW-1 as a logical consequence of HCSW-4's larger drainage area.

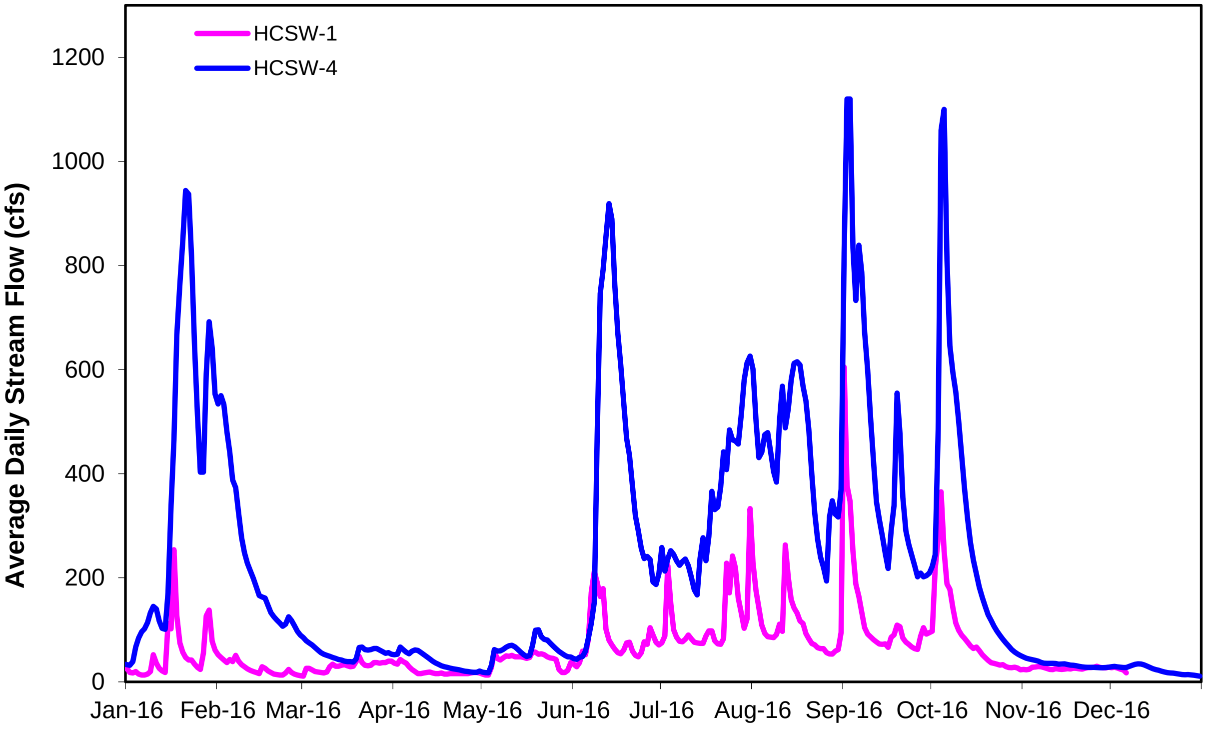


Figure 5-5. Average daily streamflow at HCSW-1 and HCSW-4 in 2016.

At HCSW-1, streamflow in 2016 was similar to previous wet years since 2003, with similar median flows to wet years (2003-2005, 2010) and average 90th percentile flows overall (Table 5-3, Figure 5-6). At HCSW-1, tenth percentile and median streamflow in 2016 were higher than those observed in 2003 to 2005 and 2010, but the ninetieth percentile was similar to high flow years. At HCSW-4, tenth percentile and median streamflow in 2016 was similar to 2003 to 2005 flows and higher than those observed in 2010 (Table 5-3). Ninetieth percentile streamflow at HCSW-4 in 2016 was around average for all other annual streamflow (Table 5-3). Compared to long-term annual average daily streamflow[15] for HCSW-1 (31.72 cfs) and HCSW-4 (188.64 cfs), streamflow in 2016 was above average at both HCSW-1 (66.71 cfs) and

---

[15] Long-term annual average of daily streamflow calculated for 1978 to 2016 for HCSW-1 and 1951 to 2016 for HCSW-4 using USGS gauging stations.

HCSW-4 (228.81 cfs). Over the course of the HCSP, 2003 to 2005, 2013, and 2015 to 2016 were wet years, while 2006 to 2008 and 2014 were very dry years (Figure 5-6), which matches up with the NOAA Palmer Modified Drought Index (PMDI[16]) for the region. In south-central Florida, the PMDI shows 2006 to 2008 to be a period of moderate to extreme drought and 2009 to 2012 to be a period of mild to moderate drought; these drought periods are reflected in the streamflow in Horse Creek.

Table 5-3. Median, 10th percentile, and 90th percentile streamflow (cfs) at HCSW-1 and HCSW-4 from 2003 to 2016.

Station	Year	10th	Median	90th
HCSW-1	2003	2	20	127
	2004	< 1	7	166
	2005	6	21	134
	2006	< 1	5	29
	2007	< 1	3	8
	2008	0	2	39
	2009	< 1	5	102
	2010	< 1	27	80
	2011	< 1	5	97
	2012	< 1	7	91
	2013	2	4	156
	2014	2	6	47
	2015	3	22	108
	2016	17	46	138
HCSW-4	2003	21	84	1222
	2004	15	56	1184
	2005	36	145	653
	2006	4	24	379
	2007	4	14	43
	2008	2	13	285
	2009	2	26	368
	2010	19	93	379
	2011	2	26	296
	2012	< 1	18	406
	2013	4	18	645
	2014	11	38	187
	2015	13	73	570
	2016	28	112	593

---

[16] The Palmer drought program calculates three intermediate parallel index values each month. Only one value is selected as the PDSI drought index for the month. This selection is made internally by the program on the basis of probabilities. If the probability that a drought is over is 100%, then one index is used. If the probability that a wet spell is over is 100%, then another index is used. If the probability is between 0% and 100%, the third index is assigned to the PDSI. The modification (PMDI) incorporates a weighted average of the wet and dry index terms, using the probability as the weighting factor." From: https://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp#.

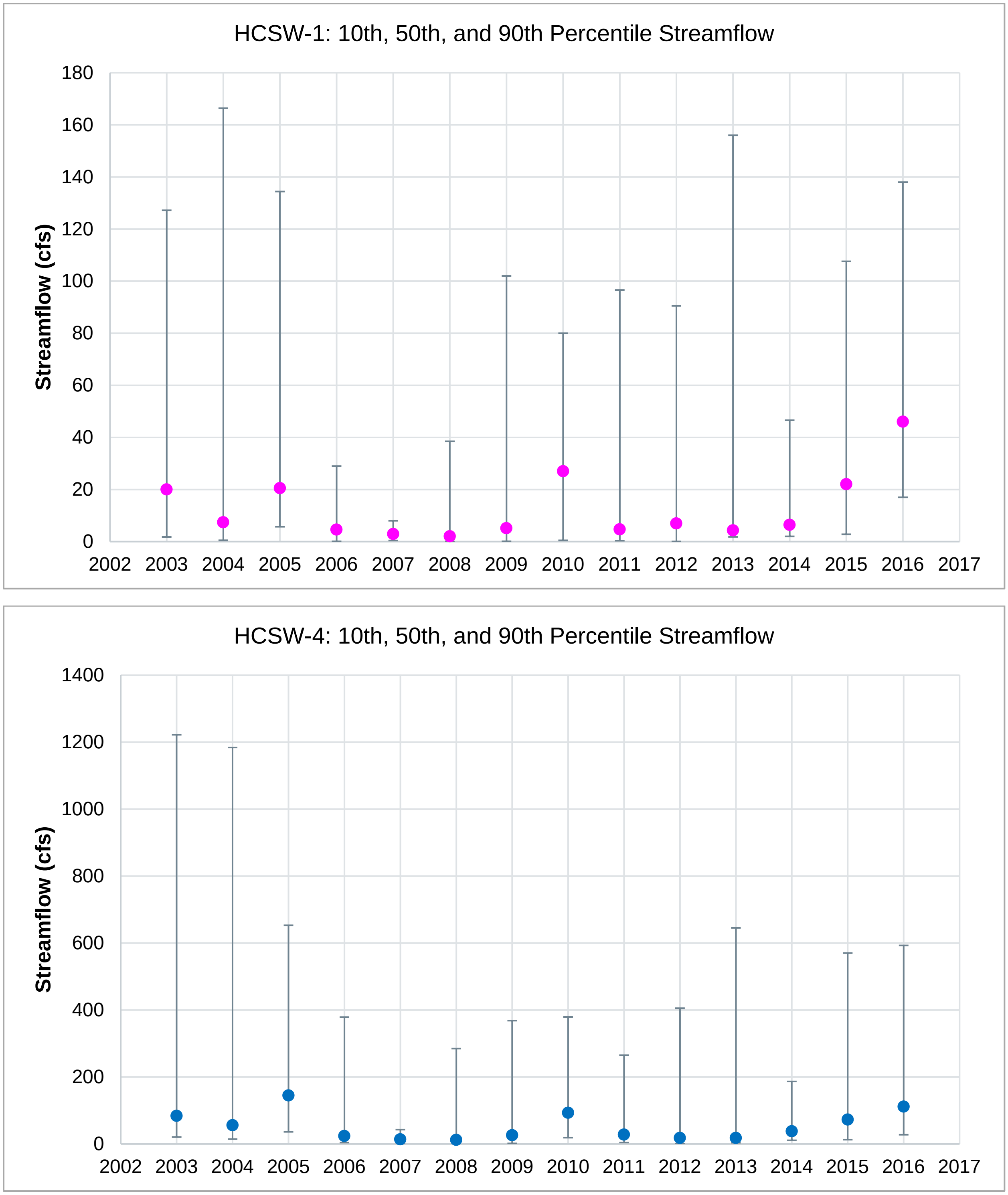


Figure 5-6. **Median (marker), 10th percentile (lower bar), and 90th percentile (upper bar) streamflow at HCSW-1 and HCSW-4 from 2003 to 2016.**

5.4 Rainfall-Runoff Relationship

Stream discharge at HCSW-1 and the average daily rainfall for 2016 (average of daily rainfall at three Mosaic rain gauges upstream of Highway 64 and SWFWMD Flatford Swamp gauge located west of Horse Creek) are compared in Figure 5-7. To examine the strength of covariation between daily stream discharge and rainfall, Spearman's rank correlation procedure was used (Zar 1999). Average monthly stream discharge at HCSW-1 was compared to total monthly rainfall at the SWFWMD Flatford Swamp gauge, the three Mosaic rain gauges, and the average total monthly rainfall of the Mosaic gauges for the years 2003 to 2016.

The correlation between stream discharge at HCSW-1 and rainfall was statistically significant for each rainfall gauge (Table 5-4). Although these results suggest that stream discharge and rainfall in Horse Creek covary more than would be expected by chance alone, not all of the variation in streamflow is explained by rainfall ($0.47 < r < 0.56$). The lag between rainfall and runoff, as well as other antecedent condition factors, are strongly affecting this relationship in the full dataset; however, there is very little lag between 2016 rainfall events and streamflow response in January and February and again in mid-June to early-October 2016 (Figure 5-7). At the beginning of the wet season, the lag effect between rainfall and streamflow is more apparent as the surrounding wetlands or small creeks either need to fill or resume flow. However, later in the wet season when the wetlands and small creeks are full, the lag is much shorter, as can be seen in Figure 5-7. To look at the relationship on a longer timeframe than the HCSP, Figure 5-8 shows the total monthly rainfall (NOAA) and the monthly average of daily stream discharge at HCSW-1 from 1978 to 2016.

Figure 5-9 illustrates the relationship between cumulative annual discharge at HCSW-1 and annual NOAA rainfall from 1978 to 2016[17]. Changes in the relationship between rainfall and stream discharge can be seen as inflection points in the overall slope. Over the HCSW-1 period of record, there were three potential inflection points. In 2000 (red line on Figure 5-9), cumulative discharge began to increase slightly relative to rainfall for a few years when rainfall was above average relative to the slope of the overall period of record, meaning there was more stream discharge per unit of rainfall. Between 2005 and 2008 (green line on Figure 5-9), which included several very dry years, cumulative discharge had almost no increase, despite changes in cumulative rainfall. Thus, as expected during a very dry period, the relationship changed and less water entered the stream per unit rainfall than happened during wetter periods. After 2008 (purple line on Figure 5-9), the slope was again similar to the wet period of 2000 to 2004 and the overall period of record slope, because rainfall began to return to average conditions and cumulative discharge began to resume previous patterns relative to cumulative rainfall.

If mining was having a significant effect on the amount of water that reached Horse Creek at HCSW-1 compared to rainfall, then one would expect to see one or more large inflection points that correspond to the beginning of mining in the basin or the mining of large tracts lasting for many years. However, for the majority of the period of record (which included pre-mining data), the relationship is remarkably constant over time, with only a few minor inflection points that correspond to unusually wet and dry periods in the 2000 decade. These findings suggest that mining activities have not changed the overall relationship between annual rainfall and stream discharge at HCSW-1, based on the data available.

---

[17] To look at the relationship between stream discharge and rainfall over the stream gauge period of record, HCSW-1 discharge was converted from cubic feet per second (cfs) to cumulative discharge in thousands of cfs days. Cumulative historical rainfall was calculated from NOAA gauges 148 and 336, which have a longer period of record than the SWFWMD or Mosaic gauges. Potential inflection points are limited to changes in slope that last at least 3 years.

Table 5-4. **Coefficients of rank correlation (r_s) for Spearman's rank correlations of HCSW-1 monthly average streamflow and total monthly rainfall at SWFWMD Flatford Swamp gauge and three Mosaic gauges from 2003 to 2016.**

Rainfall Gauge	r_s (with HCSW-1 Streamflow)	p value	N (Sample Size)*
Horse Creek North	0.47	<0.0001	158
Horse Creek South	0.48	<0.0001	167
Manson Jenkins	0.49	<0.0001	160
Average Mosaic Rainfall	0.56	<0.0001	168
SWFWMD Flatford Swamp	0.50	<0.0001	168

* Months with >10 days of missing data were omitted from the trend analysis.

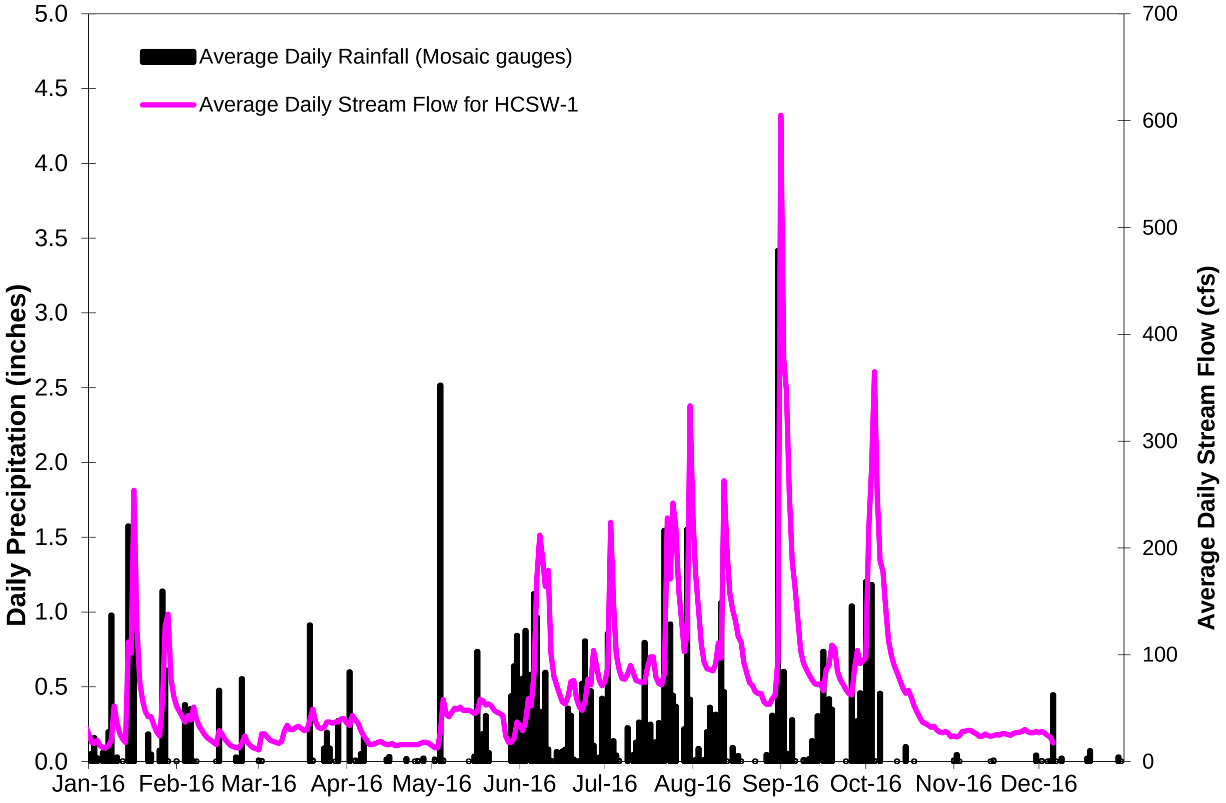


Figure 5-7. **Average daily streamflow at HCSW-1 and average daily rainfall (from three Mosaic gauges[18]) in the Horse Creek watershed in 2016.**

---

[18] Horse Creek North rain gauge was not functioning from January 5 to February 7 2016, the Horse Creek South and Manson Jenkins gauges were used during this period.

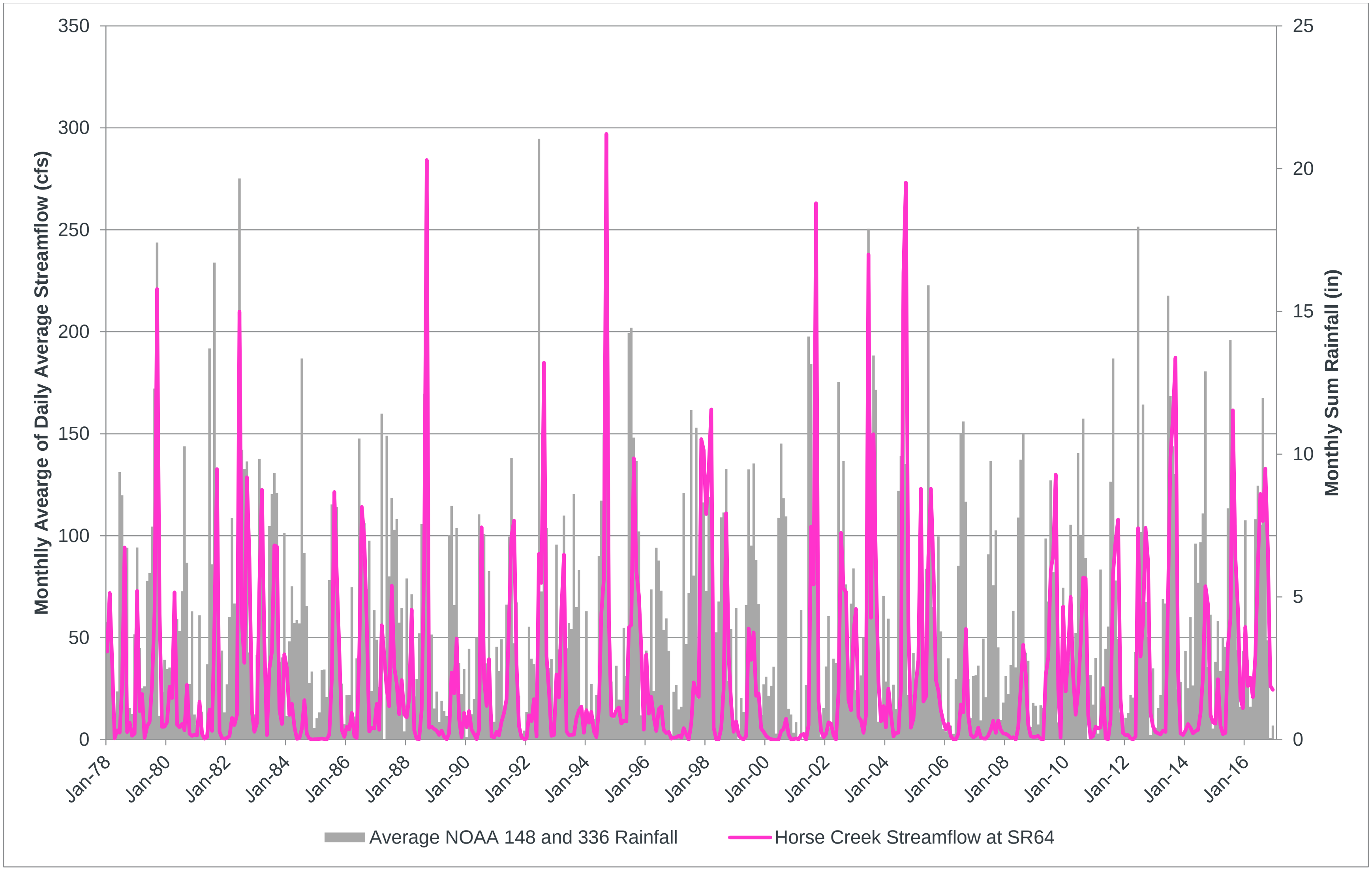


Figure 5-8. **Monthly average of average daily streamflow at HCSW-1 and monthly sum of rainfall (average of NOAA 148 and 336 gauges) in the Horse Creek watershed from 1978 to 2016.**

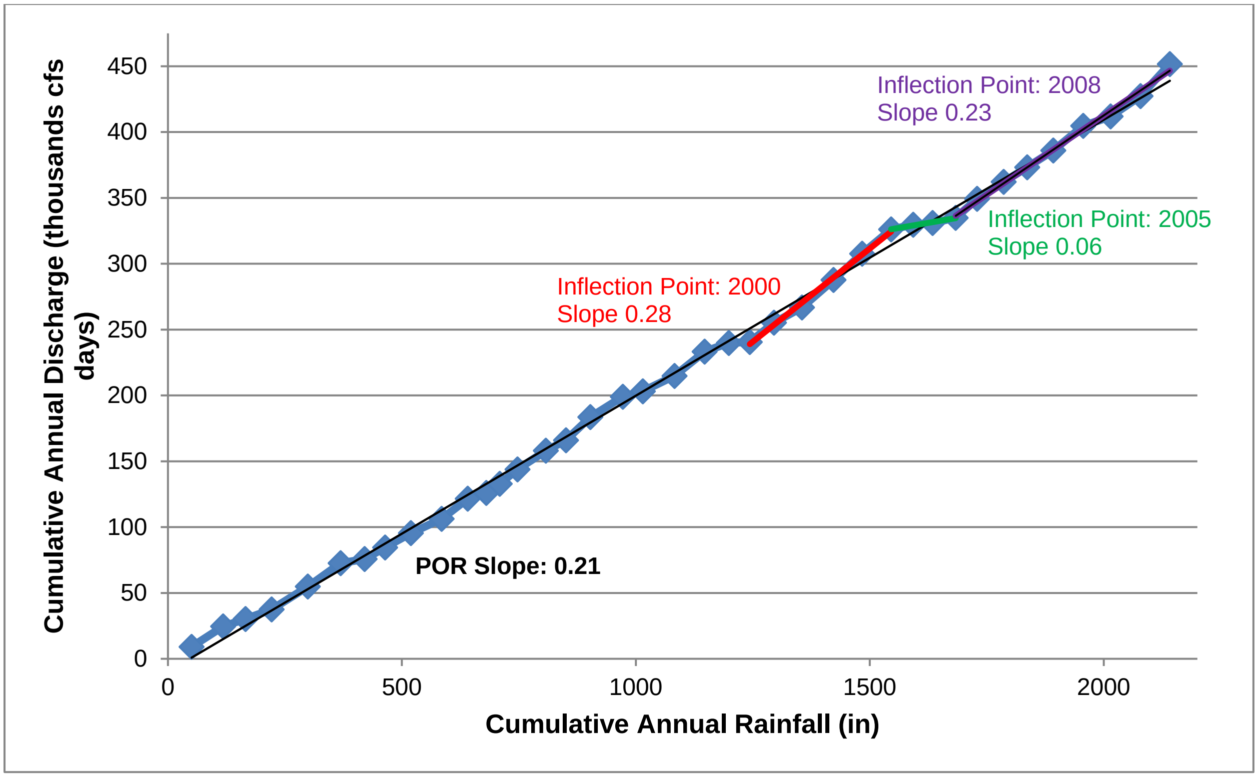


Figure 5-9. **Double mass curve of cumulative daily discharge (USGS gauge at SR64) and rainfall (NOAA gauges 148 and 36) at HCSW-1 from 1978 to 2016.**

5.5 NPDES Discharges

Industrial wastewater is discharged to Horse Creek through two outfalls (FTG-003 on the Fort Green NPDES Permit FL0027600 and WIN-004 on the Wingate NPDES Permit FL0032522, see Figure 1-1). Both outfalls are 20-foot wide concrete flumes with continuous flow measurement. A mine wastewater system consists of clay settling areas, mined but not yet reclaimed land, and unmined but disturbed lands. The runoff from all these lands is contained within the industrial wastewater system boundaries. The "loop" of wastewater from the plant to the clay settling areas with the subsequent return of clarified water to the plant for reuse is the backbone of the system. The system has a finite storage capacity and excess wastewater (as a result of rainfall into the system) is discharged from permitted outfalls. This general relationship is illustrated in the rainfall and NPDES discharge data for 2016 (Figure 5-10). Mosaic has no other discharges to Horse Creek (including from the legacy CF Industries property), and no other known industrial wastewater discharges to Horse Creek or any tributary by any other firm are known.

Because they potentially affect stream discharge, the combined 2016 daily discharge of two Mosaic NPDES outfalls (FTG-003 and WIN-004) located upstream of HCSW-1 was plotted against the 2016 daily streamflow for HCSW-1 (Figure 5-11)[19]. In 2016, the NPDES outfalls discharged for 283 days (1 March to 8 December, Table 5-5) into Horse Creek. Comparing HCSW-1 stream discharge and NPDES discharge from 2003 to 2016 using a Spearman's rank correlation procedure (Zar 1999) indicates they covary strongly ($r_s = 0.76$, $p < 0.0001$). In the observed data, generally an increase in one parameter occurs at the same time the other parameter increases. Just as streamflow at HCSW-1 was correlated with rainfall

---

[19] Mosaic gauge may be based on instantaneous rather than continuous flow.

(Table 5-4), so too is streamflow correlated with NPDES discharge (Table 5-6, Figure 5-10), with lag times and antecedent conditions affecting this relationship.

There is a lag in the start of NPDES discharge relative to rainfall (similar to the lag between rainfall and streamflow), because the NPDES system must fill to the discharge elevation, which can occur further into the wet season. NPDES discharge can also continue after the wet season rains have slowed (Figure 5-10) until water is once again below the discharge elevation in the circulation system. In 2016, NPDES discharge began in March following the abnormally wet months of January and February and continued to early-December, corresponding with periods of the highest rainfall and streamflow. NPDES discharge was a small percentage of streamflow at both stations in 2016, except from March to early-June and late-October until early-December. Rainfall in 2016 was above average, and there were multiple moderate (1.0 inch or greater) rain events during the wet season of 2016 instead of a gradual cumulative increase from June through September like most years, which potentially led to a steady volume of NPDES discharge to Horse Creek over the same period (Figure 5-10). The last major rainfall event of the year occurred the first week in October, which led to a final peak in streamflow and continued NPDES discharge through early-December (Figures 5-7 and 5-11).

Table 5-5. 2016 total monthly Mosaic NPDES discharge to Horse Creek (FTG-003 and WIN-004 outfalls).

Month	Discharge to Horse Creek (MG)
January	0
February	0
March	439.35
April	341.68
May	728.25
June	591.40
July	1082.71
August	1208.68
September	1163.17
October	842.54
November	552.13
December	96.933
Annual Total	**7046.84**

Table 5-6. Coefficients of rank correlation (r_S) for Spearman's rank correlations of monthly average NPDES discharge and USGS daily streamflow, gauge height, and total monthly rainfall at three Mosaic gauges and a SWFWMD gauge from 2003 to 2016.

Gauge	r_S (with NPDES Outfall)	p value	N (Sample Size)
HCSW-1 (USGS Streamflow)	0.76	< 0.0001	168
HCSW-1 (USGS Gauge Height)	0.76	< 0.0001	167
Horse Creek North (Rain)	0.37	< 0.001	158
Horse Creek South (Rain)	0.32	< 0.001	167
Manson Jenkins (Rain)	0.27	< 0.001	160
Average Mosaic Rainfall	0.36	< 0.001	168
SWFWMD Flatford Swamp (Rain)	0.3	< 0.0001	168

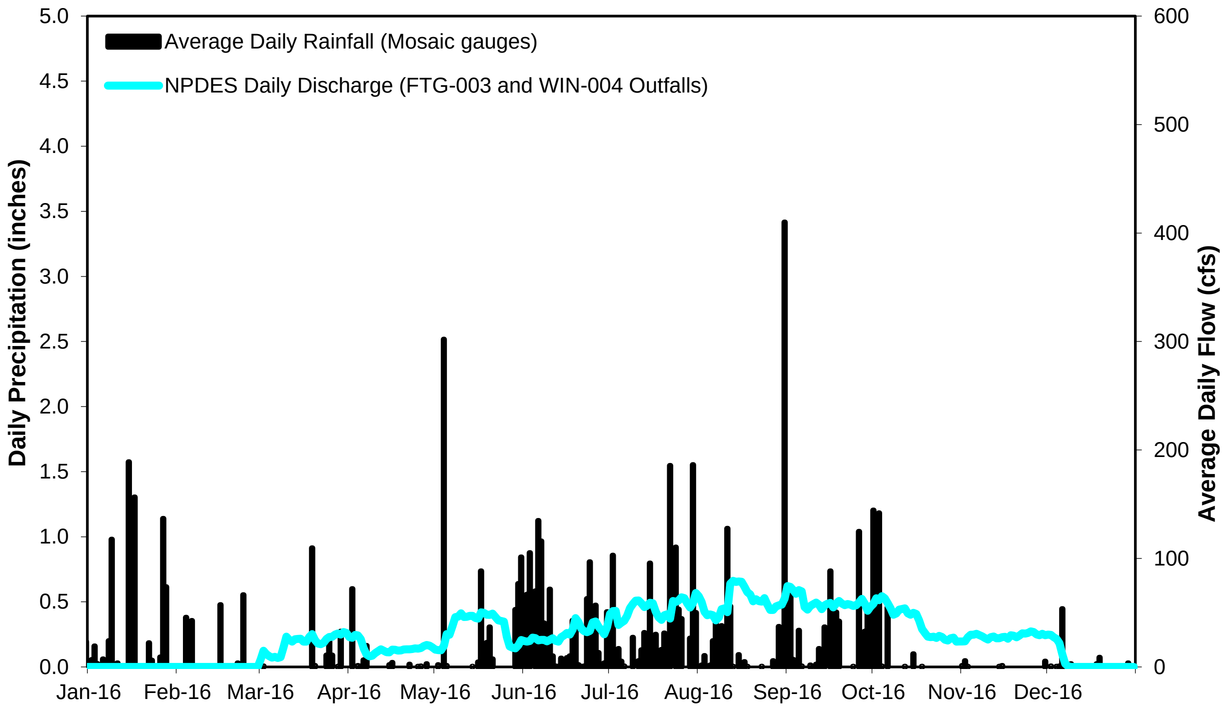


Figure 5-10. Combined Mosaic NPDES discharge and average daily rainfall in the Horse Creek watershed in 2016.

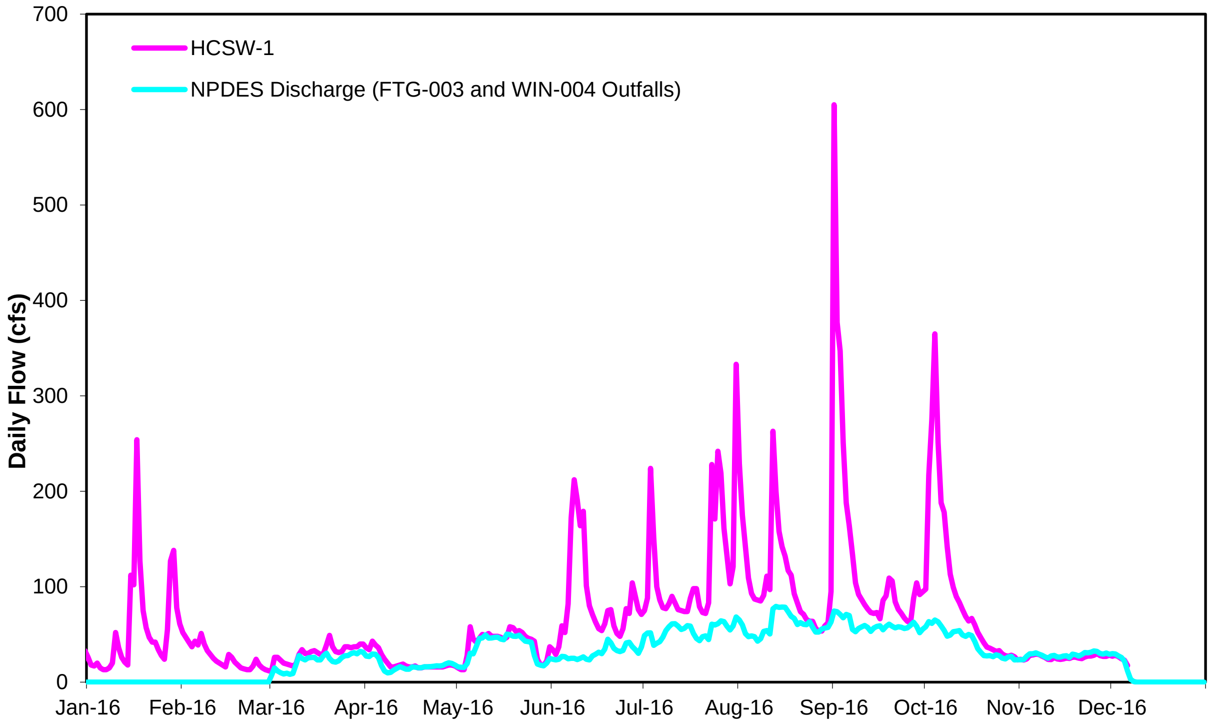


Figure 5-11. Daily streamflow at HCSW-1 and combined Mosaic NPDES discharge in 2016.

5.6 Summary of Water Quantity Results

The annual average daily streamflow at Horse Creek in 2016 at both HCSW-1 (67 cfs) and HCSW-4 (229 cfs) was above the long-term annual averages[20] of 32 and 189 cfs, respectively. Annual rainfall of 63 inches in 2016 was above the long-term average annual rainfall of 53 inches (1908-2016)[21]. In 2016, there was a period of slightly higher flow during the dry season that corresponded to heavy rain events (mid-January to mid-February). Then, flows were generally low from March to early-June before increasing rapidly; flows were then variable for the remainder of the wet season, responding to high rainfall events. Additionally, a final large increase in streamflow occurred in early-October before water levels decreased through the end of the year, similar to historical patterns (Durbin and Raymond 2006). At the beginning of the wet season, the lag effect between rainfall and streamflow is more apparent as the surrounding wetlands or small creeks either need to fill or resume flow. However, later in the wet season when the wetlands and small creeks are full, the lag is much shorter.

NPDES discharge accounted for 73 percent of streamflow on average at HCSW-1 during the period of NPDES discharge (ranging from 12 percent to 100 percent over the 283 days of discharge). NPDES discharge from March to December was a lagged response to larger rainfall events that occurred from late-January through February and multiple moderate (greater than one inch) rainfall events that continued throughout the wet season; NPDES discharge from the Horse Creek outfalls usually does not occur until sufficient water storage accumulates in the circulation system, resulting in a lag. In general, the above average rainfall in 2016 coupled with multiple moderate rain events during the wet season led to a steady volume of NPDES discharge to Horse Creek for most of the year.

There is no evidence that mining and reclamation activities in the basin caused any statistically significant decrease in total streamflow in 2016, according to the double mass curve analysis. In a previous study (Robbins and Durbin 2011) that compared streamflow during dry years in reference and potentially impacted streams before and during phosphate mining, there was no evidence that phosphate mining practices caused lower monthly flows in the potentially impacted streams (including Horse Creek) than what would be expected given the conditions in a reference stream (Charlie Creek).

---

[20] Long-term annual average of daily streamflow calculated for 1978 to 2016 for HCSW-1 and 1951 to 2016 for HCSW-4 using USGS gauging stations.

[21] Historical rainfall information came from the following stations and years: 1908 to 1943 NOAA station 148, 1944 to 2016 average of NOAA station 148 and 336.

6 Water Quality Results and Discussion

The results of field measurements and laboratory analyses of water samples obtained monthly during 2016 at each HCSP monitoring station are presented in this section (see Appendix C for water quality figures from 2003 through present). Continuous recorder data at HCSW-1 for pH, dissolved oxygen, turbidity, and specific conductivity are also presented, along with the field measurements obtained during benthic macroinvertebrate and fish sampling on 17 March and 16 November 2016. Water quality raw data are included in an Access database on the Cardno FTP site.

In September 2009, based on recommendations of the PRMRWSA and the TAG, Mosaic began sampling water quality at an additional station on Brushy Creek (BCSW-1 at Post Plant Road). Brushy Creek is a tributary to Horse Creek and flows into Horse Creek between the HCSW-1 and HCSW-2 sampling stations. This additional station was added for comparison purposes, and will not be evaluated against the HCSP trigger levels and exceedances. Mosaic does not currently have a NPDES outfall on Brushy Creek. While the Brushy Creek data has been included in the graphs of the 2016 water quality data, it was not included in any other plots or analyses.

In September 2009, Mosaic also discontinued water quality analysis for FL-PRO, total fatty acids, and total amines based on recommendations made in previous HCSP annual reports. Mosaic, PRMRWSA, and the TAG agree that the results for these parameters from 2003 to 2009 show that these parameters are present only occasionally at very low concentrations, and are not a cause for concern at this time.

Water quality of NPDES discharge is normally obtained periodically when water is discharged from Outfalls FTG-003 and WIN-004. Water was discharged for 283 days in 2016 from WIN-004, with multiple water quality samples taken. No water was discharged from FTG-003 in 2016. For all 2016 NPDES discharge water quality results, chlorophyll-*a* was the only water quality parameter above the Horse Creek trigger levels (Table 6-1). Half of the chlorophyll-*a* measurements were above the trigger level of 15 mg/m^3. All NPDES discharge water quality measurements, including chlorophyll-*a*, were within NPDES permit limits, where applicable.

Table 6-1. Water quality summary of NPDES discharge into Horse Creek during 2016 at Outfall WIN-004.

Parameter	Units	Outfall WIN-004 (March – December)			
		Count	Avg	Min	Max
pH	SU	41	7.56	7.06	8.31
Conductivity	µmhos/cm	10	550	505	599
Water Temperature	°C	10	26.4	21.2	32.8
Turbidity	NTU	41	5.91	3	11.2
Dissolved Oxygen	mg/L	10	6.81	3.64	8.53
Dissolved Oxygen	% Saturation	10	84.1	47.5	97.2
TSS	mg/L	41	5.18	2.0	10.4
Total Phosphorus	mg/L	41	1.24	0.16	2.26
Nitrate-Nitrite	mg/L	10	0.01	0.01	0.022
TKN	mg/L	10	1.25	0.855	1.74
Total Nitrogen	mg/L	10	1.25	0.858	1.75
Fluoride	mg/L	5	0.74	0.66	0.852
Sulfate	mg/L	10	182	156	209
Chlorophyll-*a*	mg/m^3	10	**17.6**	5.9	**36.9**

6.1 Data Analysis

Line graphs are used to display water quality measurements for each parameter during 2016, but the lines connecting each station's measurements are included merely to enhance visual interpretation and not to imply that the values between actual measurements are known (Appendix C contains line graphs for each parameter from 2003 to 2016). For continuous recorder data measured at HCSW-1 in 2016, the daily mean of the water quality parameter is plotted with streamflow from the USGS gauge at HCSW-1. Monthly water quality data for 2003 to 2016 were compared to other data sources (SWFWMD, FDEP, USGS) since 1990 using median box-and-whisker plots (Appendix C). Graphical representations of HCSP data include undetected values, represented by the respective MDLs for each parameter, except for total nitrogen and total radium. Total nitrogen and total radium are composite parameters without MDLs. Values of these parameters for which one or both components were undetected are circled in red. Undetected results for all parameters were changed to one-half of the MDL for any statistical analyses.

Based on a literature review on tests for water quality data trend detection (Appendix D), the best monotonic trend detection method for use in the HCSP is the Seasonal Kendall. Because the USGS recommends a minimum of five years of data collection before applying the Seasonal Kendall test (Schertz et al. 1991), the 2008 Annual Report was the first report to include this analysis. The Seasonal Kendall method is a frequently recommended method for detecting trends in water quality data (Lettenmaier 1988, Hirsch et al. 1982, Harcum et al. 1992, Helsel et al. 2006). The Seasonal Kendall was developed by and is now the method of choice for the USGS (Hirsch et al. 1982, Helsel et al. 2006).

The Seasonal Kendall test determines water quality trends after correcting for seasonality by only comparing values between similar seasons over time (Schertz et al. 1991). The Seasonal Kendall test selects one value for each season (average, median, or subsample) and makes all pair-wise comparisons between time-ordered seasonal values (Harcum et al. 1992). A test statistic (Tau) is computed by comparing the number of times a later value is larger than an earlier value in the data set, and vice-versa (Schertz et al. 1991). Results for the Seasonal Kendall include the magnitude of the statistic Tau, its significance (p), its slope (Sen slope estimator), and the direction of significant trends. The trend (Sen) slope is the median slope of all pairwise comparisons. The direction of this slope (positive or negative) is more resistant to the effects of observations below minimum detection limits and missing data than the magnitude of the slope. The slope is a measure of the monotonic trend; the actual temporal variation may include step trends or trend reversals. If alternate seasons exhibit trends in opposite directions, the Seasonal Kendall test will not detect an overall trend (Lettenmaier 1988).

Trend detection in this report is limited by several factors. With fourteen years of data, the power of the test to detect trends of small magnitude may be limited (Harcum et al. 1992, Hirsch et al. 1982). Data for parameters whose method detection limits have changed several times over the HCSP (fluoride, nitrate-nitrite, ammonia) would have to be truncated to the highest detection limit, thereby reducing the available data for the test. As a result, trends were evaluated using alternative data collected by SWFWMD for these parameters; SWFWMD reduced sampling frequency in 2011, so seasonal trend tests may not be as accurate for those parameters. Because HCSW-1 and HCSW-4 were the only stations with USGS flow data that is necessary for interpreting trends in flow-dependent parameters, they were the only stations used in this trend analysis. Any changes over time detected using the Seasonal Kendall test should be further examined to determine if the perceived change is caused by a data bias, if its magnitude is ecologically significant, and if the cause of the trend is related to Mosaic mining activities. If warranted, an impact analysis can be performed on statistically significant trends to determine if trends are caused by Mosaic mining activities and if a corrective action by Mosaic is necessary.

A summary of the Seasonal Kendall Tau results for all parameters is presented in Table 6-2 with an in depth discussion of trends presented for each individual parameter. The year was split into three seasons, corresponding to wet/dry periods. Season one encompassed the first part of peninsular Florida's dry season, January through April. Season two spanned May to September (the wet season along with May, which in this region tends to be fairly wet), and season three represented the second dry season during the calendar year, October through December. The Sen slope estimate for a parameter was only reported if the trend was statistically significant (significant p values [less than 0.05] are highlighted in yellow in Table 6-2). For those parameters where SWFWMD data was used for trend analysis (fluoride, nitrate-nitrite, and ammonia), the magnitude of the slope estimate may not be accurate because in October 2011, SWFWMD went from monthly sampling to every other month, making the slope estimates for the third season inconsistent with the analysis that used the HCSP data. For those parameters with statistically significant trends, Appendix I contains a more detailed analysis of the data than what is discussed under the relevant parameter headings in the report text below.

Parameters that were significantly correlated with USGS streamflow were corrected for the effect of annual variation in log streamflow using a LOESS smooth (F=0.5) before the Seasonal Kendall Tau was performed. LOWESS (local polynomial regression) in the seasonal Kendall Tau describes the relationship between the concentrations of a water quality parameter and streamflow using a weighted regression. The residuals of the smooth have the effect of streamflow subtracted, and are called flow-adjusted concentrations (Hirsch et al. 1991). Flow-adjusted concentrations are necessary when the variable in question has an inherent relationship with streamflow, which can confound any comparisons made of water quality between stations or times with different instantaneous flow. If the variability of a water quality parameter could be completely explained by streamflow, then during smoothing, all of the data points would fall along a single best-fit line, and all of the residuals (distance between the points and the line) would be zero. For real data, the differences between the data points and the best-fit line show the part of the variability in water quality that is not caused by changes in streamflow, i.e. the flow-adjusted concentrations. Kendall Tau analyses were performed in R (version 3.1.1) using the R function EnvStats: kendallTrendTest (Millard 2013). LOESS smoothing was done using log of streamflow within the R function stats: loess (R Core Team 2014), with a smoothing factor (span) of 0.5, symmetric family, and degree of 1 for polynomials.

Differences in water quality between stations from 2003 to 2016 for each water quality parameter were evaluated using ANOVA and Duncan’s post hoc test (Table 6-3). This analysis will help to identify potential differences among stations that can be examined in more detail as the HCSP continues. A summary of the ANOVA results for all parameters is presented in Table 6-3 with detailed discussion presented under each parameter heading below. Parameters whose MDLs have changed over the course of the program were omitted from ANOVA because of limited comparable data between sampling events and stations (i.e., fluoride, nitrate-nitrite, ammonia).

Water quality parameters were compared with water quantity variables recorded during the same month from 2003 to 2016, including average daily streamflow for the month, average daily NPDES discharge for the month, and total monthly rainfall. Because these three water quantity variables are correlated to each other (Table 5-6), a statistically significant correlation between NPDES discharge and water quality does not prove a causal relationship between water quality and mining discharge. The results of this correlation analysis are presented in Table 6-4. Each of these correlations is discussed further in each water quality section. Parameters whose MDLs have changed over the course of the program were omitted from correlation analysis because of limited comparable data between sampling events and stations (fluoride, nitrate-nitrite, ammonia).

Table 6-2. Summary of Seasonal Kendall-tau with LOESS (F=0.5) for HCSW-1 and HCSW-4 from 2003 to 2016.

Parameter	HCSW-1				HCSW-4			
	tau	p-value	slope	2016 Median	tau	p-value	slope	2016 Median
pH	**0.49**	**0.00003**	**0.05**	7.65	0.17	0.15	N/A	7.53
Dissolved Oxygen (mg/L)	**0.24**	**0.04**	**0.06**	7.51	0.09	0.45	N/A	7.39
Dissolved Oxygen[1] (%Sat)	**0.28**	**0.002**	**0.74**	89.1	0.08	0.40	N/A	83.6
Turbidity	0.04	0.75	N/A	3.82	0.22	0.07	N/A	3.95
Color, total	0.06	0.61	N/A	157.5	**0.33**	**0.004**	**4.31**	165
Nitrogen, total	0.09	0.45	N/A	1.21	0.15	0.21	N/A	1.44
Nitrogen, total Kjeldahl	0.04	0.75	N/A	1.11	0.15	0.21	N/A	1.18
Nitrogen, nitrate-nitrite*	0.17	0.15	N/A	0.08	0.04	0.75	N/A	0.21
Nitrogen, ammonia*	**-0.37**	**0.002**	**-0.001**	0.04	0.01	0.95	N/A	0.05
Orthophosphate[2]	0.05	0.66	N/A	0.516	0.06	0.64	N/A	0.397
Chlorophyll-a[2]	0.03	0.85	N/A	0.92	-0.06	0.63	N/A	1.10
Specific Conductance	**0.55**	**0.000003**	**10.39**	403	**0.33**	**0.01**	**7.94**	365
Calcium, dissolved	**0.54**	**0.000004**	**1.05**	35.1	0.20	0.09	N/A	32.3
Iron, dissolved	**-0.49**	**0.00003**	**-0.02**	0.21	**-0.37**	**0.002**	**-0.01**	0.20
Alkalinity	**0.41**	**0.001**	**2.39**	67	**0.45**	**0.0001**	**1.08**	41.9
Chloride	-0.06	0.61	N/A	12.5	0.08	0.53	N/A	16.9
Fluoride*	**0.27**	**0.02**	**0.01**	0.54	**0.41**	**0.001**	**0.01**	0.33
Sulfate	**0.49**	**0.00003**	**3.67**	96.5	0.21	0.08	N/A	92.2
Total Dissolved Solids	**0.52**	**0.00001**	**8.56**	298	**0.24**	**0.04**	**6.02**	262
Radium, total	-0.16	0.16	N/A	1.3	-0.10	0.41	N/A	1.3

*SWFWMD data was used from April 2003 to December 2016. Sampling was reduced to every other month starting October 2011, making slope estimates approximate.

[1] Percent DO calculated from DO saturation (mg/L) and temperature. Temperature data was not available for samples prior to June 2006. Analysis period for DO % saturation is from June 2006 to December 2016.

[2] Data was not correlated with streamflow for either station; LOESS was not used.

Table 6-3. Summary of results from ANOVA for differences between stations from 2003 to 2016.

Parameter	F	p-value
pH	56.69	**< 0.001**
Dissolved Oxygen (mg/L)	200.47	**< 0.001**
Dissolved Oxygen (%Sat)[1]	188.30	**< 0.001**
Turbidity	0.83	0.48
Color, total	8.87	**< 0.001**
Total Nitrogen	18.39	**< 0.001**
Total Kjeldahl Nitrogen	23.09	**< 0.001**
Orthophosphate	19.65	**< 0.001**
Chlorophyll-*a*	39.33	**< 0.001**
Specific Conductance	52.94	**< 0.001**
Calcium, dissolved	84.10	**< 0.001**
Iron, dissolved	0.07	0.97
Alkalinity	51.85	**< 0.001**
Chloride	34.09	**< 0.001**
Sulfate	66.81	**< 0.001**
Total Dissolved Solids	58.38	**< 0.001**
Radium, Total	6.73	**< 0.01**

[1] Percent DO calculated from DO saturation (mg/L) and temperature. Temperature data was not available for samples prior to June 2006. Analysis period for DO % saturation is from June 2006 to December 2016.

Table 6-4. Spearman's Rank Correlation between water quality and water quantity at HCSW-1 and HCSW-4, as represented by average daily streamflow, average daily NPDES discharge, and total rainfall for the same month from 2003 to 2016.

Parameter	HCSW-1			HCSW-4		
	Rainfall	NPDES	Streamflow	Rainfall	NPDES	Streamflow
pH	**-0.34***	-0.08	**-0.29***	**-0.26***	**-0.24***	**-0.53***
Dissolved Oxygen (mg/L)	**-0.53***	**-0.49***	**-0.51***	**-0.52***	**-0.55***	**-0.71***
Dissolved Oxygen (%Sat)[1]	**-0.41***	**-0.34***	**-0.31***	**-0.43***	**-0.56***	**-0.76***
Turbidity	**0.32***	**0.49***	**0.53***	**0.27***	**0.46***	**0.57***
True Color	**0.43***	**0.45***	**0.55***	**0.30***	**0.59***	**0.74***
Total Nitrogen	**0.49***	**0.40***	**0.54***	**0.16***	**0.17***	**0.31***
TKN	**0.51***	**0.43***	**0.56***	**0.36***	**0.49***	**0.63***
Orthophosphate	-0.14	0.10	-0.12	0.06	0.10	0.05
Chlorophyll-*a*	0.01	**0.20***	0.12	0.13	0.13	0.09
Specific Conductance	**-0.17***	**0.25***	0.03	**-0.30***	**-0.53***	**-0.79***
Calcium, dissolved	**-0.18***	**0.29***	0.03	**-0.29***	**-0.58***	**-0.80***
Iron, dissolved	**0.55***	**0.36***	**0.58***	**0.40***	**0.53***	**0.77***
Alkalinity	**-0.16***	**0.23***	0.06	**-0.49***	**-0.43***	**-0.76***
Chloride	**-0.38***	**-0.65***	**-0.73***	**-0.30***	**-0.61***	**-0.80***
Sulfate	-0.06	**0.36***	0.13	**-0.27***	**-0.54***	**-0.75***
TDS	-0.03	**0.40***	**0.21***	**-0.23***	**-0.48***	**-0.72***
Radium, Total	0.04	**-0.30***	**-0.24***	0.12	**-0.35***	**-0.18***

* - Statistically significant at $p < 0.05$

[1] Percent DO calculated from DO saturation (mg/L) and temperature. Temperature data was not available for samples prior to June 2006. Analysis period for DO % saturation is from June 2006 to December 2016.

6.2 Physio-Chemical Parameters

pH

Levels of pH, dissolved oxygen, turbidity, and specific conductivity were obtained in the field during each monthly water-quality sampling event. Values of pH were within the range of established trigger levels during all of 2016 sampling events at all stations (Figure 6-1). Values obtained during biological sampling events were slightly lower than pH levels determined during the monthly water quality sampling events (Figure 6-1). The pH levels at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (SWFWMD), although historical levels of pH collected by USGS and FDEP seem to be lower than SWFWMD and HCSP levels (Appendix C, Figures C-22 and 23). Continuous pH data obtained daily at HCSW-1 in 2016 was within a range similar to that obtained during monthly water quality sampling (data censored during November 2016 because of errors in probe readings, Figure 6-2).

HCSW-4 exhibited no monotonic trends from 2003 to 2016 for pH (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 6-2). There was a slightly increasing monotonic trend for pH at HCSW-1 (slope = 0.05 SU per year flow-adjusted concentrations). The slope for this potential trend is very small compared to limits in laboratory prediction or the observed differences between primary and duplicate field samples. The trend is further discussed in the 2016 Impact Assessment (Appendix I). Given that the increase in pH over time in the HCSP is not a monotonic trend, the Seasonal Kendall Tau may not be an appropriate method to examine the magnitude of the change over time and a change point analysis was used to supplement the evaluation. Change point analysis of the HCSP pH data shows a decline in 2004 (0.4 SU), an increase in 2007 (0.6 SU), and then a stable range from 2007 to 2016; those change points correspond to a wet year with several hurricanes (2004) and a very dry time period (2006-2008). The apparent change in pH since 2003 is not a strong trend when compared to SWFWMD data collected at the same place, and the observation of similar change-point increases at HCSW-1 and upstream stations around the drought period lead to the conclusion that pH is not having an ecologically significant increase at HCSW-1 over the course of the HCSP program and is not of concern at this time.

Levels of pH were different among stations from 2003 to 2016 (ANOVA, Table 6-3); HCSW-2 had lower pH than other stations and HCSW-1 had the highest pH (Duncan's multiple range-test, $p < 0.05$). HCSW-2 lies just downstream of the Horse Creek Prairie, a blackwater swamp complex that has the potential to add substantial organic acids from plant decomposition and decrease the pH (Reid and Wood 1976). Brushy Creek also contributes to HCSW-2, and similarly has a relatively low pH compared to HCSW-1 (Figure 6-1). Levels of pH at HCSW-1 were significantly negatively correlated with streamflow and rainfall, and at HCSW-4 pH was negatively correlated with rainfall, streamflow, and NPDES discharge (Spearman's rank correlation, Table 6-4). The negative correlation between HCSW-4 and NPDES discharge most likely has more to do with streamflow as there was no correlation between NPDES discharge and pH at HCSW-1 (station closest to the outfall).

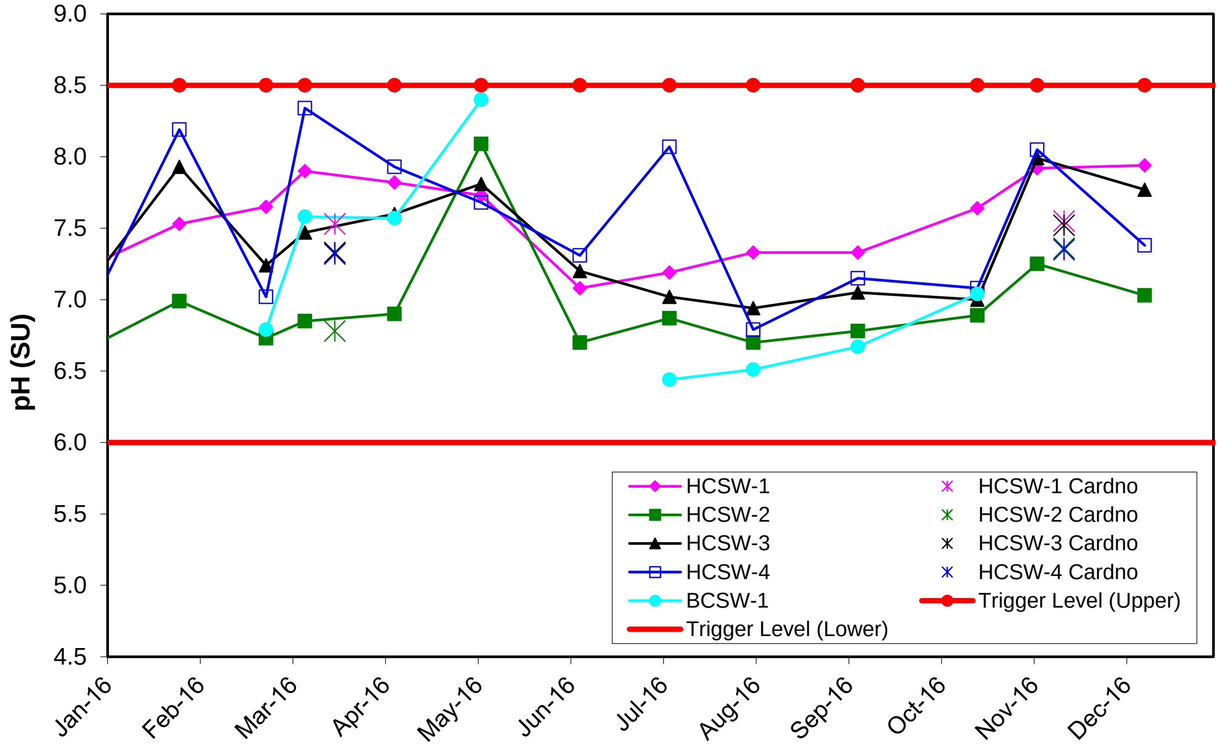


Figure 6-1. Values of pH obtained during monthly HCSP water quality sampling and biological sampling events in 2016.

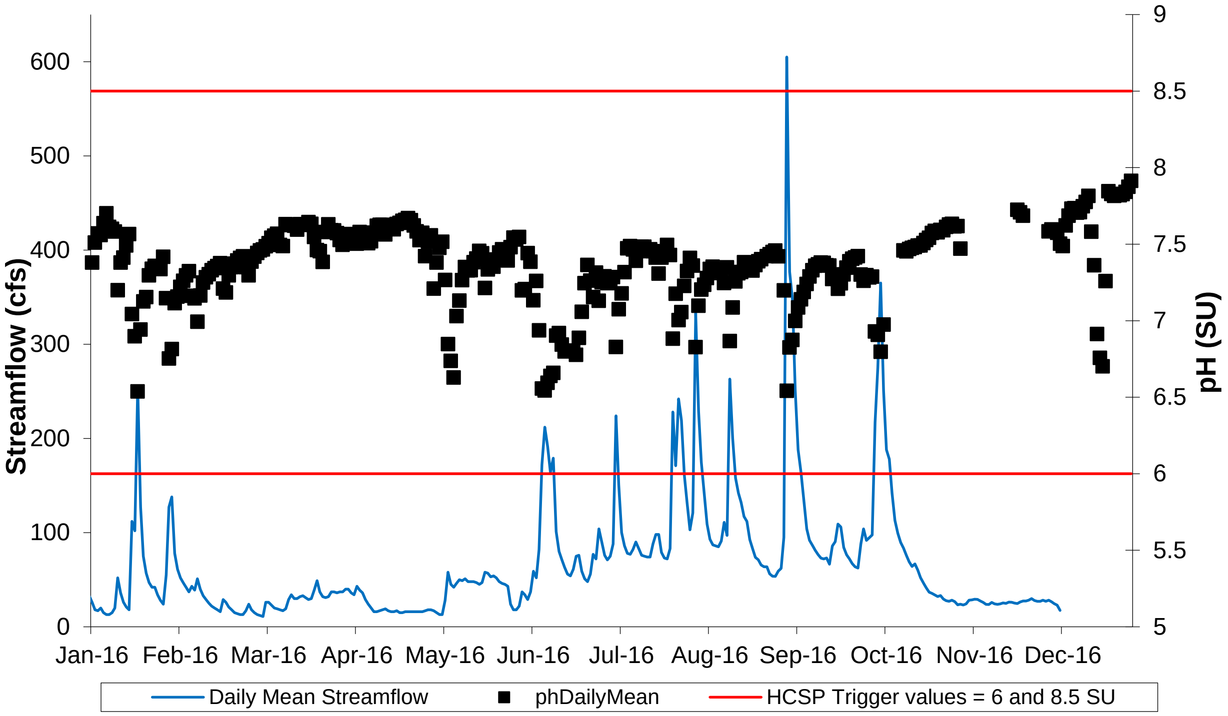


Figure 6-2. Relationship between daily mean pH (obtained from the continuous recorder at HCSW-1) and daily mean streamflow for 2016. Minimum pH detection limit = 0.1 SU.

Dissolved Oxygen

The Class III DO standard was updated by FDEP in 2013 from 5.0 mg/L (Figures 6-3 and 6-5) to be a daily average of 38 percent (Figure 6-4 and 6-6), which is adjusted for time of day when being compared to a single grab sample (not shown in graphics, see Section 4.3.1). Beginning with the 2014 report, the revised HCSP trigger level is the time of day translation of the 38 percent saturation daily average criterion. DO saturation collected as part of the HCSP in 2016 was compared to the new trigger level. The patterns of DO concentration and DO saturation are very similar for each station in 2016. Most of the DO saturation values were lower than the DO saturation trigger level at HCSW-2 (February to December 2016). This station is just downstream of the Horse Creek Prairie, a blackwater swamp that typically has low DO concentrations. DO saturations and concentrations obtained during biological sampling events and from the continuous recorder at HCSW-1 were fairly consistent with those found during the monthly water quality sampling (Figures 6-3 through 6-6). The continuous recorder did have lower concentrations and percent saturations recorded during the month of June 2016, corresponding with multiple events with high rainfall totals, most likely flushing the upstream wetland systems (Figures 6-5 and 6-6).

While no longer a trigger value, the DO concentration in mg/L was used as a reference for historical purposes. DO saturation measurements were only able to be back-calculated on older data going back to June 2006 because temperature data was not available. All HCSP monthly sampling from May 2013 to present includes both DO concentration and percent saturation.

DO concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figures C-24 and C-25). DO concentrations at HCSW-4 exhibited no monotonic trend between 2003 and 2016 (Seasonal Kendall Tau with LOESS, $p > 0.05$, Table 6-2); however, DO concentrations at HCSW-1 exhibited an increasing monotonic trend (slope = 0.06 mg/L per year flow adjusted concentrations). Similarly, DO saturation at HCSW-1 exhibited an increasing monotonic trend from 2006 to 2016 (slope = 0.74% per year flow-adjusted saturation); there was no increasing or decreasing trend in DO saturation at HCSW-4 ($p > 0.05$, Table 6-2). The trigger level for DO saturation in the HCSP is expressed as a minimum, so the observed upward trend at HCSW-1 is not of concern as it relates to a defined HCSP trigger level; over time, the program will continue to monitor this trend.

Dissolved oxygen concentration (mg/L) and saturation (%) were different among stations from 2003 to 2016 (ANOVA, Table 6-3), with both concentration and percent saturation lowest at HCSW-2 and the DO concentration highest at HCSW-1 (Duncan’s multiple range test, $p < 0.05$). Dissolved oxygen concentration and saturation was negatively correlated with all water quantity variables at both HCSW-1 and HCSW-4 (rainfall, streamflow, and NPDES discharge, Spearman’s rank correlations, Table 6-4); because streamflow and NPDES discharge are positively correlated with rainfall (with lag times), this means that dissolved oxygen is lowest during or following periods of high rainfall. During the wet season, higher temperatures in the stream drive down the oxygen saturation, and the decomposition of woody debris washed into the stream during high rains can increase oxygen demand.

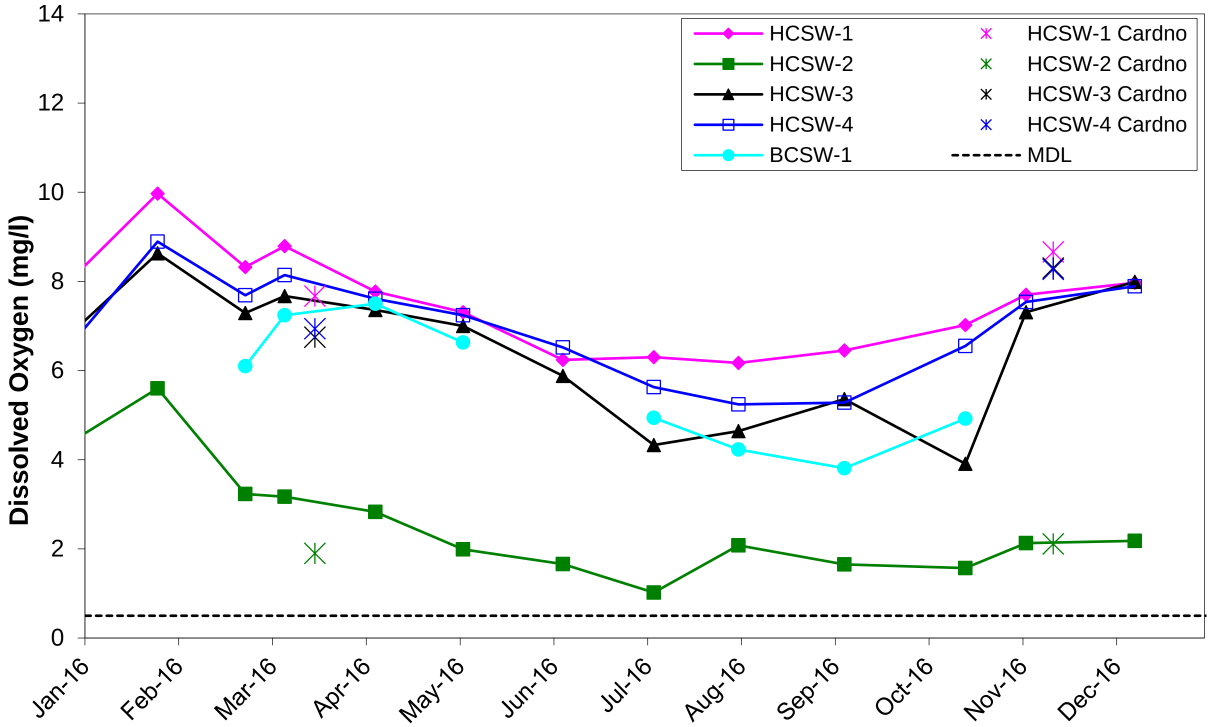


Figure 6-3. **Dissolved oxygen concentrations obtained during monthly HCSP water quality sampling and biological sampling events in 2016.**

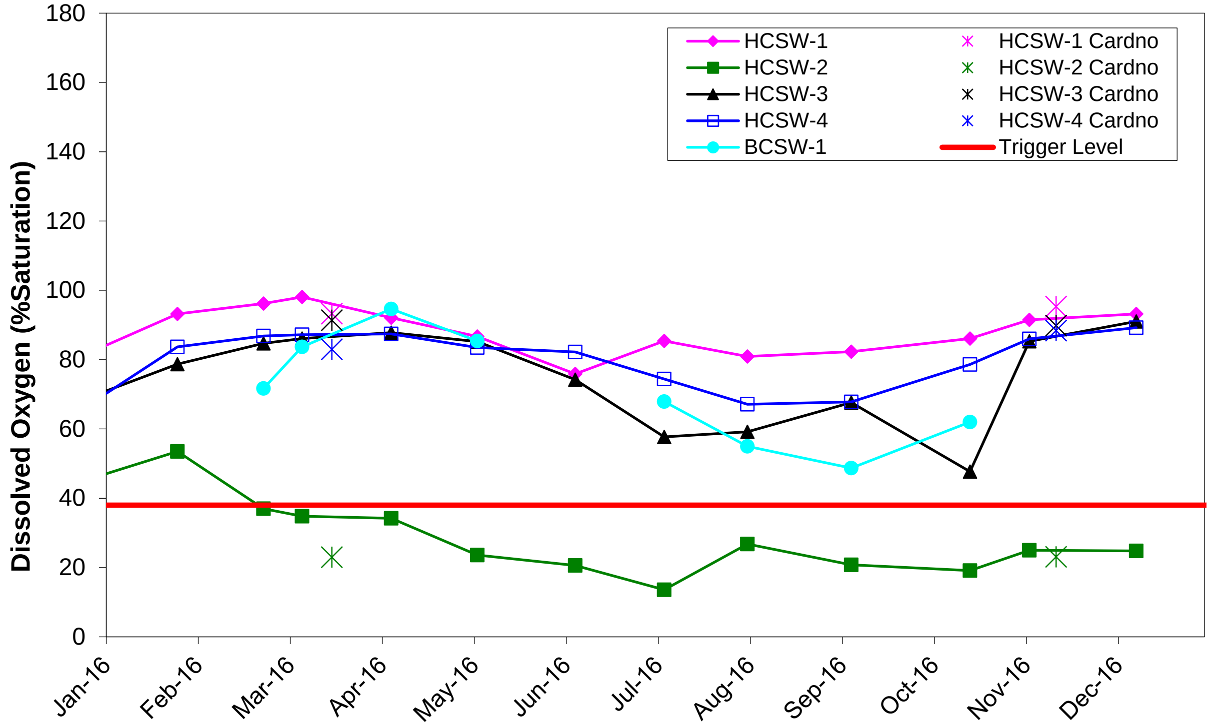


Figure 6-4. **Dissolved oxygen percent saturations obtained during monthly HCSP water quality sampling and biological sampling events in 2016.**

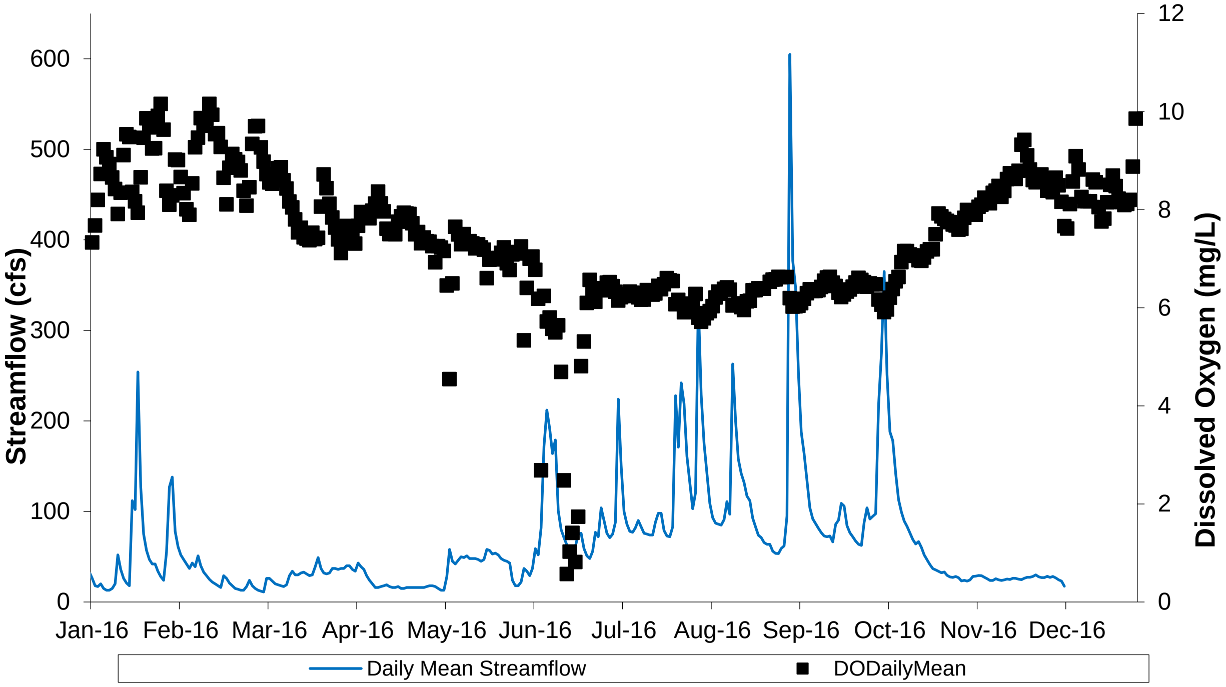


Figure 6-5. **Relationship between daily mean DO concentration (obtained from the continuous recorder at HCSW-1) and daily mean streamflow for 2016. Minimum DO detection limit = 0.5 mg/L.**

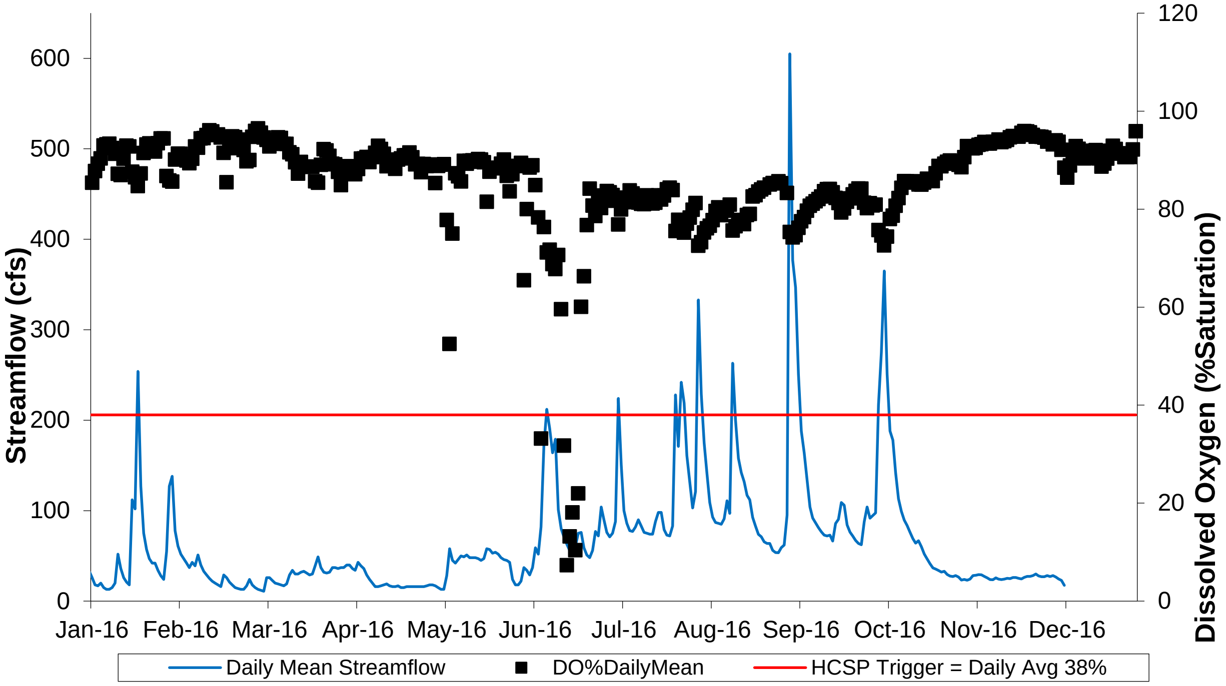


Figure 6-6. **Relationship between daily mean DO percent saturation (obtained from the continuous recorder at HCSW-1) and daily mean streamflow for 2016. Minimum DO detection limit = 1%.**

Turbidity

Turbidity levels obtained during biological sampling events were similar to those found during monthly water quality sampling events in 2016 (Figure 6-7). Turbidity levels at all stations in 2016 were below the trigger level and Class III Surface Water Quality Standard of 29 nephelometric turbidity units (NTUs). Turbidity measured by the continuous recorder was similar to monthly measurements with the exception of a few isolated higher measurements that most likely coincide with higher rainfall events (Figure 6-8). Some of the higher continuous recorder turbidity measurements did cause an alert for potential CSA dam breach (three-hour rolling average turbidity above 150 NTUs). All of the alerts were investigated and found to be false alarms as either water levels were too low for the sensor, debris from upstream became lodged within the deployment structure, or organisms (crayfish) became lodged in the deployment structure. There have been no actionable turbidity alerts since the program came online.

The turbidity levels at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figures C-26 and C-27) and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 6-2). Turbidity levels were not different among stations from 2003 to 2016 (ANOVA, Table 6-3). Turbidity was positively correlated with all water quantity parameters at HCSW-1 and HCSW-4 (rainfall, streamflow, and NPDES discharge, Spearman’s rank correlations, Table 6-4); because streamflow and NPDES discharge are positively correlated with rainfall (with lag times), this means that generally turbidity is highest during or following periods of high rainfall. Turbidity measurements at Brushy Creek were similar to Horse Creek stations (Figure 6-7).

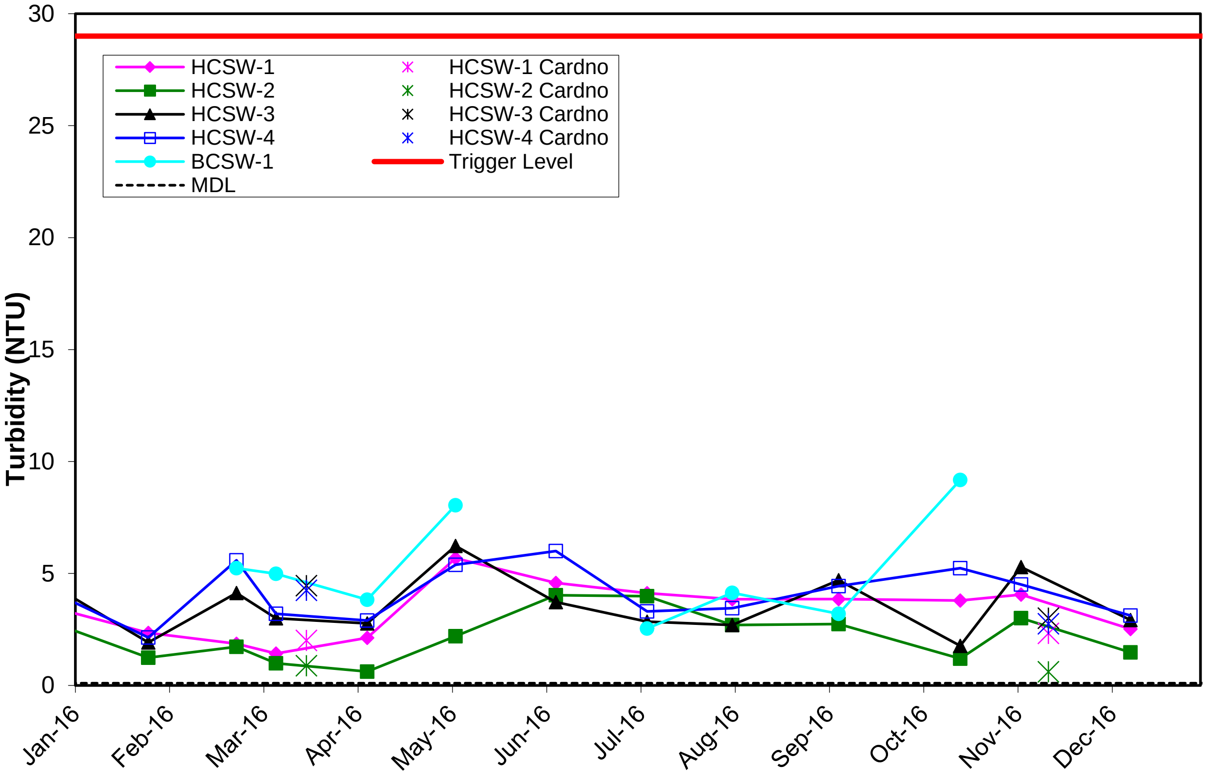


Figure 6-7. Turbidity levels obtained during monthly HCSP water quality sampling and biological sampling events in 2016.

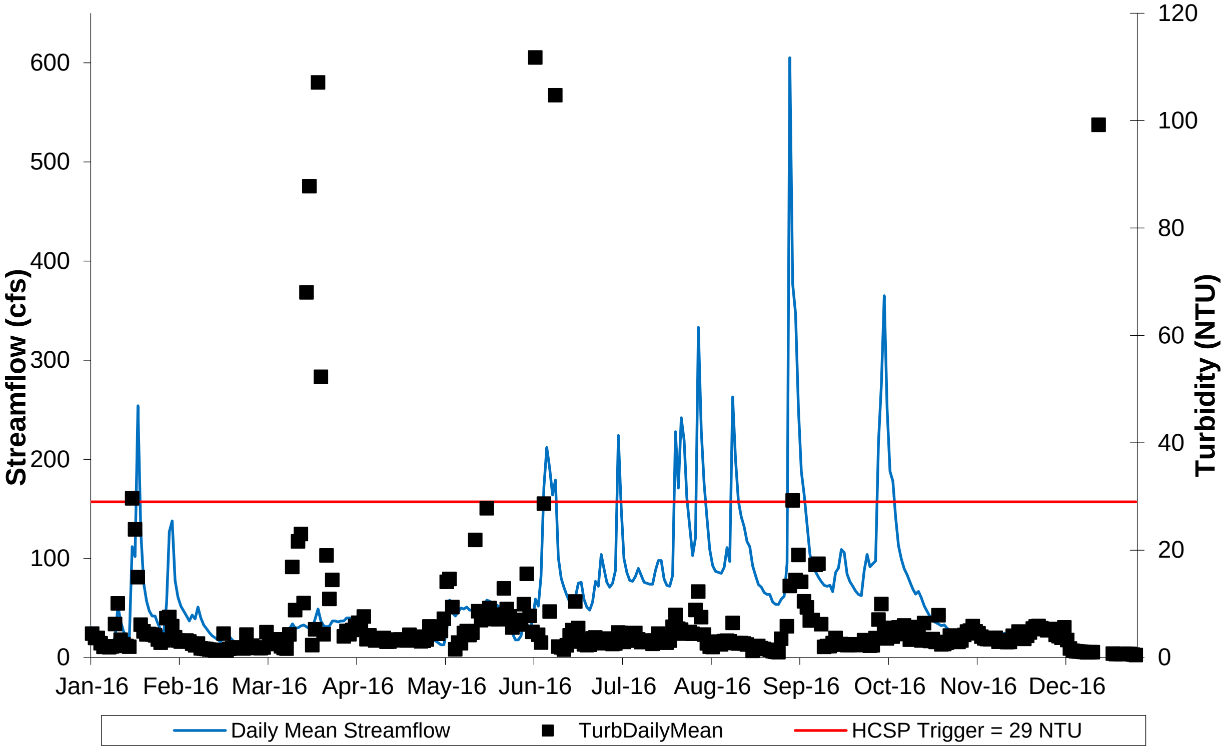


Figure 6-8. **Relationship between daily mean turbidity (obtained from the continuous recorder at HCSW-1) and daily mean streamflow for 2016. Minimum detection limit = 0.1 NTU.**

Color

All color values in 2016 were above the trigger level of 25 Platinum-Cobalt units (PCU) (indicating desirable conditions) during all events at all stations (Figure 6-9). The color levels at HCSW-1 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figure C-28) and did not exhibit any monotonic trends from 2003 to 2016 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 6-2). However, HCSW-4 exhibited an increasing monotonic trend over the 2003 to 2016 time period (slope = 4.31 PCU per year flow-adjusted concentration, Table 6-2). The trigger level for color in the HCSP is expressed as a minimum, so the observed upward trend at HCSW-4 is not of concern as it relates to a defined HCSP trigger level; over time, the program will continue to monitor this trend.

Color levels were different among stations from 2003 to 2016 (ANOVA, Table 6-3), with HCSW-2 having higher color than other stations (Duncan's multiple range test, $p < 0.05$). HCSW-2 receives input from Horse Creek Prairie which contributes higher color levels to this station. Brushy Creek generally has higher color than the Horse Creek stations and also flows into Horse Creek above HCSW-2 (Figure 6-9). Color was positively correlated with all water quantity variables at HCSW-1 and HCSW-4 (rainfall, streamflow, and NPDES discharge, Spearman's rank correlations, Table 6-4). As streamflow and NPDES discharge are positively correlated with rainfall (with lag times), this means that color values are highest during or following periods of high rainfall.

The similar pattern among the stations, with higher color in the wet, summer months, and lower levels in the dry, winter months, suggest that color is affected by the differential inputs of surface water and groundwater seepage. During the wet season when surface flows from wetland areas are highest, the transport of tannins to Horse Creek adds more color to the water (Reid and Wood 1976). This was very evident during and after Hurricane Charley in 2004 (Appendix C). As the dry season begins, groundwater seepage provides a proportionally higher contribution of clearer water to Horse Creek, thereby decreasing the color of the water. It is likely that agricultural irrigation return flows also have some impact on color in the stream by introducing clearer groundwater during the drier parts of the year or during dry years like 2006 and 2007. This agricultural influence is also noted below with respect to several other parameters.

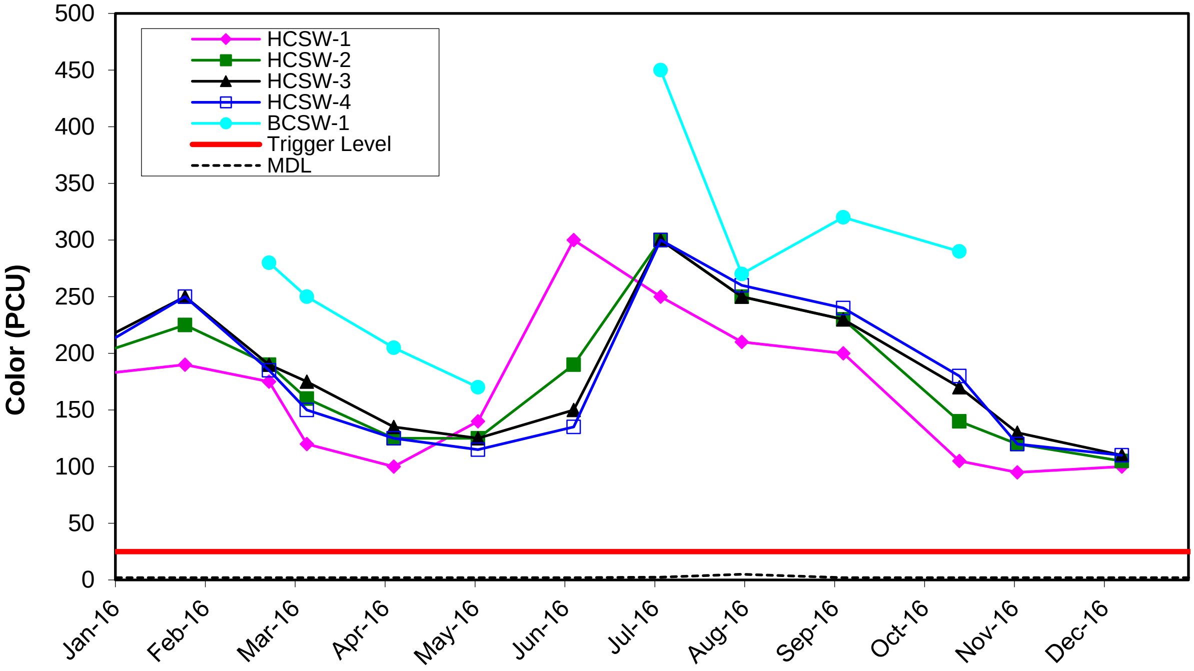


Figure 6-9. Color levels obtained during monthly HCSP water quality sampling in 2016.

6.3 Nutrients

Total Nitrogen

Total nitrogen[22] concentrations were between 0.99 and 3.5 mg/L during all sampling events at all Horse Creek stations in 2016 (Figure 6-10). During 2016, total nitrogen was consistently below the trigger value of 3.0 mg/L at all stations, with the exception of HCSW-3 during February 2016. The major component of total nitrogen in nearly all samples was organic nitrogen. The total nitrogen concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figures C-30 and C-31) and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 6-2). Total nitrogen concentrations were different among stations from 2003 to 2016 (ANOVA, Table 6-3), with lower concentrations at HCSW-1 than other stations, followed by HCSW-3 (Duncan's multiple range test, $p < 0.05$). Total nitrogen was positively correlated with all water quantity variables at HCSW-1 and HCSW-4 (rainfall, streamflow, and NPDES discharge, Spearman's rank correlations, Table 6-4). As streamflow and NPDES discharge are positively correlated with rainfall (with lag times), this means that total nitrogen values are highest during or following periods of high rainfall. Total nitrogen concentrations at Brushy Creek were slightly higher than almost all concentrations at the Horse Creek stations (Figure 6-10).

In addition to the trigger level for TN, HCSW-1, the station with the highest percent of upstream mined lands, was evaluated against the recently approved state numeric nutrient standards. Under those standards, in order to avoid being listed as impaired for nutrients, a stream must pass a combination of biological and/or numerical criteria. According to 62-302 and 62-303 F.A.C., biological and nutrient data collected during the HCSP at HCSW-1 indicate no nutrient impairment. Appendix I, Table I-10 lists some of the ways that HCSW-1 passes nutrient criteria standards.

As of December 2016, HCSW-1 meets the nutrient criteria set in 62-302.351(2)(c), because it shows no imbalance of flora and fauna (chlorophyll, RPS, and LVS) and has healthy benthic macroinvertebrate conditions (SCI). HCSW-1 shows no evidence of persistent algal blooms, has annual geometric mean concentrations of chlorophyll < 3.2 µg/L, and has nine passing Rapid Periphyton Surveys (RPS) and Linear Vegetation Surveys (LVS) from 2012 to 2016. The HCSW-1 average of SCI scores is > 40, with neither of the two most recent scores < 35. HCSW-1 also meets the SCI portion of the Biological Heath Assessment in 62-303.330 with the two most recent SCI scores > 35 and within 20 points of the historic maximum (if the historic maximum is above 64).

---

[22] Total nitrogen is calculated as the arithmetic sum of TKN and nitrate-nitrite. As requested by the PRMRWSA, if either TKN or nitrate-nitrite is undetected, the MDL of the undetected constituent will be used as part of the total nitrogen calculation. Note that this use of MDL for undetected constituents is inconsistent with typical laboratory and DEP SOPs and may result in artificially high estimates of total nitrogen.

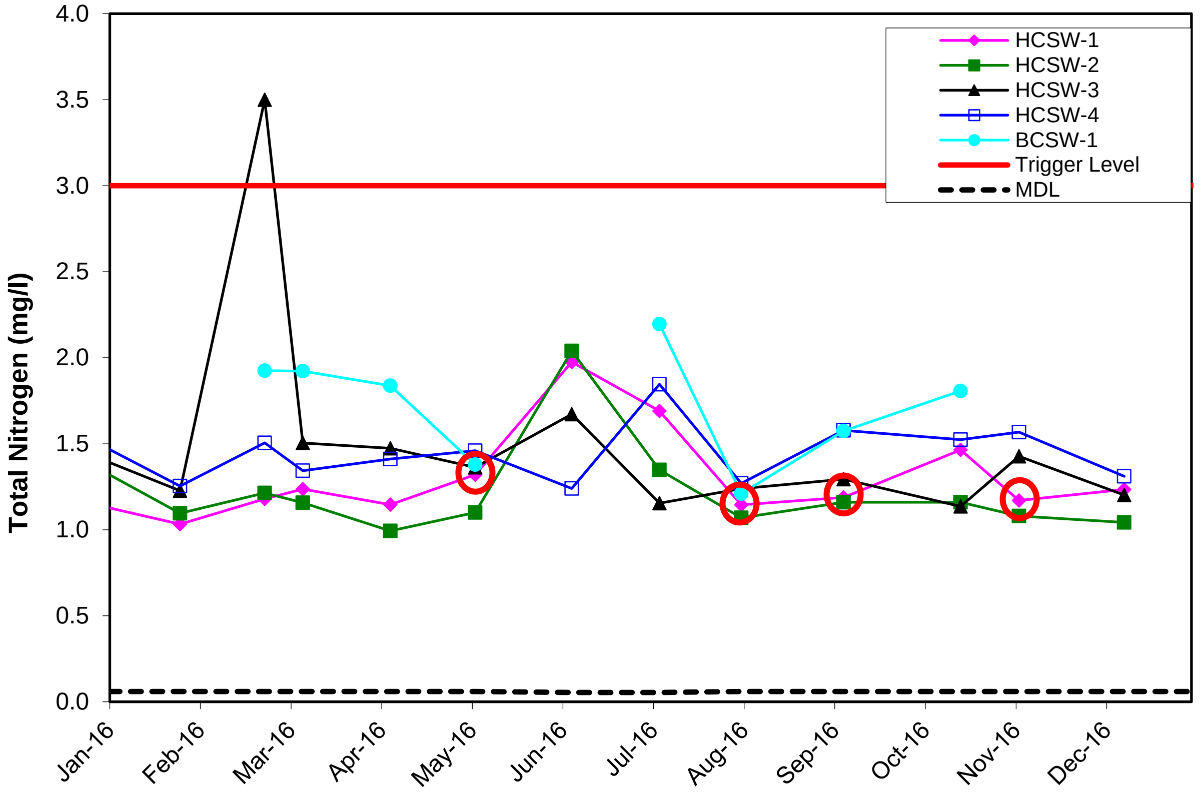


Figure 6-10. **Total nitrogen concentrations obtained during monthly HCSP water quality sampling in 2016 (Data from samples where nitrate-nitrite nitrogen was undetected are circled in red.)**

Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen (TKN) comprised the majority (41 to 99 percent) of total nitrogen in most samples in 2016 and the majority of the TKN concentration was from organic nitrogen (Figure 6-11, compare with Figure 6-10 and 6-13). The HCSP does not have an independent trigger value for TKN. The TKN concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figures C-32 and C-33) and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 6-2). Concentrations of TKN were different among stations from 2003 to 2016 (ANOVA, Table 6-3), with HCSW-2 having a higher concentration than the other three stations (Duncan's multiple range test, $p < 0.05$). Brushy Creek, which contributes to HCSW-2, has higher TKN concentrations than the Horse Creek stations (Figure 6-11). TKN was positively correlated with rainfall, streamflow, and NPDES discharge at HCSW-1 and HCSW-4 (Spearman's rank correlations, Table 6-4). As streamflow and NPDES discharge are positively correlated with rainfall (with lag times), this means that TKN values are highest during or following periods of high rainfall.

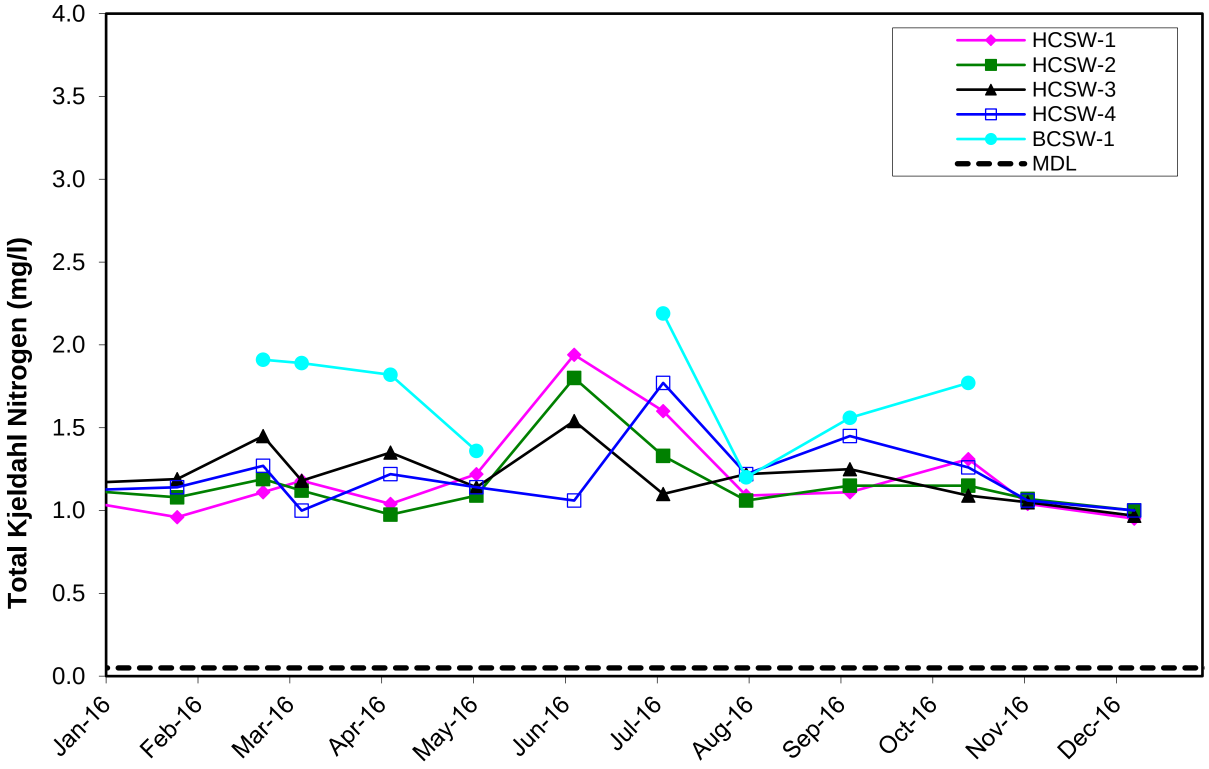


Figure 6-11. TKN concentrations obtained during monthly HCSP quality sampling in 2016.

Nitrate-Nitrite Nitrogen

In general, nitrate-nitrite concentrations are greater at the downstream Horse Creek stations, possibly because of agriculture (Figure 6-12). Nitrate-nitrate concentrations at the two upstream locations (HCSW-1 and HCSW-2) generally make up less than 10 percent of total nitrogen, while concentrations at the downstream locations (HCSW-3 and HCSW-4) accounted for up to 59 percent of total nitrogen (average of 15 percent) in 2016. Nitrate-nitrite concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figures C-33 and C-34), but the HCSP data could not be analyzed for monotonic trends, correlations with water quantity, or differences between the four HCSP stations because of changes in MDL's over the course of the HCSP (Appendix C). Based on trend analysis performed with data collected by SWFWMD from 2003 to 2016, there are no monotonic trends in nitrate-nitrite for HCSW-1 or HCSW-4 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 6-2).

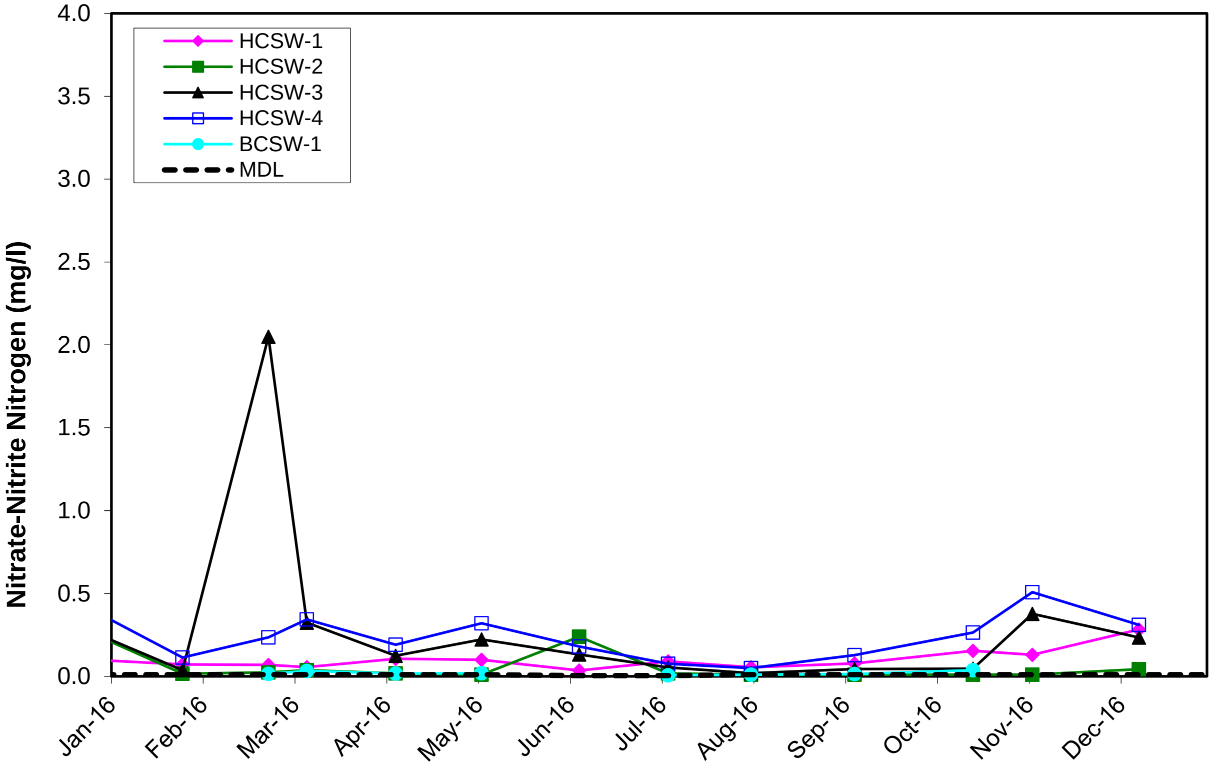


Figure 6-12. **Nitrate-nitrite nitrogen concentrations obtained during monthly HCSP water quality sampling in 2016.**

Total Ammonia Nitrogen

Total ammonia nitrogen levels were within a similar range during almost all sampling events at all stations, with no stations exceeding the trigger level during 2016 (Figure 6-13). The ammonia concentrations at HCSW-1 and HCSW-4 measured by the HCSP are at levels within the normal range for the last decade of data (Appendix C, Figures C-36 and C-37). The HCSP data could not be analyzed for monotonic trends, correlations with water quantity, or differences between the four HCSP stations because of changes in MDL's over the course of the HCSP (Appendix C). Based on trend analysis performed using data collected by SWFWMD since 2003, there are no monotonic trends in total ammonia nitrogen at HCSW-4 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 6-2); however, there was a decreasing trend over time at HCSW-1 (slope = -0.001 mg/L per year flow-adjusted concentration, Table 6-2). The decreasing trend in ammonia at HCSW-1 is not an adverse change, and it is therefore not addressed in detail in the impact assessment in Appendix I.

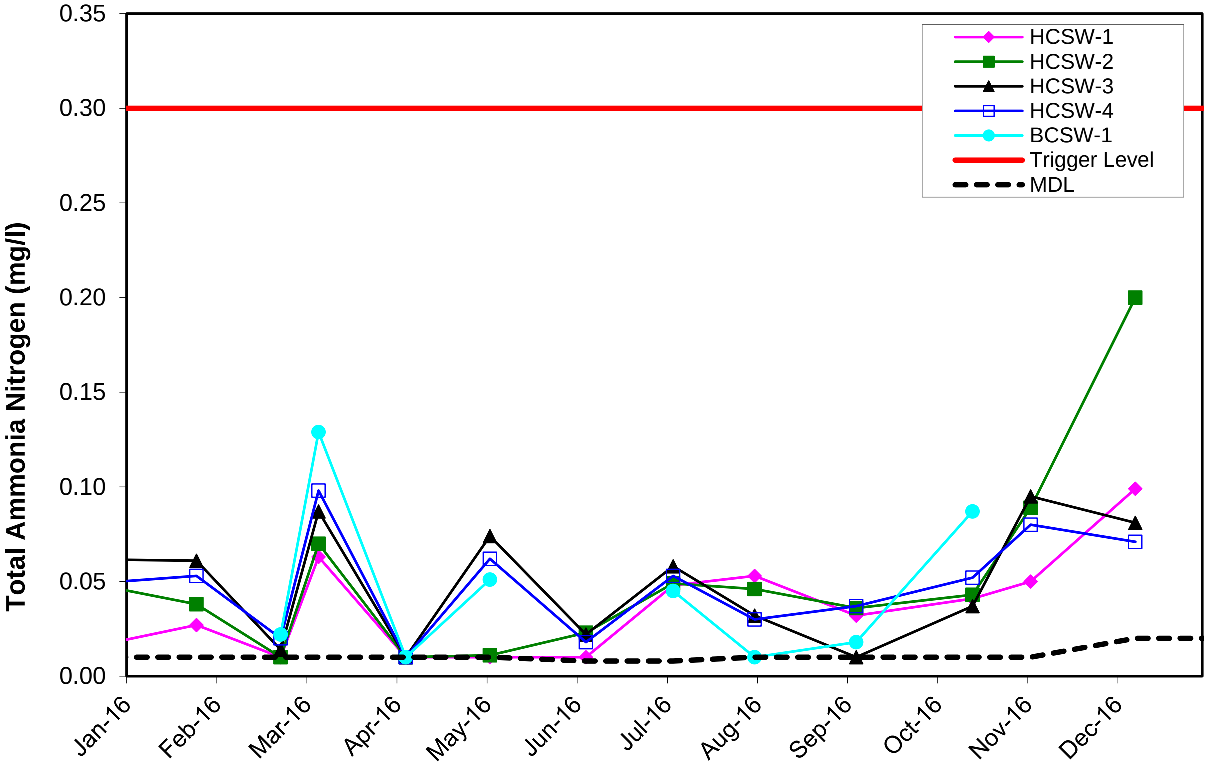


Figure 6-13. Total ammonia nitrogen concentrations obtained during monthly HCSP water quality sampling in 2016.

Orthophosphate

Orthophosphate concentrations were well below the trigger level of 2.5 mg/L in 2016 (Figure 6-14). The orthophosphate concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figures C-38 and C-39). There are no increasing or decreasing monotonic trends at HCSW-1 or HCSW-4 over the 2003 to 2016 time period (Seasonal Kendall Tau, $p > 0.05$, Table 6-2).

Orthophosphate concentrations were different among stations from 2003 to 2016 (ANOVA, Table 6-3), with concentrations lowest at HCSW-2 followed by HCSW-3 (Duncan's multiple range test, $p < 0.05$). Orthophosphate was not correlated with any water quantity parameter at HCSW-1 or HCSW-4 (Spearman's rank correlation, Table 6-4). Orthophosphate concentrations at Brushy Creek were similar to Horse Creek during sampling events in 2016 (Figure 6-14).

In addition to the trigger level for orthophosphate, HCSW-1, the station with the highest percent of upstream mined lands, was evaluated against the state numeric nutrient criteria standards (see Appendix I, Table I-10). As discussed above under Total Nitrogen, HCSW-1 meets the nutrient criteria standards.

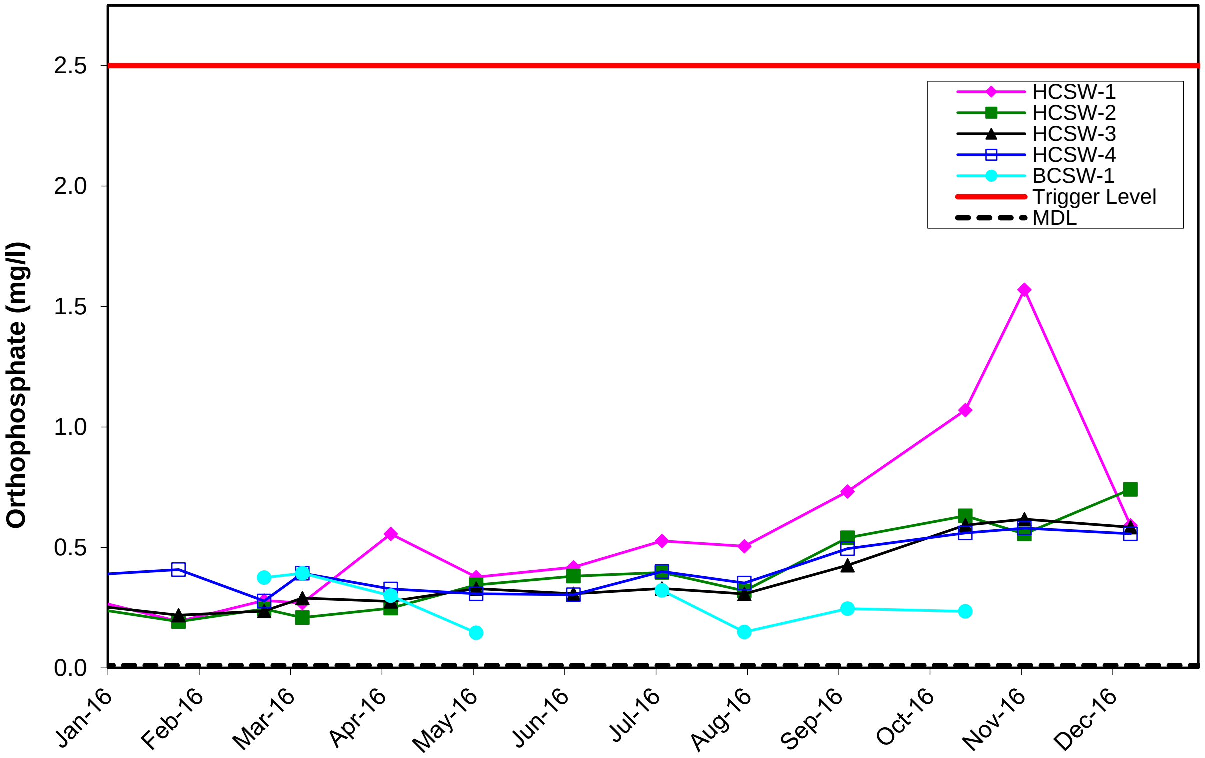


Figure 6-14. **Orthophosphate concentrations obtained during monthly HCSP water quality sampling in 2016.**

Chlorophyll-*a*

Chlorophyll-a values were well below the trigger level of 15 mg/m^3 during all sampling events at all four Horse Creek stations in 2016 (Figure 6-15). The chlorophyll-a concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figure C-40 and C-41) and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau, $p > 0.05$, Table 6-2). Chlorophyll-a concentrations were different between stations from 2003 to 2016 (ANOVA, Table 6-3), with concentrations at HCSW-2 (downstream of Horse Creek Prairie) higher than other stations (Duncan's multiple range test, $p < 0.05$). Chlorophyll-a was not correlated with rainfall, streamflow, and NPDES discharge at HCSW-4, and was only weakly positively correlated with NPDES discharge at HCSW-1 (Spearman's rank correlation, Table 6-4). Chlorophyll-a concentrations at Brushy Creek were slightly higher than concentrations at some Horse Creek stations.

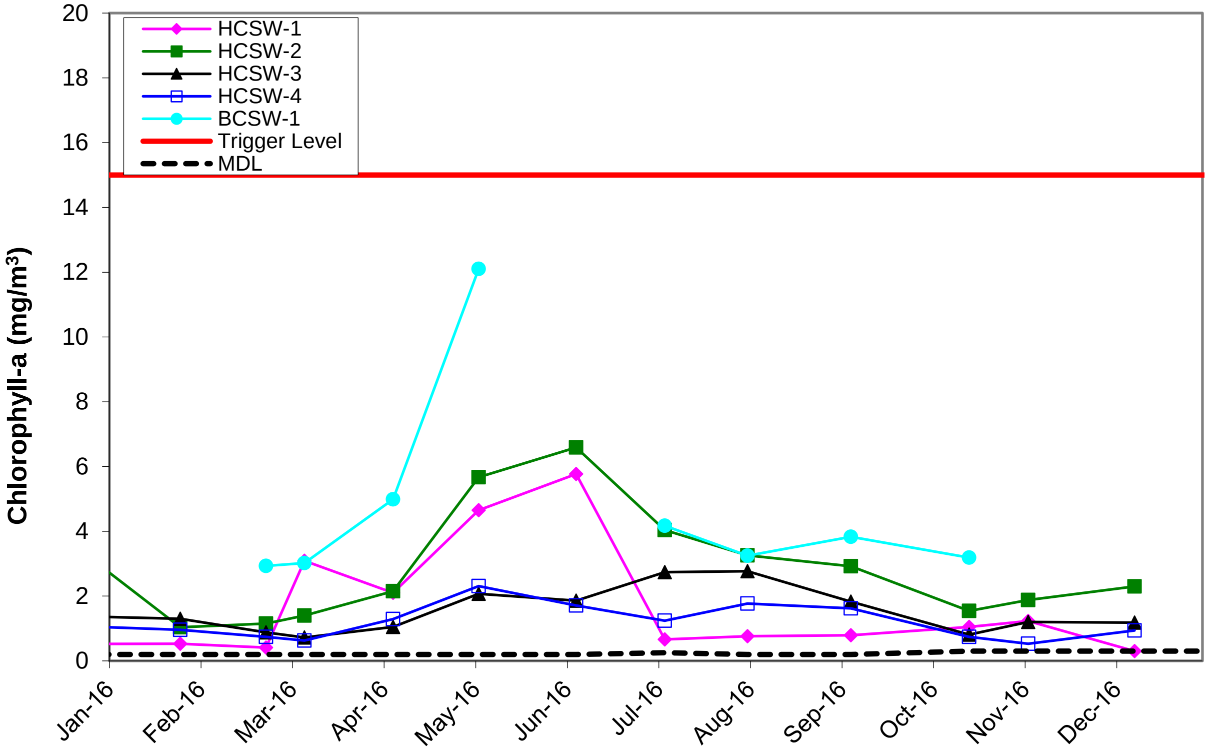


Figure 6-15. **Chlorophyll-*a* concentrations obtained during monthly HCSP water quality sampling in 2016.**

6.4 Dissolved Minerals, Mining Reagents, and Radionuclides

Specific Conductivity

During all sampling events and stations, specific conductivity measurements were well below the trigger level of 1275 µmhos/cm2 in 2016 (Figure 6-16). Specific conductivity in 2016 followed the same general pattern at all stations with lower measurements during higher rainfall months and higher measurements during low rainfall months (Figure 6-16). Specific conductivity measured during each biological sampling event was consistent with measurements obtained during monthly water quality sampling events (Figure 6-16). Mean daily specific conductivity values obtained from the recorder at HCSW-1 were within the range obtained during the monthly water quality sampling events but showed more variability from June to October 2016 (Figure 6-17). The specific conductivity at both HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figure C-42 and C-43). Concentrations at Brushy Creek were lower than Horse Creek stations throughout 2016.

Specific conductivity exhibited an increasing monotonic trend since 2003 at HCSW-1 and HCSW-4 (Seasonal Kendall Tau with LOWESS, Sen slope = 10.39 µmhos/cm and 7.94 µmhos/cm per year flow-adjusted concentrations, respectively, Table 6-2). The trend for HCSW-1 is discussed in the impact analysis in Appendix I. Given that the increase in conductivity over time is not a monotonic trend; the Seasonal Kendall Tau may not be an appropriate method to examine the magnitude of the change over time. A change-point analysis of the dissolved ion data for HCSW-1 shows change-point increases around drought periods (1999 and 2007 for SWFWMD specific conductivity; 2006 to 2007 for HCSP specific conductivity, alkalinity, calcium, fluoride, sulfate, and TDS). Following the 2006 to 2007 drought period, specific conductivity and other ions had either relatively stable concentrations (fluoride, alkalinity), or had a cyclical pattern of step-changes (specific conductivity, sulfate, calcium, TDS), that ended with conditions similar in 2016 to those seen in 2007. The trend for specific conductivity and other ions may have been influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities, but the current concentrations are stable and not biologically harmful. Any small portion of the change in specific conductivity that may have been affected by changes in NPDES water quality is likely to stay relatively constant at HCSW-1 in the near future given planned mining practices and the stable range of concentrations shown since Wingate mine began discharging to Horse Creek in 2008. The biological data from HCSW-1 do not indicate any significant effects of the step-change in conductivity, but the program will continue to monitor this closely.

Specific conductivity was different among stations over the 2003 to 2016 time period (ANOVA, Table 6-3), with the lowest overall readings at HCSW-2 followed by HCSW-1, HCSW-3, and HCSW-4 (Duncan's multiple range test, $p < 0.05$). Specific conductivity was negatively correlated with rainfall, streamflow, and NPDES discharge at HCSW-4 (Spearman's rank correlations, Table 6-4). At HCSW-1, specific conductivity was positively correlated with NPDES discharge and negatively correlated with rainfall (Table 6-4). Higher conductivity at downstream stations over the course of the HCSP was probably the cumulative result of contributions of groundwater that either seeped into Horse Creek directly or ran off of agricultural lands as a result of irrigation water pumped from the aquifer. This pattern has been present for many years, and is more apparent in the review of the long-term data in a separate report (Durbin and Raymond 2006). It is possible that some of the conductivity differential may simply be the result of changes in geology of the watershed from high elevations in the upper part of the basin to low elevations in the lower part of the basin near the Peace River. Groundwater from the intermediate aquifer, which generally contains more concentrated dissolved ions than surface water or groundwater from the surficial aquifer, is closer to the surface in the lower Horse Creek Basin, making seepage into the stream more likely. A review of land use types in the basin also shows more land under agricultural use in the lower basin than the upper basin, suggesting a higher potential for higher ion levels in the lower basin due to agricultural irrigation runoff.

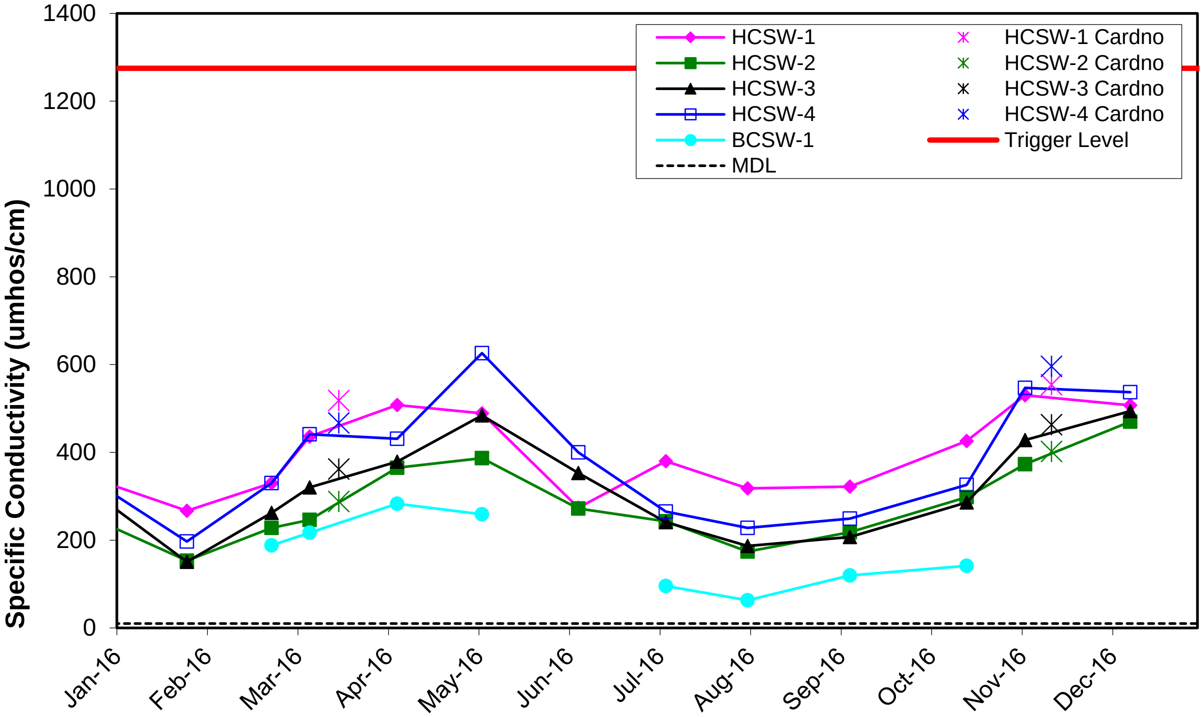


Figure 6-16. **Specific conductivity measurements obtained during monthly HCSP water quality sampling and biological sampling events in 2016.**

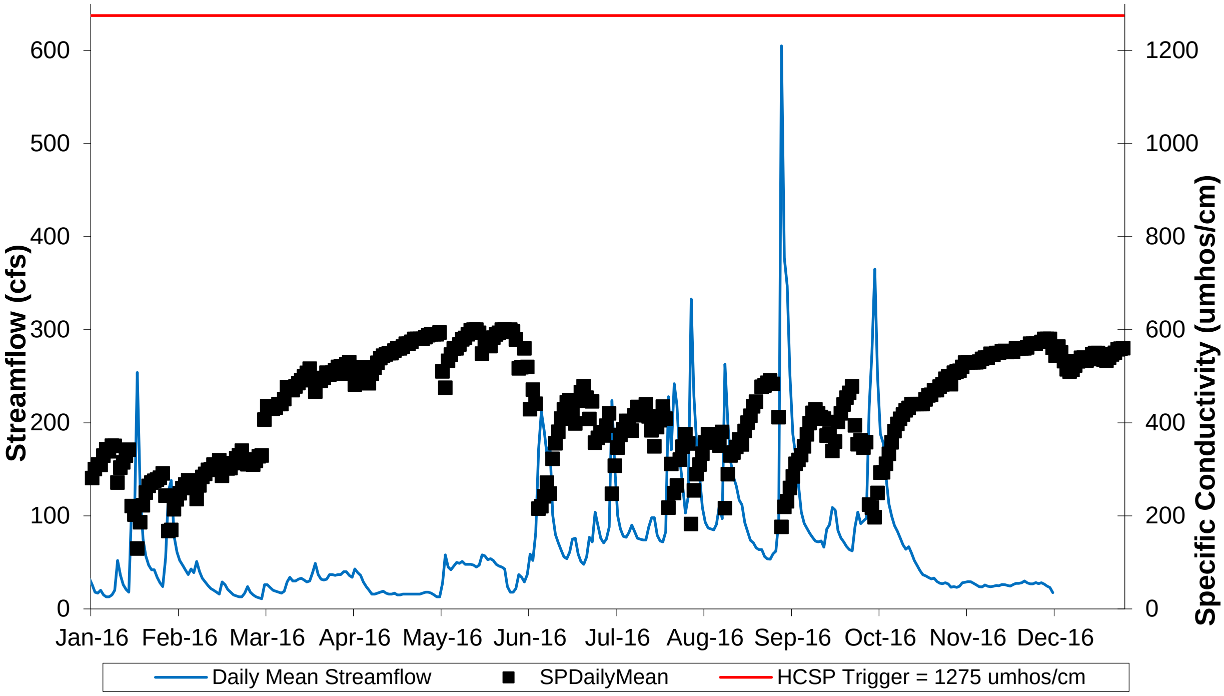


Figure 6-17. **Relationship between daily mean specific conductivity (obtained from the continuous recorder at HCSW-1) and daily mean streamflow for 2016. Minimum detection limit = 10 µmhos/cm.**

Dissolved Calcium

Dissolved calcium concentrations were lower than the trigger value of 100 mg/L at all Horse Creek stations during all events in 2016 (Figure 6-18). Brushy Creek had lower calcium concentrations than the Horse Creek stations. The calcium concentrations at HCSW-4 measured by the HCSP show no monotonic trend from 2003 to 2016 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 6-2); however, HCSW-1 exhibited an increasing trend since 2003 (slope = 1.05 mg/L per year flow-adjusted concentration, Table 6-2). The trend for calcium, like specific conductivity, may have been influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities, but the current concentrations are stable and not biologically harmful (Appendix I).

Concentrations of calcium were different between stations from 2003 to 2016 (ANOVA, Table 6-3), with the lowest overall readings at HCSW-2 and the highest at HCSW-4 (Duncan's multiple range test, $p < 0.05$). As with specific conductivity, calcium concentrations may be higher downstream because of increased groundwater seepage or irrigation runoff, especially during the dry years of 2006 to 2007. Calcium was negatively correlated with rainfall, streamflow, and NPDES discharge at HCSW-4 (Spearman's rank correlations, Table 6-4), but at HCSW-1, it was positively correlated with NPDES discharge and negatively correlated with rainfall (Table 6-4).

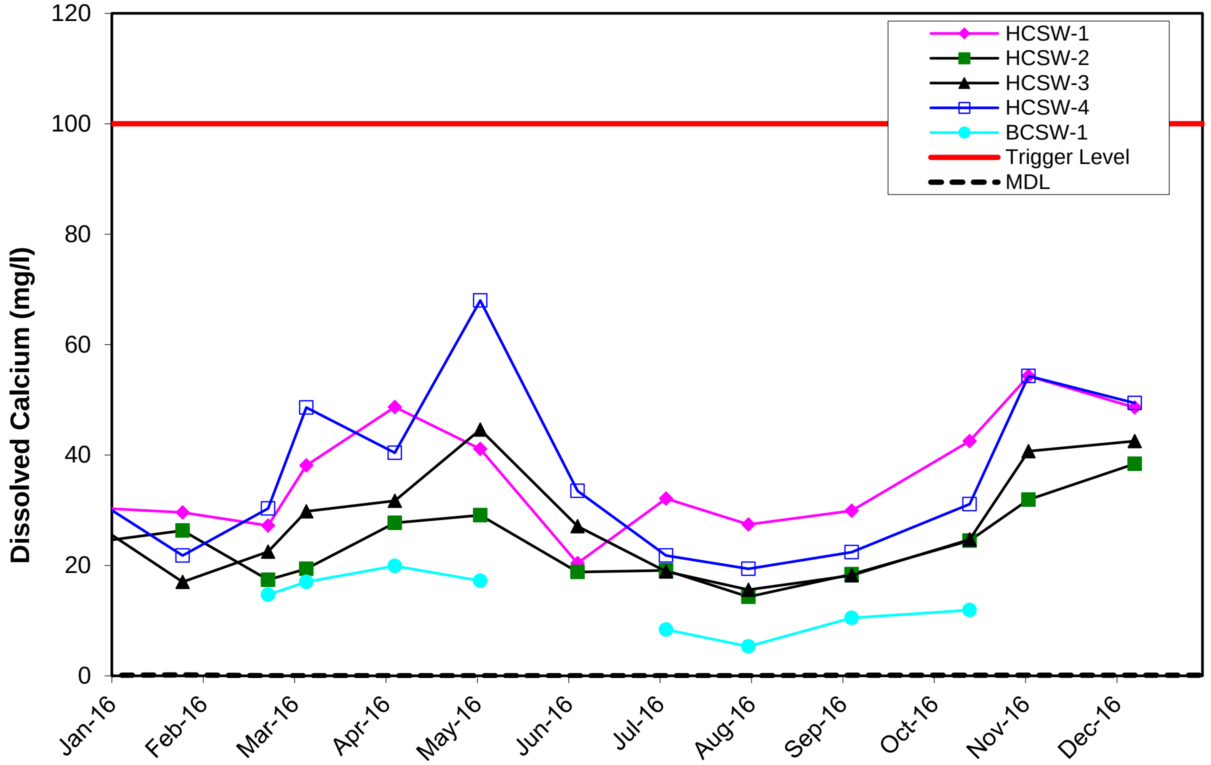


Figure 6-18. **Dissolved calcium concentrations obtained during monthly HCSP water quality sampling in 2016.**

Dissolved Iron

Dissolved iron concentrations at all stations were below 1 mg/L (the trigger level of HCSW-1, HCSW-2, and HCSW-3) during all sampling events in 2016 (Figure 6-19). Dissolved iron concentrations at HCSW-4 exceeded the trigger value of 0.3 mg/L established for that sampling station from July to September 2016. HCSW-4 has a different trigger level for iron because of its location upstream of a segment of the Peace River that is designated as Class I waters, which carries a lower standard value for iron (0.3 mg/L) than Class III waters (1.0 mg/L); it was determined during an impact assessment in 2003 that setting the HCSW-4 iron trigger level at the lower Class I standard resulted in a threshold that was too low based on historical conditions at that station (Appendix G). The iron concentrations at HCSW-1 and HCSW-4 measured by the HCSP were not compared to data collected by other sources because the historical data is limited for this water quality parameter.

There were decreasing monotonic trends for dissolved iron since 2003 at both HCSW-1 (Seasonal Kendall Tau with LOWESS, slope = -0.02 mg/L per year flow-adjusted concentration) and HCSW-4 (slope = -0.01 mg/L per year flow-adjusted concentration, Table 6-2). Because the direction of this potential trend is opposite that of the HCSP trigger level, it is not of concern (Appendix I). The program will continue to monitor this condition over time.

Dissolved iron concentrations were not different among stations over the 2003 to 2016 time period (ANOVA, Table 6-3). Iron was positively correlated with all water quantity variables at HCSW-1 and HCSW-4 (rainfall, streamflow, and NPDES discharge, Spearman's rank correlations, Table 6-4); because streamflow and NPDES discharge are positively correlated with rainfall (with lag times), this means that iron is generally highest during or following periods of high rainfall. Brushy Creek had slightly higher iron concentrations than most Horse Creek stations in 2016.

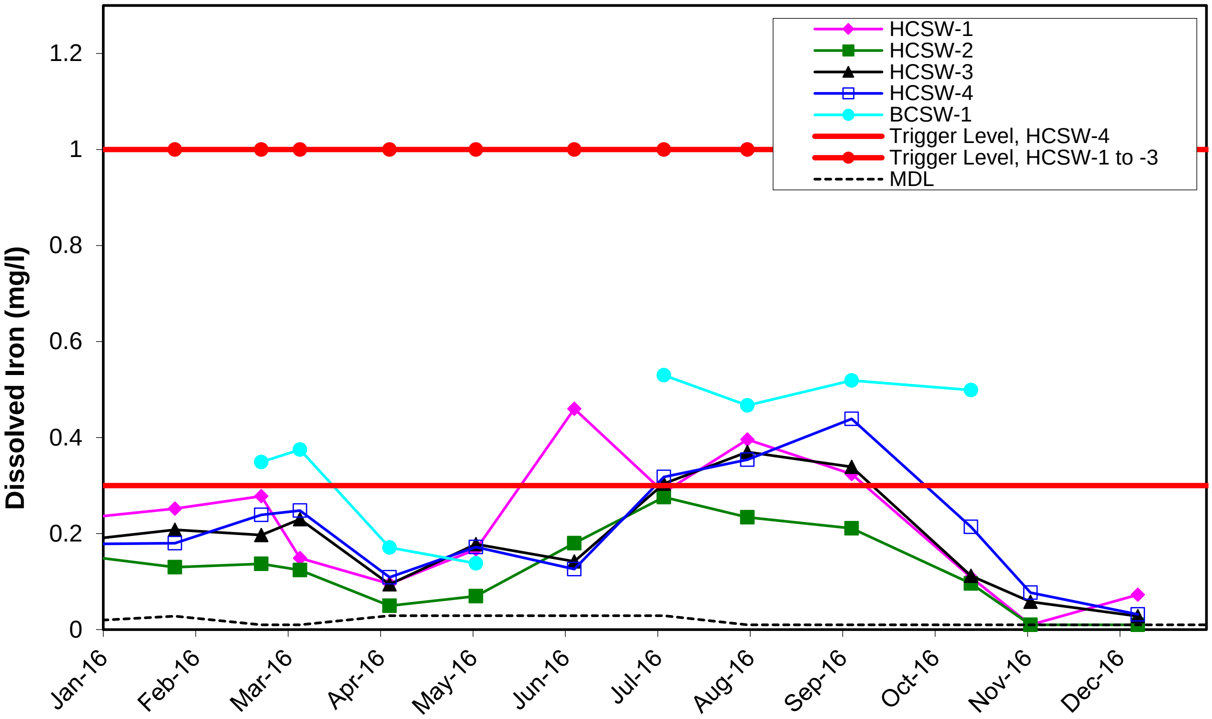


Figure 6-19. **Dissolved iron concentrations obtained during monthly HCSP water quality sampling in 2016.**

Total Alkalinity

Total alkalinity concentrations were below the trigger value of 100 mg/L during 2016 at all stations with the exception of the December HCSW-1 measurement (Figure 6-20). The alkalinity concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figures C-46 and C-47). Brushy Creek had similar alkalinity concentrations to Horse Creek stations during the dry season events but lower alkalinity concentrations from July to October 2016. There was an increasing monotonic trend present from 2003 to 2016 at both HCSW-1 (Seasonal Kendall Tau with LOWESS, slope = 2.39 mg/L per year flow-adjusted concentration) and HCSW-4 (slope = 1.08 mg/L per year flow-adjusted concentration, Table 6-2). The estimated slope for HCSW-1 and HCSW-4 is small compared to the differences between primary and field duplicate samples (≤17 mg/L). The trend for alkalinity, like specific conductivity, may have been influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities, but the current concentrations are stable and not biologically harmful (Appendix I).

Total alkalinity was different among stations from 2003 to 2016 (ANOVA, Table 6-3), with highest levels at HCSW-1 followed by HCSW-4 (Duncan's multiple range test, $p < 0.05$, Figure 6-20). Alkalinity was negatively correlated with rainfall, streamflow, and NPDES discharge at HCSW-4 (Spearman's rank correlation, Table 6-4), which is consistent with the concept that higher flows from rainfall would reflect the lower alkalinity of rainwater, compared with dry season inputs of groundwater. This condition suggests that groundwater seepage and agriculture irrigation runoff may also contribute to higher levels of alkalinity at HCSW-4. However, at HCSW-1, alkalinity was positively correlated with NPDES discharge and negatively correlated with rainfall (Table 6-4). High levels of alkalinity at HCSW-1 may be partly attributed to the exposed substrate in the stream banks that is unique to that station and other factors that are discussed as part of the specific conductivity impact assessment described in Appendix I.

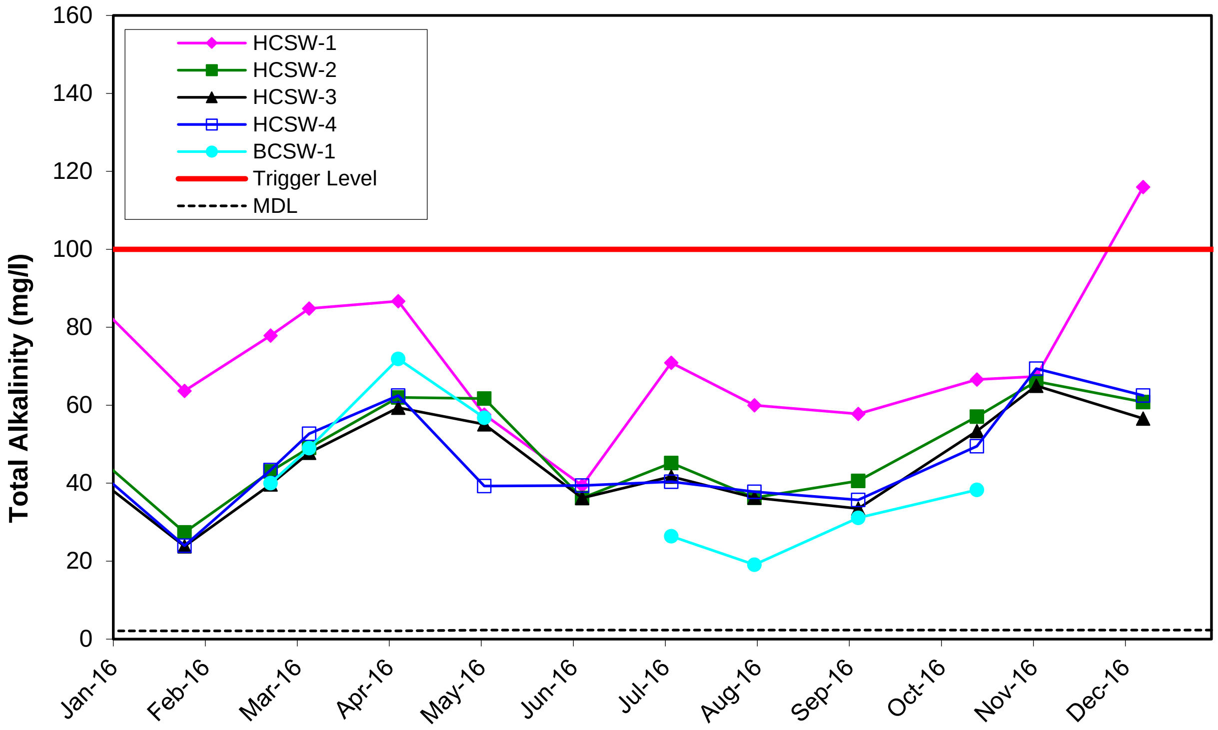


Figure 6-20. Total alkalinity concentrations obtained during monthly HCSP water quality sampling in 2016.

Chloride

Chloride concentrations were below 40 mg/L during 2016 at all Horse Creek stations, which was considerably lower than the trigger level of 250 mg/L (Figure 6-21). The chloride concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figures C-48 and C-49) and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 6-2).

Chloride concentrations were different among stations during all sampling events from 2003 to 2016 (ANOVA, Table 6-3), with a pattern of increasing concentrations from upstream to downstream, suggesting again the possible influence from groundwater seepage and agriculture irrigation runoff (Figure 6-21). Chloride was negatively correlated with all water quantity parameters at HCSW-1 and HCSW-4 (rainfall, streamflow, and NPDES discharge, Spearman's rank correlations, Table 6-4); because streamflow and NPDES discharge are positively correlated with rainfall (with lag times), this means that chloride tends to be lowest during or following periods of high rainfall. Brushy Creek had similar concentrations to the Horse Creek stations.

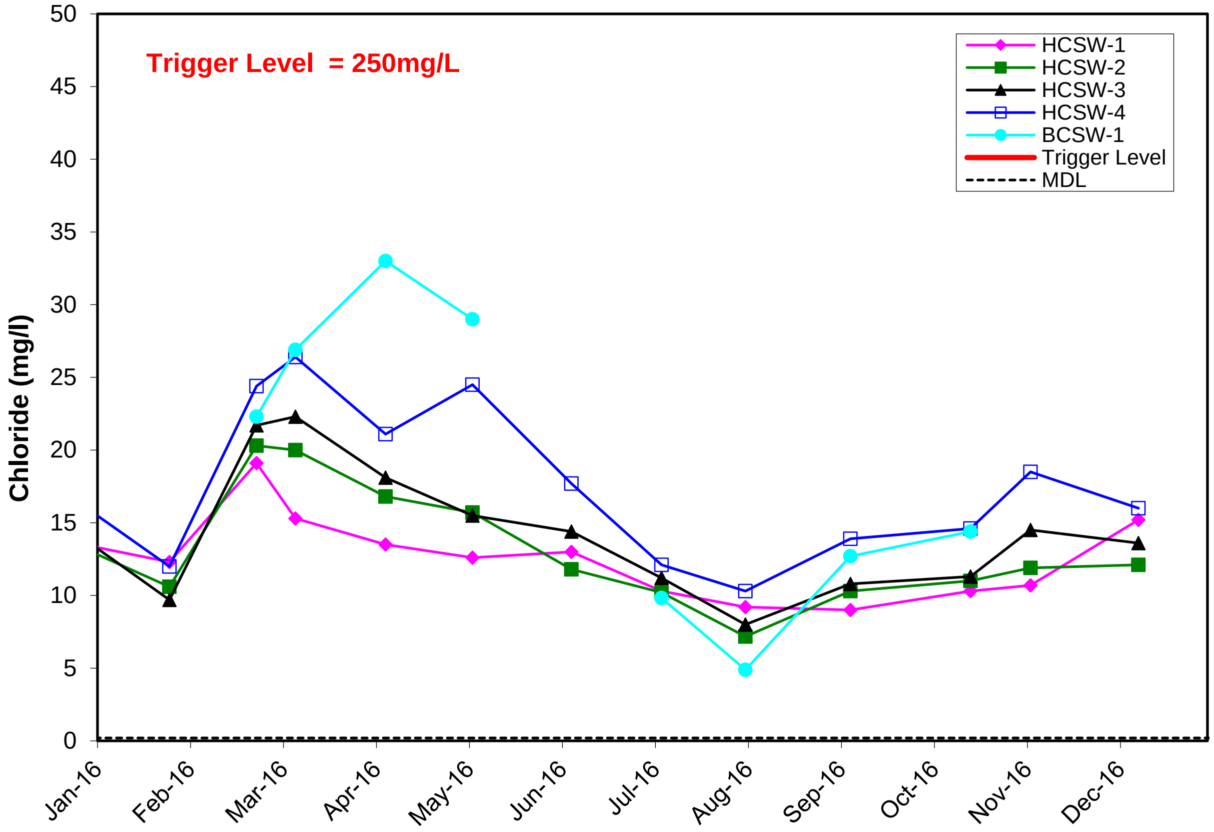


Figure 6-21. Chloride concentrations obtained during monthly HCSP water quality sampling in 2016. (HCSP trigger value for chloride is 250 mg/L.)

Fluoride

Fluoride concentrations were well below the trigger levels of 4.0 mg/L established for HCSW-1, HCSW-2, and HCSW-3, as well as the 1.5 mg/L trigger level for HCSW-4 in 2016 (Figure 6-22). Brushy Creek had lower concentrations Horse Creek stations during most of 2016. The HCSP data could not be analyzed for monotonic trends, correlations with water quantity, or differences between the four HCSP stations because of changes in MDL's over the course of the HCSP (Appendix C). After changes with the MDL for fluoride in 2007 during a drought, the MDLs have now been minimized and did not change from April 2008 through 2016. The fluoride concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figures C-50 and C-51).

Using monthly SWFWMD data, fluoride showed an increasing monotonic trend from 2003 to 2016 at both HCSW-1 and HCSW-4 (Seasonal Kendall Tau with LOWESS, slope = 0.01 mg/L per year flow-adjusted concentration at both stations, Table 6-2). Both increasing trends have very small slopes, well within the range of measurement error for fluoride. The trend for fluoride, like specific conductivity, may have been influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities, but the current concentrations are stable and not biologically harmful (Appendix I).

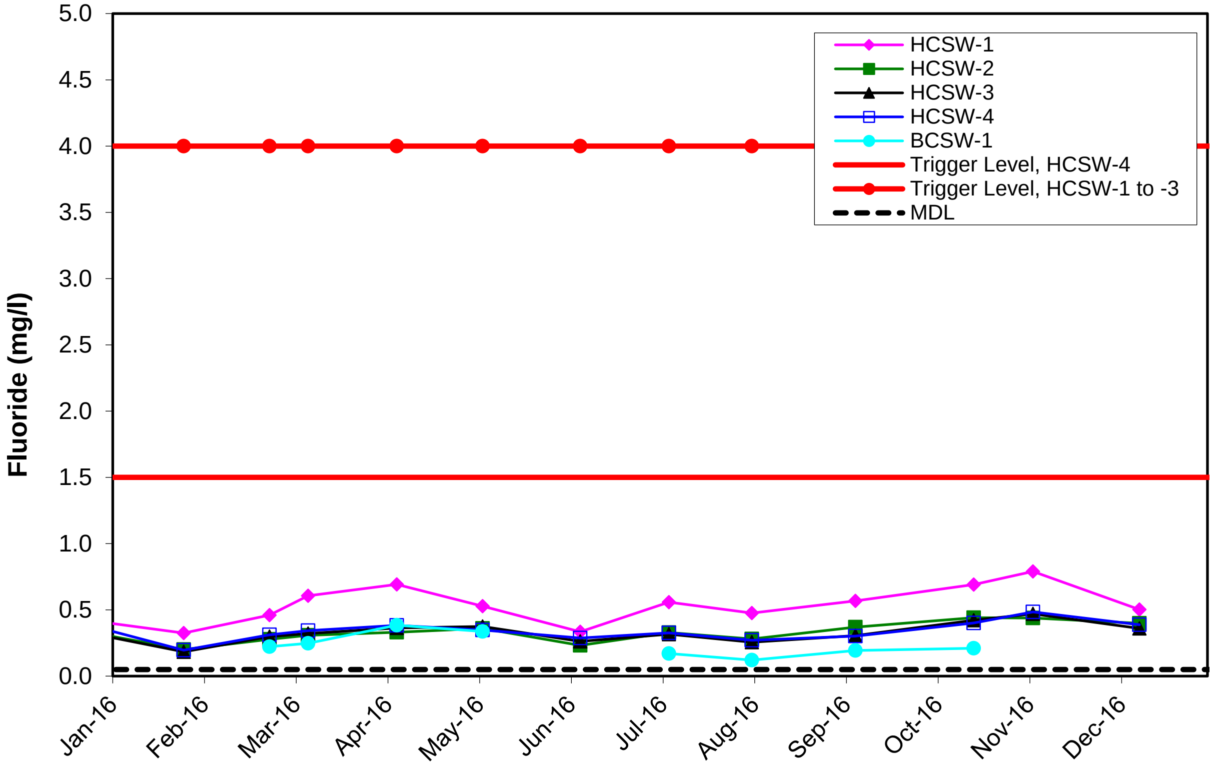


Figure 6-22. Fluoride concentrations obtained during monthly HCSP water quality sampling in 2016.

Sulfate

Sulfate concentrations were below the trigger level of 250 mg/L during all sampling events at all sampling stations in 2016 (Figure 6-23). Brushy Creek concentrations were lower than at Horse Creek stations during all events. The sulfate concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figures C-52 and C-53), and there was a slight increasing trend observed at HCSW-1 (Seasonal Kendall Tau with LOWESS, slope = 3.67 mg/L per year flow-adjusted concentration); there was no increasing or decreasing trend at HCSW-4 (Table 6-2). The trend for sulfate, like conductivity, may have been influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities, but the current concentrations are stable and not biologically harmful (Appendix I).

From 2003 to 2016, sulfate concentrations were different among stations (ANOVA, Table 6-3), with lowest levels at HCSW-2 and HCSW-1, then increasing when moving downstream (Duncan's multiple range test, $p < 0.05$). As with specific conductivity and calcium, sulfate concentrations may be higher downstream because of increased groundwater seepage or irrigation runoff, especially during the dry years of 2006 to 2007. At HCSW-4, sulfate was negatively correlated with rainfall, streamflow, and NPDES discharge (Spearman's rank correlation, Table 6-4), but at HCSW-1 was positively correlated with NPDES discharge (Table 6-4).

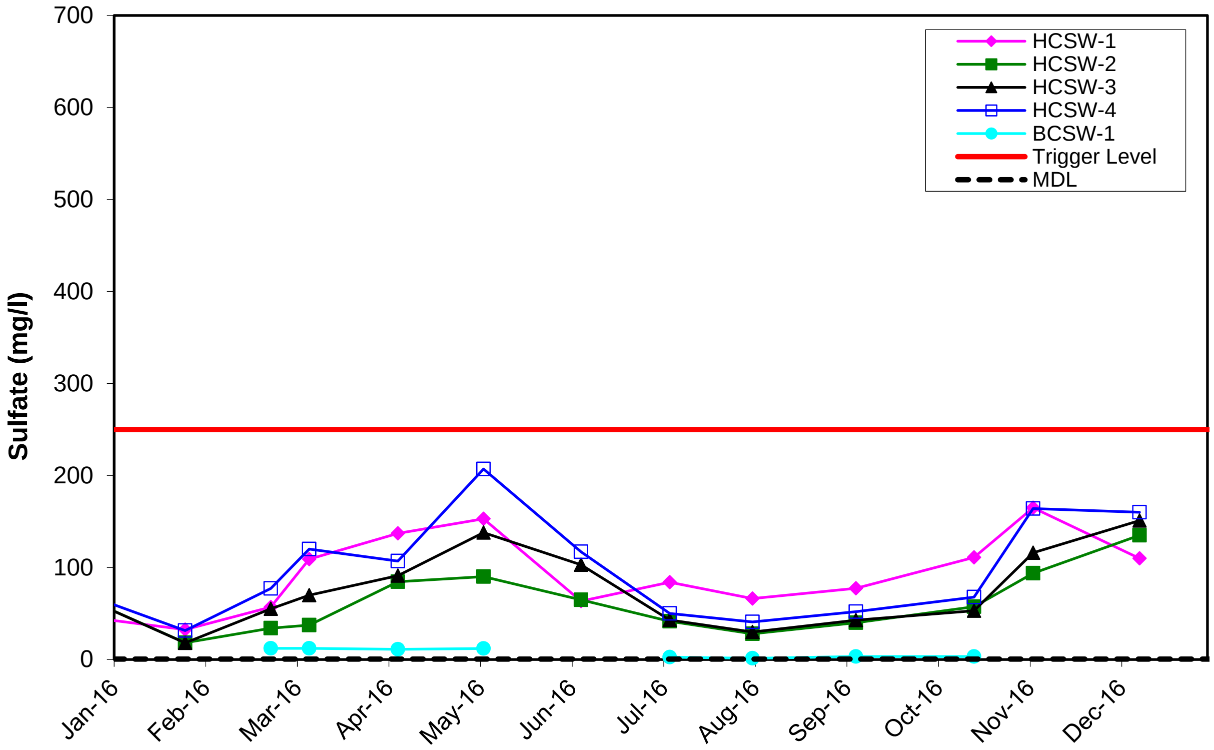


Figure 6-23. Sulfate concentrations obtained during monthly HCSP water quality sampling in 2016.

Total Dissolved Solids

Total dissolved solids (TDS) concentrations were below the trigger level of 500 mg/L during all sampling events at stations in 2016 (Figure 6-24). Brushy Creek concentrations were lower than at Horse Creek stations. The TDS concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Appendix C, Figures C-54 and C-55). HCSW-1 exhibited increasing trends since 2003 (Seasonal Kendall Tau with LOWESS, slope = 8.56 mg/L per year flow-adjusted concentration) as did HCSW-4 (slope = 6.02 mg/L per year flow-adjusted concentration, Table 6-2). The trend for TDS and other ions may have been influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities, but the current concentrations are stable and not biologically harmful (Appendix I).

As with sulfate concentrations, TDS concentrations over the course of the 2003 to 2016 period of record were lowest at HCSW-2 and HCSW-1 then increased when moving downstream (ANOVA, Duncan's multiple range test, $p < 0.05$, Table 6-3). TDS levels were negatively correlated with rainfall, streamflow, and NPDES discharge at HCSW-4 (Spearman's rank correlation, Table 6-4), but positively correlated with NPDES discharge and streamflow at HCSW-1 (Table 6-4). Both sulfate and TDS at downstream stations are probably affected by agricultural irrigation return flows and groundwater seepage downstream in the same manner as discussed above for conductivity and calcium.

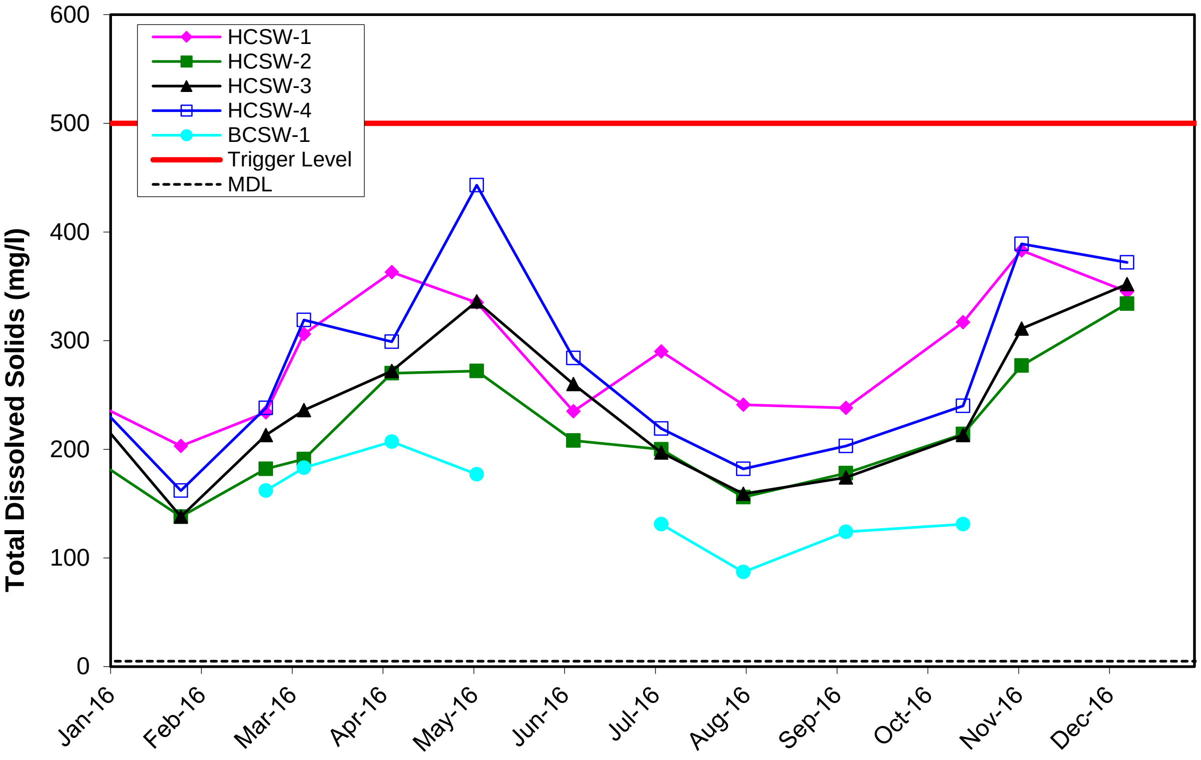


Figure 6-25. **Total dissolved solids concentrations obtained during monthly HCSP water quality sampling in 2016.**

Total Radium

Phosphate ore is a source of radioactivity as naturally occurring uranium-238 disintegrates into isotopes of radium and radon, which emit alpha particles in water. A water quality study of unmined and reclaimed basins in phosphate-mining areas found that radium concentrations of surface waters were slightly higher in unmined areas than in reclaimed basins, probably because of undisturbed phosphate deposits near the surface of unmined lands (Lewelling and Wylie 1993). Clay-settling areas may trap radioactive chemicals associated with clay slurry, but release only small amounts of radioactive chemicals into surface waters (Lewelling and Wylie 1993).

In Horse Creek during 2016, total radium[23] levels were below the trigger level of 5 pCi/L (Figure 6-25) at all stations during all sampling events. Brushy Creek concentrations were similar to Horse Creek stations. There were no monotonic trends observed since 2003 for total radium at HCSW-1 or HCSW-4 (Seasonal Kendall Tau, $p > 0.05$, Table 6-2). Total radium levels from 2003 to 2016 were different among stations (ANOVA, Table 6-3) with lowest levels at HCSW-2 (Duncan's multiple range test, $p < 0.05$). Total radium was negatively correlated with NPDES discharge and streamflow at HCSW-1 and HCSW- 4 (Spearman's rank correlations, Table 6-4), indicating that radium was higher when NPDES discharge and streamflow were low. Some of the correlation analyses with radium and water quantity may be affected by an apparent step decrease that occurred in 2008, coincident with a change in analytical laboratories (Appendix K).

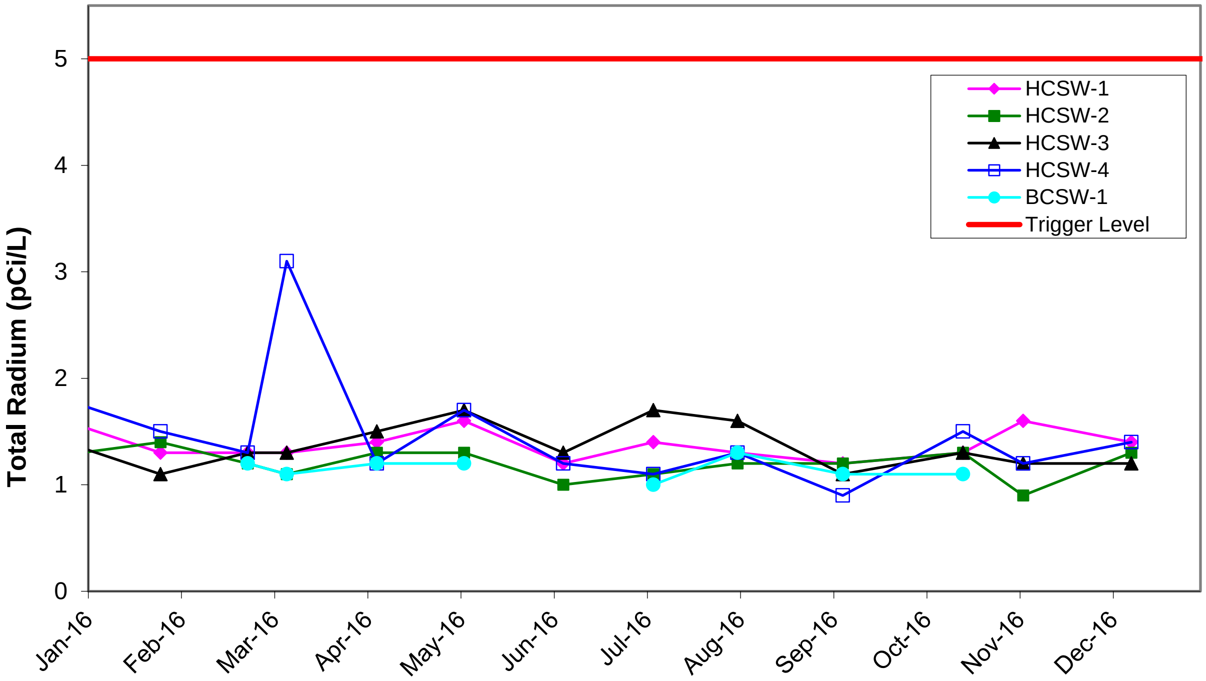


Figure 6-25. Levels of total radium obtained during monthly HCSP water quality sampling in 2016. (All of the samples were undetected for Radium 228 except for July 2016 at HCSW-3 and March 2016 at HCSW-4.)

---

[23] The HCSP methodology specifies that "Radium 226 + 228" be analyzed as part of the monthly sampling. This data has been reported as both individual constituents and as a total (Appendix E). Starting in December 2003 and continuing through the present, the data has been analyzed and reported as Radium 226 and Radium 228 separately and an arithmetic sum of the two numbers ("Radium 226 + 228"). As requested by the PRMRWSA, if either Radium 226 or Radium 228 is undetected, the MDL of the undetected constituent will be used as part of the "Radium 226 + 228." This use of MDL for undetected constituents as part of a calculated constituent is contrary to both laboratory and DEP SOPs.

6.5 Summary of Water Quality Results

Water quality parameters in 2016 were almost always within the desirable range relative to trigger levels and water quality standards at the station with the highest percent of upstream mined lands (HCSW-1, Table 6-5). Alkalinity was the only parameter above the trigger level at HCSW-1 during 2016, but the exceedance was only 16 mg/L above the trigger and did not occur during a time of NPDES discharge (Table 6-5). The dissolved oxygen trigger level was exceeded during most of the year at HCSW-2 (February through December 2016). Based upon historical conditions in Horse Creek (Durbin and Raymond 2006), the reported values for dissolved oxygen at HCSW-2 are the result of natural conditions (proximity to hypoxic segment of stream – Horse Creek Prairie) and are not related to mining activities. Total nitrogen was above the trigger level in February 2016 at HCSW-3; this sample was also comprised mainly of nitrate-nitrite. There did not appear to be a lab error for this sampling event, but the sample was collected following a few days of high rainfall totals. Dissolved iron concentrations consistently exceeded the trigger value set at HCSW-4 (July to September 2016), but Mosaic and the PRMRWSA agree that the trigger value at that station has been set too low given historical and upstream concentrations of dissolved iron. Based on impact assessments already completed, none of the observed exceedances pose a significant adverse ecological impact to Horse Creek that would be attributable to mining.

Twelve water quality parameters showed statistically significant increasing or decreasing trends in 2016 at HCSW-1 or HCSW-4. Several of the trends detected during the statistical analysis either have an estimated slope that 1) was not in the direction of an adverse trend (dissolved oxygen concentration, dissolved oxygen saturation, color, ammonia, and dissolved iron) or 2) was very small compared to the observed differences between primary and duplicate field samples (pH and fluoride) (Table 6-6). Specific conductivity, TDS, and various dissolved ions had reported trends with higher estimated rates of change. The potential trends for pH and specific conductivity (with reference to TDS and other ions) are discussed in Appendix I. The apparent change in pH since 2003 is not a strong trend when compared to SWFWMD data collected at the same place, and the observation of similar change-point increases at HCSW-1 and upstream stations around the drought period lead to the conclusion that pH is not having an ecologically significant increase at HCSW-1 over the course of the HCSP program and is not of concern at this time.

For specific conductivity, a significant increasing trend was detected at HCSW-1 even when the period of record was expanded, but an analysis of other stations shows the influence of climatic and upstream conditions. At least part of the increase may be caused by regional influences, as Charlie Creek (an unmined stream) and Horse Creek closely mirror each other; Charlie Creek and Horse Creek show a step-change increase in conductivity around 2006 to 2007, followed by stable or decreasing levels through 2016. Specific conductivity at Horse Creek and West Fork Horse Creek stations upstream of the NPDES outfalls show similar trends and step-change increases. In addition, the trends at the upstream stations begin well before the beginning of the HCSP program. Specific conductivity at HCSW-1 began to rise during a very dry period in 2006 to 2008 (from 100–400 µmhos/cm to 200–500 µmhos/cm) when Mosaic had very little NPDES discharge into Horse Creek, and the stream was dominated by baseflow (surficial aquifer) contributions. Water resulting from Wingate dredge mining activities began to discharge from the two Horse Creek NPDES outfalls in late 2008; dredge mining is more influenced by groundwater than conventional mining. Although HCSW-1 specific conductivity remained at higher levels (200–600 µmhos/cm) after 2008, concentrations at three of the four Horse Creek stations upstream of the NPDES outfalls were also higher during that time period.

When compared to another upstream station on West Fork Horse Creek or station on Charlie Creek, the majority of HCSW-1 observations fall within the 95% prediction interval of the other stations. In recent years, the highest specific conductivity at HCSW-1 was recorded during the dry season when no NPDES discharge was occurring; during those periods, HCSW-1 conductivity was very similar to that of West Fork Horse Creek stations. Thus, while some isolated conductivity values at HCSW-1 may be related to increased groundwater influence at NPDES discharges, the majority of the increasing trend at HCSW-1 can be explained by other factors. The trend for specific conductivity and other ions may have been influenced by regional factors unrelated to mining, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities, but the current concentrations are stable and not biologically harmful. Any small portion of the change in specific conductivity (and other related ions) that may have been affected by changes in NPDES water quality is likely to stay relatively constant at HCSW-1 in the near future given planned mining practices and the stable range of concentrations shown since Wingate mine began discharging to Horse Creek in 2008.

Dissolved ion concentrations at HCSW-1 in recent years still meet all applicable state drinking water and Class III surface water standards, except where otherwise noted in previous monthly impact assessments. In addition, the current specific conductivity concentrations at HCSW-1 are within the preferred range of Horse Creek freshwater fish species, and the diversity and composition of fish populations have remained steady over the HCSP study period with no correlation with specific conductivity. SCI scores, an indicator of benthic macroinvertebrate community health, have also remained steady over the HCSP study period and show no relationship with specific conductivity.

Significant differences between stations were evident for several parameters. When stations were compared, HCSW-2 was the most dissimilar from the other three stations, especially in pH, dissolved oxygen, color, chlorophyll-*a*, and some dissolved ions. Some nutrients (nitrate-nitrite) and dissolved ions (specific conductivity, calcium, chloride, and sulfate) had higher concentrations downstream in Horse Creek, probably because of increased groundwater seepage and agricultural irrigation runoff in the lower Horse Creek basin during dry periods. Differences in topography, geology, and land use that could account for these station differences in Horse Creek are examined in the Horse Creek Stewardship Program Historical Report (Durbin and Raymond 2006).

Water quality parameters were compared with water quantity variables recorded during the same month: average daily streamflow for the month, average daily NPDES discharge for the month, and total monthly rainfall (Figure 6-26). In general, pH, dissolved oxygen, and most dissolved ions are higher when the overall quantity of water in the Horse Creek system is low. (In this report, chlorophyll-a, specific conductivity, calcium, alkalinity, sulfate, and TDS showed the opposite pattern with NPDES discharge at HCSW-1.) Conversely, turbidity, color, iron, and nitrogen are high when the water quantity is also high. When water quantity in Horse Creek is low, the stream is often pooled or slow-moving, leading to algal blooms that may increase pH and chlorophyll-a. In addition, the majority of water in the stream during low quantity periods may be from groundwater (seepage or agricultural runoff); groundwater has a higher concentration of dissolved ions than surface water. When water quantity is high because of rainfall or streamflow, an increased amount of sediment and organic debris is washed into the stream, leading to increases in turbidity, color, iron, and nitrogen.

Table 6-5. Instances of trigger level exceedance observed in 2016 HCSP monthly monitoring.

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at Goose Pond Road	HCSW-2	2/23/2016	Dissolved Oxygen (%Saturation)	37.0	43.0
Horse Creek at Goose Pond Road	HCSW-2	3/7/2016	Dissolved Oxygen (%Saturation)	34.8	39.7
Horse Creek at Goose Pond Road	HCSW-2	4/6/2016	Dissolved Oxygen (%Saturation)	34.2	42.5
Horse Creek at Goose Pond Road	HCSW-2	5/5/2016	Dissolved Oxygen (%Saturation)	23.6	43.0
Horse Creek at Goose Pond Road	HCSW-2	6/7/2016	Dissolved Oxygen (%Saturation)	20.6	42.0
Horse Creek at Goose Pond Road	HCSW-2	7/7/2016	Dissolved Oxygen (%Saturation)	13.6	42.0
Horse Creek at Goose Pond Road	HCSW-2	8/4/2016	Dissolved Oxygen (%Saturation)	26.8	40.9
Horse Creek at Goose Pond Road	HCSW-2	9/8/2016	Dissolved Oxygen (%Saturation)	20.8	39.2
Horse Creek at Goose Pond Road	HCSW-2	10/18/2016	Dissolved Oxygen (%Saturation)	19.1	39.2
Horse Creek at Goose Pond Road	HCSW-2	11/7/2016	Dissolved Oxygen (%Saturation)	25.0	42.0
Horse Creek at Goose Pond Road	HCSW-2	12/13/2016	Dissolved Oxygen (%Saturation)	24.8	41.3
Horse Creek at State Road 70	HCSW-3	2/23/2016	Total Nitrogen (mg/L)	3.5	3.0
Horse Creek at State Road 72	HCSW-4	7/7/2016	Dissolved Iron (mg/L)	0.318	0.3
Horse Creek at State Road 72	HCSW-4	8/4/2016	Dissolved Iron (mg/L)	0.354	0.3
Horse Creek at State Road 72	HCSW-4	9/8/2016	Dissolved Iron (mg/L)	0.439	0.3
Horse Creek at State Road 64	HCSW-1	12/13/2016	Alkalinity (mg/L)	116	100

Table 6-6. Summary of trends over time (2003 to 2016) from Seasonal Kendall-tau analysis.

Parameter	HCSW-1 Slope	HCSW-4 Slope	Discussion
pH	0.05 SU/yr		Slope very small in magnitude. Isolated step change. Not of concern. See further discussion in Appendix I.
DO (mg/L)	0.06 mg/yr		Not an adverse trend
DO (% Saturation)	0.74%/yr		Not an adverse trend
Color		4.31 PCU/yr	Not an adverse trend
Nitrogen, Ammonia	-0.001 mg/L/yr		Not an adverse trend
Specific Conductance	10.4 µmhos/cm/yr	7.94 µmhos/cm/yr	See further discussion in Appendix I
Calcium	1.05 mg/L/yr		Related to Conductance Trend Discussion (See Appendix I)
Iron	-0.02 mg/L/yr	-0.01 mg/L/yr	Not an adverse trend
Alkalinity	2.39 mg/L/yr	1.08 mg/L/yr	Related to Conductance Trend Discussion (See Appendix I)
Fluoride	0.01 mg/L/yr	0.01 mg/L/yr	Related to Conductance Trend Discussion (See Appendix I)
Sulfate	3.67 mg/L/yr		Related to Conductance Trend Discussion (See Appendix I)
TDS	8.56 mg/L/yr	6.02 mg/L/yr	Related to Conductance Trend Discussion (See Appendix I)

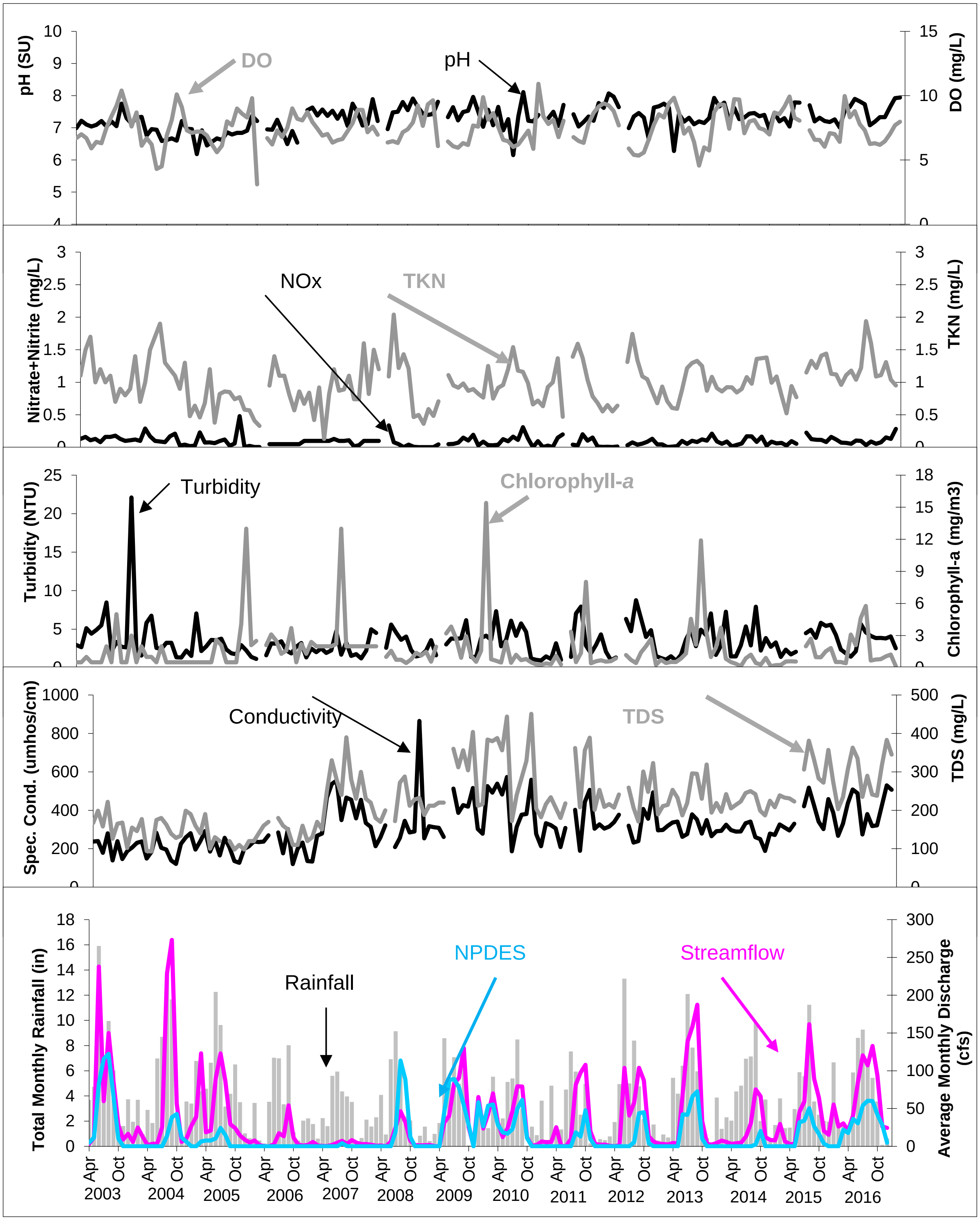


Figure 6-26. HCSP water quality correlations with average monthly NPDES discharge, average monthly streamflow, and total monthly rainfall at HCSW-1 from 2003 to 2016.

7 Biological Results and Discussion

7.1 Benthic Macroinvertebrates

Benthic macroinvertebrate sampling was conducted at all stations during the 14 March and 16 November sampling events. Only two sampling events occurred in 2016 because of high water levels and flows that prohibited a summer sampling event. The Brushy Creek location is not included in the macroinvertebrate sampling component of the HCSP.

As discussed in Section 4.4, the calculation methodology for the SCI was initially revised by DEP in June 2004, and sampling conducted from 2003 to 2006 uses that methodology. In 2007, the FDEP SCI protocol[24] was again revised, this time to include provisions for the taxonomic analysis of two aliquots for every SCI sample collected to account for variation in sample sorting (DEP-SOP-002/01 LT 7200). Under the new protocol, the SCI score for each sample is the arithmetic average of the SCI scores of the two aliquots. In addition to the change in aliquots in 2007, the new protocol also gives a slightly different ecological interpretation of SCI scores (Table 4-5). The SCI protocol was revised again in 2012 (DEP-SOP-003/11 SCI 1000), making changes to the SCI calculation but not the sampling methodology. This report has scores in the tables and graphics updated to the 2012 methodology. Scores from the 2004 SCI formulae (collected from 2003 to 2006) and the 2012 SCI formulae (collected from 2007 to 2016 with two vials) may not be directly comparable, given the differences in how they were collected (noted in Figures 7-2 to 7-5). Any statistical analysis conducted on the invertebrate sampling in this report omits the samples collected under the 2004 SCI protocol (collected from 2003 to 2006); however, data is graphed in Figures 7-2 to 7-5 and a summary of all scores by protocol is presented in Appendix J.

7.1.1 Stream Habitat Assessment

The majority of the habitat assessment parameters evaluated through the DEP procedure are not directly related to mining, but they are generally related to the nature of the system being examined and its surroundings (e.g., substrate diversity and availability, artificial channelization, bank stability, buffer width, and vegetation quality). Parameters that might be hypothesized to have some linkage to mining are water velocity and habitat smothering, primarily as a result of NPDES discharges to a stream. Because the turbidity of the NPDES discharge in 2016 was relatively low, it is unlikely that suspended particles within the discharge made a significant contribution to sediment deposition in the stream.

For the habitat assessment metric on smothering, the productive habitats are evaluated and the degree to which they are smothered is recorded (none, slight, moderate, or severe). HCSW-1 is higher up in the basin and receives less sediment load that could smother the various habitats (roots, snags, and rock) from upstream sources. The more downstream locations have a larger basin area that contributes both sediment and flowing water. HCSW-3 and HCSW-4 have higher smothering that occurs in the productive habitats (roots, snags, and aquatic vegetation) usually after high flows when sediment settles out after flow decreases.

The habitat quality of Horse Creek ranged between 105 and 131 (”sub-optimal” to “optimal” range in FDEP SOP) during all sampling events in 2016 (Table 7-1, Figure 7-1), similar to past events. HCSW-1, the station closest to mining, scored as “optimal” during both sampling events. Some of the minor variation among the sampling events for a given station primarily reflects differences in habitat quality and quantity caused by changes in stream stage, which affects the availability and ratios of in-stream habitats, and also the inherent variability in the habitat scoring protocol itself. The fall sampling event is usually immediately following summer high flows where the banks are scoured (lower habitat stability) and there may not be any vegetation in the water to sample as a productive habitat (lower substrate diversity and

---

[24] Appendix J includes SCI 2004, 2007, and 2012 scores for comparison.

availability). For those reasons, the overall habitat assessment score tends to be lower in the summer or fall.

Table 7-1. Habitat scores obtained during HCSP biological sampling events in 2016.

Habitat Characteristic		HCSW-1		HCSW-2		HCSW-3		HCSW-4	
		17-Mar-16	16-Nov-16	17-Mar-16	16-Nov-16	17-Mar-16	16-Nov-16	17-Mar-16	16-Nov-16
Substrate Diversity		15	14	13	12	11	9	14	9
Substrate Availability		10	12	8	5	3	5	6	6
Water Velocity		20	20	13	13	20	19	20	20
Habitat Smothering		13	17	12	12	13	13	14	12
Artificial Channelization		18	18	17	17	19	19	18	18
Bank Stability	Right Bank	9	10	8	7	6	5	6	6
	Left Bank	9	7	7	5	4	5	6	6
Riparian Buffer Zone Width	Right Bank	10	9	10	10	10	10	10	10
	Left Bank	7	9	10	10	10	10	10	10
Riparian Zone Vegetation Quality	Right Bank	8	8	8	7	7	6	6	8
	Left Bank	6	7	8	7	7	6	5	6
Total Score*		**125**	**131**	**114**	**105**	**110**	**107**	**115**	**111**
Habitat Descriptor		Optimal	Optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal

* - The maximum possible score under this protocol is 160 (121-160 Optimal, 81-120 Suboptimal, 41-80 Marginal, <40 Poor).

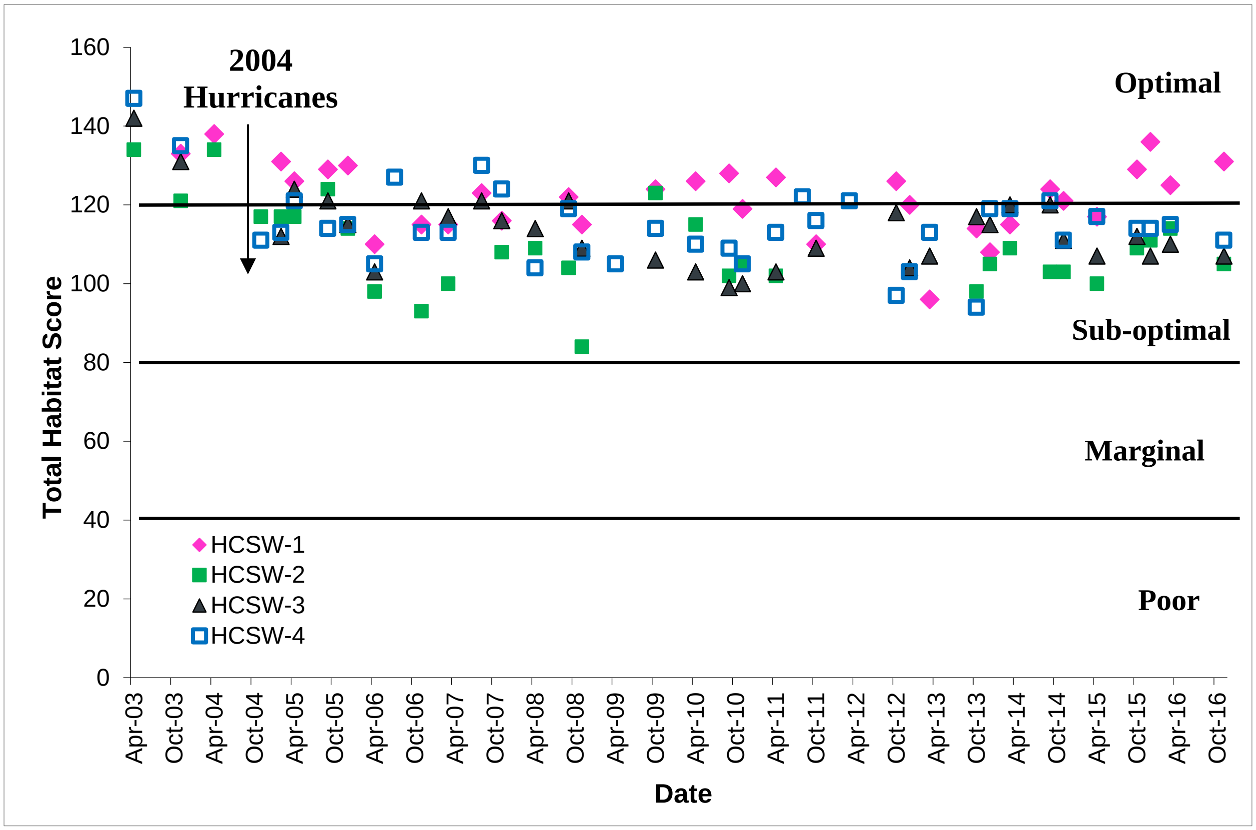


Figure 7-1. **Total habitat scores obtained during HCSP biological sampling events at all locations from 2003 to 2016.**

7.1.2 Stream Condition Index

A database containing a list of the benthic macroinvertebrate taxa collected from 2003 to 2016 is provided on the Cardno FTP site[25]. Table 7-2 provides the SCI metrics, resulting SCI values, and total SCI scores calculated as a vial average for the benthic macroinvertebrates collected at the four stations during each sampling event in 2016. The numbers of individuals included in Table 7-2 represent the number extracted from the whole sample for identification (i.e., all 20 dipnet sweeps), which were analyzed by the taxonomist (only a portion of each sample is sorted and processed, per the SOP). The SCI scores in 2016 were above 35 (four rated as “Healthy” and three rated as “Exceptional” according to the FDEP SOP) for all stations and events except HCSW-2 in November 2016; the biological sampling location at HCSW-2 frequently has lower flow and dissolved oxygen conditions than the other stations.

Final SCI scores for the samples ranged from 31 (HCSW-2 in November) to 78 (HCSW-4 in November) in 2016, similar to other years (Table 7-2 and Figure 7-2). When considered over time from 2007 to 2016 (period when SCI 2012 formulae can be used), the overall SCI scores were variable at each station; when all stations were combined the annual median and spring SCI scores increased over time (Kendall Tau = 0.30 and 0.32, $p < 0.05$). The same increases were observed in annual medians and spring SCI scores

---

[25] Beginning with the 2010 annual report (Appendix J), the HCSP SCI data was reevaluated with strict interpretation of FDEP SOP guidance, including the upper and lower limits of the SOP target number of individuals, the SOP target of a minimum velocity of 0.05 m/sec 28 days prior to sampling, the SOP target of waiting at least 90 days after abatement of a stream dessication event (i.e. no refugia for organisms), and the SOP target of less than a 0.5 m water level increase in the previous 28 days. As a result of this evaluation, some SCI scores have been removed from the analysis (Appendix J, *red italics*). In addition, some SCI results with more than the target number of individuals were randomly resampled to provide an unbiased result.

at HCSW-4 by itself (Kendall Tau = 0.56 and 0.51; $p < 0.05$), but there were no significant trends for other single stations. Because of naturally low streamflow and dissolved oxygen concentrations related to an upstream wetland system, the SCI scores were lower at HCSW-2 than other stations (ANOVA: F = 23.31, $p < 0.0001$, Duncan's multiple range test: $p < 0.05$, long term average of 32 compared to 61-64).

Table 7-2. SCI 2012 metrics calculated for benthic macroinvertebrates collected at four locations in Horse Creek during 2016.

SCI Metric	HCSW-1				HCSW-2			
	17-Mar-16		16-Nov-16		17-Mar-16		16-Nov-16	
	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value
Total Taxa	31.5	**6.88**	20.0	**2.08**	22.0	**2.92**	31.5	**6.88**
Ephemeropteran Taxa	2.5	**5.00**	3.0	**6.0**	1.0	**2.00**	1.5	**3.00**
Trichopteran Taxa	4.5	**6.43**	3.5	**5.0**	2.0	**2.86**	0	**0**
Percent Filterer Taxa	29.21	**6.63**	6.05	**1.25**	47.69	**10**	6.83	**1.43**
Long-lived Taxa	1.0	**3.33**	1.0	**3.33**	0.5	**1.67**	0	**0**
Clinger Taxa	7.0	**9.29**	5.0	**7.14**	4.0	**5.71**	1.5	**2.14**
Percent Dominant Taxon	30.79	**6.64**	39.43	**4.91**	27.00	**7.40**	39.97	**4.81**
Percent Tanytarsini	31.73	**9.95**	4.25	**4.83**	62.69	**10**	10.00	**7.05**
Sensitive Taxa	3.5	**5.00**	3.5	**5.00**	1.0	**1.43**	0	**0**
Percent Very Tolerant Taxa	5.07	**7.25**	1.65	**9.34**	6.00	**6.90**	36.68	**2.68**
Total SCI Score	**74**		**54**		**57**		**31**	
Interpretation	**Exceptional**		**Healthy**		**Healthy**		**Impaired**	
Total Number of Individuals	**148**		**152.5**		**150**		**150**	

SCI Metric	HCSW-3				HCSW-4			
	17-Mar-16		16-Nov-16		17-Mar-16		16-Nov-16	
	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value
Total Taxa	34.0	**7.92**	32.5	**7.29**	33.0	**7.50**	33.5	**7.71**
Ephemeropteran Taxa	3.0	**6.00**	5.0	**8.00**	3.5	**7.00**	4.5	**9.00**
Trichopteran Taxa	4.0	**5.71**	5.5	**7.86**	4.0	**5.71**	6.5	**8.57**
Percent Filterer Taxa	4.45	**0.87**	10.48	**2.27**	25.246	**5.71**	18.61	**4.16**
Long-lived Taxa	2.0	**6.67**	2.5	**6.67**	1.5	**5.00**	1.5	**5.00**
Clinger Taxa	3.5	**5.00**	5.0	**7.14**	8.0	**10**	9.0	**10**
Percent Dominant Taxon	27.37	**7.33**	29.87	**6.83**	29.07	**6.99**	28.17	**7.17**
Percent Tanytarsini	5.41	**5.43**	3.73	**4.56**	23.64	**9.42**	10.09	**7.07**
Sensitive Taxa	2.0	**2.86**	2.5	**3.57**	4.0	**5.71**	5.0	**7.14**
Percent Very Tolerant Taxa	21.3	**3.99**	20.69	**4.06**	17.25	**4.50**	17.72	**4.45**
Total SCI Score	**58**		**65**		**75**		**78**	
Interpretation	**Healthy**		**Healthy**		**Exceptional**		**Exceptional**	
Total Number of Individuals	**157**		**147.5**		**156.5**		**149**	

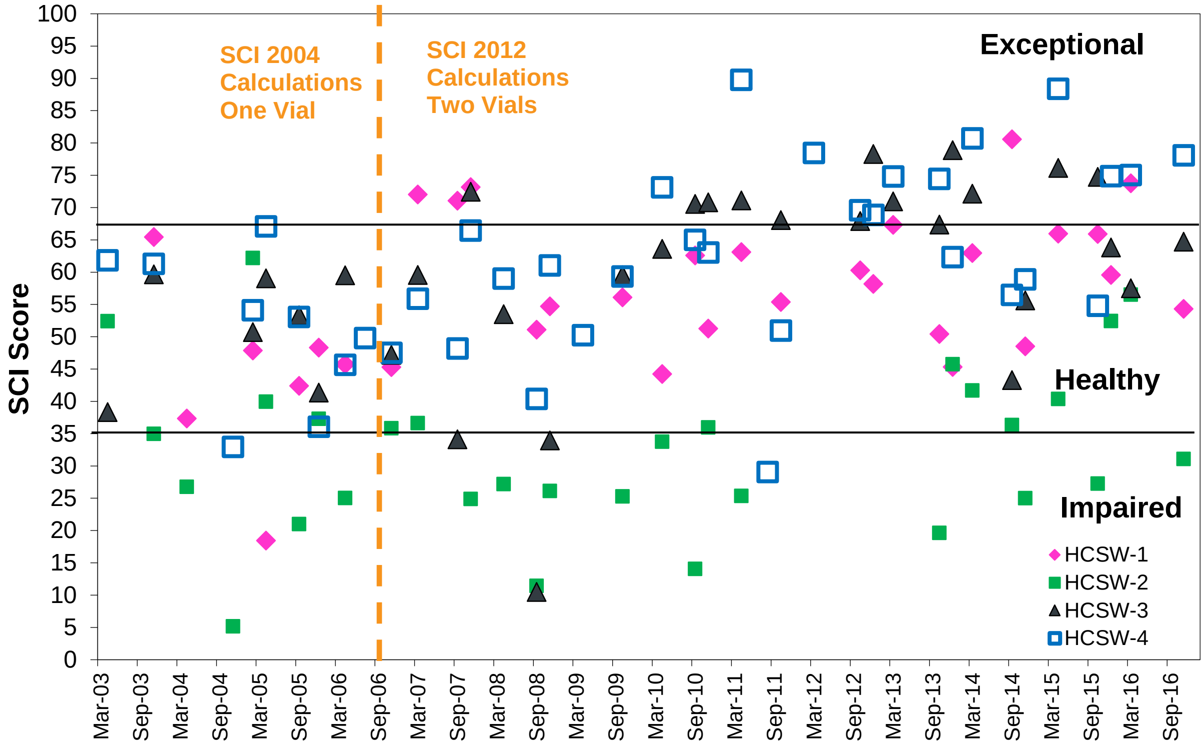


Figure 7-2. **SCI scores for samples collected at all HCSP locations from 2003 to 2016.**

7.1.3 Total Taxa

In general, a healthy stream system will support colonization by a diverse number of taxa. Therefore, the more taxa a station is shown to have, the healthier that system is regarded. Figure 7-3 illustrates the number of taxa collected at each of the HCSP stations during the monitoring events. Differences in taxa numbers among samples are expected, both spatially and temporally, as a result of natural variability, as well as differences in sampling conditions and sample processing, even when the invertebrate communities are very similar. The number of invertebrate taxa collected in each sample was similar to historic sampling in the basin (Durbin and Raymond 2006). When considered over time from 2007 to 2016 (period when SCI 2012 formulae can be used), total taxa were variable over time when all stations were combined, but there were no increasing or decreasing trends. However, when the individual stations were evaluated, there was an increasing trend observed during spring sampling events (Kendall Tau = 0.49, p <0.05) at HCSW-3. The total taxa scores were different among stations, with the greatest number of taxa at HCSW-3 and HCSW-4 (ANOVA: F = 4.31, p < 0.01, Duncan's multiple range test: p < 0.05).

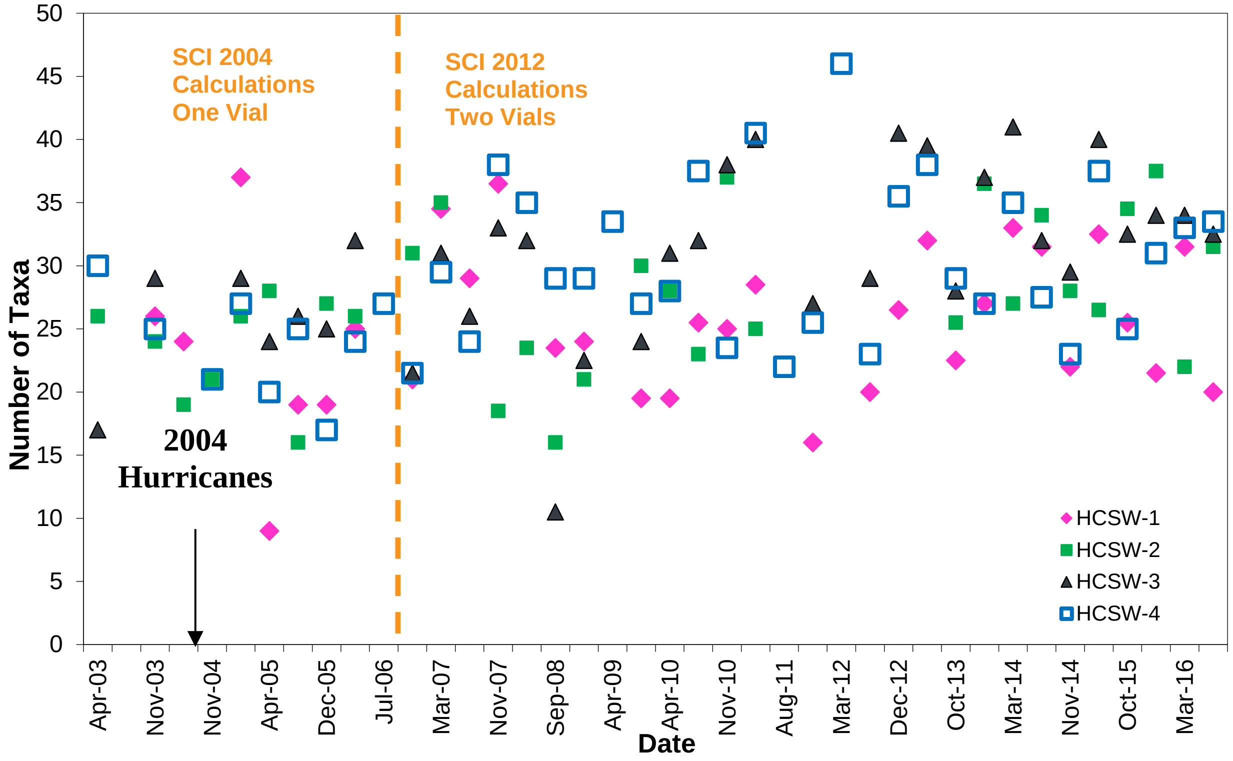


Figure 7-3. **Number of invertebrate taxa collected at all locations for the HCSP from 2003 to 2016.**

7.1.4 Shannon-Wiener Diversity Index

Although not a component of the SCI protocol, the Shannon-Wiener Diversity Index is calculated for generic diversity for each benthic macroinvertebrate sampling event at each location. This index, one of the most popular measures of diversity, is based on information theory and is a measure of the degree of uncertainty in predicting what taxa would be drawn at random from a collection of taxa and individuals (Ludwig and Reynolds 1988). The Shannon-Wiener Index assumes that all taxa are represented in a sample and that the sample was obtained randomly:

$$H' = \sum_{i=1}^{S} (p_i)(\log_2 p_i)$$

where, H' = Information content of sample (bits/individual), index of taxa diversity,

S = Number of taxa, and

p_i = Proportion of total sample belonging to i^{th} taxa.

The Shannon-Wiener Index, H', increases with the number of taxa in the community and theoretically can reach very large values (Krebs 1998). In practice, however, H' does not generally exceed 5.0 for biological communities. The index is affected both by the number of taxa and their relative abundance; a greater number of taxa and a more even distribution of individuals across taxa both increase diversity as measured by *H'*. For example, consider two communities, each with 100 individuals of 10 taxa captured. Community A is dominated by one taxa (91 of 100 individuals), while only one individual was captured for each of the other nine taxa. Community B, however, is even, with 10 individuals captured for each of the ten taxa. While taxa richness is the same for both communities, the Shannon-Wiener Diversity Index shows that Community B is much more diverse than Community A (H' = 3.3 and 0.7, respectively), because Community A is dominated by only one taxa.

For the Horse Creek data, generic diversity[26], rather than species diversity, was used to account for the high variability of species present from year to year. In Horse Creek in 2016, the Shannon-Wiener Diversity Index ranged from 2.69 (November, HCSW-1) to 3.82 (November, HCSW-4, Figure 7-4). When considered over time from 2007 to 2016, diversity was variable at each station but did not increase or decrease over time at all stations combined (Kendall Tau, $p > 0.05$). When stations and dates within years were combined, diversity was not different among years from 2007 to 2016 (ANOVA, $p > 0.05$, Figure 7-5). When results from all events from 2007 to 2016 were combined by station (Figure 7-6), there was a difference between stations (ANOVA: $F = 5.88$, $p < 0.05$), where HCSW-4 and HCSW-3 had higher diversity than HCSW-2 and HCSW-1 (Duncan's multiple range test, $p < 0.05$).

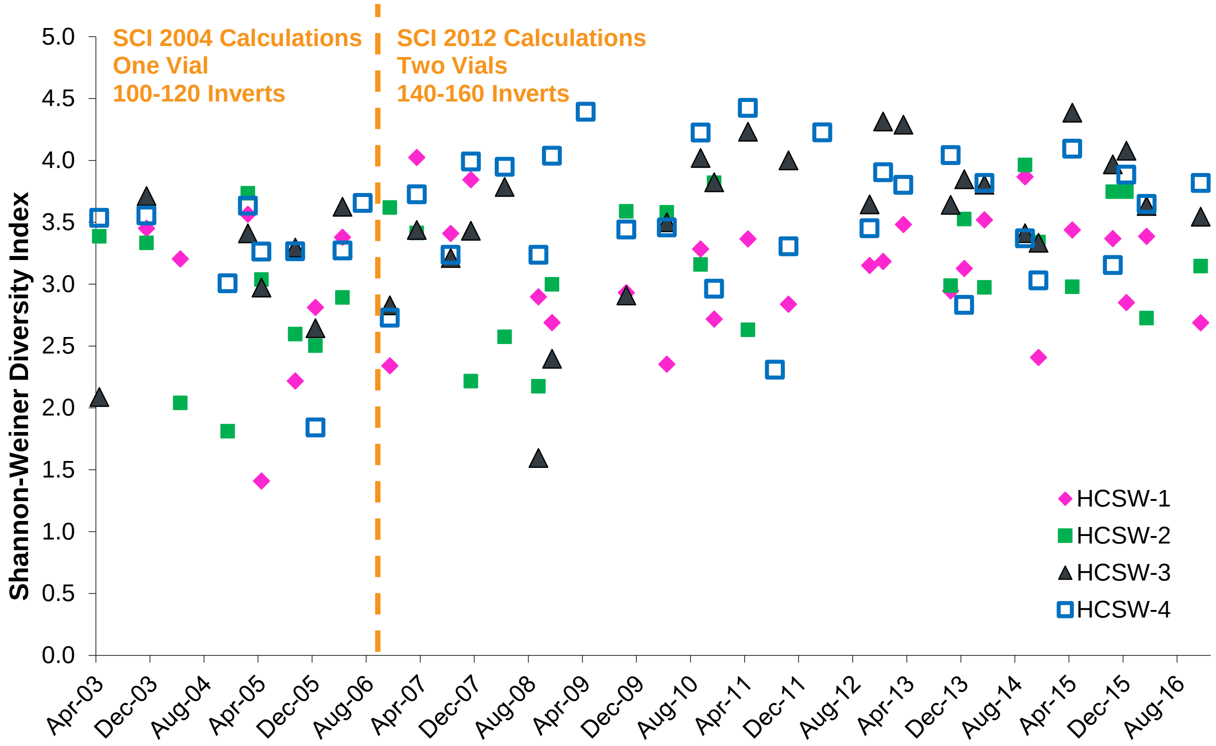


Figure 7-4. **Shannon-Wiener diversity indices for benthic macroinvertebrate genera from all HCSP locations from 2003 to 2016.**

---

[26] After a conversation with Dr. John Epler (entomologist) about updates to the accuracy of the species identification of a few Tanytarsini spp., an overall review of the data was performed. Some of the taxonomic classifications of older data (prior to 2006) had changed, so the database had multiple names for the class, family, or genus of some individuals. Taxonomic names were updated and consolidated where appropriate, which changed the number of individual genera counted for each sampling event. The richness and diversity stats were rerun for each sampling event, along with the combined diversity measures for the year and sampling location. All graphs and tables represent the updated generic diversity scores after data review and consolidation.

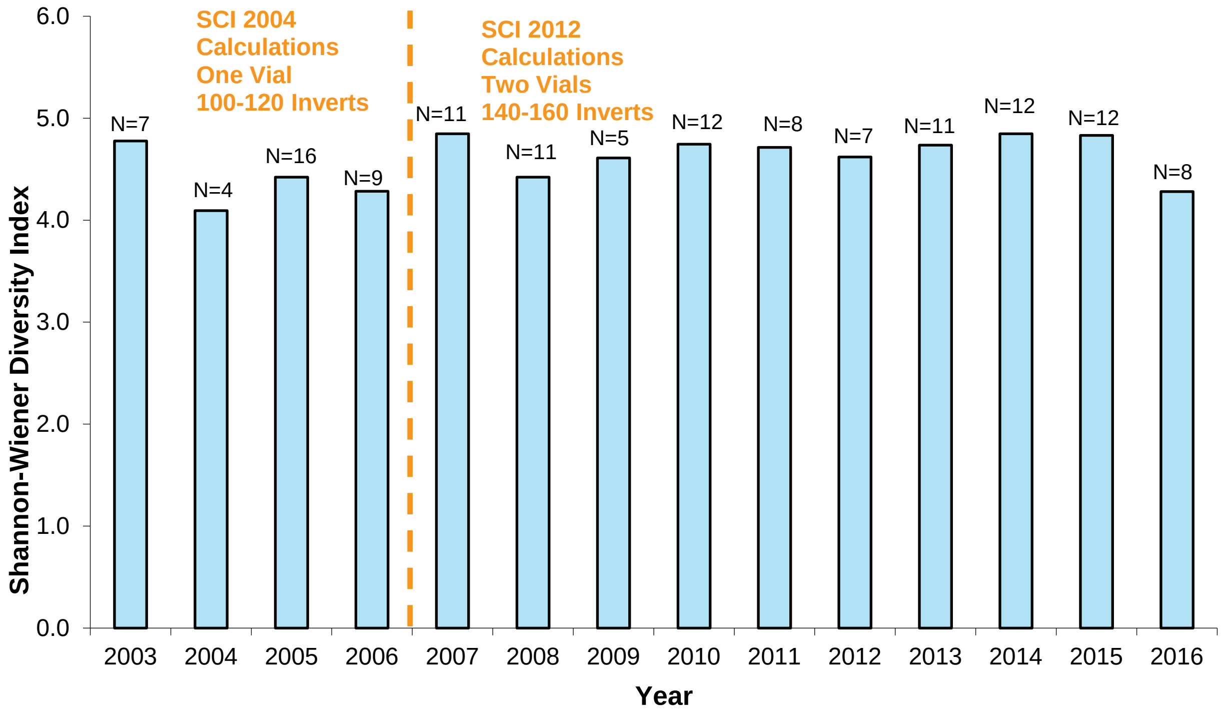


Figure 7-5. **Shannon-Wiener diversity indices for benthic macroinvertebrate genera per year from Horse Creek for Combined sample dates and stations.**

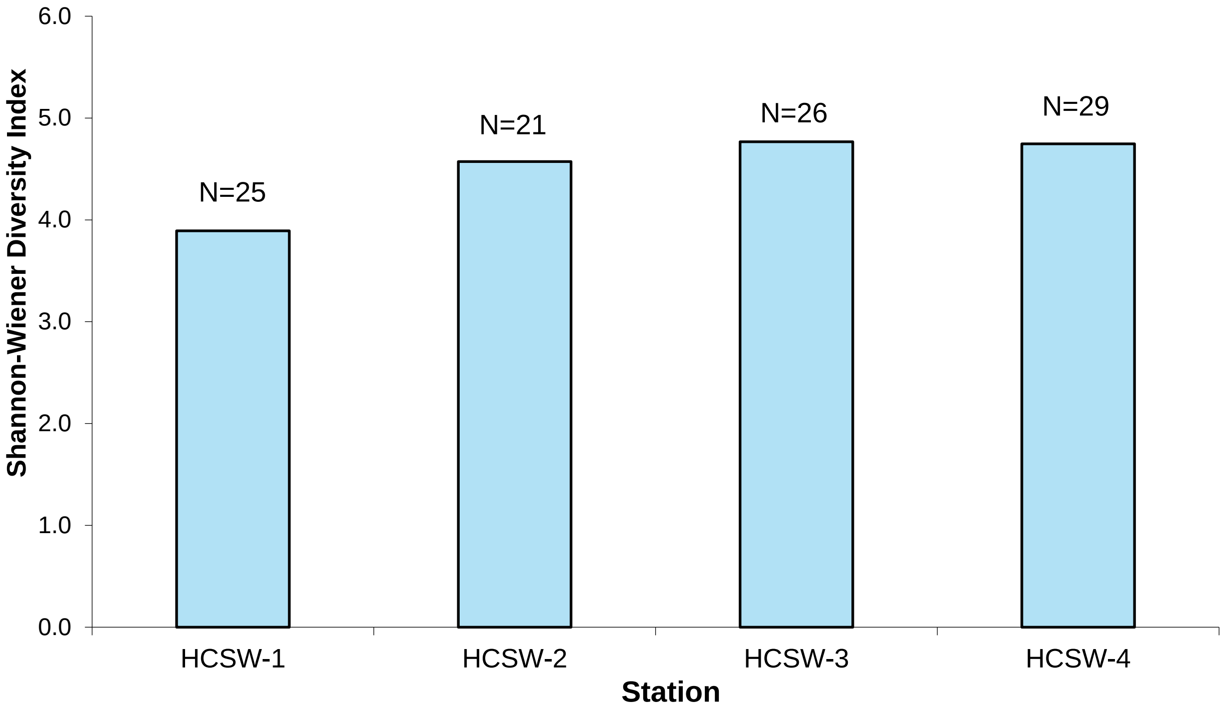


Figure 7-6. **Shannon-Wiener diversity indices for benthic macroinvertebrate genera per station at Horse Creek for combined sample dates.**

7.1.5 Summary of Benthic Macroinvertebrate Results

The general quality of the macroinvertebrate community at the Horse Creek stations was within the range commonly observed by Cardno in similarly-sized natural streams in this region of Florida. Habitat scores ranged from 105 to 131 (“sub-optimal” to “optimal” range in FDEP SOP) at all stations in 2016, which is typical of previous scores for the HCSP. Recent SCI scores at three of the four stations are consistently above 35 (“Healthy” or “Exceptional” from FDEP SOP); in 2016 station HCSW-2 had one SCI score above 35 (“Healthy” in FDEP SOP) and one below 35 (“Impaired” in FDEP SOP) similar to past scores because of unique, natural upstream conditions.

Following the adoption of the revised SCI calculation procedure in 2007, FDEP found that the majority of the reference/background stations it had sampled fell into the Healthy category when calculated under the new SCI (R. Frydenborg, pers. comm.). This indicates that the sampled segments of Horse Creek are considered healthy and thus comparable in quality (as determined via the SCI) to other reference streams in Florida.

Benthic invertebrate taxa diversity and SCI metrics in Horse Creek exhibited both seasonal and year-to-year variation. Overall, taxa diversity indices and SCI metrics show few monotonic trends over time and are very similar between sampling events and stations. Where there are trends over time, the changes are positive from increases in benthic community health metrics. However, HCSW-2 has statistically significant lower SCI scores (long term average of 32 compared to 61-64) than other stations because of natural conditions. Natural habitat conditions at HCSW-2 include lower streamflow, dissolved oxygen, and pH than other Horse Creek stations; these conditions are related to the lower than average streamflow and rainfall during some previous years, and the presence of Horse Creek Prairie, the large marsh located upstream of the HCSW-2 biological sampling station.

7.2 Fish

Fish sampling was conducted at all stations during the 17 March and 16 November 2016 sampling events. Only two sampling events occurred in 2016 because of high water levels and flows that prohibited a summer sampling event. The Brushy Creek location is not included in the fish sampling component of the HCSP.

During 2016, 23 species of fish were collected from the four Horse Creek sampling stations; they are listed in Table 7-3 (Access database is provided on the Cardno FTP site). A new species, the Asian swamp eel (*Monopterus javanensis*) was observed at HCSW-1. This is a new non-native fish that has been observed in Horse Creek; it has been previously caught throughout the Peace River from 2012 to 2016. Additionally, two new fish species was observed at HCSW-2; the hogchoker (*Trinectes maculatus*) was caught in March and November 2016 and the blue tilapia (*Oreochromis aureus*) was caught in November 2016. A total of 44 species of fish[27] have been observed in Horse Creek from 2003 to 2016, with a range of 18 to 32 species seen each year. In 2016, 23 fish species were observed, which is within the range of previous years.

Of the native species collected, most are quite common regionally, and none were unexpected for this portion of Florida. Catfishes, killifishes, shiners and sunfishes were the most commonly collected groups. Eleven of the 44 species collected from 2003 to 2016 are not native to Florida: the African jewelfish (*Hemichromis letourneuxi*), Asian swamp eel, blue tilapia, brown hoplo (*Hoplosternum littorale*), Nile tilapia[28] (*Oreochromis niloticus*), oriental weatherfish (*Misgurnus anguillicaudatus*), Orinoco sailfin catfish (*Pterygoplichthys pardalis*), *Pterygoplichthys gibbiceps*, sailfin catfish (*Pterygoplichthys pardalis*), vermiculated sailfin catfish[29] (*Pterygoplichthys disjunctivus*), and walking catfish (*Clarias batrachus*).

7.2.1 Taxa Richness and Abundance

Most of the individuals collected at each sampling station consisted of eastern mosquitofish (*Gambusia holbrooki*), sailfin molly (*Poecilia latipinna*), coastal shiners (*Notropis petersoni*), or least killifish (*Heterandria formosa*). This can generally be attributed to conditions that are conducive to seining for small species. Eastern mosquitofish were collected at all sampling stations during all the 2016 sampling events. Coastal shiners, golden silversides[30] (*Labidesthes vanhyningi*), hogchokers (*Trinectes maculatus*), sailfin mollies, spotted sunfish (*Lepomis punctatus*), and walking catfish were collected at three of four sampling stations the majority of the time in 2016. Small numbers (as few as one) of individual fish were collected for some of the species found in 2016 (Table 7-3). During both sampling events, a slightly lower number of taxa were collected at HCSW-1 (4-8) compared to the downstream stations (9-13) (Table 7-3, Figure 7-7). Taxa richness showed no monotonic trend over time at any station (Kendall Tau of annual median, $p > 0.05$).

---

[27] HCSP fish samples have been periodically sent to the fish collection of Florida Museum of Natural History (FLMNH). Fish species identifications from the museum collection were used to update the HCSP database and all diversity and richness calculations.

[28] Previously identified in 2014 Annual Report as *Oreochromis aureus* (blue tilapia). Confirmation identification as *O. niloticus* by FLMNH.

[29] Previously identified in 2004 Annual Report as *Hypostomus plecostomus* (suckermouth catfish). Confirmation identification as *P. disjunctivus* by FLMNH.

[30] This species was previously considered brook silversides (*Labidesthes sicculus*), but was confirmed by the FLMNH to actually be the golden silverside. Any previous reference to brook silverside should be considered a golden silverside.

Table 7-3. Fish collected from Horse Creek during sampling events in 2016.

Scientific Name	Common Name	HCSW-1		HCSW-2		HCSW-3		HCSW-4	
		17-Mar-16	16-Nov-16	17-Mar-16	16-Nov-16	17-Mar-16	16-Nov-16	17-Mar-16	16-Nov-16
Hemichromis letourneuxi	African jewelfish*				2	5	25	3	7
Monopterus javanensis	Asian swamp eel*	2	3						
Oreochromis aureus	blue tilapia*				1		2		
Lucania goodei	bluefin killifish		1		3	1			
Ictalurus punctatus	channel catfish								2
Notropis petersoni	coastal shiner	10	4			12	6	21	23
Gambusia holbrooki	eastern mosquitofish	42	5	460	549	746	131	59	39
Elassoma evergladei	Everglades pygmy sunfish							1	
Jordanella floridae	flagfish					1			
Labidesthes vanhyningi	golden silverside	1					1	1	1
Fundulus chrysotus	golden topminnow				1				
Trinectes maculatus	hogchoker			1	1		1	2	2
Notropis chalybaeus	ironcolor shiner	2							
Heterandria formosa	least killifish			39	3	12		9	
Lepomis microlophus	redear sunfish							2	
Pterygoplichthys pardalis	sailfin catfish	1							
Poecilia latipinna	sailfin molly			1	10	53	69	1	5
Fundulus seminolis	Seminole killifish					5	3	2	2
Lepomis punctatus	spotted sunfish	1				1	4	3	10
Noturus gyrinus	tadpole madtom							3	
Pterygoplichthys disjunctivus	vermiculated sailfin catfish*						1		
Clarias batrachus	walking catfish*		1				1	2	2
Lepomis gulosus	warmouth	1					2		
Total Taxa		**8**	**5**	**4**	**8**	**9**	**12**	**13**	**10**
Total Individuals		**60**	**14**	**501**	**570**	**836**	**246**	**109**	**93**

*Non-native species

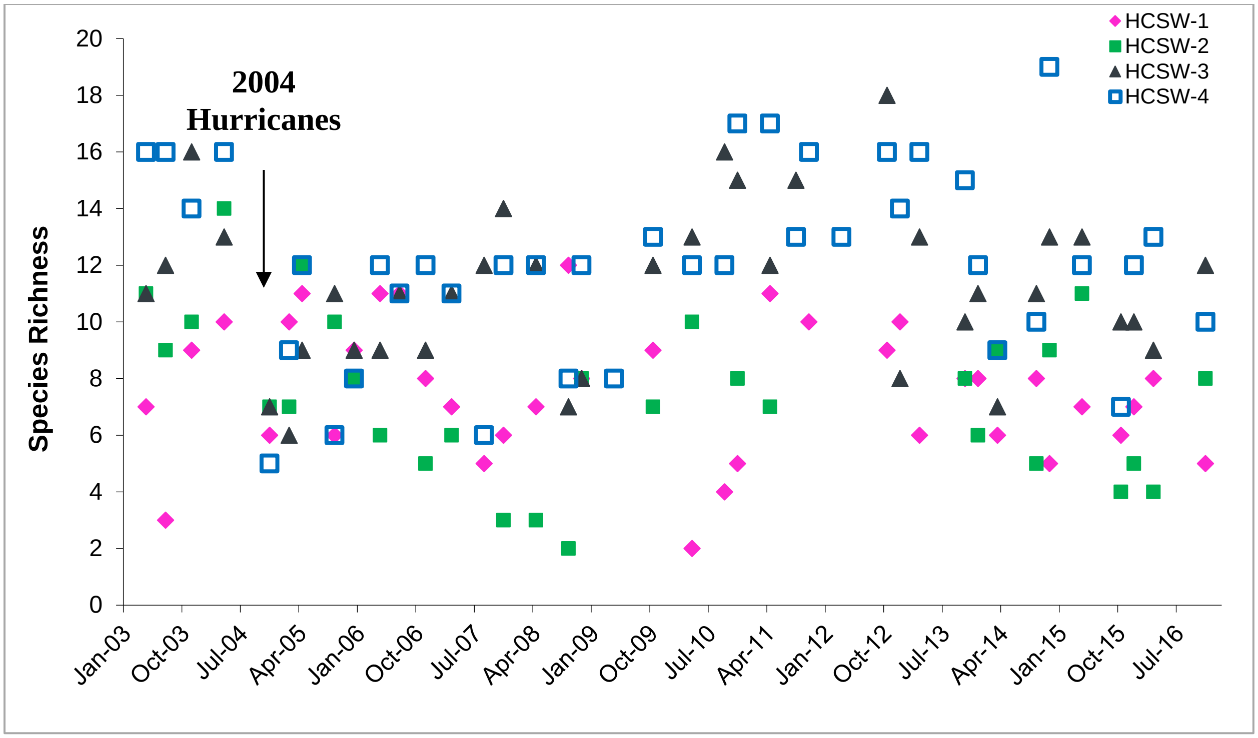


Figure 7-7. **Species richness for fish at all HCSP locations from 2003 to 2016[31].**

7.2.2 Shannon-Wiener Diversity Index

From 2003 to 2015, the typical range (10th to 90th percentile) of fish diversity at each station was 0.90-2.33 at HCSW-1, 0.29-1.56 at HCSW-2, 0.71-2.51 at HCSW-3, and 0.99-2.78 at HCSW-4. Each station in 2016 had event diversity within the previously stated typical ranges for that station, except for HCSW-3 in March which was below the 10th percentile but still above the site minimum (Figure 7-8). Fish diversity by sampling event and station in 2016 ranged from 0.29 (HCSW-2, November) to 2.30 (HCSW-4, November), similar to the ranges during events from 2003 to 2015 (Figure 7-8).

When fish samples were combined across all sampling events within a year, HCSW-1 had the highest species diversity from 2004 to 2006 (after the hurricanes), but it had lower diversity in 2003 and 2010 than other stations (Figure 7-9). HCSW-4 had lower diversity in late 2004 and 2005 after the hurricanes and in 2010 and 2011 after abnormally cold winters. HCSW-3 followed the same pattern as HCSW-4 until 2008 and 2009; the lower diversity in late 2008 and 2009 may be related to difficulties in accessing fish habitats at this station when stream stage is high. Fish diversity at HCSW-2 was lower from 2003 to 2009, because of changes in the amount of fish and fish habitat available for sampling; those changes were related to climate changes that affected flow and dissolved oxygen concentrations and physical changes to the stream segment where biological sampling occurs. Diversity increased at HCSW-2 during 2010 and 2011, but there were a limited number of sampling events in those years; diversity was lower again during 2015 and 2016 at HCSW-2.

Over all sampling years combined (Figure 7-11), fish diversity was lower at HCSW-2 than at the other stations and higher at HCSW-4 (ANOVA, F = 17.09, $p < 0.001$, Duncan's multiple range test, $p < 0.05$). Because the diversity at HCSW-2 was different from the three other stations in most years because of

---

[31] Because of a malfunction with the backpack electrofishing unit, fish were only collected using the seine method during the 27 October 2015 sampling event. Data may not be comparable to other sampling events.

natural conditions, it was excluded from additional trend analysis of fish data. Fish diversity (and previously discussed richness) was compared seasonally and annually at only HCSW-1, HCSW-3 and HCSW-4 as the lower diversity scores may influence the all site median diversity trend analysis.

Diversity was similar between dates when stations were combined (ANOVA, $p > 0.05$, Figure 7-10). When data combined by year (Figure 7-12), fish diversity was lower in 2010 and higher in 2013 (ANOVA $F = 1.80$, $p < 0.05$); there were no increasing or decreasing trends in diversity by year from 2003 to 2016 (Kendall Tau of medians, $p > 0.05$). There were no increasing or decreasing trends for all stations combined or for individual stations in annual median diversity, summer event diversity, or winter event diversity, but there was a small decreasing trend in diversity during spring sampling events (Kendall Tau = -0.27, $p < 0.05$). It appears that the small downward trend in the data is being driven by three factors: starting the analysis with a high diversity pre-2004 hurricanes; decreases in diversity after the hurricanes; and very low spring fish diversities during 2010 at all stations.

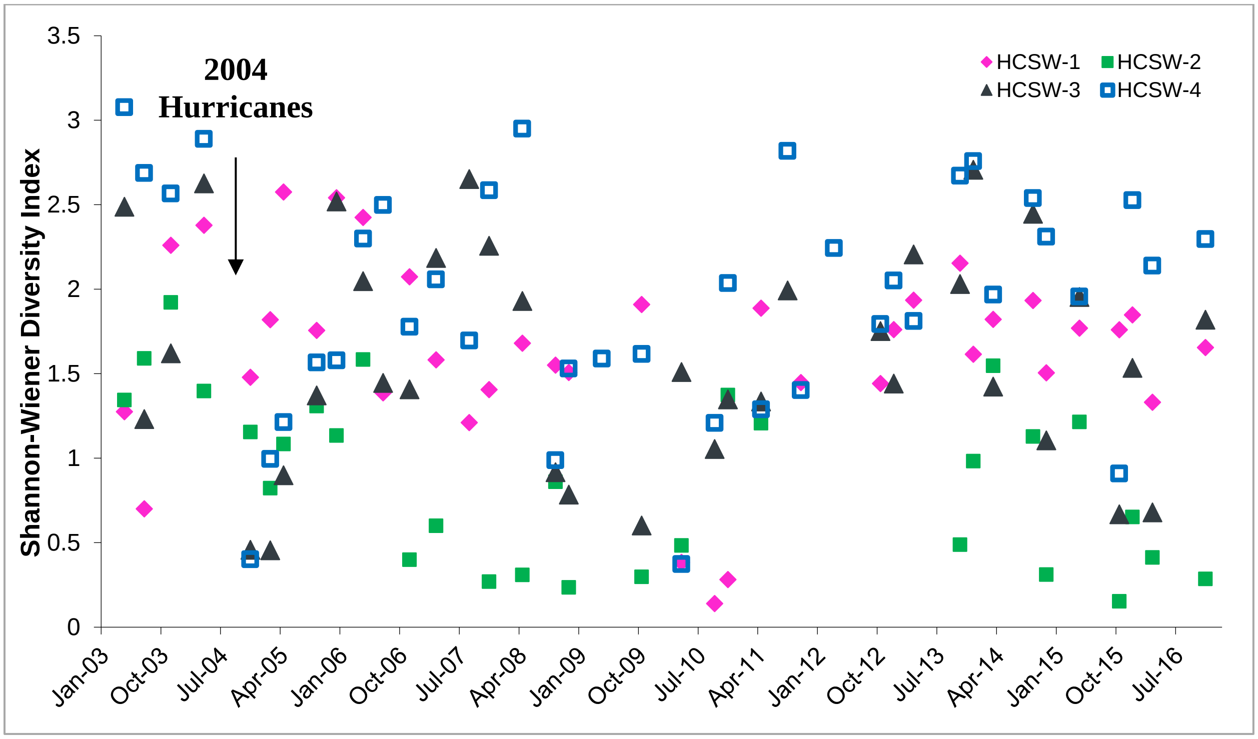


Figure 7-8. **Shannon-Wiener diversity indices for fish samples from all HCSP locations from 2003 to 2016[31].**

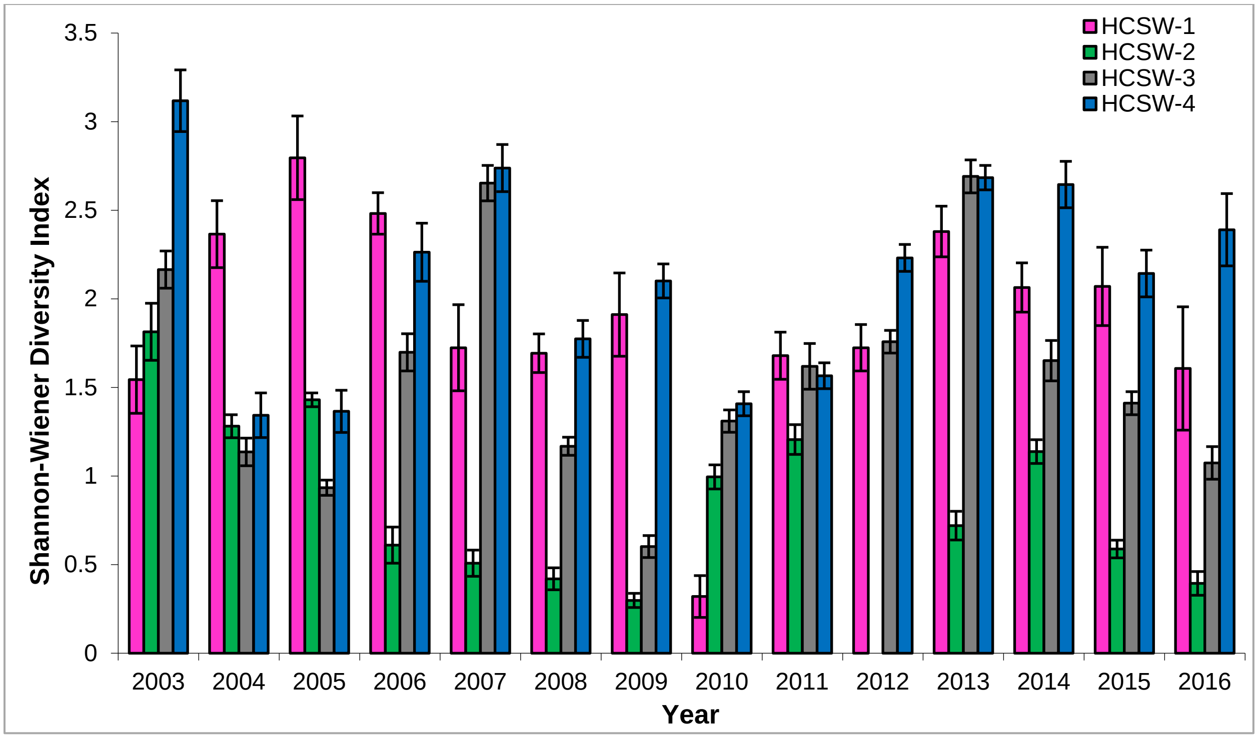


Figure 7-9. **Shannon-Wiener diversity indices and 95% confidence limits for fish samples from four stations in Horse Creek, summarized over sampling events within each year[31].**

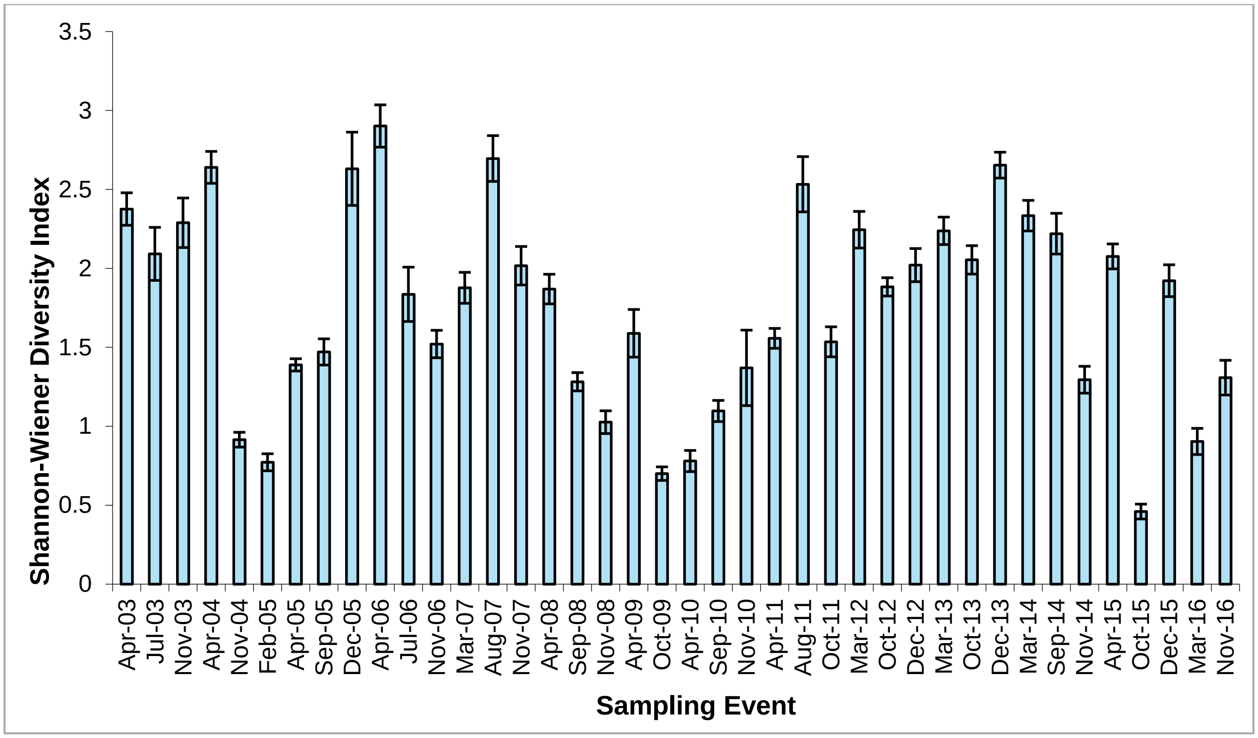


Figure 7-10. **Shannon-Wiener diversity indices and 95% confidence limits for fish samples from Horse Creek summarized over all stations per sampling event[31].**

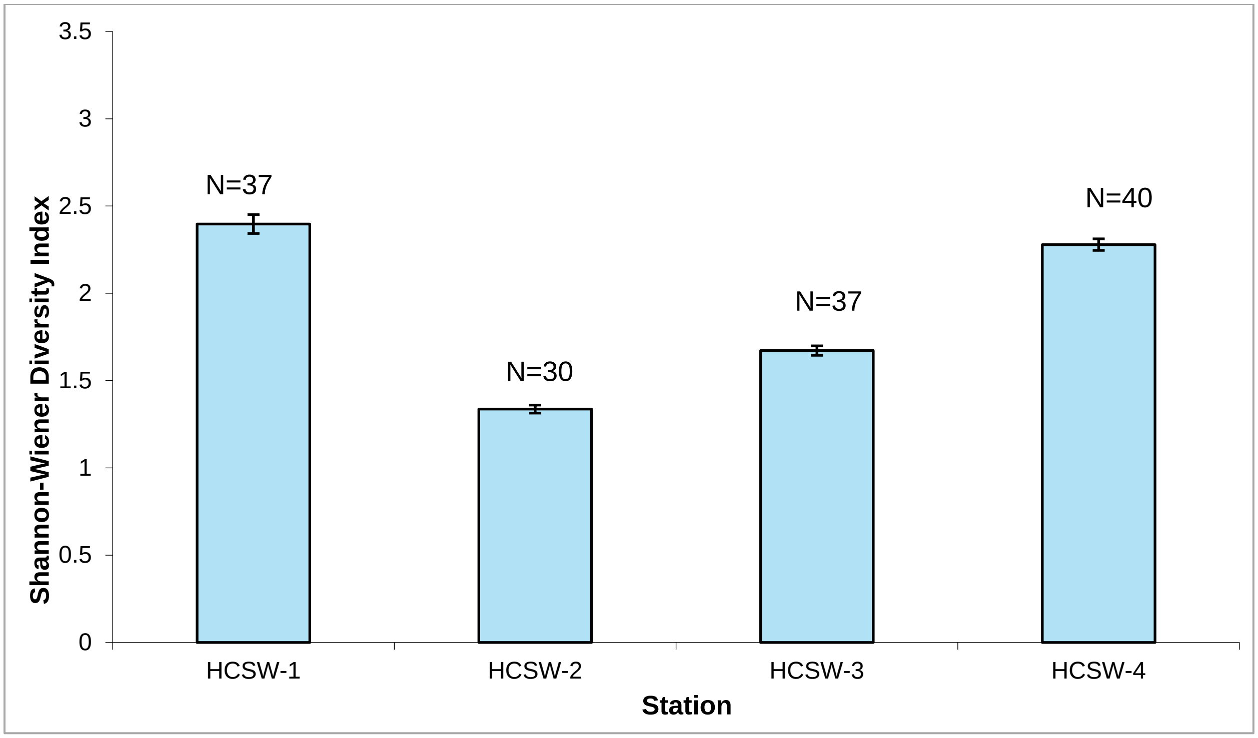


Figure 7-11. **Shannon-Wiener diversity indices and 95% confidence limits for fish samples from four stations in Horse Creek summarized over all sampling dates[31].**

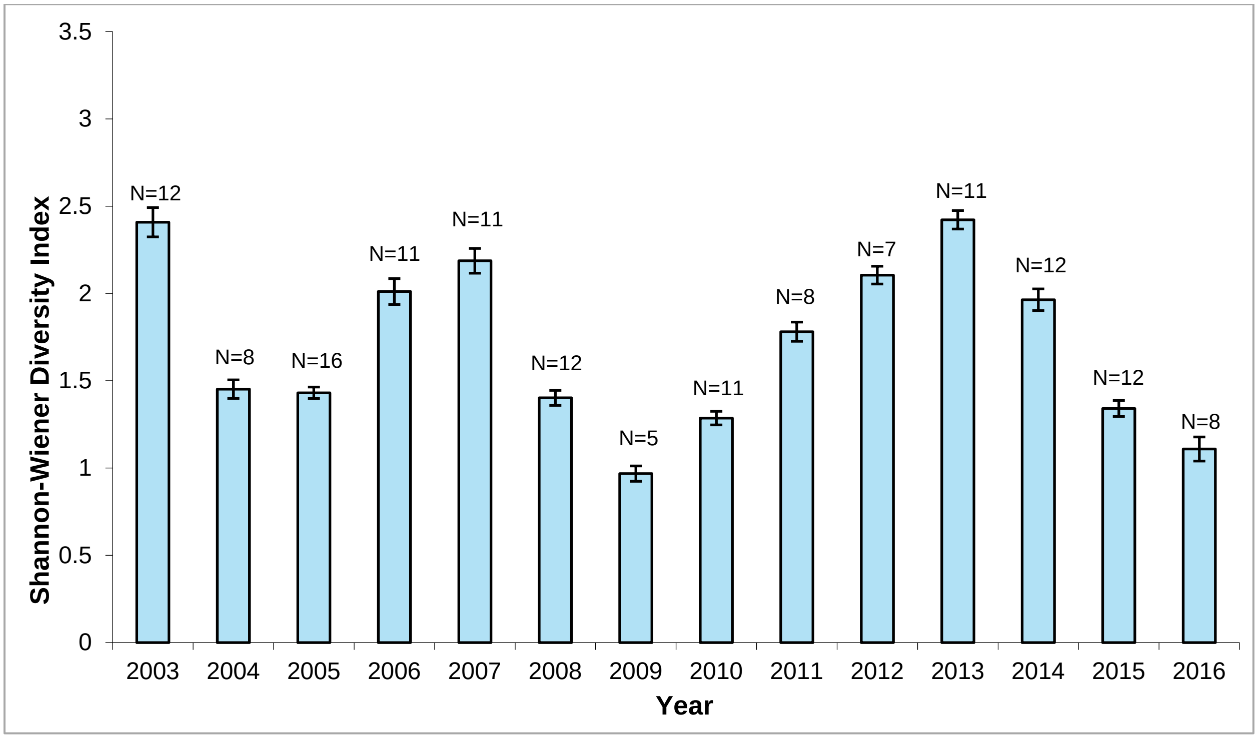


Figure 7-12. **Shannon-Wiener diversity indices and 95% confidence limits for fish samples from fourteen years at Horse Creek summarized over all stations combined[31].**

7.2.3 Morisita's Index of Similarity

Morisita's Index of Similarity measures the similarity of two communities by comparing the relative abundance of each species within and between communities. Of the similarity measures available, this index is preferred because it is nearly independent of sample size (Krebs 1998). Morisita's Index of Similarity is calculated as:

$$C_\lambda = \frac{2\sum X_{ij} X_{ik}}{(\lambda_1 + \lambda_2) N_j N_k}$$

Where C_λ = Morisita's index of similarity between sample *j* and *k*

X_{ij}, X_{ik} = Number of individuals of species *i* in sample *j* and sample *k*

N_j = Σ X_{ij} = Total number of individuals in sample *j*

N_k = Σ X_{ik} = Total number of individuals in sample *k*

Morisita's Index varies from 0 (no similarity – no species in common) to about 1 (complete similarity – all species in common) (Krebs 1998).

Table 7-4 includes Morisita's Index values combined by year or station. When all sampling events for a given station are combined, fish communities were very similar (83% - 99%, Table 7-4), with HCSW-1 being the least similar to other stations because it has a higher percentage of non-poecilid fish captures compared to the other stations. When all sampling events for a given year are combined, fish communities were very similar (87% - 100%, Table 7-4), with 2013 being the least similar to other years.

Table 7-4. Morisita's Similarity Index matrix comparing sapling dates within stations or within years for 2003 to 2016 samples.

	HCSW-1	HCSW-2	HCSW-3	HCSW-4
HCSW-1	1	0.83	0.86	0.94
HCSW-2		1	0.99	0.95
HCSW-3			1	0.98
HCSW-4				1

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
2003	1	0.96	0.96	0.99	0.99	0.96	0.92	0.94	0.98	0.98	0.97	0.99	0.95	0.93
2004		1	0.98	0.99	0.95	1	0.99	1	0.99	0.95	0.90	0.99	0.99	0.99
2005			1	0.98	0.94	0.97	0.94	0.97	0.99	0.94	0.88	0.98	0.96	0.96
2006				1	0.99	0.99	0.97	0.98	0.99	0.98	0.95	1	0.98	0.97
2007					1	0.96	0.93	0.94	0.97	0.99	0.98	0.99	0.95	0.93
2008						1	0.99	1	0.99	0.95	0.90	0.99	1	1
2009							1	1	0.96	0.93	0.87	0.97	0.99	1
2010								1	0.98	0.95	0.89	0.98	1	1
2011									1	0.96	0.92	0.99	0.98	0.97
2012										1	0.98	0.98	0.96	0.94
2013											1	0.95	0.91	0.88
2014												1	0.98	0.97
2015													1	1
2016														1

7.2.4 Summary of Fish Results

Forty-four species of fish were collected from 2003 to 2016, with most captured individuals belonging to one of five families (Table 7-5). System wide, very few additional species are expected to be collected during future monitoring events, as there has only been the addition of five (5) species over the last 10 years (a total of 39 species were collected in 2006, 40 species in 2008, 41 species at the end of 2012, and 44 species at the end of 2016), and the species accumulation curves based on the samples collected through 2016 appear to have reached a threshold (Figure 7-13). Most of the recent species additions have come after review by the Florida Museum of Natural History. Some native species may be present in Horse Creek but were not collected during the HCSP from 2003 to 2016. These include the American eel (*Anguilla rostrata*) and black crappie (*Pomoxis nigromaculatus*).

Samples collected from 2003 to 2016 for the HCSP included 11 exotic species: African jewelfish, Asian swamp eel, blue tilapia, brown hoplo, Nile tilapia, oriental weatherfish, Orinoco sailfin catfish, *P. gibbiceps*, sailfin catfish, vermiculated sailfin catfish, and walking catfish. Over 30 species of exotic fish have established reproducing populations in Florida (http://floridafisheries.com), and more will likely continue to be introduced in spite of laws restricting such introductions; thus, additional exotic species are expected to be collected in Horse Creek during future monitoring events as new introductions occur and as such species expand their ranges in Florida.

Table 7-6 presents a summary of the number of individual fish captured for several major fish groups at each station per year, including exotic fish species. At each station, the number of individuals per fish groups varies considerably over time and is heavily influenced by sampling conditions. The inherent variability of the data, as well as small differences in sampling effort between years and stations, makes it difficult to look for trends in fish group abundance over time, but a visual examination shows no general trends of increase or decrease in the exotic group or the native fish groups.

During 2016, 23 species of fish were collected from the four Horse Creek sampling stations. Abnormally cold winters in 2009 to 2010 and 2010 to 2011 may have led to decreased fish diversity at some stations in 2010 and 2011, with evidence of recovery and recruitment in 2012 and 2013. Over the period of record, fish richness and diversity was lowest at HCSW-2, but there were no increasing or decreasing trends in richness over time at any station. Fish communities were similar by sampling date when data were combined by station, but diversity was lower in 2010 and higher in 2013 when stations were combined by year. There were no increasing or decreasing trends for all stations combined or for individual stations in annual median diversity, summer event diversity, or winter event diversity, but there was a small decreasing trend in diversity during spring sampling events. It appears that the small downward trend in the data is being driven by three factors: starting the analysis with a high diversity pre-2004 hurricanes; decreases in diversity after the hurricanes; and very low spring fish diversities during 2010 at all stations. No consistent patterns over time were evident in the abundance of fish from exotic and native fish groups (Table 7-6).

Table 7-5. Percentage of individual fish captures per year for most abundant fish families/groups in Horse Creek from 2003 to 2016 as part of the HCSP.

Fish Family	HCSW-1	HCSW-2	HCSW-3	HCSW-4	Total
Poeciliidae	54%	97%	89%	74%	86%
Cyprinidae	29%	0.02%	3%	10%	5%
Centrarchidae	7%	0.6%	2%	5%	2%
Cyprinodontidae	1%	1.1%	2%	4%	2%
Athererinidae	5%	0%	1%	3%	1%
Exotics	2%	0.8%	2%	3%	2%

Table 7-6. **Number of individual fish captured per year for major native and exotic fish groups in Horse Creek from 2003 to 2016 as part of the HCSP[31].**

HCSW-1														
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Native Poecilids	181	78	75	341	25	275	47	328	308	213	42	61	57	47
Native Sunfish	46	26	31	20	23	24	14	7	14	9	23	12	4	2
Native Catfish	5	9	3	4	3	2	0	1	2	1	2	1	2	0
Native Other	25	69	57	140	87	268	33	4	164	155	148	168	58	18
Exotics	2	1	5	0	0	1	7	0	1	6	19	7	2	1
Total Fish	259	183	171	505	138	570	101	340	489	384	234	249	123	68
Sampling Events	3	2	4	3	3	3	1	3	2	2	3	3	3	2

HCSW-2														
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Native Poecilids	363	1735	3093	568	908	1335	2519	1695	394	0	981	1514	2702	1062
Native Sunfish	41	15	9	13	2	1	1	1	1	0	12	8	5	0
Native Catfish	1	2	0	0	0	0	0	0	0	0	0	0	2	0
Native Other	21	61	43	1	6	12	4	50	13	0	15	38	34	6
Exotics	4	2	22	1	4	40	3	2	0	0	48	17	4	3
Total Fish	430	1815	3167	583	920	1388	2527	1748	408	0	1056	1577	2747	1071
Sampling Events	3	2	4	2	2	3	1	2	1	0	2	3	3	2

HCSW-3														
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Native Poecilids	669	1606	4125	727	489	3122	1677	2874	1364	2092	383	738	2117	1011
Native Sunfish	49	24	35	31	44	19	5	78	78	28	35	28	20	7
Native Catfish	1	0	0	0	4	1	0	1	1	2	7	0	0	0
Native Other	180	114	23	145	202	106	11	215	143	299	211	101	162	30
Exotics	1	14	37	12	17	23	53	7	3	80	67	52	38	34
Total Fish	900	1758	4220	915	756	3271	1746	3175	1589	2501	703	919	2337	1082
Sampling Events	3	2	4	3	3	3	1	3	2	2	3	3	3	2

HCSW-4														
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Native Poecilids	172	713	705	280	62	794	409	2423	2112	998	772	276	248	113
Native Sunfish	52	27	5	67	54	62	66	38	97	74	84	41	21	15
Native Catfish	6	2	2	0	0	1	0	0	1	1	17	1	1	5
Native Other	77	52	12	53	174	173	311	205	188	425	465	146	198	55
Exotics	15	6	31	20	4	12	5	19	3	20	129	64	17	14
Total Fish	322	800	755	420	294	1042	791	2685	2401	1518	1467	528	485	202
Sampling Events	3	2	4	3	3	3	2	3	3	3	3	3	3	2

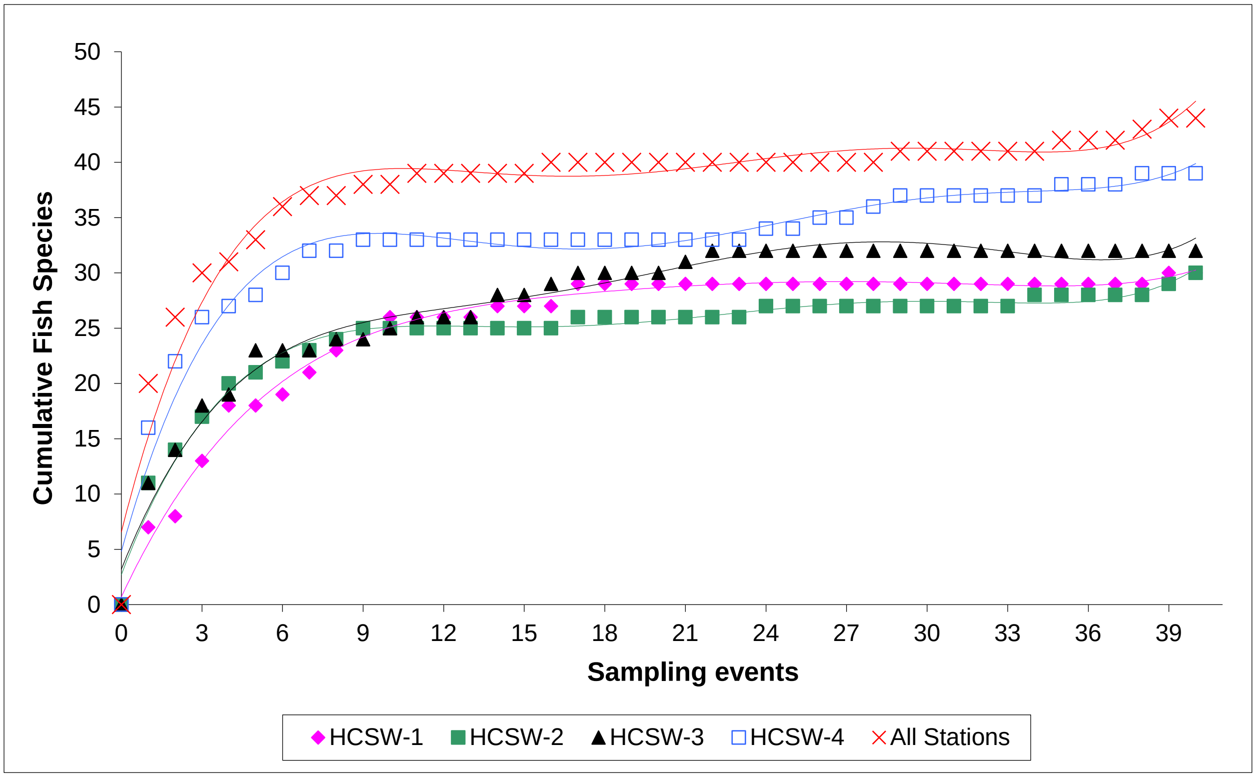


Figure 7-13. Species accumulation curve for each HCSP station and at all stations combined from 2003 to 2016.

8 Conclusions

8.1 Water Quantity Results

The annual average daily streamflow at Horse Creek in 2016 at both HCSW-1 (67 cfs) and HCSW-4 (229 cfs) was above the long-term annual averages[32] of 32 and 189 cfs, respectively. Annual rainfall of 63 inches in 2016 was above the long-term average annual rainfall of 53 inches (1908-2016)[33]. In 2016, there was a period of slightly higher flow during the dry season that corresponded to heavy rain events (mid-January to mid-February). Then, flows were generally low from March to early-June before increasing rapidly; flows were then variable for the remainder of the wet season, responding to high rainfall events. Additionally, a final large increase in streamflow occurred in early-October before water levels decreased through the end of the year, similar to historical patterns (Durbin and Raymond 2006). At the beginning of the wet season, the lag effect between rainfall and streamflow is more apparent as the surrounding wetlands or small creeks either need to fill or resume flow. However, later in the wet season when the wetlands and small creeks are full, the lag is much shorter.

NPDES discharge accounted for 73 percent of streamflow on average at HCSW-1 during the period of NPDES discharge (ranging from 12 percent to 100 percent over the 283 days of discharge). NPDES discharge from March to December was a lagged response to larger rainfall events that occurred from late-January through February and multiple moderate (greater than one inch) rainfall events that continued through the wet season; NPDES discharge from the Horse Creek outfalls usually does not occur until sufficient water storage accumulates in the circulation system, resulting in a lag. In general, the above average rainfall in 2016 coupled with multiple moderate rain events during the wet season led to a steady volume of NPDES discharge to Horse Creek.

There is no evidence that mining and reclamation activities in the basin caused any statistically significant decrease in total streamflow in 2016, according to the double mass curve analysis. In a previous study (Robbins and Durbin 2011) that compared streamflow during dry years in reference and potentially impacted streams before and during phosphate mining, there was no evidence that phosphate mining practices caused lower monthly flows in the potentially impacted streams (including Horse Creek) than what would be expected given the conditions in a reference stream (Charlie Creek).

8.2 Water Quality Results

Water quality parameters in 2016 were almost always within the desirable range relative to trigger levels and water quality standards at the station with the highest percent of upstream mined lands (HCSW-1). Alkalinity was the only parameter above the trigger level at HCSW-1 during 2016, but the exceedance was only 16 mg/L above the trigger and did not occur during a time of NPDES discharge. The dissolved oxygen trigger level was exceeded during most of the year at HCSW-2 (February through December 2016). Based upon historical conditions in Horse Creek (Durbin and Raymond 2006), the reported values for dissolved oxygen at HCSW-2 are the result of natural conditions (proximity to hypoxic segment of stream – Horse Creek Prairie) and are not related to mining activities. Total nitrogen was above the trigger level in February 2016 at HCSW-3; this sample was also comprised mainly of nitrate-nitrite. There did not appear to be a lab error for this sampling event, but the sample was collected following a few days of high rainfall totals. Dissolved iron concentrations consistently exceeded the trigger value set at HCSW-4 (July to September 2016), but Mosaic and the PRMRWSA agree that the trigger value at that station has been set too low given historical and upstream concentrations of dissolved iron. Based on impact

---

[32] Long-term annual average of daily streamflow calculated for 1978 to 2016 for HCSW-1 and 1951 to 2016 for HCSW-4 using USGS gauging stations.

[33] Historical rainfall information came from the following stations and years: 1908 to 1943 NOAA station 148, 1944 to 2016 average of NOAA station 148 and 336.

assessments already completed, none of the observed exceedances pose a significant adverse ecological impact to Horse Creek that would be attributable to mining.

Twelve water quality parameters showed statistically significant increasing or decreasing trends in 2016 at HCSW-1 or HCSW-4. Several of the trends detected during the statistical analysis either have an estimated slope that 1) was not in the direction of an adverse trend (dissolved oxygen concentration, dissolved oxygen saturation, color, ammonia, and dissolved iron) or 2) was very small compared to the observed differences between primary and duplicate field samples (pH and fluoride). Specific conductivity, TDS, and various dissolved ions had reported trends with higher estimated rates of change. The potential trends for pH and specific conductivity (with reference to TDS and other ions) are discussed in Appendix I. The apparent change in pH since 2003 is not a strong trend when compared to SWFWMD data collected at the same place, and the observation of similar change-point increases at HCSW-1 and upstream stations around the drought period lead to the conclusion that pH is not having an ecologically significant increase at HCSW-1 over the course of the HCSP program and is not of concern at this time.

For specific conductivity, a significant increasing trend was detected at HCSW-1 even when the period of record was expanded, but an analysis of other stations shows the influence of climatic and upstream conditions. At least part of the increase may be caused by regional influences, as Charlie Creek (an unmined stream) and Horse Creek closely mirror each other; Charlie Creek and Horse Creek show a step-change increase in conductivity around 2006 to 2007, followed by stable or decreasing levels through 2016. Specific conductivity at Horse Creek and West Fork Horse Creek stations upstream of the NPDES outfalls show similar trends and step-change increases.

In addition, the trends at the upstream stations began well before the beginning of the HCSP program. Specific conductivity at HCSW-1 began to rise during a very dry period in 2006 to 2008 (from 100–400 µmhos/cm to 200–500 µmhos/cm) when Mosaic had very little NPDES discharge into Horse Creek, and the stream was dominated by baseflow (surficial aquifer) contributions. Water resulting from Wingate dredge mining activities began to discharge from the two Horse Creek NPDES outfalls in late 2008; dredge mining is more influenced by groundwater than conventional mining. Although HCSW-1 specific conductivity remained at higher levels (200–600 µmhos/cm) after 2008, concentrations at three of the four Horse Creek stations upstream of the NPDES outfalls were also higher during that time period.

When compared to another upstream station on West Fork Horse Creek or station on Charlie Creek, the majority of HCSW-1 observations fall within the 95% prediction interval of the other stations. Thus, while some isolated conductivity values at HCSW-1 may be related to increased groundwater influence at NPDES discharges, the majority of the increasing trend at HCSW-1 can be explained by other factors. The trend for specific conductivity and other ions may have been influenced by regional factors unrelated to mining, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities, but the current concentrations are stable and not biologically harmful. Any small portion of the change in specific conductivity (and other related ions) that may have been affected by changes in NPDES water quality is likely to stay relatively constant at HCSW-1 in the near future given planned mining practices and the stable range of concentrations shown since Wingate mine began discharging to Horse Creek in 2008.

Dissolved ion concentrations at HCSW-1 in recent years still meet all applicable state drinking water and Class III surface water standards, except where otherwise noted in previous monthly impact assessments. In addition, the current specific conductivity concentrations at HCSW-1 are within the preferred range of Horse Creek freshwater fish species, and the diversity and composition of fish populations have remained steady over the HCSP study period with no correlation with specific conductivity. SCI scores, an indicator of benthic macroinvertebrate community health, have also remained steady over the HCSP study period and show no relationship with specific conductivity.

Significant differences between stations were evident for several parameters. When stations were compared, HCSW-2 was the most dissimilar from the other three stations, especially in pH, dissolved oxygen, color, chlorophyll-*a*, and some dissolved ions. Some nutrients (nitrate-nitrite) and dissolved ions (specific conductivity, calcium, chloride, and sulfate) had higher concentrations downstream in Horse Creek (at HCSW-3 and HCSW-4), probably because of increased groundwater seepage and agricultural irrigation runoff in the lower Horse Creek basin. Differences in topography, geology, and land use that could account for these station differences in Horse Creek are examined in the Horse Creek Stewardship Program Historical Report (Durbin and Raymond 2006).

Water quality parameters were compared with water quantity variables recorded during the same month: average daily streamflow for the month, average daily NPDES discharge for the month, and total monthly rainfall. In general, pH, dissolved oxygen, and most dissolved ions are higher when the overall quantity of water in the Horse Creek system is low. (In this report, chlorophyll-a, specific conductivity, calcium, alkalinity, sulfate, and TDS showed the opposite pattern with NPDES discharge at HCSW-1.) Conversely, turbidity, color, iron, and nitrogen are high when the water quantity is also high. When water quantity in Horse Creek is low, the stream is often pooled or slow-moving, leading to algal blooms that may increase pH and chlorophyll-a. In addition, the majority of water in the stream during low quantity periods may be from groundwater (seepage or agricultural runoff); groundwater has a higher concentration of dissolved ions than surface water. When water quantity is high because of rainfall or streamflow, an increased amount of sediment and organic debris is washed into the stream, leading to increases in turbidity, color, iron, and nitrogen.

8.3 Benthic Macroinvertebrate Results

The general quality of the macroinvertebrate community at the Horse Creek stations was within the range commonly observed by Cardno in similarly-sized natural streams in this region of Florida. Habitat scores ranged from 105 to 131 at all stations in 2016, which is typical of previous scores for the HCSP. Recent SCI scores at three of the four stations are consistently above 35; in 2016 station HCSW-2 had one SCI score above 35 and one below 35 similar to past scores because of unique, natural upstream conditions (Horse Creek Prairie).

Benthic invertebrate taxa diversity and SCI metrics in Horse Creek exhibited both seasonal and year-to-year variation. Overall, taxa diversity indices and SCI metrics show few monotonic trends over time and are very similar between sampling events and stations. However, HCSW-2 has lower SCI scores (long term average of 32 compared to 61-64) than other stations because of natural conditions. Natural habitat conditions at HCSW-2 include lower streamflow, dissolved oxygen, and pH than other Horse Creek stations; these conditions are related to the lower than average streamflow and rainfall of the previous few years and the presence of Horse Creek Prairie, the large marsh located upstream of the biological sampling station.

8.4 Fish Results

During 2016, 23 species of fish were collected from the four Horse Creek sampling stations. Abnormally cold winters in 2009 to 2010 and 2010 to 2011 may have led to decreased fish diversity at some stations in 2010 and 2011, with evidence of recovery and recruitment in 2012 and 2013. Over the period of record, fish richness and diversity was lowest at HCSW-2, but there were no increasing or decreasing trends in richness over time at any station. Fish communities were similar by sampling date when data were combined by station, but diversity was lower in 2010 and higher in 2013 when stations were combined by year. There were no increasing or decreasing trends for all stations combined or for individual stations in annual median diversity, summer event diversity, or winter event diversity, but there was a small decreasing trend in diversity during spring sampling events. It appears that the small downward trend in the data is being driven by three factors: starting the analysis with a high diversity pre-2004 hurricanes; decreases in diversity after the hurricanes; and very low spring fish diversities during 2010 at all stations. No consistent patterns over time were evident in the abundance of fish from exotic and native fish groups.

9 Recommendations

9.1 Previous TAG and Annual Report Recommendations

During the TAG meeting for the 2014 Draft Annual Report (December 9, 2016) the following recommendations were made:

- Mosaic will provide the conservation easement areas in the southern reserves as well as provide information on the criteria and requirements on mining and the timing of reclamation or release. Work on this action item is in progress in 2017.
    - **Description of timing of reclamation activities included in Section 3.2 of 2015 Annual Report.**
- Mosaic and Cardno will update the mining/reclamation/reconnection total acres going back to 2004 with the inclusion of legacy CFI. They will also look into when acres were reconnected for Horse Creek at SR37 and Horse Creek Inlet. Work on this action item is in progress in 2017.
    - **Included in 2015 Annual Report.**
- Mosaic will investigate the water table elevation along Horse Creek as well as water use. Where practical, cross-sections of Horse Creek during the mining process will be provided. In addition inter-basin water transfers across Mosaic mining areas will be provided. Work on this action item is in progress in 2017.
    - **Mosaic will provide Cardno with piezometer data for devices located near the Horse Creek Basin in order to plot water table elevation changes over time compared to rainfall. This information and analysis will be submitted as an appendix in the 2017 annual report.**
- Mosaic and Cardno will create a "Decision Memo" that would include the new permitted outfalls in the Horse Creek and Brushy Creek basins along with where water would be sent. Work on this action item is in progress in 2017.
    - **Information on permitted outfalls in the Horse Creek and Brushy Creek basins will be postponed until Mosaic submits a draft NPDES application for these outfalls.**
- Mosaic will internally discuss improved sampling methods to ensure that "no flow" systems are not sampled and look into SC and iron at Horse Creek at SR37. Work on this action item is in progress in 2017.
    - **This has been discussed with Mosaic's Field Services Team and training has taken place outlining the FDEP Procedures on when stream sampling is not appropriate. Additionally, Mosaic Field Sheets have been adjusted beginning in February 2018.**
- Cardno will emphasize the dry period since 2005 in the water quantity section of the 2014 report.
    - **Included in 2014 Annual Report.**
- In Appendix I of the 2014 report, Cardno will include a plot of the SC from the NPDES discharge, discuss how HCSW-4 shows the same step-change in SC as HCSW-1 (and describe what the aqua boxes on the change point graphs mean), and add that HCSW-2 is not positively correlated with NPDES so any outfall influence is not going downstream. In Appendix I, Cardno will discuss trends at the downstream stations in addition to HCSW-1.
    - **Graphs that include NPDES data for both pH and SC Included in 2014 Annual Report. Statements were added that step-change analysis of pH and SC data at**

    - **HCSW-4 was similar to HCSW-1, confirming the decision that a detailed analysis of changes at only HCSW-1 was necessary.**

- Cardno will add year labels to the inflection points in the 2014 report and investigate other shorter inflections like 1983-1984 or 1999-2000 in the 2015 report.
    - **Included in 2014 Annual Report.**
- Cardno will investigate why iron was correlated with high flow, and see if time of day influences pH measurements in Horse Creek in the 2015 report. Cardno will also look into higher nitrate-nitrite values in the 2015 report. A formal discussion was not added to the report as it is only speculation that the elevated concentrations in nitrate-nitrite are being caused from agriculture run-off as there are no data from the small tributaries leading to Horse Creek upstream of stations HCSW-3 and HCSW-4.
    - **Time of day analysis of pH is not feasible by site as samples are collected monthly at each station within a 2-hour time frame.**

9.2 Current TAG Recommendations

- TAG members will get any additional comments on the 2015 and 2016 annual reports to the Authority by October 31, 2018.
    - **Last set of comments sent to Cardno by the Authority on October 30, 2018.**
- Cardno will provide a PDF version of the PowerPoint presentation to the TAG members.
    - **Completed October 31, 2018.**
- Cardno will provide a Word document of all reviewers’ questions/comments and responses to the Authority for transmittal to TAG members for the 2015 and 2016 annual reports.
    - **Submitted with the finalized version of each report.**

9.3 Current Annual Report Recommendations

- Cardno and Brown and Caldwell will add a general description of the Horse Creek fish diversity to the annual report.
    - **Added to finalized versions of 2015 and 2016 annual reports.**
- Cardno will add the fish species accumulation curves back to the annual reports.
    - **Added to finalized versions of 2015 and 2016 annual reports.**

10 References

American Fisheries Society. 2004. Common and Scientific Names of Fishes from the United States, Canada and Mexico. 6th ed. American Fisheries Society Publication. Maryland.

Ardaman and Associates, Inc., Armac Engineers, Inc., Joshua C. Dickinson, Environmental Science and Engineering, Inc., P.E. Lamoreaux and Associates, Inc., and Zellars-Williams, Inc. 1979. Development of Regional Impact Application for Development Approval Phosphate Mining and Chemical Fertilizer Complex, Hardee County, Florida.

Berryman, D., B. Bobee, D. Cluis, and J. Haemmerli. 1988. Nonparametric tests for trend detection in water quality time series. Water Resources Bulletin of American Water Resources Association. 24(3): 545 – 556.

Cowherd, D., W. G.. Henderson, Jr., E. J. Sheehan, and S. T. Ploetz. 1989. Soil Survey of DeSoto County, Florida. United States Department of Agriculture, Soil Conservation Service in cooperation with the University of Florida, Institute of Food and Agriculture Services, Agricultural Experiment Stations, and Soil Science Department, and with the Florida Department of Agriculture and Consumer Services.

Durbin, D. J. and K. M. N. Raymond. 2006. Horse Creek Stewardship Program: Summary of Historical Information on Water Quantity, Quality, and Aquatic Biology. Prepared by Biological Research Associates for the Mosaic Company.

Durbin, D. J. and K. M. N. Raymond. 2007. Horse Creek Stewardship Program: 2005 Annual Report. Prepared by Biological Research Associates for the Mosaic Company.

Durbin, D. J. and K. M. N. Robbins. 2008. Horse Creek Stewardship Program: 2006 Annual Report. Prepared by Biological Research Associates for the Mosaic Company.

Durbin, D. J. and K. M. N. Robbins. 2009. Horse Creek Stewardship Program: 2007 Annual Report. Prepared by ENTRIX Inc. for the Mosaic Company.

Durbin, D. J., K. M. N. Robbins, and S. Huelster. 2010. Horse Creek Stewardship Program: 2008 Annual Report. Prepared by ENTRIX Inc. for the Mosaic Company.

Environmental Science and Engineering, Inc. 1982. Draft Environmental Impact Statement, U.S. Environmental Protection Agency Region IV, Resource Document, Section K, Aquatic Ecology. Gainesville, Florida.

Florida Department of Environmental Protection (FDEP). 2013. Technical Support Document: Derivation of Dissolved Oxygen Criteria to Protect Aquatic Life in Florida's Fresh and Marine Waters. Division of Environmental Assessment and Restoration. DEP-SAS-001/13. March 2013.

Fore, L. S. 2004. Development and Testing of Biomonitoring Tools for Macroinvertebrates in Florida Streams. Prepared for the FDEP.

Hammett, K. M. 1990. Land Use, Water Use, Streamflow Characteristics, and Water Quality Characteristics of the Charlotte Harbor Inflow Area, Florida. U.S. Geological Survey. Water-Supply Paper 2359-A. Tallahassee, Florida.

Harcum, J. B., J. C. Loftis, and R. C. Ward. 1992. Selecting trend tests for water quality series with serial correlation and missing values. Water Resources Bulletin of American Water Resources Association. 28(3): 469 – 478.

Harrel, R. C., B. J. Davis, and T. C. Dorris. 1967. Stream order and species diversity of fishes in an intermittent Oklahoma stream. American Midland Naturalist 78:428-436.

Heath, R. C. and C. S. Conover. 1981. Hydrological Almanac of Florida. US Geological Survey Open File Report 81-1107, Tallahassee, Florida.

Helsel, D. R., D. K. Mueller, and J. R. Slack. 2006. Computer program for the Kendall family of trend tests. U.S. Geological Survey Scientific Investigations Report: 2005-5275. 4 p.

Hirsch, R. M., J. R. Slack, and R. A. Smith. 1982. Techniques of trend analysis for monthly water quality data. Water Resources Research 18(1): 107 – 121.

Krebs, C. J. 1998. Ecological Methodology, 2nd Edition. Harper Collins Publishers, Inc., New York, New York.

Lettenmaier, D. P. 1988. Multivariate nonparametric tests for trend in water quality. Water Resources Bulletin of American Water Resources Association. 24(3): 505 – 512.

Lewelling, R. R. 1997. Hydrologic and Water Quality Conditions in the Horse Creek Basin, October 1992 – February 1995. U.S. Geological Survey Water-Resources Investigations Report 97-4077. Tallahassee, Florida.

Lewelling, B. R. and R. W. Wylie. 1993. Hydrology and water quality of unmined and reclaimed basins in phosphate-mining areas, west-central Florida. U.S. Geological Survey. Water-Resources Investigations Report 93-4002. Tallahassee, FL.

Ludwig, J. A. and J. F. Reynolds. 1988. Statistical Ecology: A Primer on Methods and Computing. John Wiley and Sons, Inc, New York, New York.

Merritt R.W. and K. W. Cummins. 1996. An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publishing Company, Dubuque, Iowa.

R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Patel, S. K. and A. E. Schreiber. 2001. Fate and Consequences to the Environment of Reagents Associated with Rock Phosphate Processing. Prepared for Florida Institute of Phosphate Research, FIPR Project #94-02-104. Bartow, Florida.

Parker, I. M., D. Simberloff, W. M. Lonsdale, K. Goodell, M. Wonham, P. M. Kareiva, M. H. Williamson, B. Von Holle, P. B. Moyle, J. E. Byers, and L. Goldwasser. 1999. Impact: Toward a framework for understanding the ecological effects of invaders. Biological Invasions 1:3-19.

Post, Buckley, Schuh, and Jernigan, Inc. and W. Dexter Bender and Associates, Inc. 1999. Synthesis of Technical Information, Volume 1: A Characterization of Water Quality, Hydrologic Alterations, and Fish and Wildlife Habitat in the Greater Charlotte Harbor Watershed. Technical Report No. 99-02. Prepared for: Charlotte Harbor National Estuary Program.

R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Reid, G. K. and R. D. Wood. 1976. Ecology of Inland Waters and Estuaries, 2nd ed. D. Van Nostrand Company, New York, New York.

Robbins, J. M., R. D. Ford, J. T. Werner, and W. D. Cowherd. 1984. Soil Survey of Hardee County, Florida. United States Department of Agriculture In cooperation with University of Florida, Institute of Food and Agriculture Sciences, Agricultural Experiment Stations and Soil Science Department, and Florida Department of Agriculture and Consumer Services.

Robbins, K.M.N. and D.J. Durbin. 2011. Analysis of Streamflow Differences Between Pre-Mining and During-Mining for Dry Years for Impacted and Reference Streams: A BACI (Before, After, Control, Impact) Paired Series Test. Prepared for The Mosaic Company. Riverview, Florida.

Robbins, K.M.N., and S.A. Huelster. 2015. Horse Creek Stewardship Program: 2011 Annual Report. Prepared by Cardno for Mosaic Fertilizer, LLC.

Robbins, K.M.N., and S.A. Huelster. 2015. Horse Creek Stewardship Program: 2012 Annual Report. Prepared by Cardno for Mosaic Fertilizer, LLC.

Robbins, K.M.N., and S.A. Huelster. 2016. Horse Creek Stewardship Program: 2013 Annual Report. Prepared by Cardno for Mosaic Fertilizer, LLC.

Robbins, K.M.N., and S.A. Huelster. 2017. Horse Creek Stewardship Program: 2014 Annual Report. Prepared by Cardno for Mosaic Fertilizer, LLC.

Robbins, K.M.N., and S.A. Huelster. 2018. Horse Creek Stewardship Program: 2015 Annual Report. Prepared by Cardno and Brown & Caldwell for Mosaic Fertilizer, LLC.

Robbins, K.M.N., S.A. Huelster, and D.J. Durbin. 2011. Horse Creek Stewardship Program: 2009 Annual Report. Prepared by Cardno for Mosaic Phosphates Company.

Robbins, K.M.N., S.A. Huelster, and D.J. Durbin. 2014. Horse Creek Stewardship Program: 2010 Annual Report. Prepared by Cardno for the Mosaic Company.

Schertz, T. L., R. B. Alexander, and D. J. Ohe. 1991. The computer program EStimate TREND (ESTREND), a system for the detection of trends in water-quality data: U.S. Geological Survey Water-Resources Investigations Report 91-4040. 63 p.

Sheldon, A. L. 1988. Conservation of stream fishes: Patterns of diversity, rarity, and risk. Conservation Biology 2:149-156.

South West Florida Water Management District. 2000. Resource Evaluation of the Horse Creek Project, Draft. Brooksville, Florida.

StatSoft, Inc. (2005). STATISTICA (data analysis software system), version 7.1. www.statsoft.com.

Whiteside, B. G. and R. M. McNatt. 1972. Fish species diversity in relation to stream order and physiochemical conditions in the Plum Creek drainage basin. American Midland Naturalist 88:90-101.

Wilson, E. O. 1992. The Diversity of Life. W.W. Norton & Company, New York.

Zar, J. H. 1999. Biostatistical Analysis, 4th Edition. Prentice Hall, Upper Saddle River, New Jersey.

APPENDIX

A

HORSE CREEK STEWARDSHIP PROGRAM

Appendix A
Horse Creek Stewardship Program

Intent

The purpose of this program is two-fold. First, it provides a protocol for the collection of information on physical, chemical and biological characteristics of Horse Creek during IMC Phosphates' (IMC) mining activities in the watershed in order to detect any adverse conditions or significant trends that may occur as a result of mining. Second, it provides mechanisms for corrective action with regard to detrimental changes or trends caused by IMC's' activities, if any are found.

The overall goals of the program are to ensure that IMC Phosphates' mining activities do not interfere with the ability of the Peace River/Manasota Regional Water Supply Authority (Authority) to withdraw water from the Peace River for potable use nor adversely affect Horse Creek, the Peace River or Charlotte Harbor.

There are three basic components to this stewardship program:

- Monitoring and Reporting on Stream Quality,
- Investigating Adverse Conditions or Significant Trends Identified Through Monitoring, and
- Implementing Corrective Action for Adverse Stream Quality Changes Attributable to IMC Activities

An important aspect of this program is that it will not rely solely upon the exceedance of a standard or threshold to bring about further investigation and, where appropriate, corrective action. The presence of a significant temporal trend alone will be sufficient to initiate such steps. This protection mechanism is not present in the vast majority of regulatory scenarios.

The mission of the Authority is to provide a reliable and safe drinking water supply to the citizens of the four counties comprising the Authority, Charlotte, DeSoto, Manatee and Sarasota Counties. The Peace River Facility is a critical component of the Authority's water supply system. The Peace River Facility located in DeSoto County utilizes the Peace River as its supply source.

It is critical for the Authority to protect the Peace River from impacts that would be detrimental to the operation of the Peace River Facility. As a tributary to the Peace River, the Authority's goal for the Horse Creek Stewardship Program is to provide assurance that the quantity and quality of Horse Creek flow as it contributes to the Peace River does not adversely impact the operation of the Peace River Facility.

Program Implementation and Oversight

IMC will implement and fund the Horse Creek Stewardship Program with oversight by the Authority. The Authority will create and coordinate a Technical Advisory Group (TAG) to consist of a representative from each of its members to review and provide input on the program throughout the duration of the monitoring. IMC will create a project-specific quality assurance and quality control (QA/QC) plan for the program detailing all sampling, laboratory procedures, benthic and fish monitoring protocols and data analysis. The QA/QC plan will be consistent with the analogous protocols established in the HydroBiological Monitoring Program (HBMP) for the Lower Peace River/Upper Charlotte Harbor.

Historical, Background and Contemporaneous Data

IMC will compile available data collected by others on water quality, quantity and aquatic biology of Horse Creek. This is expected to include, but is not limited to, information collected by the U.S. Geological Survey (USGS), the Florida Department of Environmental Protection (DEP), the Southwest Florida Water Management District (SWFWMD), the Charlotte Harbor Environmental Center (CHEC). Horse Creek data contained in the U.S. Environmental Protection Agency's (EPA) STORET database will also be obtained. Historic data will be reviewed to provide background information on Horse Creek, and data from ongoing collection efforts will be obtained to supplement that collected by IMC.

Monitoring Period

Water quantity, water quality, macroinvertebrates and fish will be monitored as outlined below during the time that IMC Phosphates is conducting mining and reclamation in the Horse Creek watershed. Monitoring will begin no later than April 2003. In the event of temporary interruptions in mining activities (up to one year), this monitoring will continue during the period of inactivity. Monitoring will cease when mining and reclamation operations are completed in the Horse Creek watershed.

Surface Water Monitoring Stations

Four locations on Horse Creek will be monitored for physical, chemical and biological parameters:

HCSW-1 - Horse Creek at State Road 64 (USGS Station 02297155)
HCSW-2 - Horse Creek at County Road 663A (Goose Pond Road)
HCSW-3 - Horse Creek at State Road 70
HCSW-4 - Horse Creek at State Road 72 (USGS Station 02297310)

As indicated above by their station ID numbers, HCSW-1 and HCSW-4 are also long-term US Geological Survey (USGS) gauging stations, with essentially continuous stage and discharge records since 1977 and 1950, respectively.

Water Quantity Monitoring and Analysis

Discharge data will be obtained from the USGS for stations HCSW-1 and HCSW-4 for compilation with other data collected through this monitoring program. If not already present, staff gauges will be installed in the stream at HCSW-2 and HCSW-3 and surveyed to NGVD datum. If not already available, stream cross sections will be surveyed at those locations, extending to the approximate limits of the 25-year floodplain. Staff gauge readings will be recorded at the time of any sampling efforts at those stations. Data on rainfall will be obtained using IMC's rain gauge array (including any additional gauges installed in the Horse Creek basin in the future).

Data analysis will focus upon, but not necessarily be limited to, the ongoing relationship between rainfall and streamflow in the Horse Creek watershed. This relationship can be established from data collected early in the monitoring program and used to track the potential effects of mining on streamflow. Analytical approaches are outlined under Water Quality below and such methods will be more fully described in the QA/QC plan to be developed as part of this stewardship program.

Surface Water Quality Monitoring and Analysis

Water quality data will be obtained monthly at each station where flow is present. Field measurements will be made of temperature, pH, specific conductance, turbidity and dissolved oxygen. Grab samples will be collected and analyzed for:

Nitrate + Nitrite
Total Kjeldahl Nitrogen
Total Nitrogen
Total Ammonia Nitrogen
Ortho Phosphate
Chlorophyll a
Calcium
Iron
Color
Total Alkalinity
Chloride
Fluoride
Radium 226 + 228
Sulfate
Mining Reagents (petroleum-based organics, fatty acids, fatty amido amines).

At Station HCSW-1, a continuous monitoring unit will be installed to record temperature, pH, conductivity, dissolved oxygen and turbidity. Because this station is located at a bridge crossing for a highway, the unit will be located some distance (within 100 m) upstream or downstream from the bridge to minimize the likelihood of vandalism. The unit will be permanently installed and its location surveyed. Data will be recorded frequently (at least hourly) and will be downloaded at least monthly. This data will provide for the characterization of natural background fluctuations and may allow for the detection of general water quality changes not observed during the collection of monthly grab samples.

Table 1 presents the analytical schedules and procedures. All sampling will be conducted according to DEP’s Standard Operating Procedures (SOP) for field sampling. Laboratory analyses will be performed by experienced personnel according to National Environmental Laboratory Accreditation Council (NELAC) protocols, including quality assurance/quality control considerations. Invertebrate sampling will be conducted by personnel with training and experience in the DEP’s SOP for such sampling.

Results will be tabulated to allow for comparisons among stations and sampling events and through time. Results will be compared with available historic data for Horse Creek and its tributaries, and with applicable Florida surface water quality standards. Typical parametric and non-parametric statistics will be used to describe the results. In particular, regression analysis is expected to be employed to examine the relationship between each parameter and time. Both linear and non-linear regression will be considered, depending upon the patterns observed in the data. Since at least some of the parameters can be expected to vary seasonally, use of methods such as the Seasonal Kendall’s Tau Test is anticipated. Other potential methods include Locally Weighted Scatterplot Smooth (LOWESS). In addition to trend analyses, annual reports will contain general statistics such as mean, median, standard deviation and coefficient of variance for each numerical parameter. Such general statistics will be calculated on both an annual and seasonal basis. Because the data will be maintained in a standard software format (i.e., MS Excel or MS Access), there will be virtually no logistical limitations on the types of analyses that can be conducted. The only limitations will result from the nature of the data itself (i.e., data quantity, distributions, etc.).

For each parameter, data analysis will focus upon, but not necessarily be limited to, (1) the relationship between measured values and the “trigger values” as presented in Table 1 and (2) temporal patterns in the data which may indicate a statistically significantly trend toward the trigger value. Statistical significance will be based upon $\alpha=0.05$, unless data patterns/trends or other related information indicate that use of another significance level is more appropriate. Since the purpose of this monitoring is to detect trends toward the trigger values, should they be present, trend analyses and other statistical tests will generally focus only upon changes toward the trigger values. This will increase the statistical power for detecting such changes.

At least initially, the term over which trends are analyzed will be dependent upon the data collected to date. As the period of record increases, data analysis can move from a comparison of months, to seasons, to years. As noted above, seasonal patterns will always be considered during data analysis and attention will be given to differentiation between natural seasonal/climatic variation and anthropogenic effects (including mining), where possible. Where historic data exist for a given parameter or station, such data can be evaluated relative to that collected through this effort, although sampling frequency and consistency may not be sufficient to conduct standard trend analysis methods. Analytical methods will be more fully described in the QA/QC plan to be developed as part of this stewardship program.

Aquatic Macroinvertebrate Sampling and Analysis

Macroinvertebrate sampling will be performed three times annually and, in general, will be conducted concurrently with a monthly water quality sampling event. The first event would occur in March or April, the second event in July or August, and the third event in October or November. Specific months when sampling occurs may change from year to year to avoid very low or very high flows, which would impede representative sampling.

In accordance with the DEP Standard Operating Procedures (DEP-SOP-001/01 FS 7000 General Biological Community Sampling), invertebrate sampling will not be conducted ". . . during flood stage or recently dry conditions." This is interpreted here to mean that a given sampling station will not be sampled for macroinvertebrates if (a) water is above the top of the stream bank, or is too deep or fast-moving to sample safely, or (b) if the stream has been dry during the preceding 30 days. In the event either of these situations occurs, the station will be revisited approximately one month later to determine whether sampling is appropriate at that time. If the stream is still in flood, or has again been dry during the preceding 30 days, invertebrate sampling will be postponed until the next season's sampling event. Note that the above situations are expected to be quite rare at the Horse Creek stations, and sampling efforts will generally be planned to avoid such conditions.

Sampling will be conducted at the same four stations on Horse Creek used for flow and water quality monitoring. The aquatic habitats at each station will be characterized, streamside vegetation surveyed, and photostations established. Qualitative macroinvertebrate sampling will be performed according to the Stream Condition Index (SCI) protocol developed by DEP (DEP-SOP-002/01 LT 7200) or subsequently DEP-approved sampling methodology. Consistent with DEP protocols, each invertebrate sample will be processed and taxonomically analyzed. Data from the samples will be used to determine the ecological index values presented in Table 1. Additional indices may also be calculated to further evaluate the invertebrate community. As noted in Table 1, the focus of the analysis will be to screen for statistically significant declining trends with respect to presence, abundance, and distribution of native species, as well as SCI values. Results may also be compared with available historic macroinvertebrate data for Horse Creek and its tributaries, or with data from other concurrent collecting efforts in the region, if appropriate. Analysis of invertebrate community characteristics will include consideration of flow conditions, habitat conditions and selected water quality constituents.

Analytical approaches are outlined under Water Quality Monitoring and Analysis section above and such methods will be more fully described in the QA/QC plan to be developed as part of this Horse Creek Stewardship Program.

Fish Sampling and Analysis

Fish sampling will be conducted three times annually, concurrent with aquatic macroinvertebrate sampling at the same four stations on Horse Creek. Based upon stream morphology, flow conditions and in-stream structure (logs, sand bars, riffles, pools, etc.); several methods of sampling may be used, including seining, dipnetting, and electrofishing. Sample collection will be timed to standardize the sampling efforts among stations and between events.

All fish collected will be identified in the field according to the taxonomic nomenclature in Common and Scientific Names of Fishes from the United States and Canada (American Fisheries Society 1991, or subsequent editions). Voucher specimens will be taken of uncommonly encountered species and of individuals that cannot be readily identified in the field; with such specimens being preserved and logged in a reference collection maintained for this monitoring program. All fish will be enumerated and recorded. Total length and weight will be determined and recorded for individuals, however, for seine hauls with very large numbers of fish of the same species (a common occurrence with species like *Gambusia holbrooki*, *Heterandria formosa* and *Poecilia latipinna*), individuals of the same species may be counted and weighed en masse, with only a randomly selected subset (approximately 10 to 20 individuals of each such species) being individually measured for length and weight. Any external anomalies observed on specimens will be recorded.

Taxa richness and abundance and mean catch per unit effort will be determined for each station and each event, and data can be compared among stations and across sampling events. The ecological indices presented in Table 1 will be calculated and additional indices may also be calculated to evaluate the fish community, including similarity indices, species accumulation/rarefaction curves, diversity indices and evenness indices. As noted in Table 1, the focus of the analysis will be to screen for statistically significant declining trends with respect to presence, abundance and distribution of native species. Results may also be compared with available historic fisheries data for Horse Creek and its tributaries, and with data from other concurrent regional collecting efforts, if applicable. Analysis of fish community characteristics will include consideration of flow conditions, habitat conditions and selected water quality constituents.

Analytical approaches are outlined under Water Quality above and such methods will be more fully described in the QA/QC plan to be developed as part of this stewardship program.

Reporting

All data collected through this monitoring program will be compiled annually (January - December records) and a report will be generated summarizing the results. This report will include narrative, tabular and graphical presentation of the discharge records, surface water quality data, macroinvertebrate and fish sampling results. Results of statistical analyses will also be provided. Discussion will be included comparing across the sampling stations, as well as among seasons and sampling years. Emphasis will be placed upon identifying spatial and/or temporal trends in water quality and/or biological conditions. Where available, data collected from the same stations prior to the initiation of this program will be reviewed and incorporated to allow for longer-term evaluation of Horse Creek. In addition, data available from sampling/monitoring efforts by agencies or other public entities will be reviewed and incorporated, where pertinent. Each report will also provide general information on the location and extent of IMC mining activities in the Horse Creek watershed, as they relate to this monitoring effort. Reports will be submitted to the Authority, as well as to the DEP Bureau of Mine Reclamation (BMR) and Southwest Florida Water Management District (SWFWMD).

In addition to the reporting outlined above, raw data compiled through sampling will be provided to the Authority monthly. This data will be submitted within six (6) weeks of each sampling event (pending the completion of laboratory/taxonomic analyses).

Monitoring Program Evaluation

To ensure this program is providing useful information throughout its tenure, it will be evaluated regularly. Each annual report will include a section devoted to a summary of the immediate and long-term utility of each information type being collected. Recommendations will also be provided in the report regarding possible revisions, additions or deletions to the monitoring program to ensure that it is appropriately focused. Based upon such recommendations, IMC Phosphates will coordinate with the Authority and TAG on a regular basis regarding amendments to the monitoring program. Coordination on this issue may be initiated at any time by either party and will occur at least once every five years, whether or not either party individually requests it.

Protocol for Addressing Potential Problems Identified Through Monitoring

An important element of the monitoring program will be the ongoing analyses of data to detect exceedances of specific trigger values (see Table 1) as well as statistically significant temporal trends toward, but not necessarily in excess of, those values. The analyses will evaluate the data collected through this Horse Creek Stewardship Program, as well as that reported by other entities where appropriate.

Impact Assessment/Characterization

In the event the annual data evaluation identifies trigger value exceedances or statistically significant trends in Horse Creek, IMC will conduct an impact assessment to identify the cause of the adverse trend. The impact assessment may include more intensive monitoring of water quality in terms of frequency of sampling, laboratory analyses conducted, or locations monitored. In all cases, however, the impact assessment will include supplemental quantitative and qualitative data evaluations and consultation with Authority scientists, as well as perhaps other investigations within the basin (e.g., examination of land use changes, discharge monitoring records reviews of others, water use permit reports of others, etc.).

If the “impact assessment” demonstrates to the satisfaction of IMC and Authority scientists that IMC’s activities in the Horse Creek watershed did not cause the exceedance or trend, IMC would support the Authority’s efforts to implement actions to reverse or abate the conditions. IMC’s support will focus upon scientific solutions where IMC can assist in the abatement of others’ problems.

If the impact assessment indicates or suggests that IMC is the cause of the exceedances or trend, then IMC shall take immediate corrective actions. The intensity of such actions would be based upon the potential for ecological harm to the ecology of Horse Creek or the integrity of the potable water supply to the Authority.

Corrective Action Alternatives Evaluation and Implementation

The first step in the corrective action process shall be to prepare quantitative projections of the short-term and long-term impacts of the trigger value exceedance or adverse trends. Quantitative models and other analytical tools will provide IMC and Authority scientists with the analyses necessary to determine: (1) whether the impacts will persist or subside over the long term; (2) the cause(s) of the adverse trend(s) in terms of specific IMC activities that are contributing to the trend(s); and (3) alternative steps that IMC could effectuate to reverse the adverse trend, if needed.

If impact modeling confirms that adverse trends in water quality or a trigger value exceedance is caused by IMC activities in the Horse Creek watershed, IMC shall meet with Authority within 30 days of detection of the adverse trend or trigger exceedance to evaluate alternative solutions developed by IMC. IMC shall begin implementation of its proposed alternative solution selected by the Authority within 30 days and report to Authority as implementation milestones are reached. Throughout the modeling, alternatives assessment, and preferred alternative implementation steps of the corrective action process, more intensive impact assessment monitoring will continue to track the continuation, or the abatement, of the trigger value exceedance or adverse trend. Only when the impact assessment monitoring demonstrated conclusively that the condition has been reversed, with respect to the particular parameter(s) of concern, would IMC reduce its efforts back to the general monitoring and reporting program.

Alternative solutions may include conventional strategies such as the implementation of additional best management practices, raw material substitutions, hydraulic augmentation of wetlands, etc. IMC shall consider “out of the box” solutions (such as discharges of water to result in lower downstream concentrations of a parameter of concern, where the pollutant does not originate from IMC’s activities) and emerging principles and technologies for water quantity management, water quality treatment and watershed protection, as well as other innovative solutions recommended by Authority.

Table 1. Parameters, General Monitoring Protocols and Corrective Action Trigger Values for the Horse Creek Stewardship Plan

Pollutant Category	Analytical Parameters	Analytical Method	Reporting Units	Monitoring Frequency	Trigger Level	Basis for Initiating Corrective Action Process
General Physio-chemical Indicators	pH	Calibrated Meter	Std. Units	Monthly	<6.0->8.5	Excursions beyond range or statistically significant trend line predicting excursions from trigger level minimum or maximum.
	Dissolved Oxygen	Calibrated Meter	mg/L(1)	Monthly	<5.0	Excursions below trigger level or statistically significant trend line predicting concentrations below trigger level.
	Turbidity	Calibrated Meter	NTU(2)	Monthly	>29	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Color	EPA 110-2	PCU	Monthly	<25	Excursions below trigger level or statistically significant trend line predicting concentrations below trigger level.
Nutrients	Total Nitrogen	EPA 351 + 353	mg/L	Monthly	>3.0	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Ammonia	EPA 350.1	mg/L	Monthly	>0.3	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Ortho Phosphate	EPA 365	mg/L	Monthly	>2.5	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Chlorophyll *a*	EPA 445	mg/L	Monthly	>15	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
Dissolved Minerals	Specific Conductance	Calibrated Meter	µs/cm(3)	Monthly	>1,275	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Alkalinity	EPA 310.1	mg/L	Monthly	>100	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Calcium	EPA 200.7	mg/L	Monthly	>100	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Iron	EPA 200.7	mg/L	Monthly	>0.3 (6); >1.0(7)	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Chloride	EPA 325	mg/L	Monthly	>250	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Fluoride	EPA 300	mg/L	Monthly	>1.5(6); >4(7)	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Radium 226+228	EPA 903	pCi/L(4)	Quarterly	>5	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Sulfate	EPA 375	Mg/L	Monthly	>250	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total Dissolved Solids	EPA 160	Mg/L	Monthly	>500	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
Mining Reagents	Petroleum Range Organics	EPA 8015 (FL-PRO)	mg/L	Monthly(5)	>5.0	Exceedance of or statistically significant trend line predicting concentrations in excess of, trigger level.
	Total fatty acids, including Oleic, Linoleic, and Linolenic acid.	EPA/600/4-91/002	mg/L	Monthly(5)	>NOEL	Statistically significant trend line predicting concentrations in excess of the No Observed Effects Level (NOEL to be determined through standard toxicity testing with IMC reagents early in monitoring program, NOEL to be expressed as a concentration–e.g., mg/L)
	Fatty amido-amines	EPA/600/4-91-002	mg/L	Monthly(5)	>NOEL	Statistically significant upward trend line predicting concentrations in excess of No Observed Effects Level (NOEL to be determined through standard toxicity testing with IMC reagents early in monitoring program, NOEL to be expressed as a concentration – e.g., mg/L)
Biological Indices: Macroinvertebrates	Total Number of Taxa	Stream Condition Index (SCI) sampling protocol, taxonomic analysis, calculation of indices according to SOP-002/01 LT 7200 Stream Condition Index (SCI) Determination	Units vary based upon metric or index	3 times per year	N/A	Statistically significant declining trend with respect to SCI values, as well as presence, abundance or distribution of native species
	Abundance					
	Percent Diptera					
	Number of Chironomid Taxa					
	Shannon Weaver Diversity(a)					
	Florida Index					
	EPT Index					
	Percent Contribution of Dominant Taxon					
	Percent Suspension Feeders/Filterers					
Biological Indices: Fish	Total Number of Taxa	Various appropriate standard sampling methods, taxonomic analysis, calculation of indices using published formulas	Units vary based upon metric or index	3 times per year	N/A	Statistically significant declining trend with respect to presence, abundance or distribution of native species
	Abundance					
	Shannon-Weaver Diversity(a)					
	Species Turnover (Morisita Similarity Index(a)					
	Rarefaction/Species Accumulation Curves(b)					

Notes:

(1) Milligrams per liter
(2) Nephelometric turbidity units
(3) Microsiemens per centimeter.
(4) PicoCuries per liter.
(5) If reagents are not detected after two years, sampling frequency will be reduced to quarterly - if subsequent data indicate the presence of reagents, monthly sampling will be resumed.
(6) At Station HC SW-4 only, recognizing that existing levels during low-flow conditions exceed the trigger level.
(7) At Stations HC SW-1, HC SW-2, and HC SW-3

References:

(a) Brower, J. E., Zar, J. H., von Ende, C. N. Field and Laboratory Methods for General Ecology. 3rd Edition. Wm. C. Brown Co., Dubuque, IA. pp. 237; 1990
(b) Gotelli, N.J., and G.R. Graves. 1996. Null Models in Ecology. Smithsonian Institution Press, Washington, DC.

Horse Creek Stewardship
Program

APPENDIX

B

CUMULATIVE CHRONOLOGICAL LIST OF PROCEDURAL CHANGES TO THE HCSP

Appendix B

Cumulative Chronological List of Procedural Changes to the HCSP

Change 1: Summer Biological sampling from July – Aug to July – Sep.
Year Implemented: 2004
Comments: Allows flexibility with sampling during high flows.
Provisional Acceptance: 2004
Final Acceptance: April 4, 2007

Change 2: Fall Biological sampling from Oct – Nov to Oct – Dec.
Year Implemented: 2004
Comments: Allows flexibility with sampling during high flows.
Provisional Acceptance: 2004
Final Acceptance: April 4, 2007

Change 3: Biological sampling should be separated by at least 6 weeks in time.
Year Implemented: 2004
Comments: Ensures that sample results capture seasonal variation.
Provisional Acceptance: 2004
Final Acceptance: April 4, 2007

Change 4: Accept that historical background levels of dissolved iron at HCSW-4 exceeds the trigger level of 0.3 mg/l.
Year Implemented: 2004
Comments: Station HCSW-4 trigger levels reflect the more stringent Class I levels. Historically Station HCSW-4 background levels for dissolved iron are similar to the rest of the basin but also higher than 0.3.
Provisional Acceptance: 2004
Final Acceptance: April 4, 2007

Change 5: Accept that historical background levels of dissolved oxygen and chlorophyll at HCSW-2 exceeds the trigger level.
Year Implemented: 2004
Comments: Station HCSW-2 is directly downstream of Horse Creek Prairie which routinely delivers slow moving water low in dissolved oxygen and high in chlorophyll to station HCSW-2
Provisional Acceptance: 2004
Final Acceptance: April 4, 2007

Change 6: Continue to compile, compare, present and discuss ongoing Horse Creek Data from WMD, DEP and USGS with HCSP data.
Year implemented: 2005
Comments: Enhances program
Provisional Acceptance: July 2006
Final Acceptance: April 4, 2007

Change 7: Biological Sampling stage level criteria from > 10 ft at HCSW-1 & > 5 ft at HCSW-4 to > 10 ft at HCSW-1 & > 4 ft at HCSW-4
Year implemented: 2007
Comments: Biological samples will be collected when stage levels are below these stated levels to ensure safety and quality samples.
Provisional Acceptance: July 2006
Final Acceptance: April 4, 2007

Change 8: The data range used in the historical water quality comparison should be static historical data beginning somewhere around 1990-1993.
Year Implemented: Beginning with the 2007 Annual Report.
Comments: Historical water quality comparison should be static instead of a moving window allowing consistent and continuous comparison with historical data.
Provisional Acceptance: June 2008
Final Acceptance: November 4, 2009

Change 9: Add clay settling area (CSA) FM-1 to existing monitoring program.
Year Implemented: Prior to 2009 wet season.
Comments: Recently constructed SCA FM-1 will be added to existing CSA's providing real time monitoring to Authority.
Provisional Acceptance: March 2009
Final Acceptance: November 4, 2009

Change 10: Deletion of three water quality parameters: FL-PRO, Fatty Acids, and Total Amines.
Year Implemented: 2009
Comments: These parameters have rarely been above the detection limit and chemical processing plants are not found in the Horse Creek watershed.
Provisional Acceptance: March 2009
Final Acceptance: November 4, 2009

Change 11: Addition of new water quality sample location for Brushy Creek @ Hwy 64.
Year Implemented: 2009
Comments: In lieu of deleted three parameters Mosaic will collect samples and provide data monthly from this location minus trigger levels and impact assessments.
Provisional Acceptance: March 2009
Final Acceptance: November 4, 2009

Change 12: Modifications to CSA monitoring methodology.
Year Implemented: 2014
Comments: Mosaic presented a monitoring proposal utilizing rolling averages of continuously measured turbidity values at HCSW-1, with a set point of 150 NTU. This set point was based on a review of historic data at the station and was selected to be sensitive enough to detect any potential turbidity excursions that might result from an upstream CSA dam breach, but not so sensitive as to result in a number of false positives. The telemetric equipment would send text messages and email alerts to Mosaic when the 3-hour rolling average exceeds 150 NTU and send alerts to Mosaic and PRMRWSA when the 6-hour rolling average exceeds 150 NTU. Three hour alerts would trigger Mosaic investigation of the source of high turbidity, and necessary follow-up with PRMRWSA staff in the event that the cause of the alarm was associated with a dam breach or other significant upset condition at Mosaic's operations. Three tests were conducted, and following the final test, PRMRWSA staff authorized the removal of the old liquid

level monitoring equipment located in the field on Mosaic property and the equipment located at the PRMRWSA's facility.
Provisional Acceptance: February 2014
Final Acceptance: July 14, 2014

Change 13: Change of the dissolved oxygen trigger level from concentration (mg/L) to percent saturation.
Year Implemented: 2014 Annual Report, November 2015 Monthly Report
Comments: In 2013, FDEP changed the Class III state water quality standard from concentration in mg/L to percent saturation. For the Florida peninsula region, the new daily average standard is 38% for continuous recorder data and time of day translation saturation for grab samples. A memo describing these changes was provided to the TAG on November 18, 2015.
Provisional Acceptance: November 9, 2015
Final Acceptance: January 21, 2016

Horse Creek Stewardship
Program

APPENDIX

C

ADDITIONAL WATER QUALITY GRAPHS

Appendix C
Additional Water Quality Graphs

C.1 Period of record HCSP water quality data from 2003 to 2016.

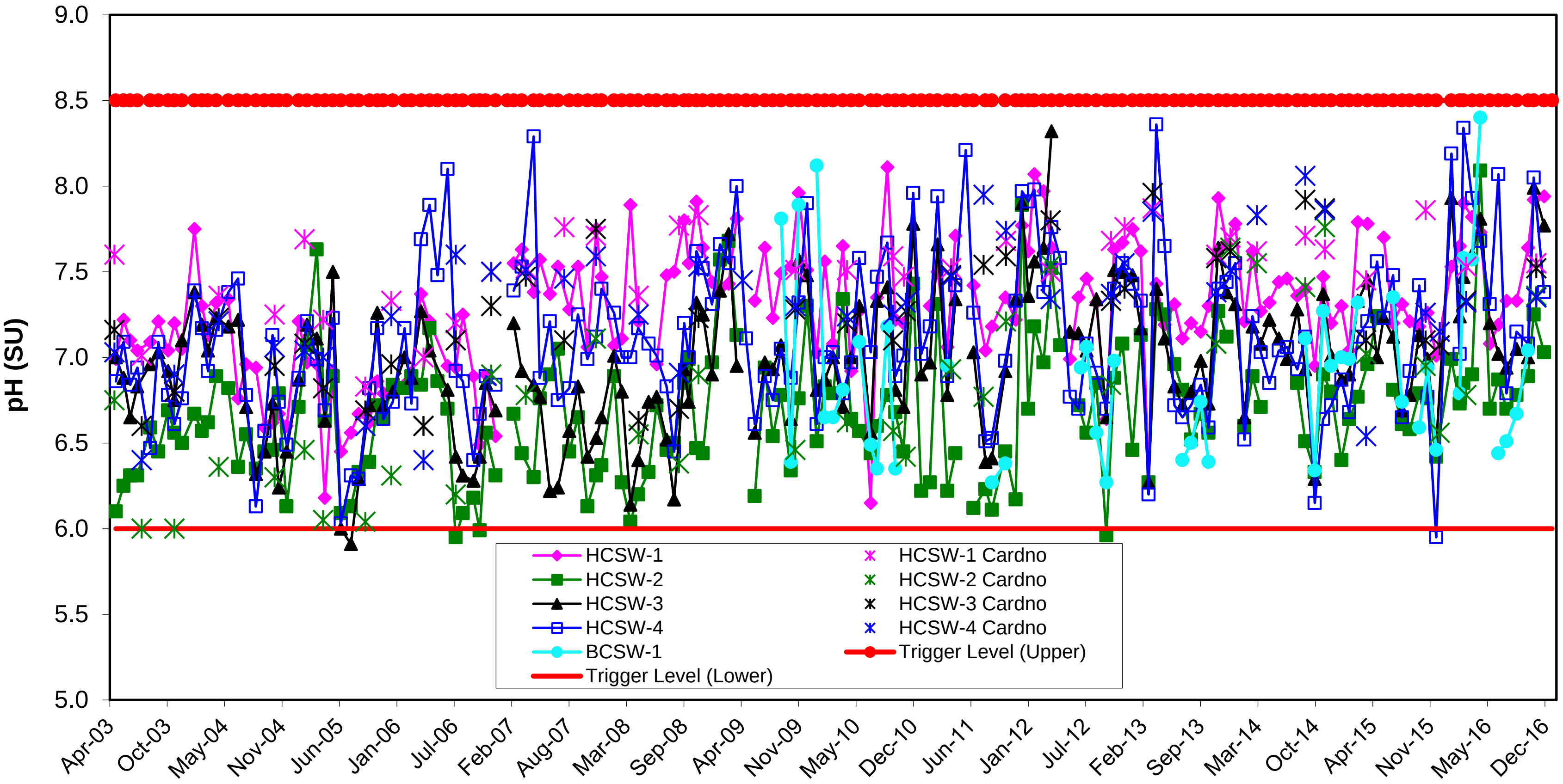


Figure C-1. Values of pH obtained during monthly HCSP water quality sampling and biological sampling events from 2003 to 2016.

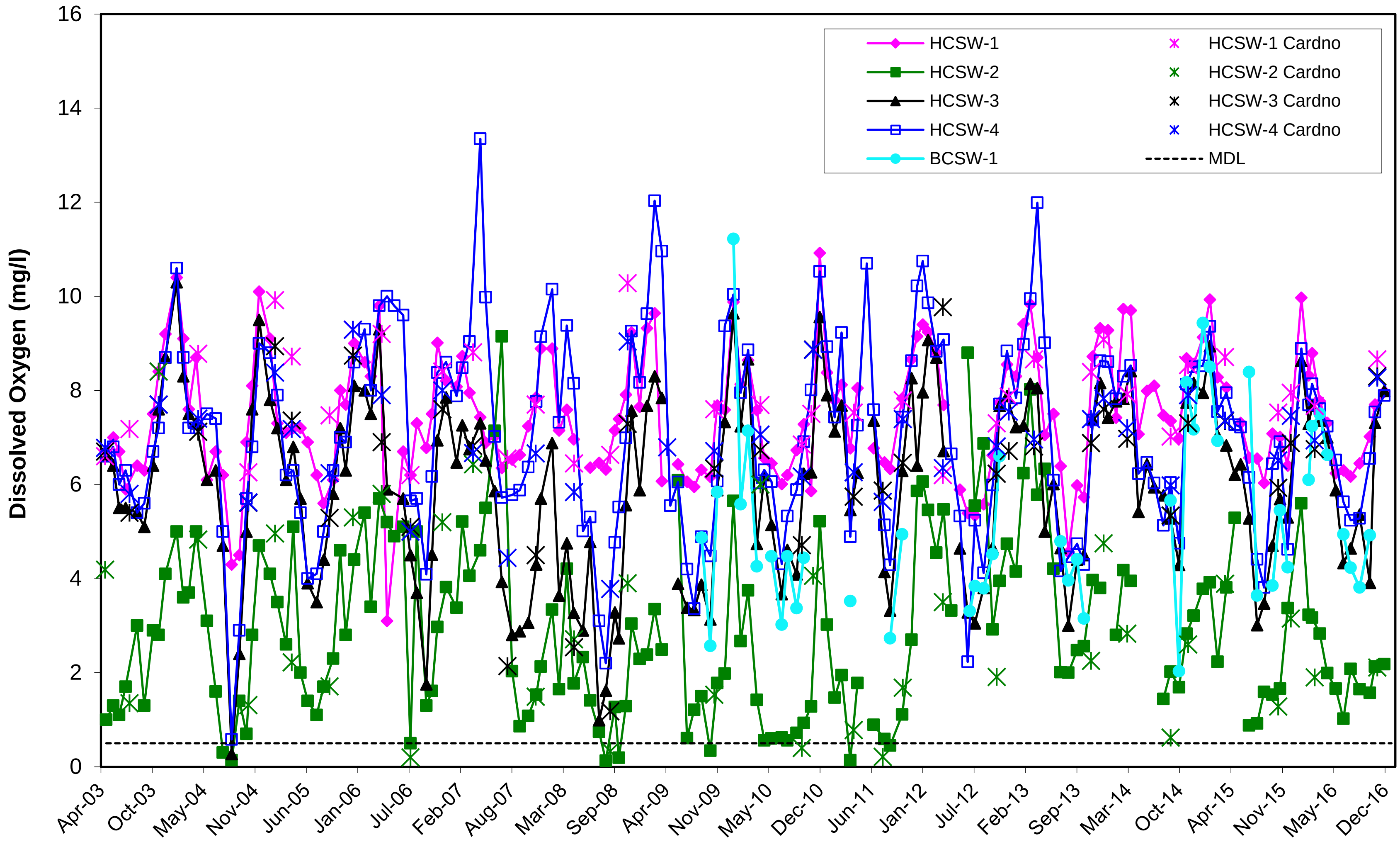


Figure C-2 Dissolved oxygen concentrations obtained during monthly HCSP water quality sampling and biological sampling events from 2003 to 2016.

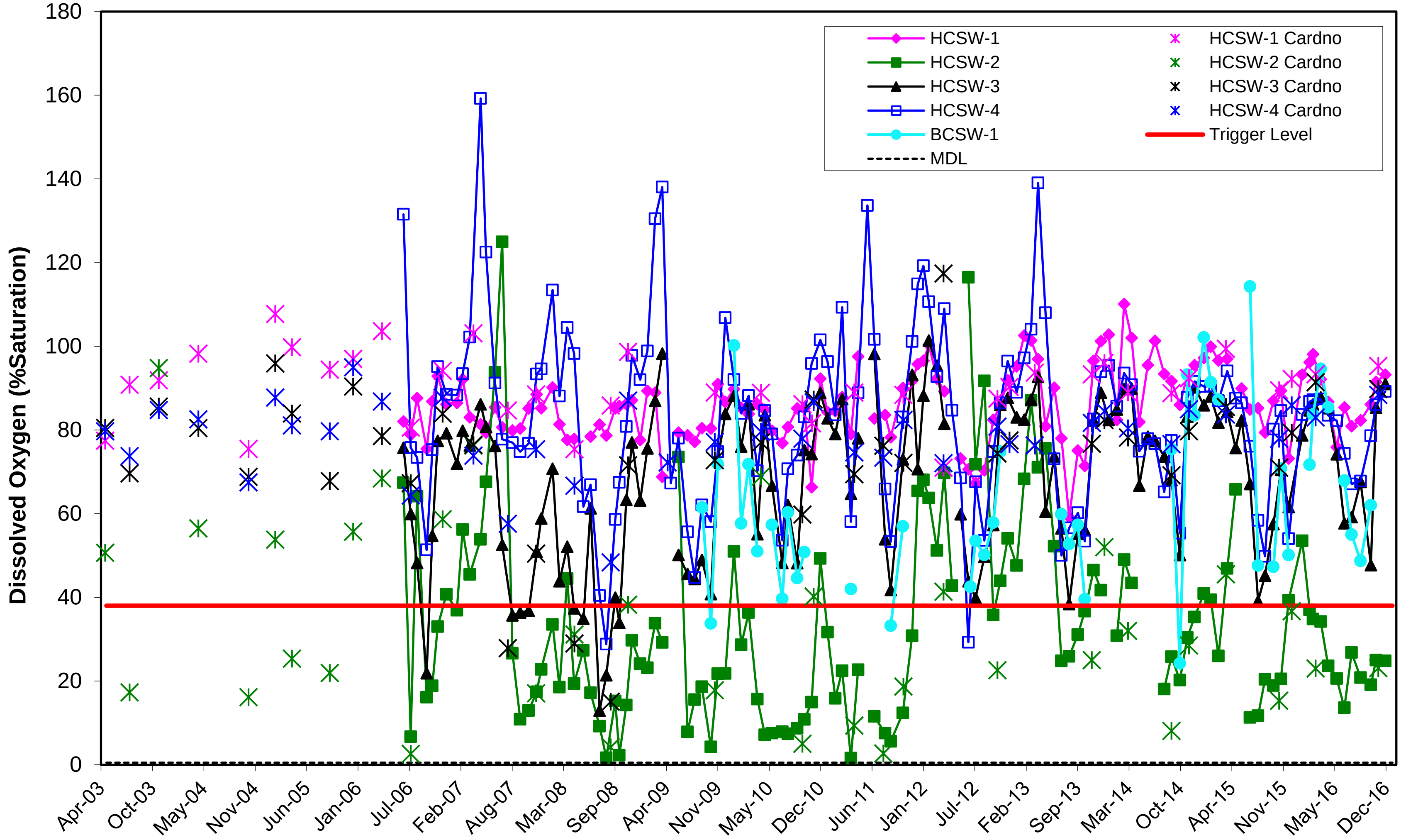


Figure C-3. **Dissolved oxygen percent saturation obtained during monthly HCSP water quality sampling and biological sampling events from 2003 to 2016.**

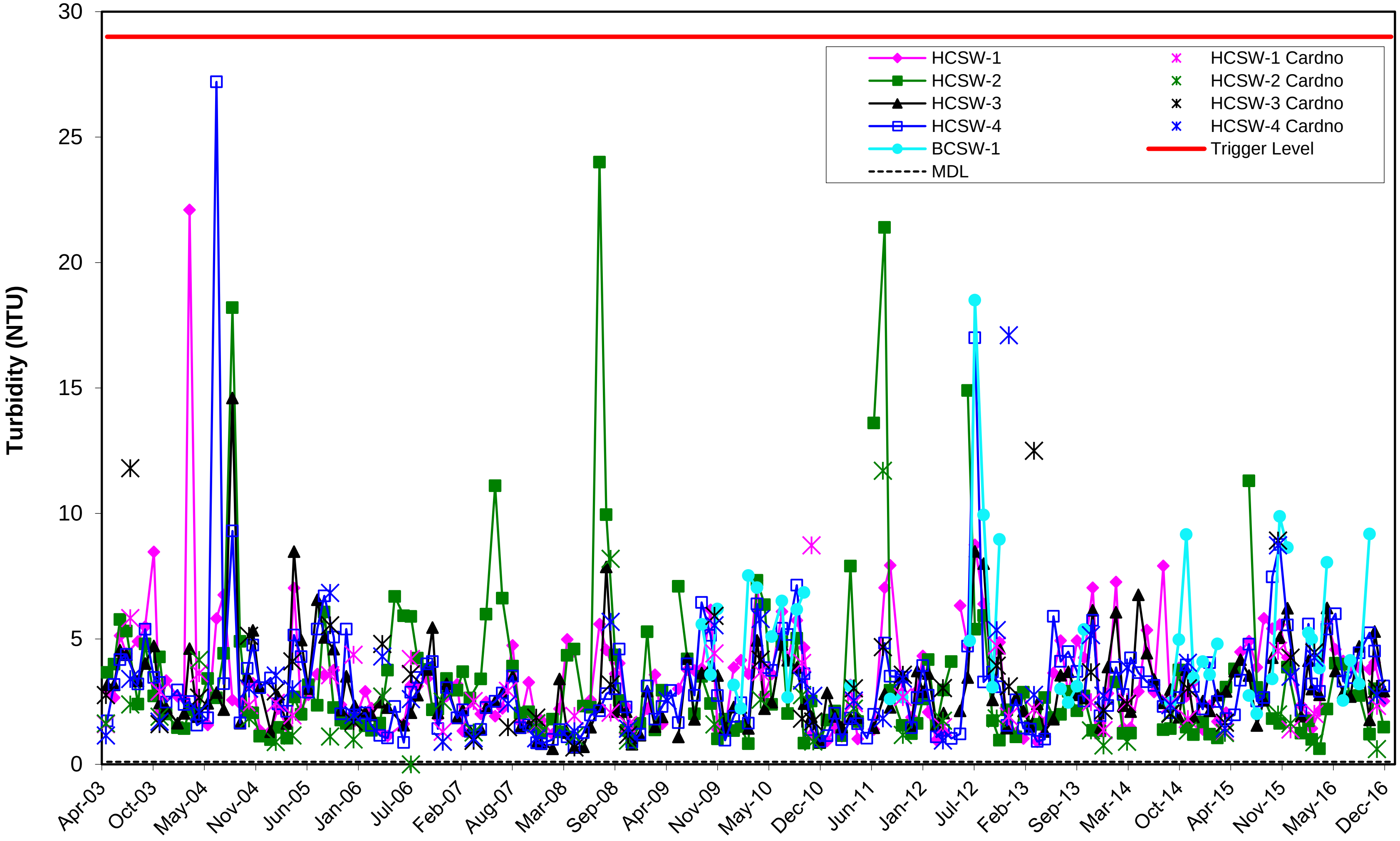


Figure C-4. **Turbidity levels obtained during monthly HCSP water quality sampling and biological sampling events from 2003 to 2016.**

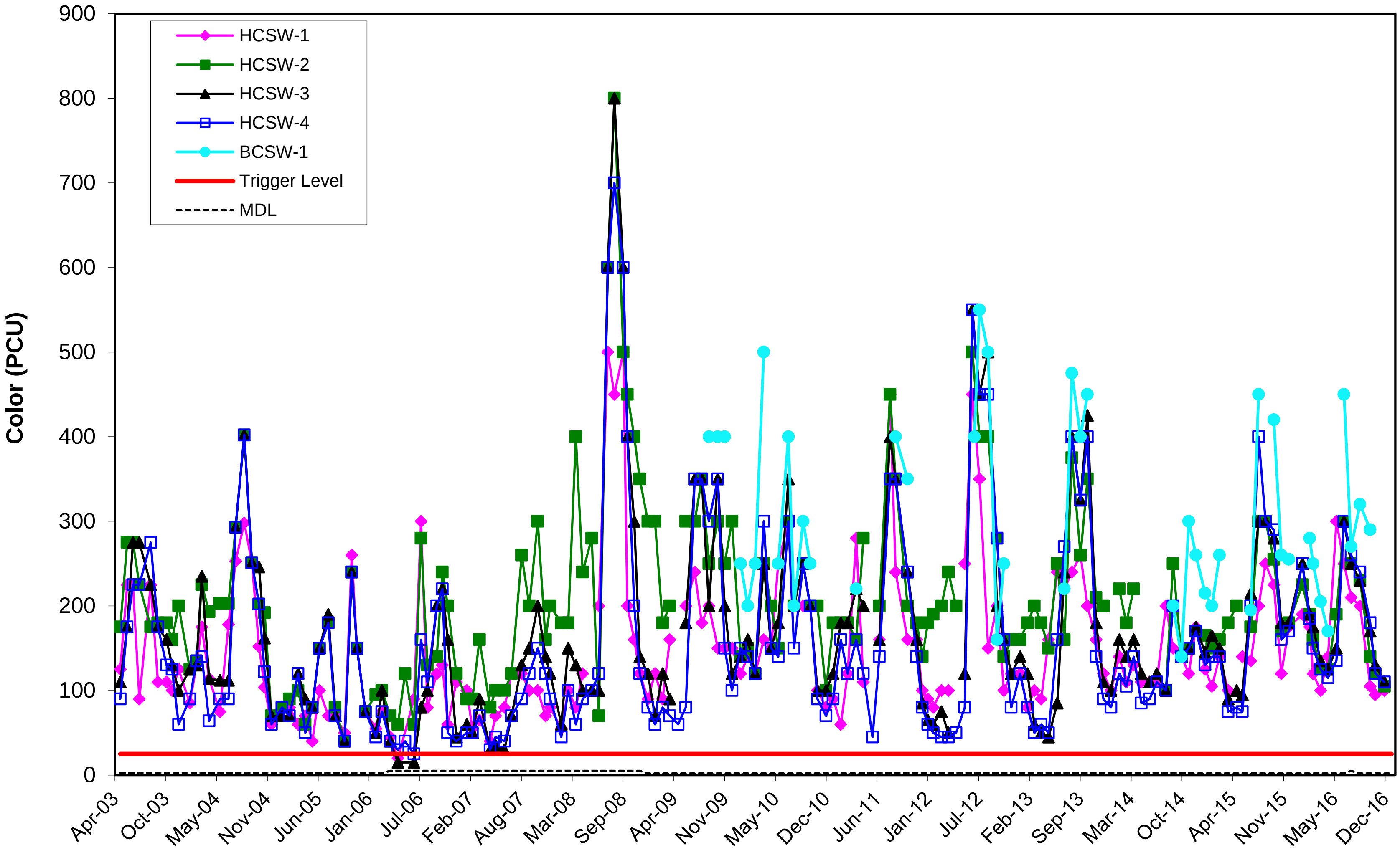


Figure C-5. **Color levels obtained during monthly HCSP water quality sampling from 2003 to 2016.**

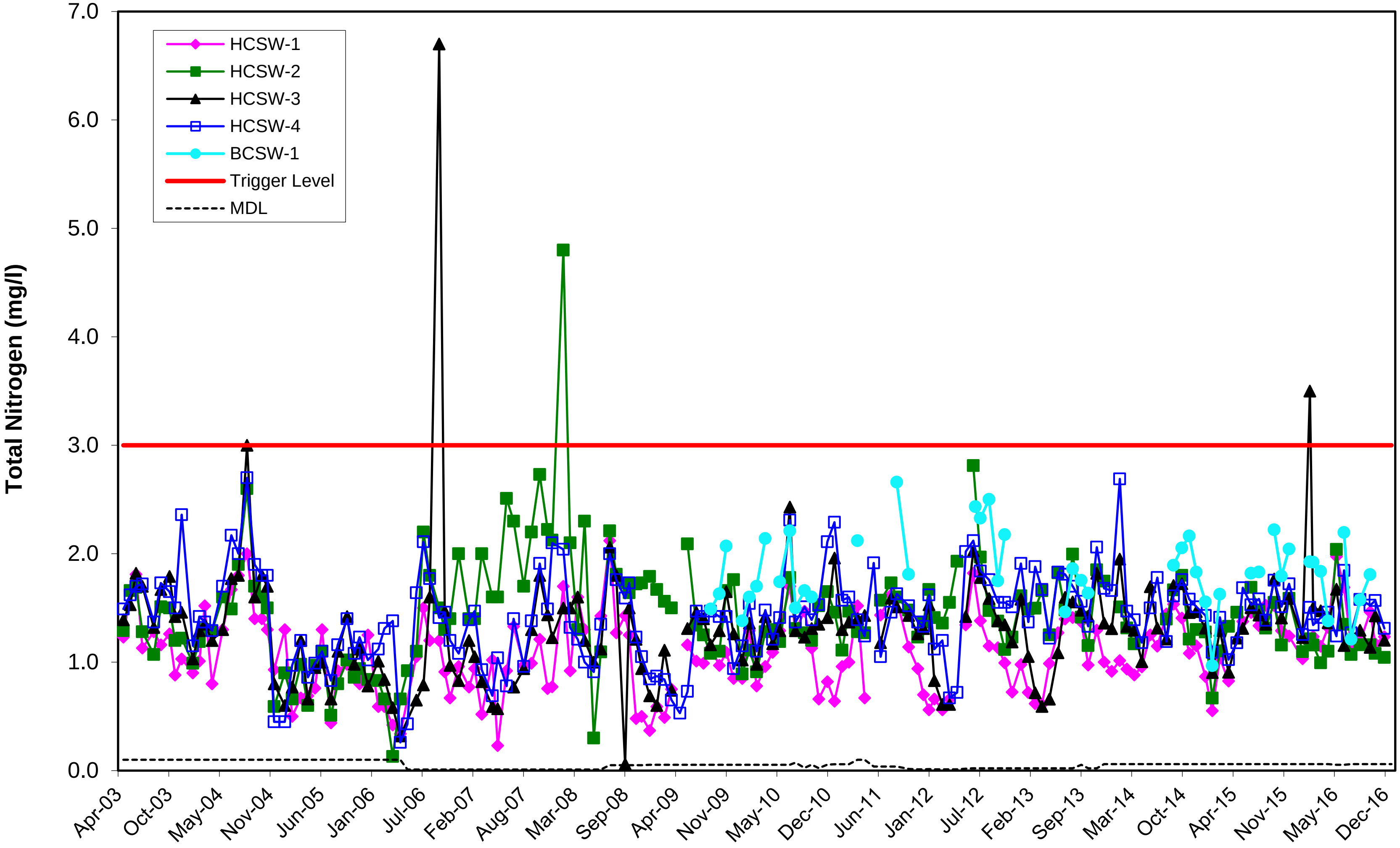


Figure C-6. **Total nitrogen concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

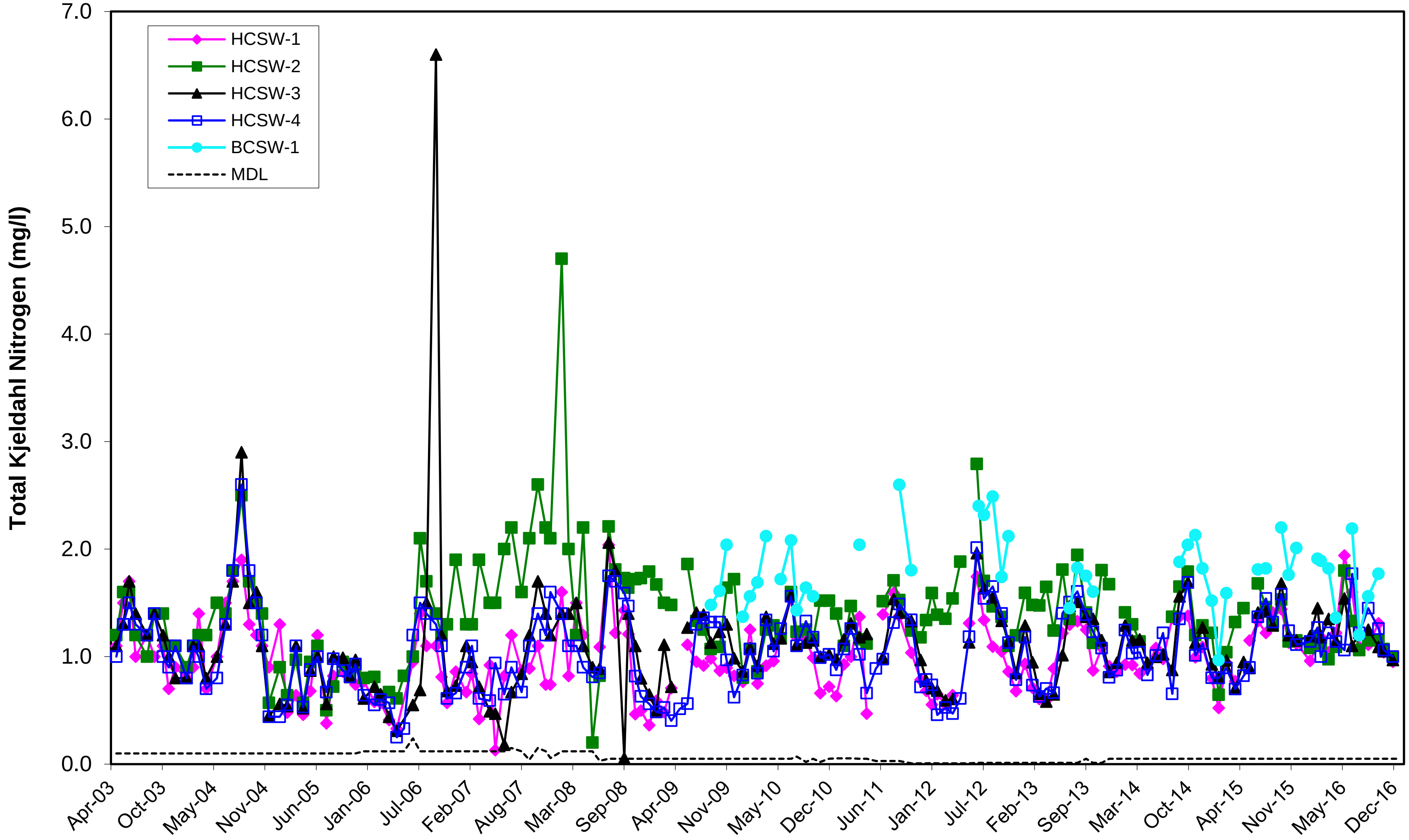


Figure C-7. **Total Kjeldahl nitrogen concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

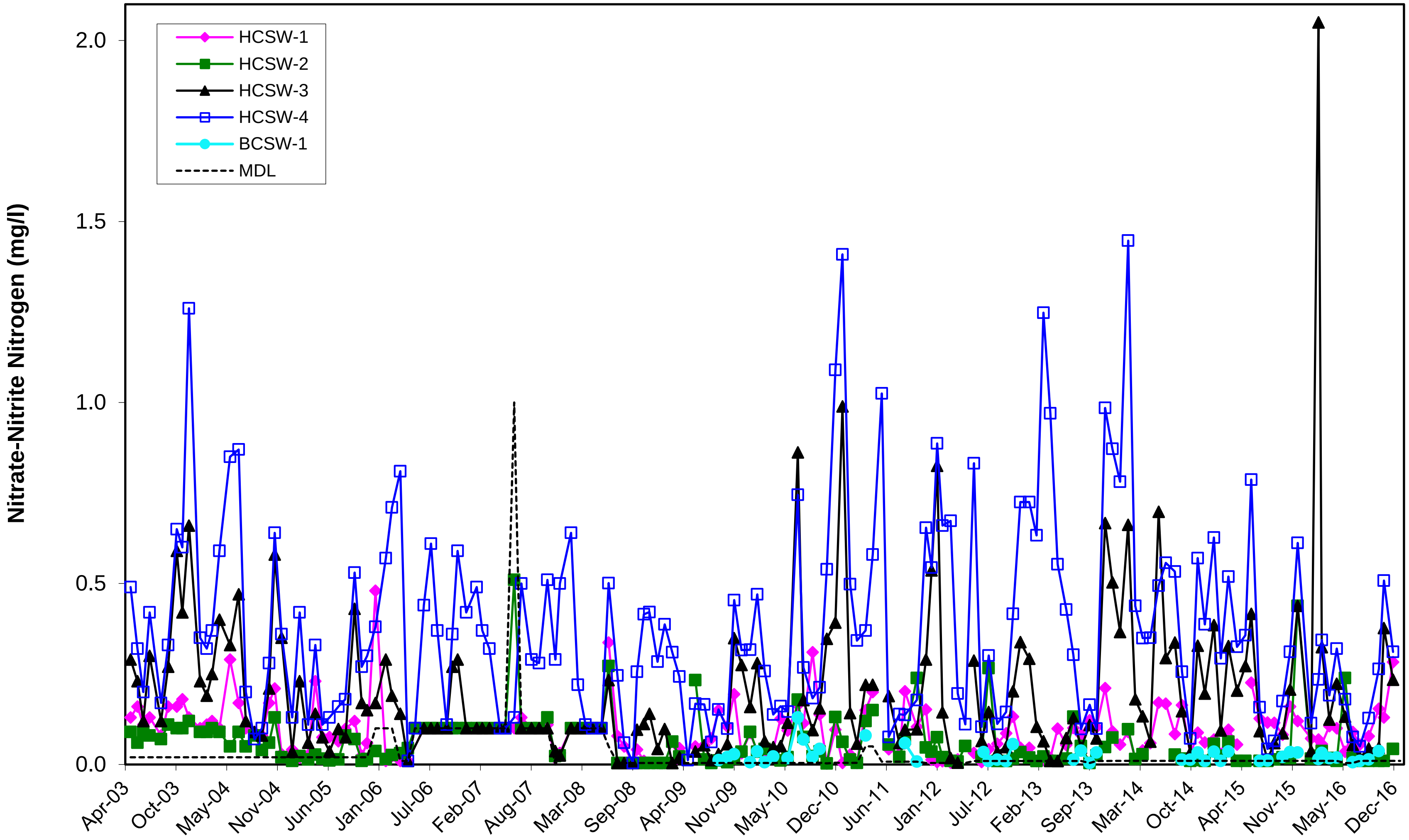


Figure C-8. **Nitrate-nitrite nitrogen concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

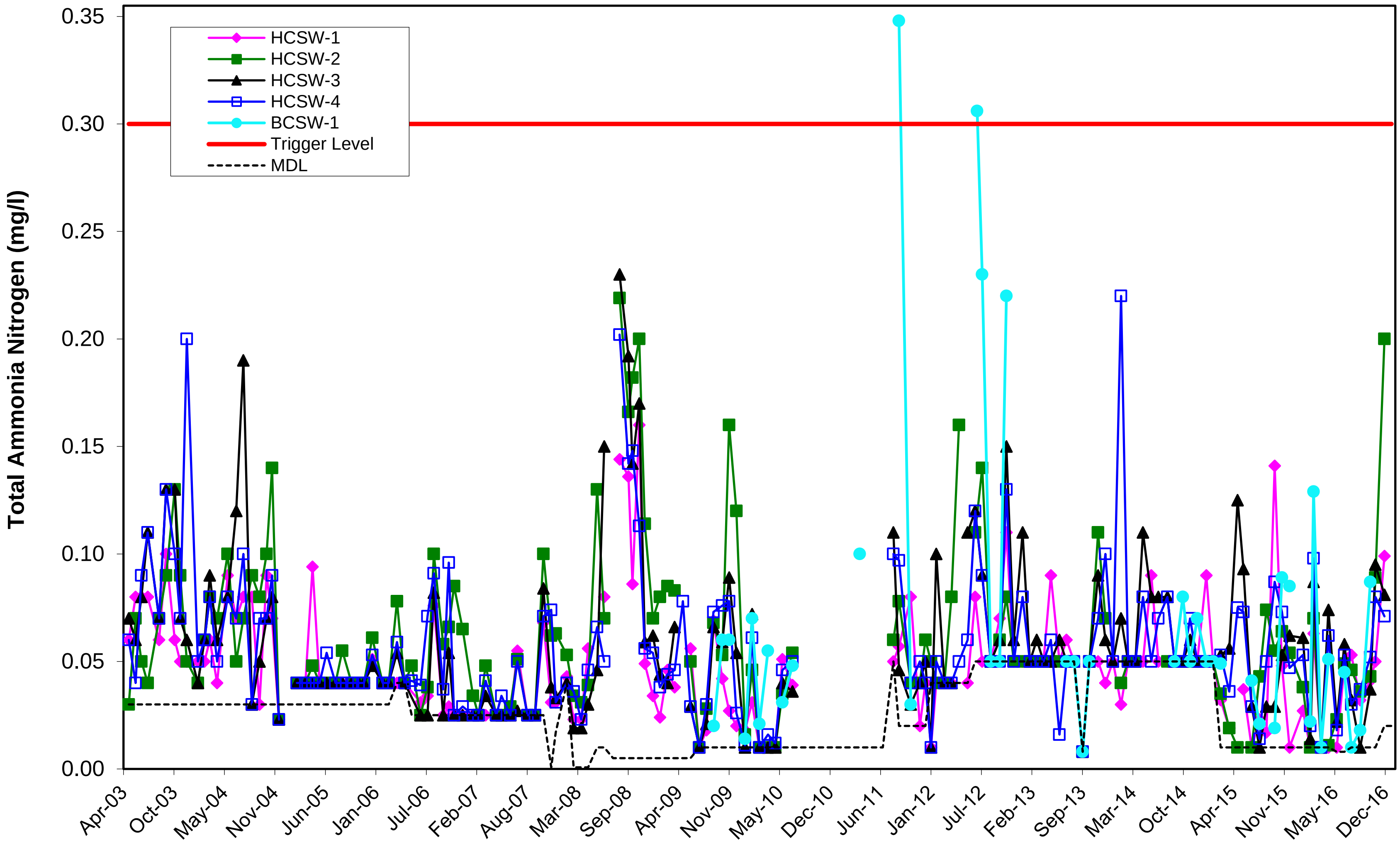


Figure C-9. **Total ammonia nitrogen concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

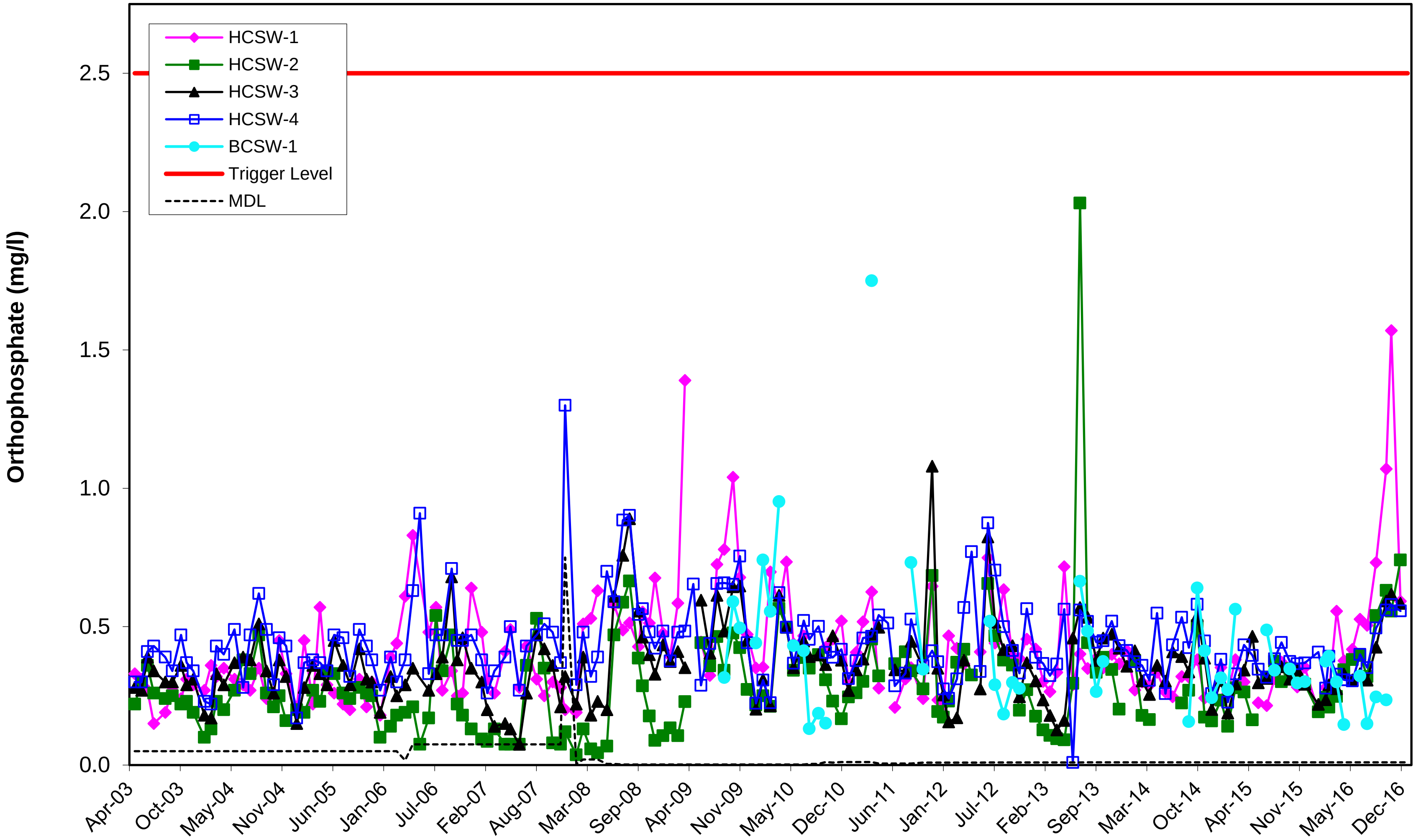


Figure C-10. **Orthophosphate concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

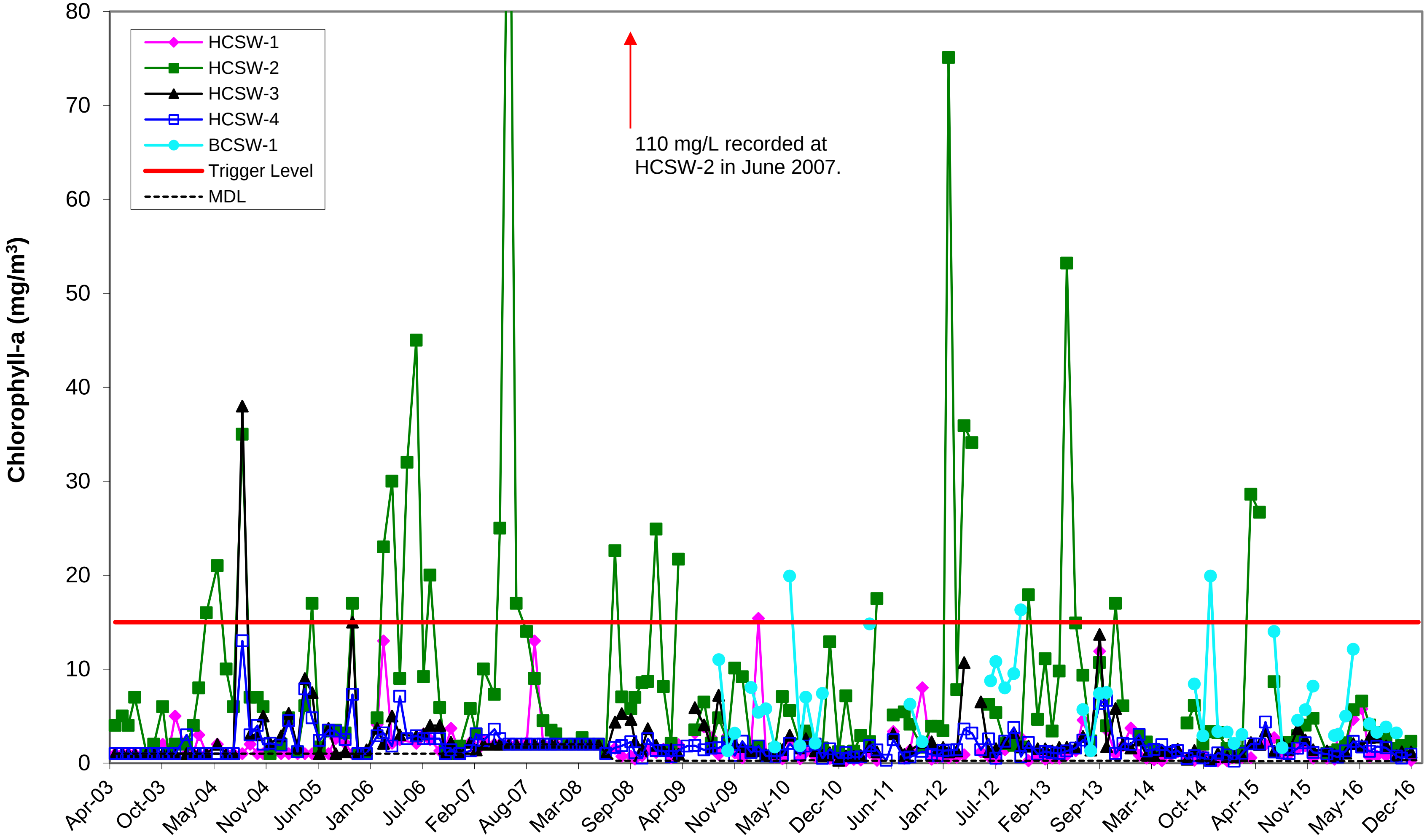


Figure C-11. **Chlorophyll-*a* concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

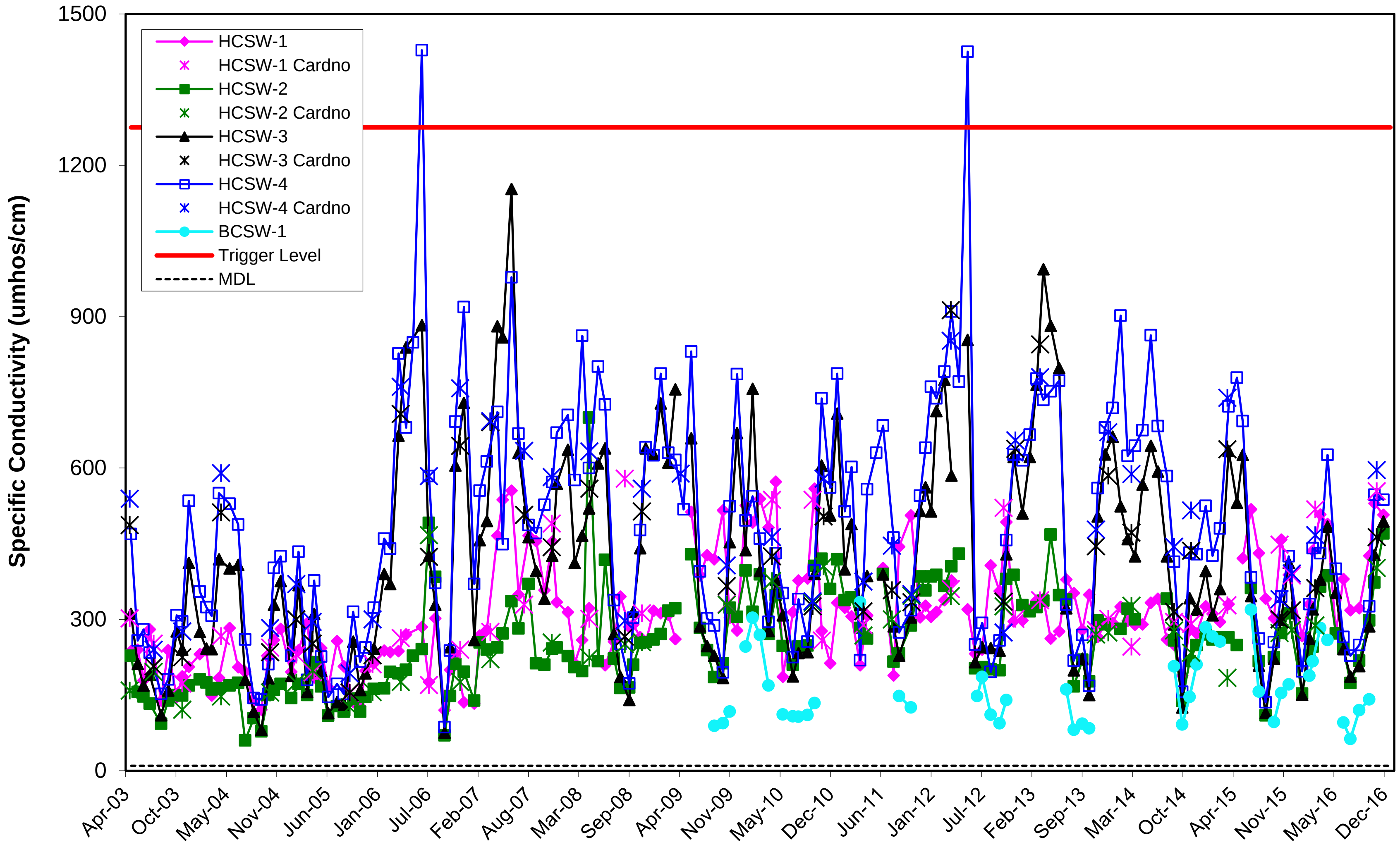


Figure C-12. **Levels of specific conductivity obtained during monthly HCSP water quality sampling and biological sampling events from 2003 to 2016.**

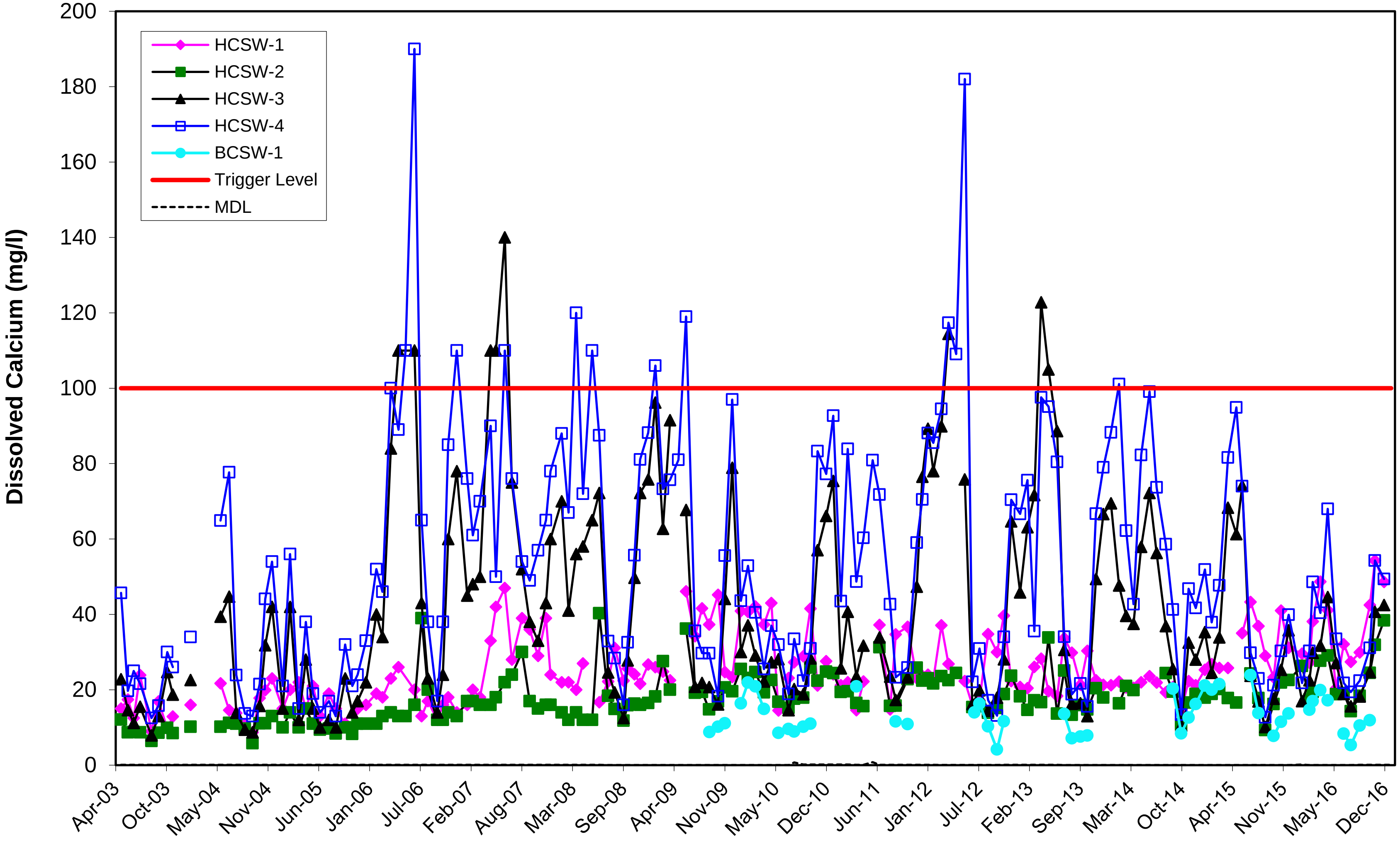


Figure C-13. **Dissolved calcium concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

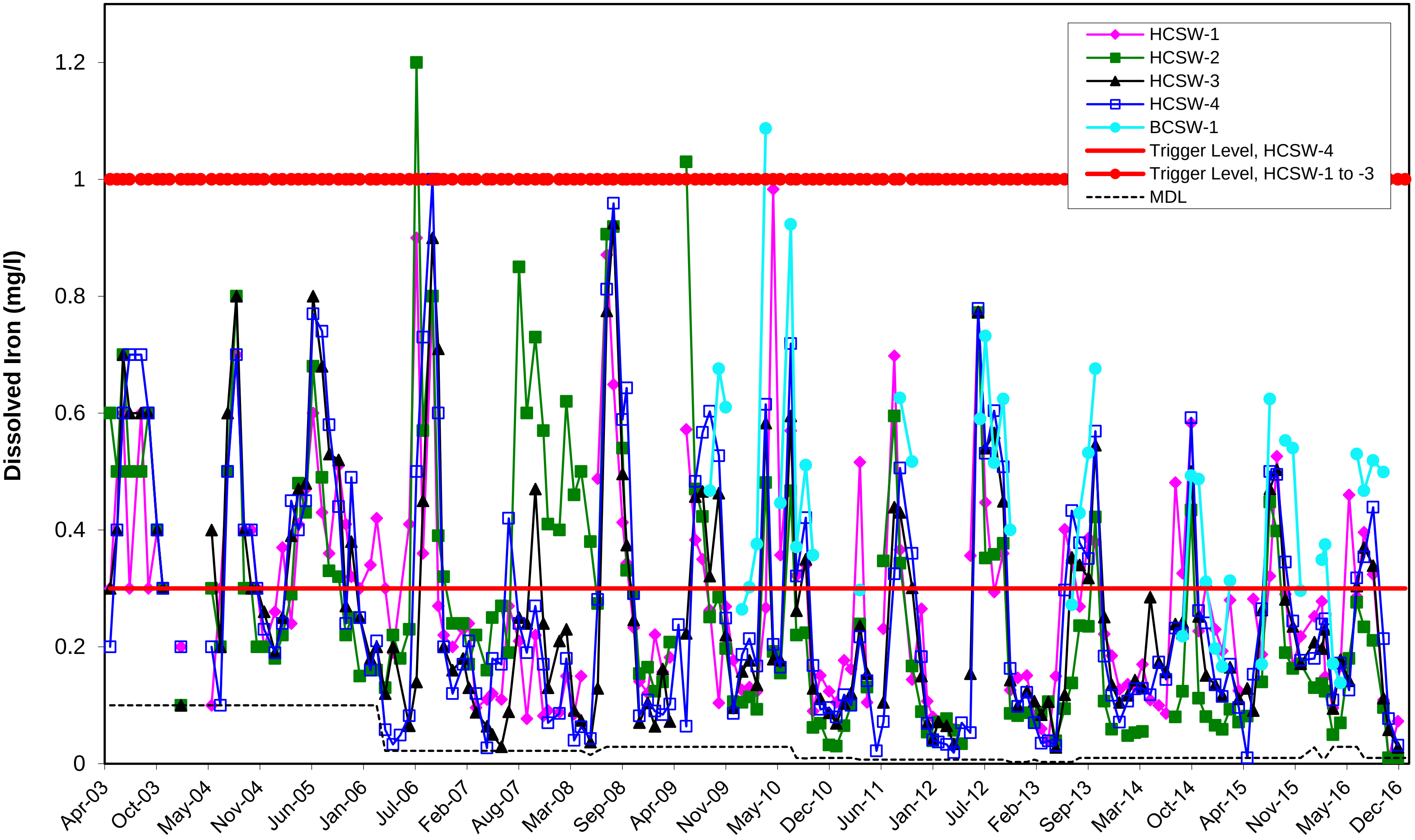


Figure C-14. Dissolved iron concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.

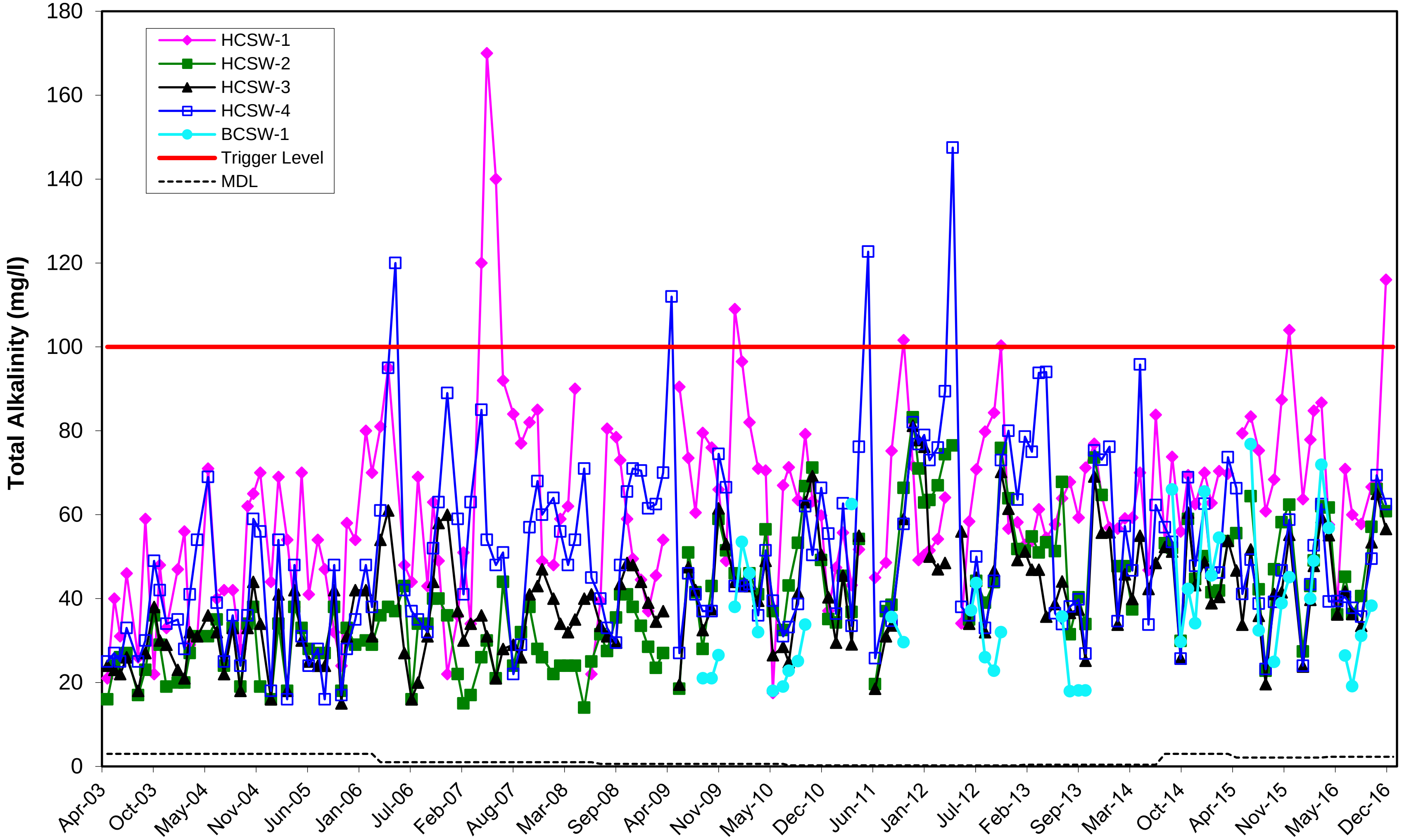


Figure C-15. **Total alkalinity concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

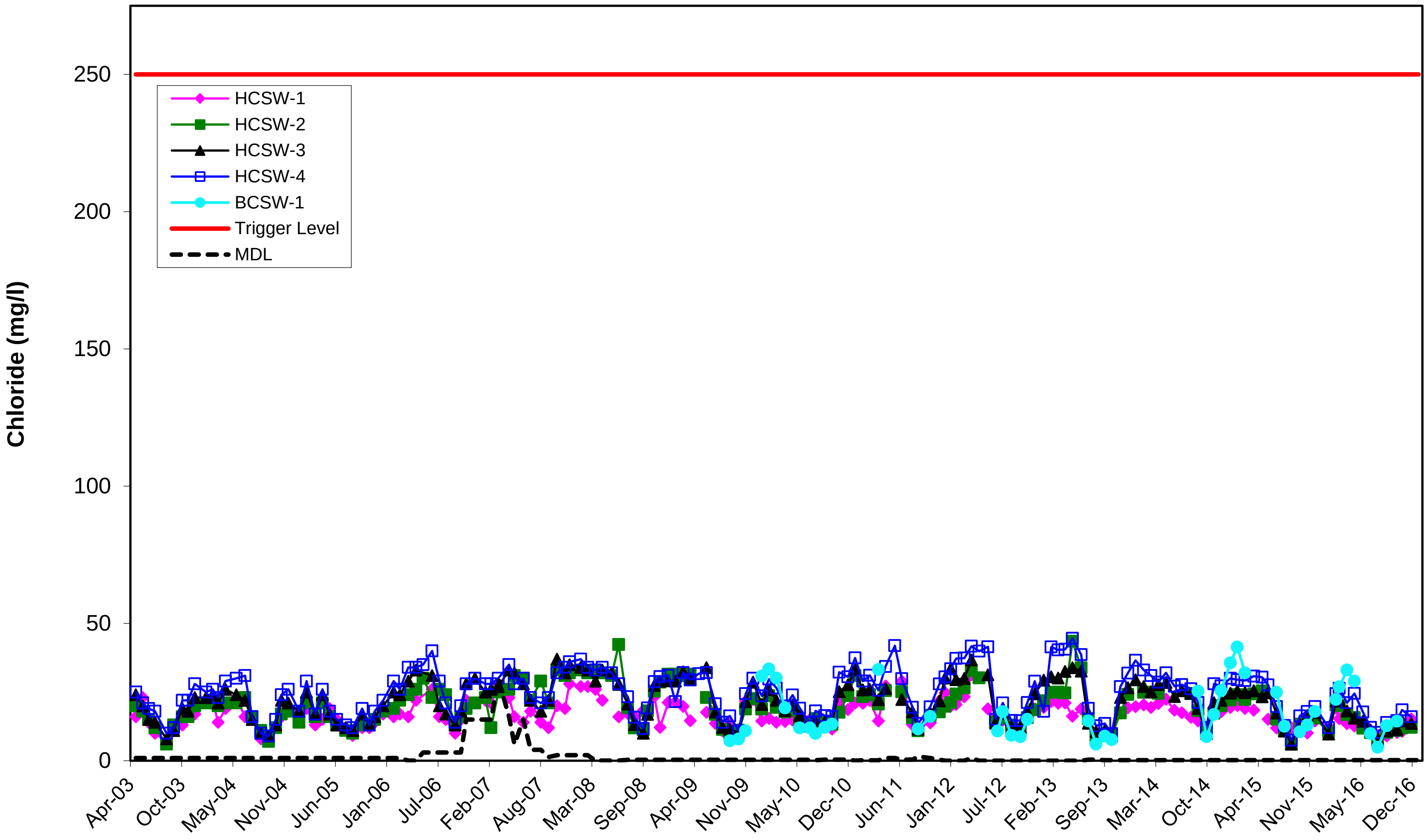


Figure C-16. **Chloride concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

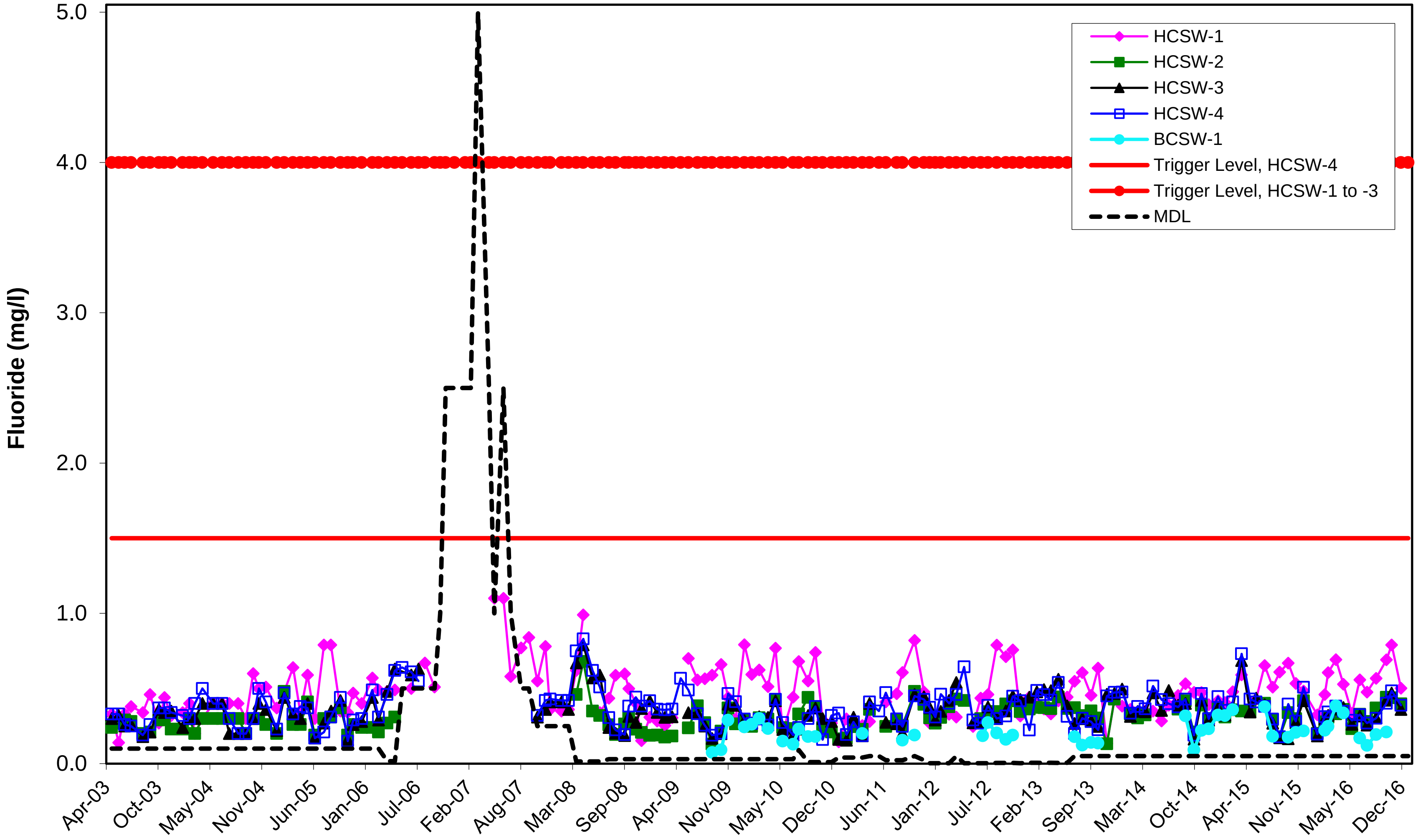


Figure C-17. **Fluoride concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

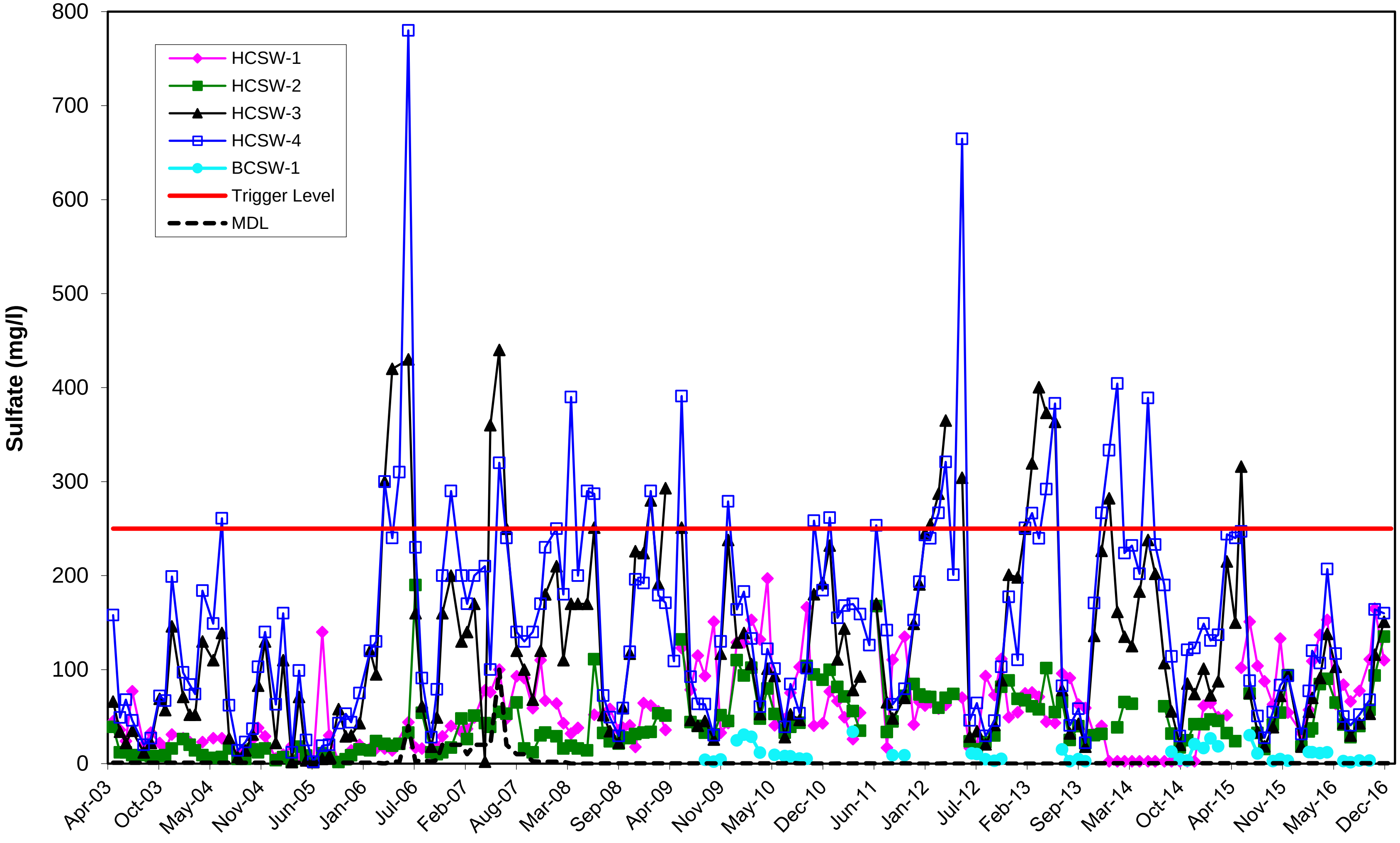


Figure C-18. **Sulfate concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

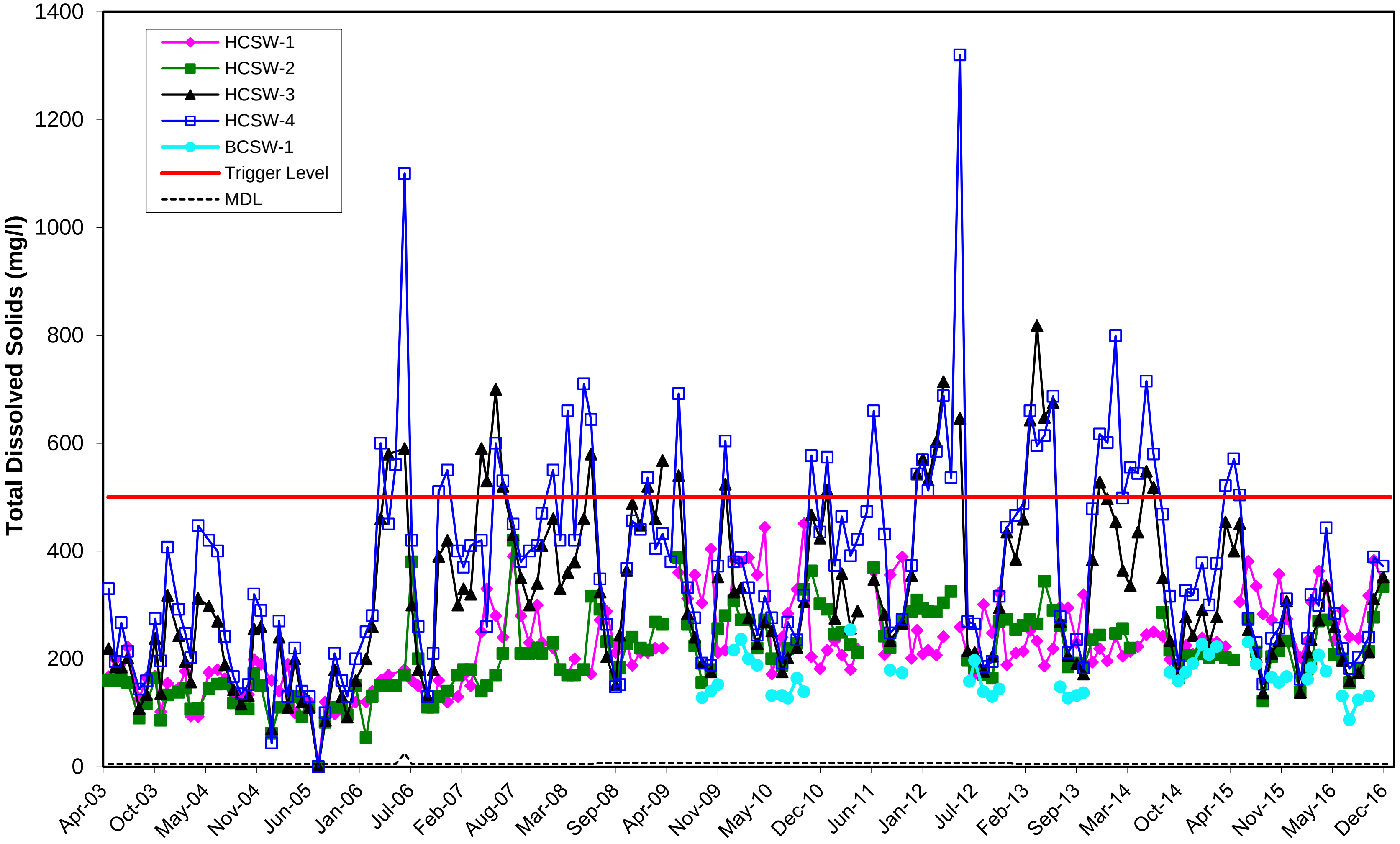


Figure C-19. Total dissolved solids concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.

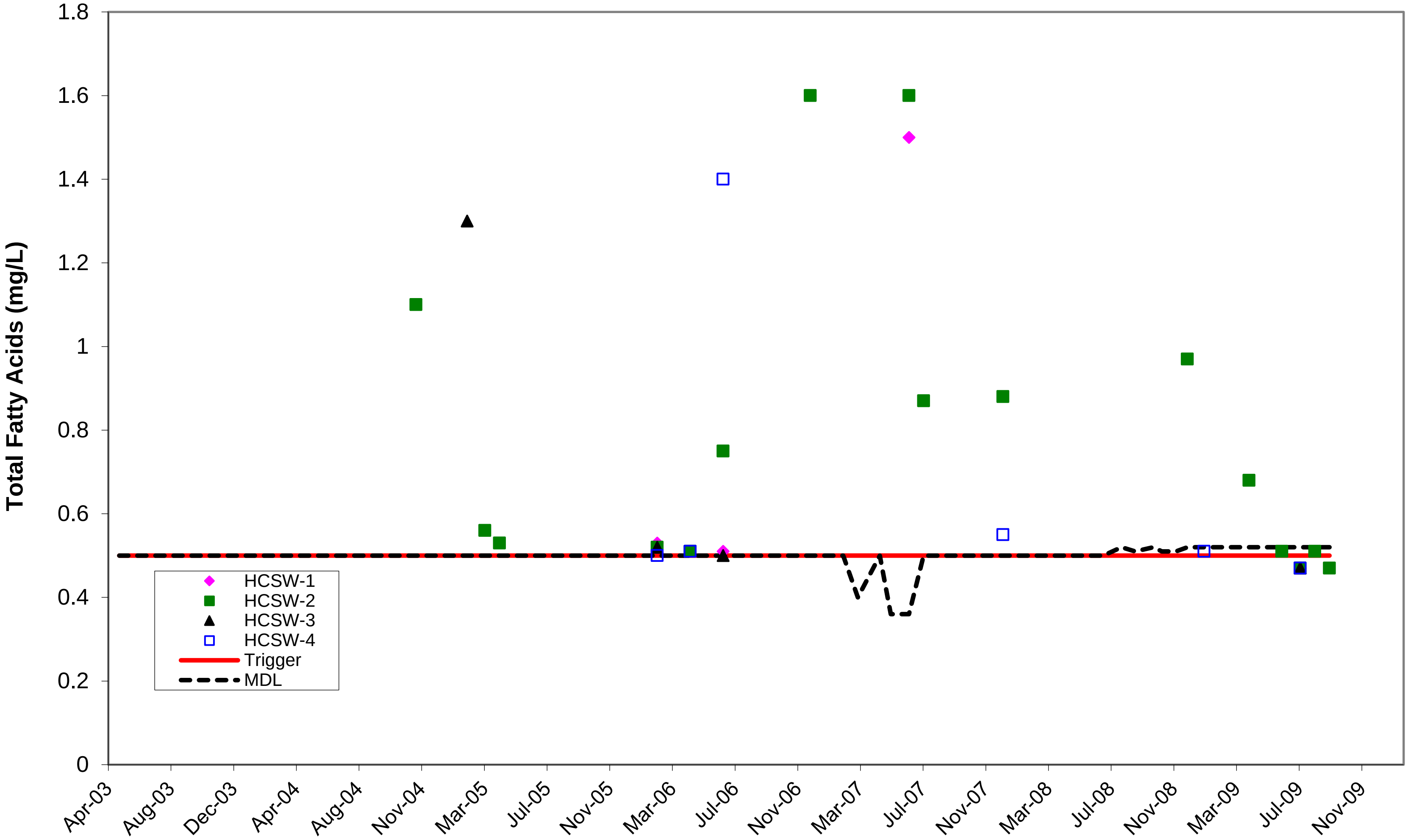


Figure C-20. **Total fatty acids (above MDL only) concentrations obtained during monthly HCSP water quality sampling from 2003 to 2009.**

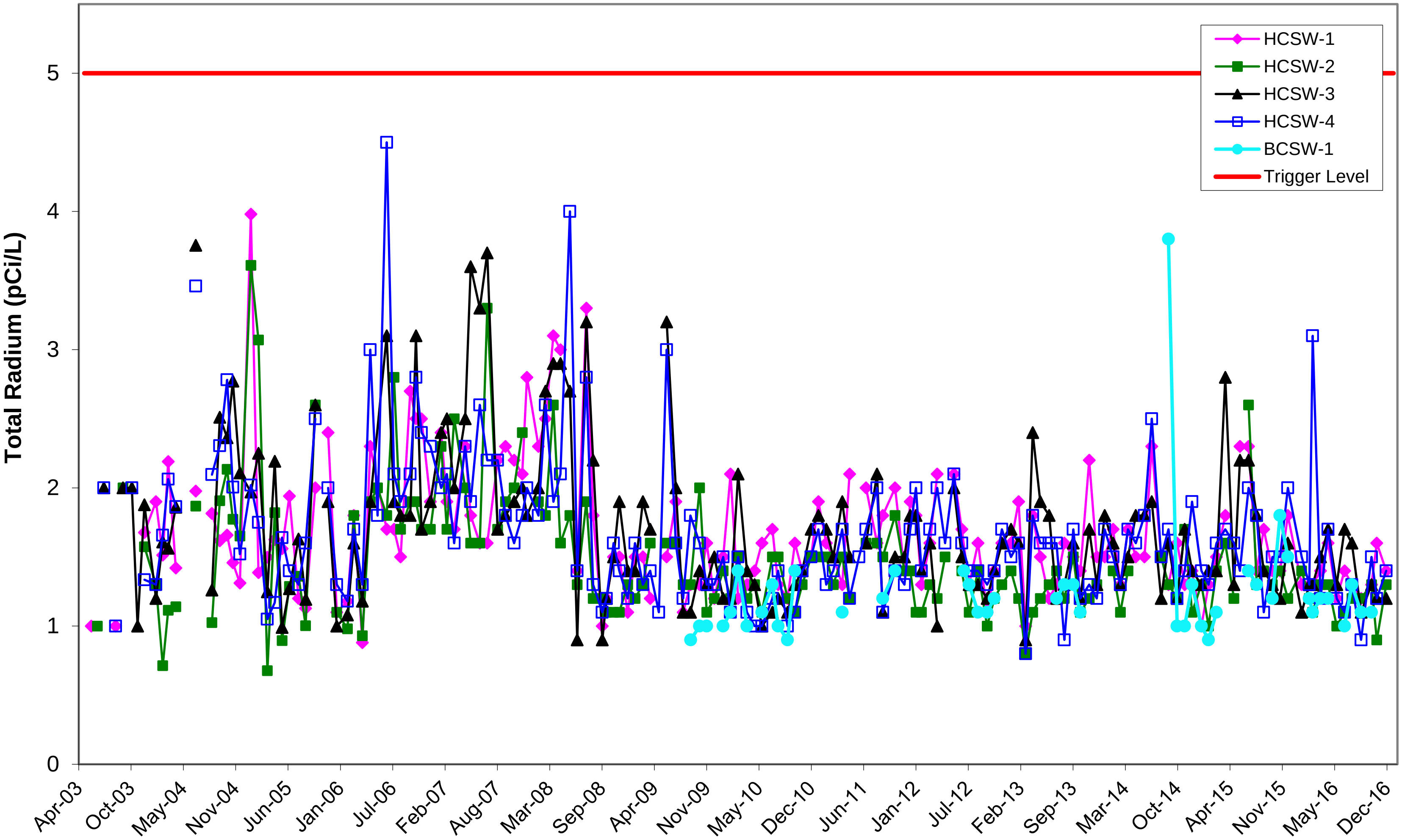


Figure C-21. **Levels of total radium (combination of radium 226 and radium 228) obtained during monthly HCSP water quality sampling from 2003 to 2016.**

C.2 Historical Water Quality Data Boxplots[1]: Public Sources (1990 to 2016) and HCSP (2003 to 2016)

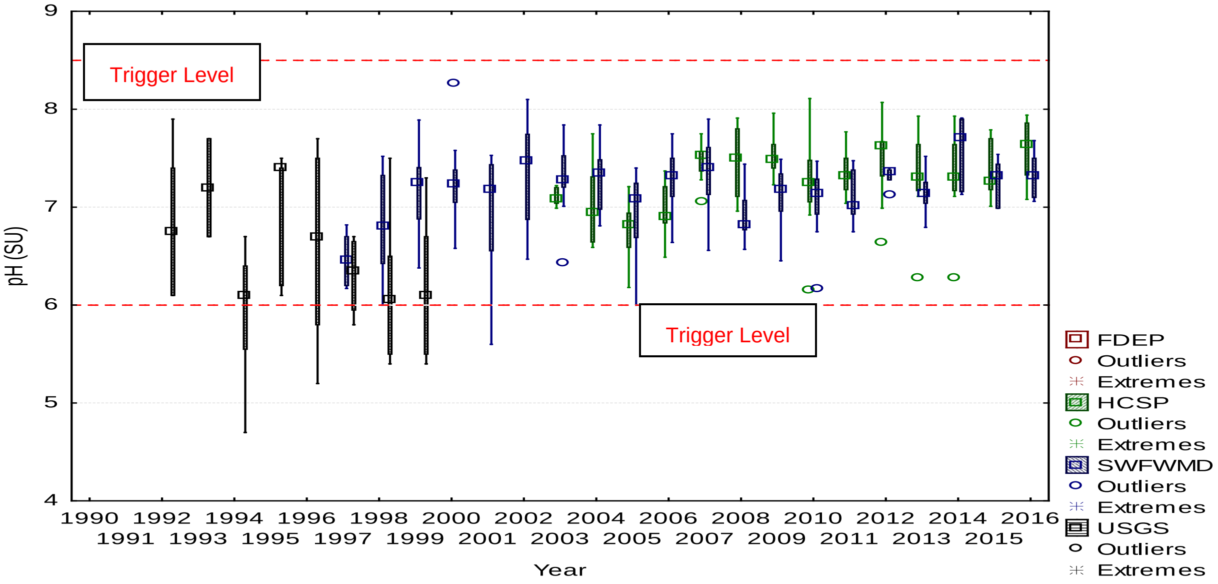


Figure C-22. HCSW-1 values of pH obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.

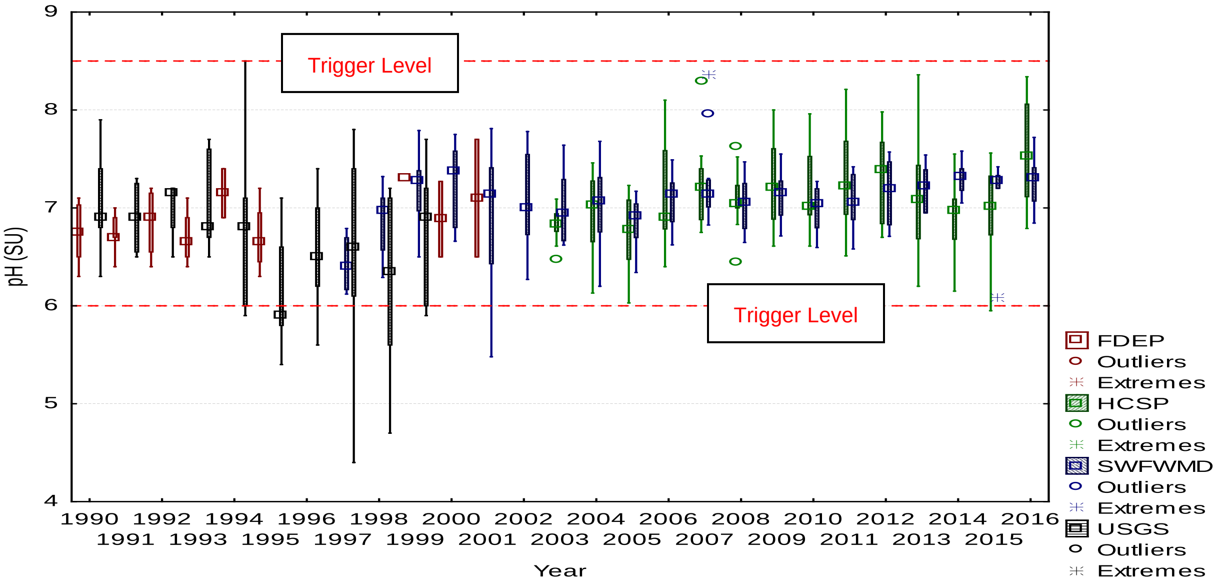


Figure C-23. HCSW-4 values of pH obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.

---

[1] In median box-and-whisker plots, the small center square is the median of the distribution, and the large box is bounded by the 25% (mean – standard error) and 75% (mean + standard error) quartiles of the distribution. The length of the large box is designated H, and the "whiskers" represent the range of values between the box limits and 1.5H above and below the box limits. Outside the whiskers lie outliers and extreme values. Outliers are values that lie between 1.5H and 3H from the box limits, and extreme values lie beyond 3H from the box limits (StatSoft, Inc 2005).

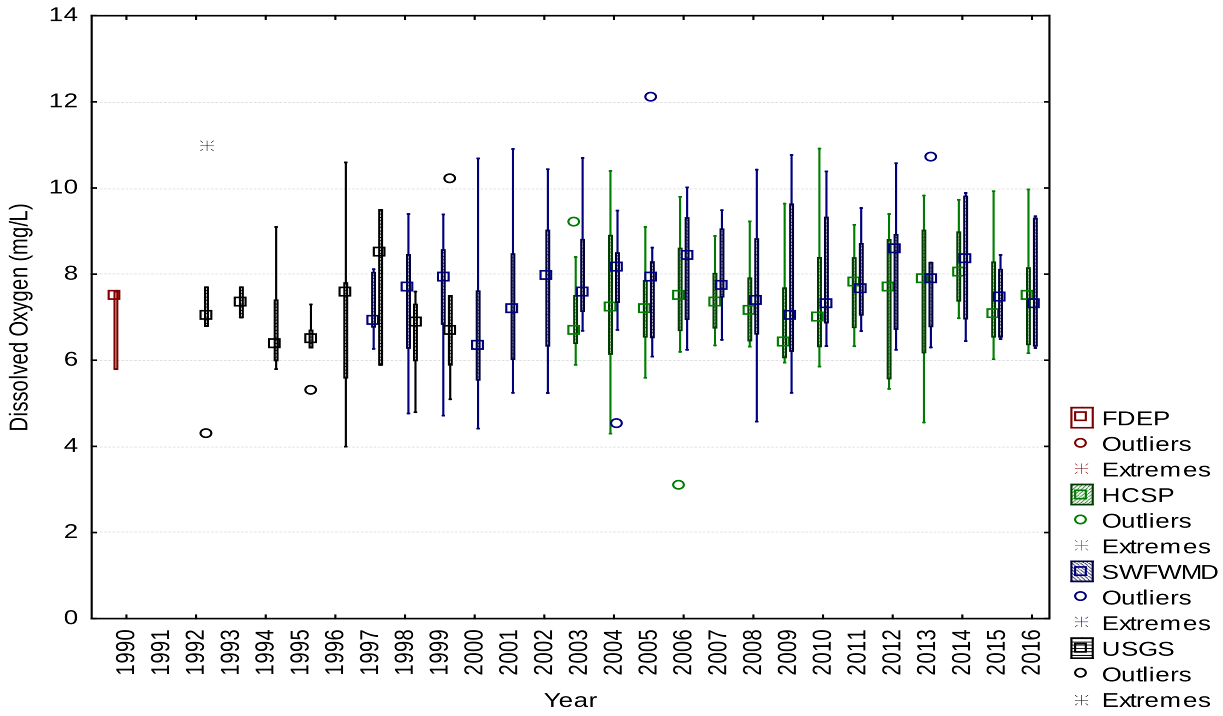


Figure C-24. **HCSW-1 DO concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

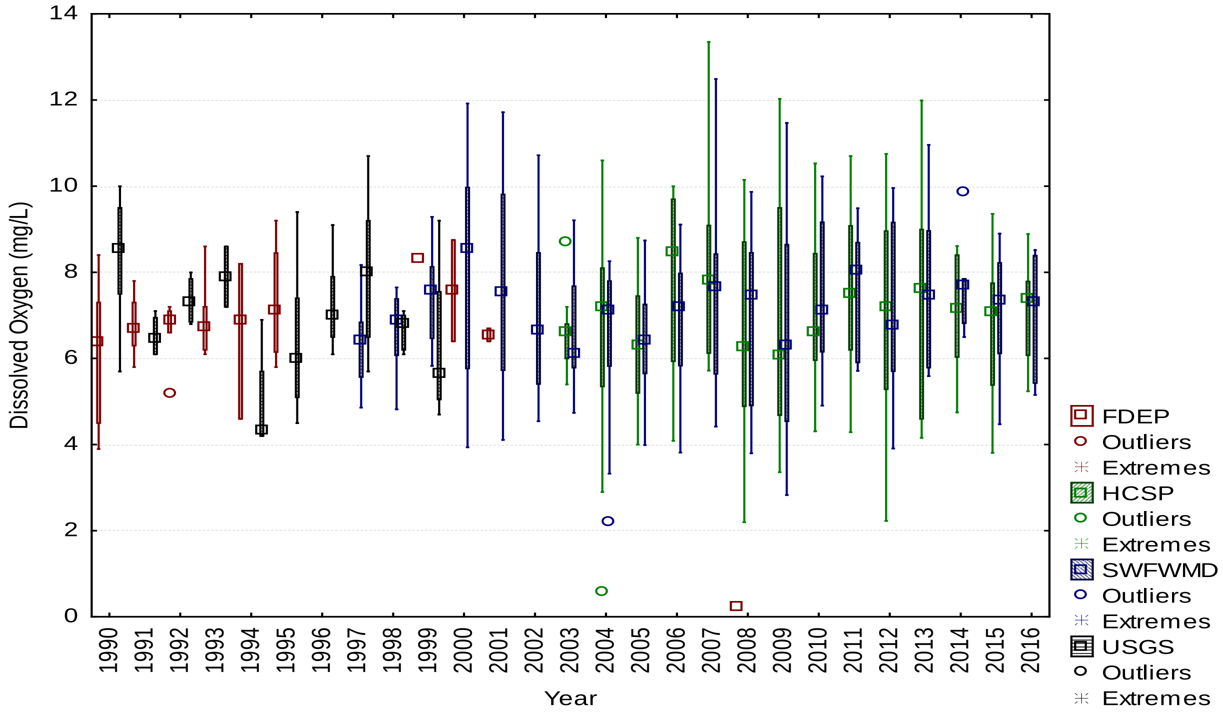


Figure C-25. **HCSW-4 DO concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

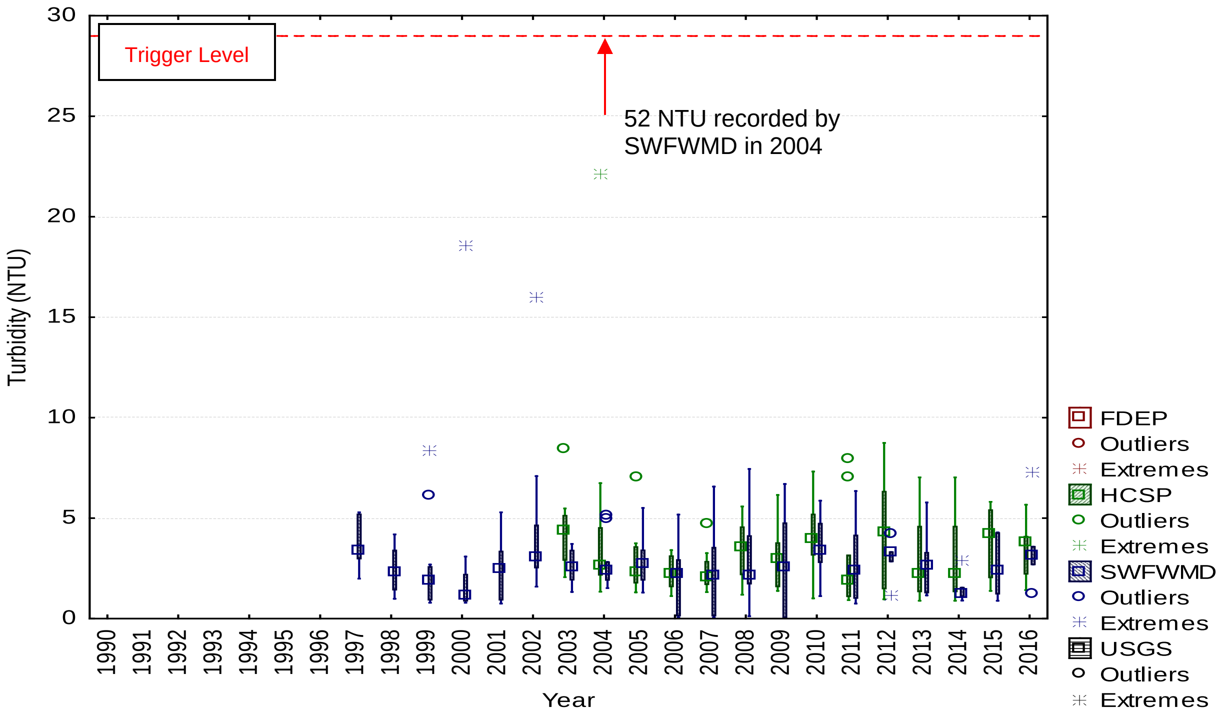


Figure C-26. HCSW-1 values of turbidity obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.

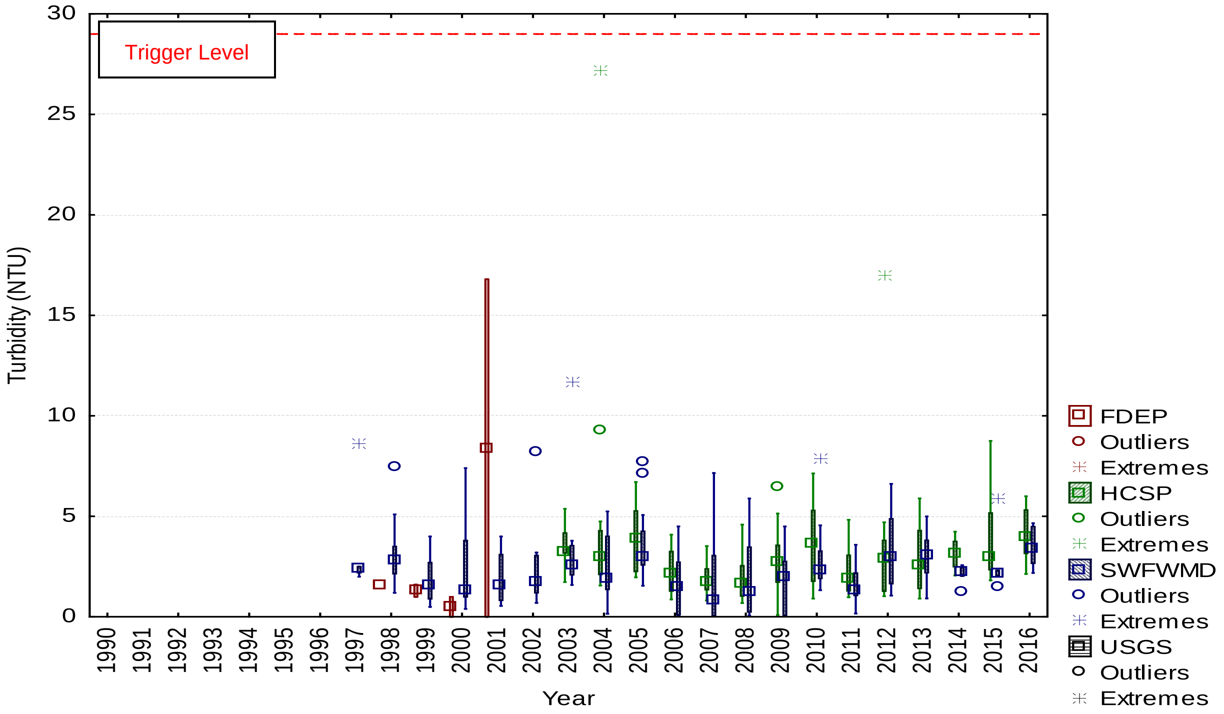


Figure C-27. HCSW-4 values of turbidity obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.

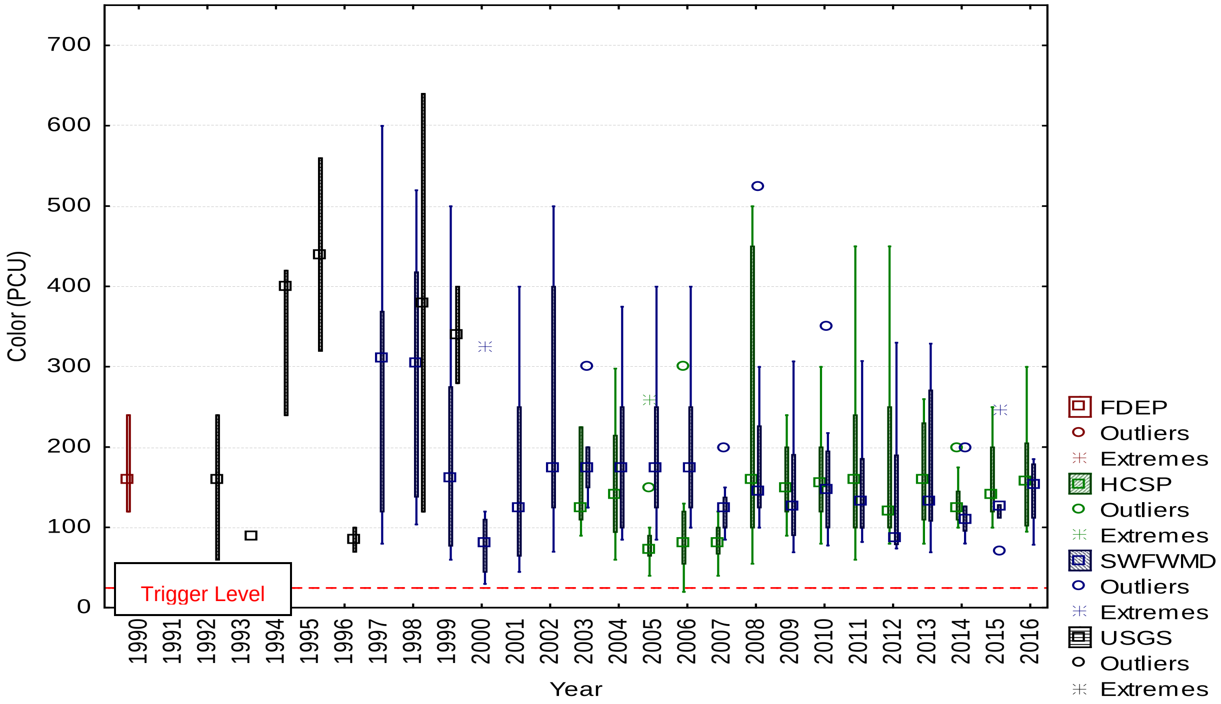


Figure C-28. HCSW-1 values of color obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.

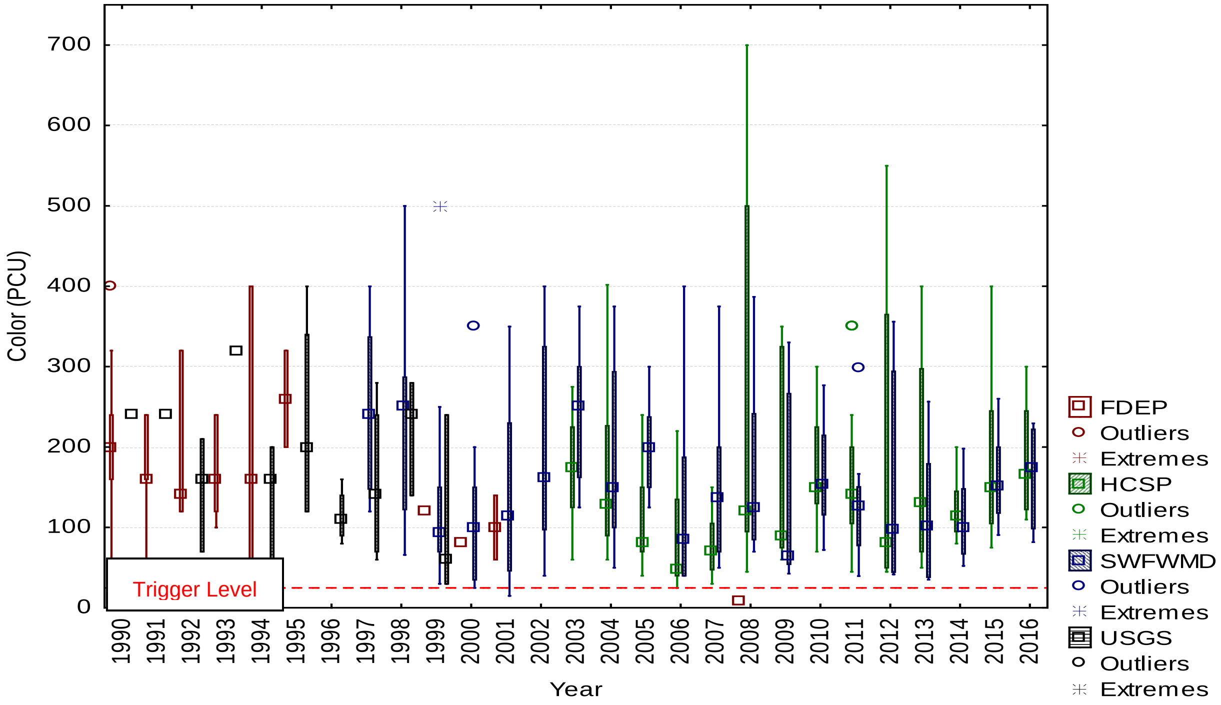


Figure C-29. HCSW-4 values of color obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.

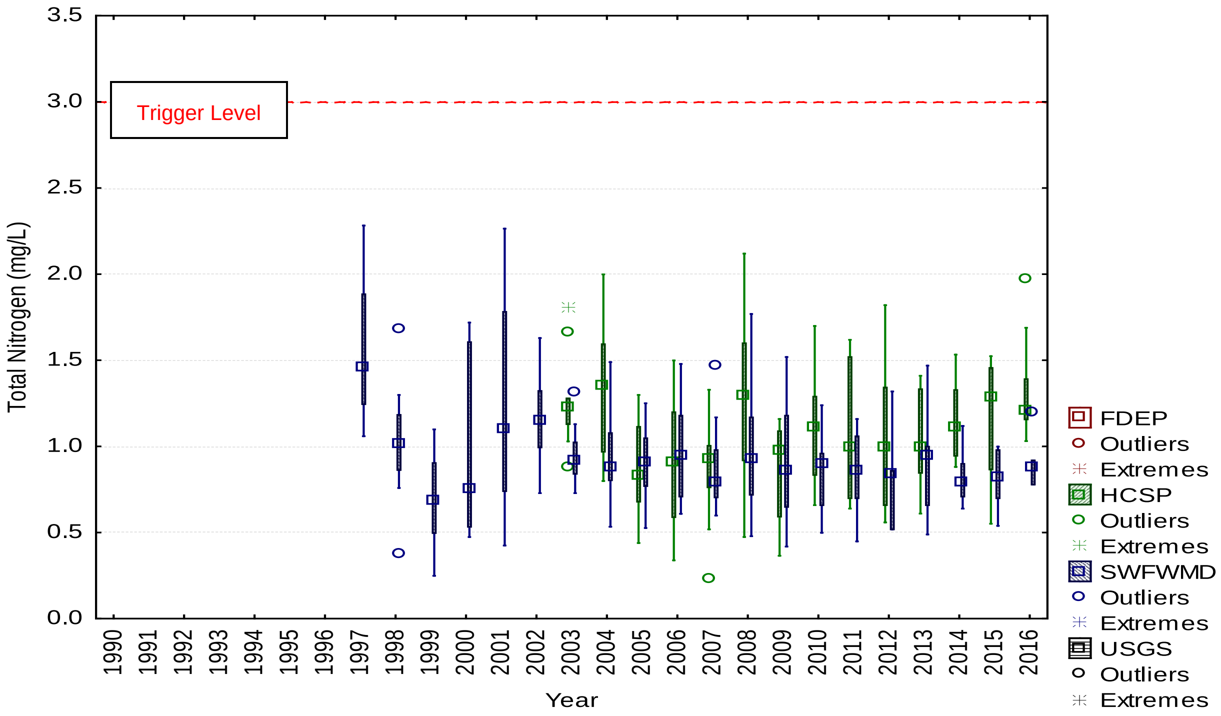


Figure C-30. **HCSW-1 total nitrogen concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

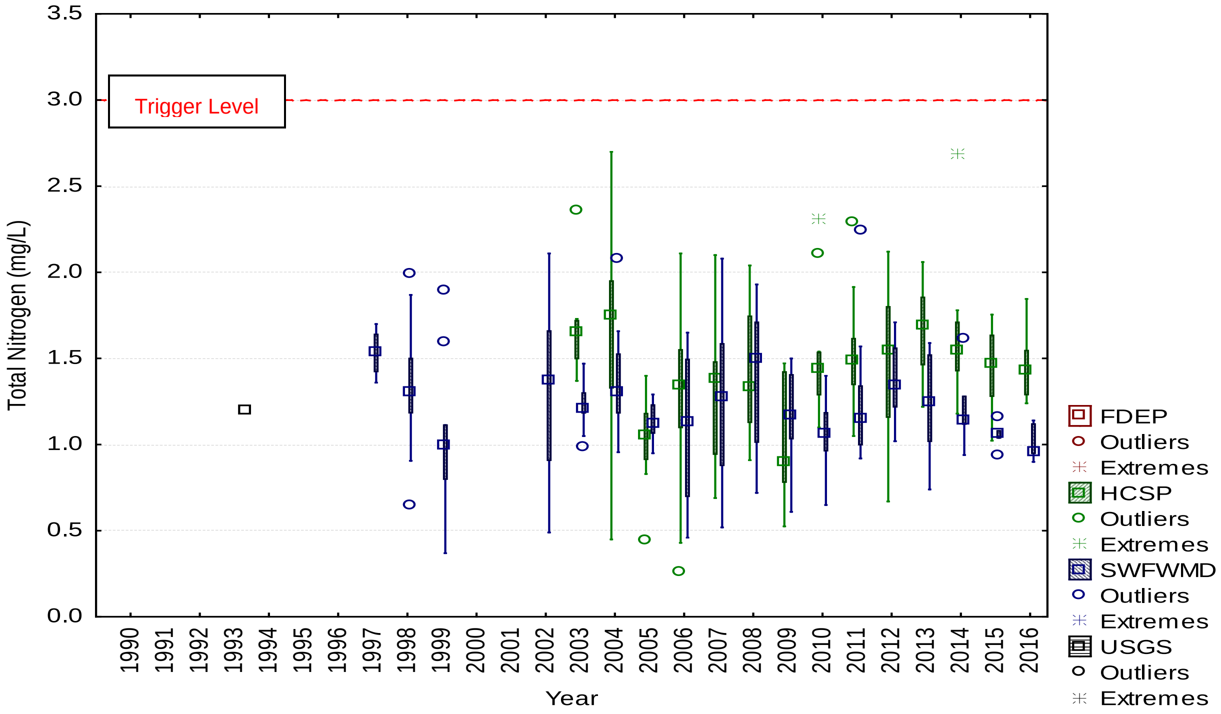


Figure C-31. **HCSW-4 total nitrogen concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

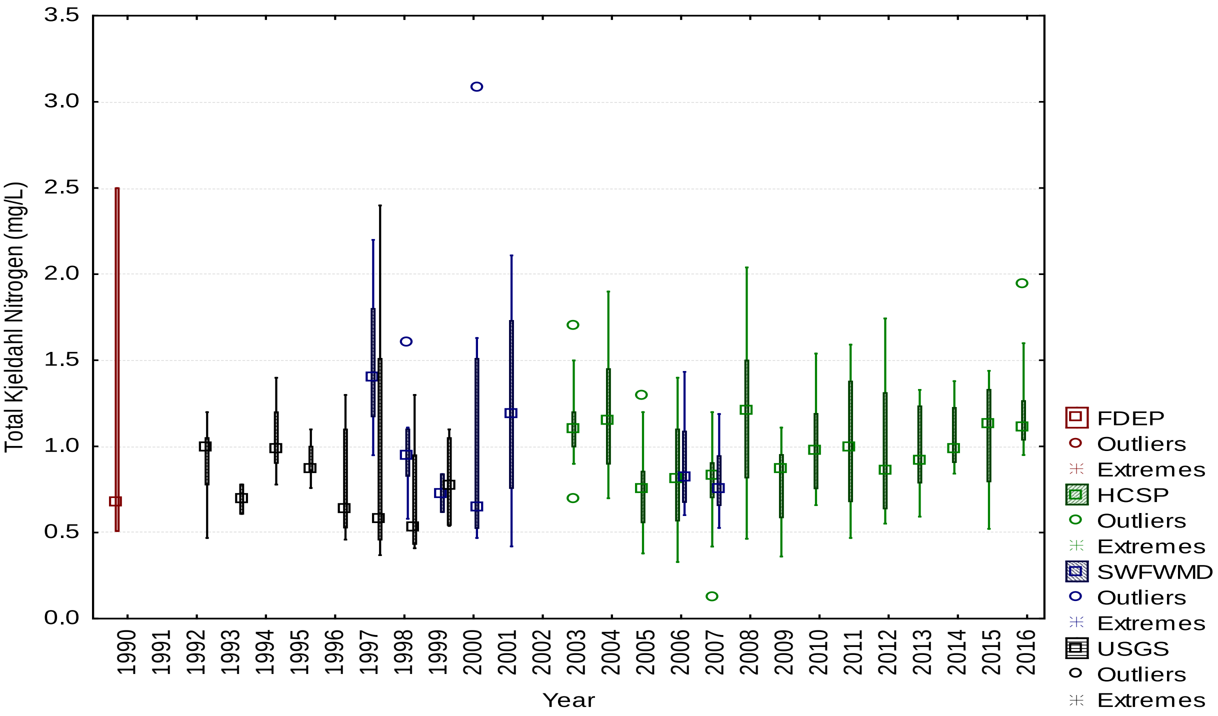


Figure C-32. **HCSW-1 TKN concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

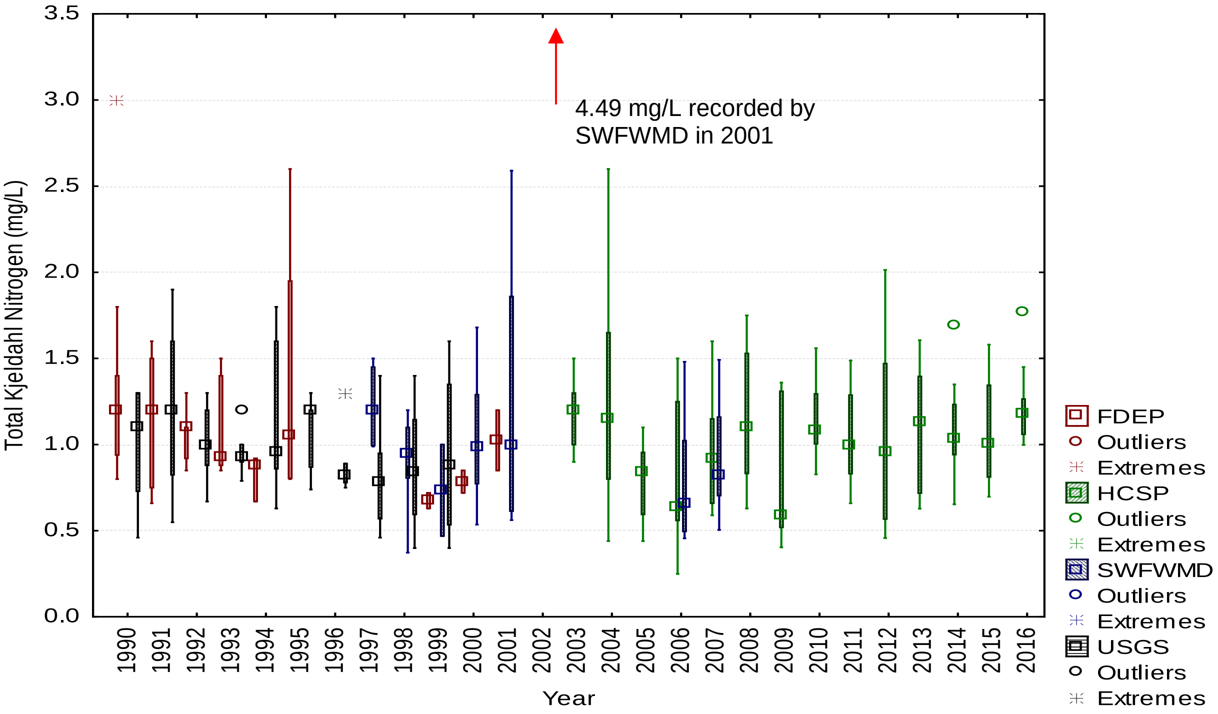


Figure C-33. **HCSW-4 TKN concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

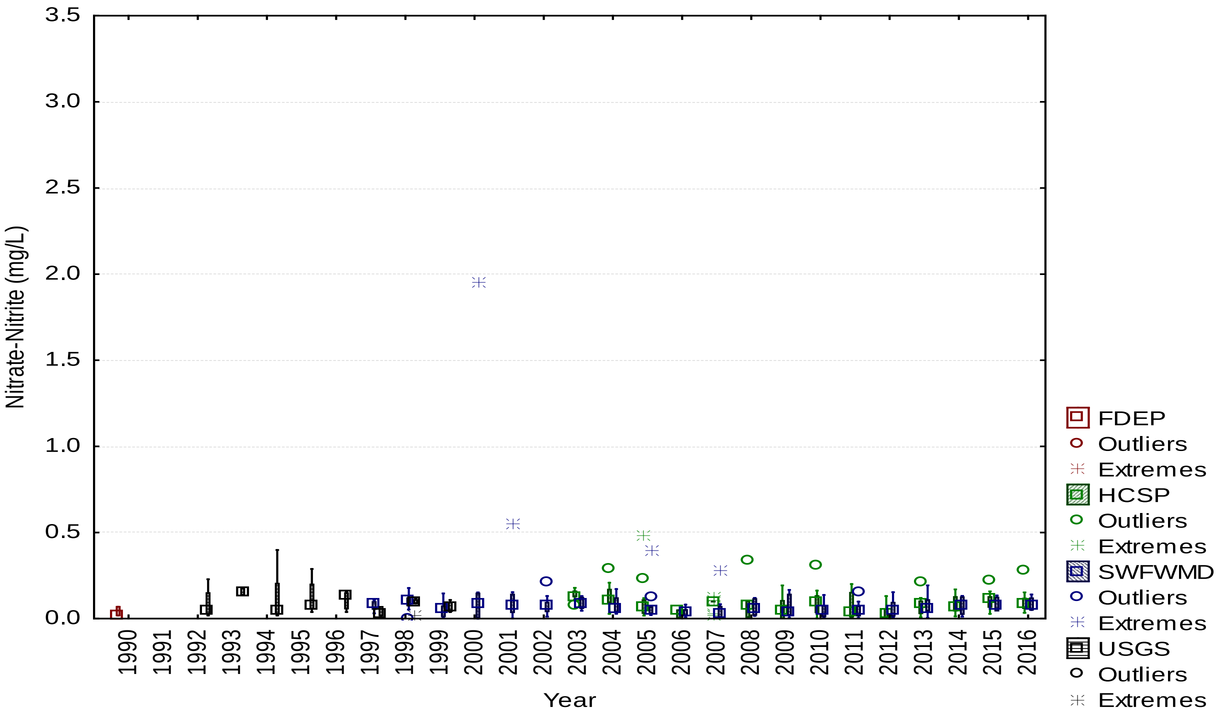


Figure C-34. HCSW-1 nitrate-nitrite concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.

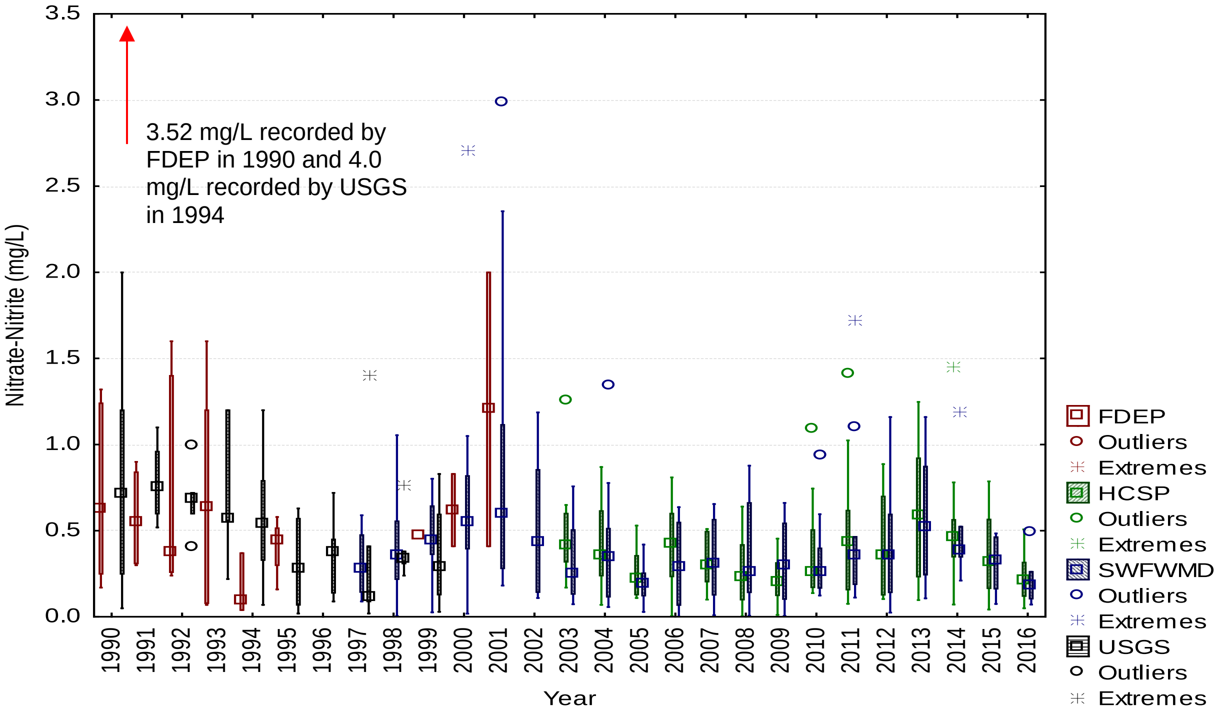


Figure C-35. HCSW-4 nitrate-nitrite concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.

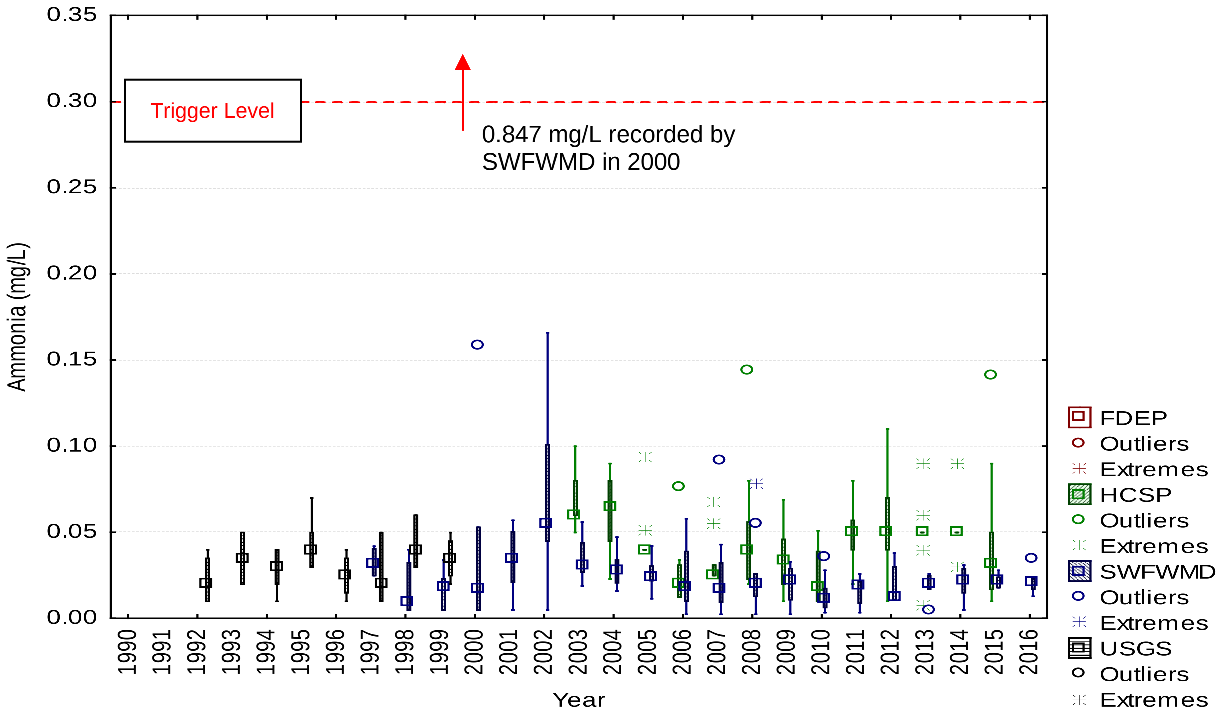


Figure C-36. **HCSW-1 ammonia concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

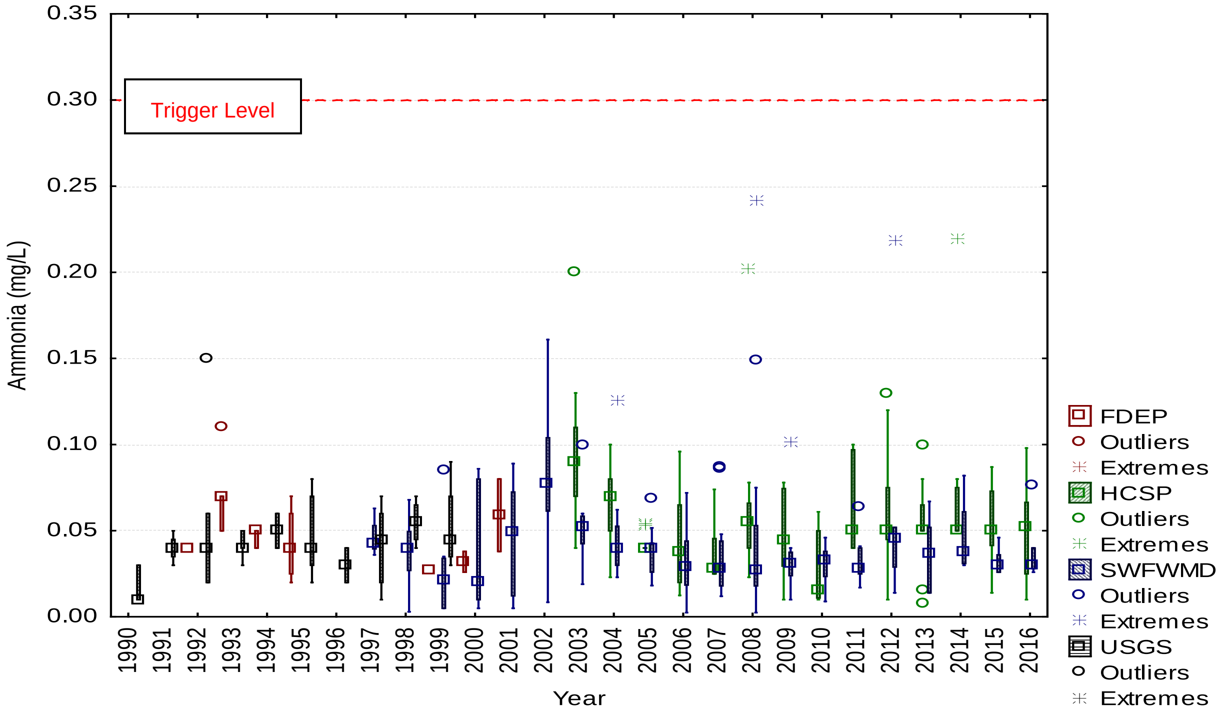


Figure C-37. **HCSW-4 ammonia concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

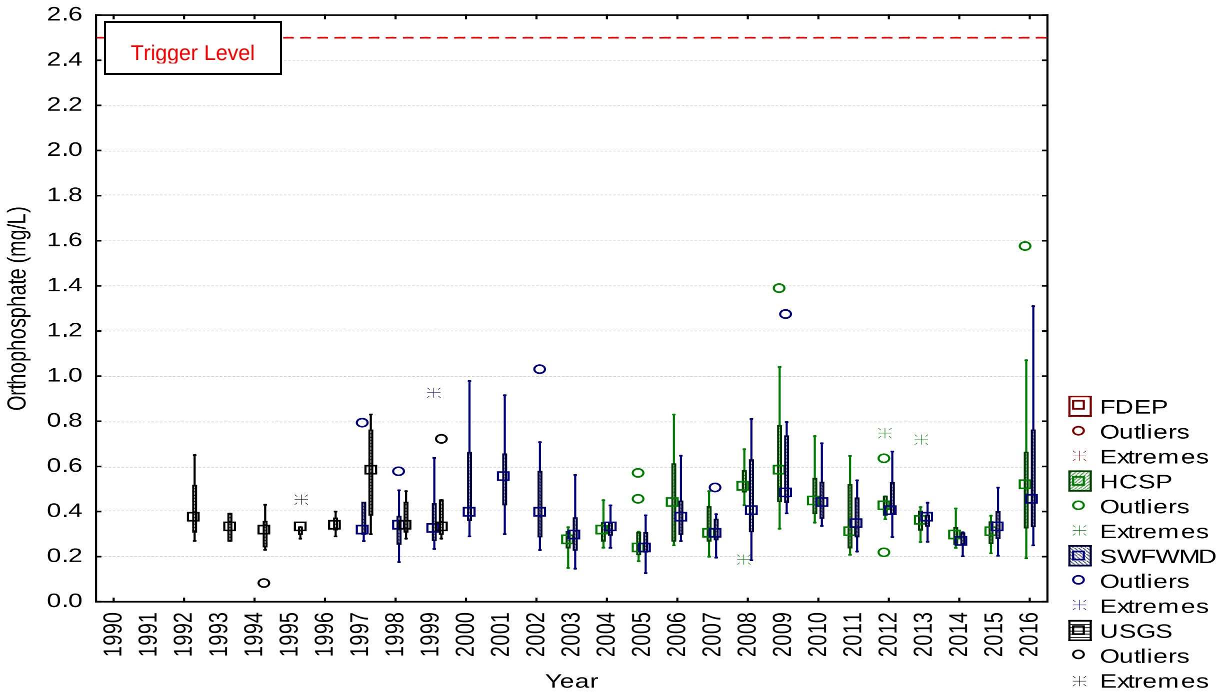


Figure C-38. HCSW-1 orthophosphate concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.

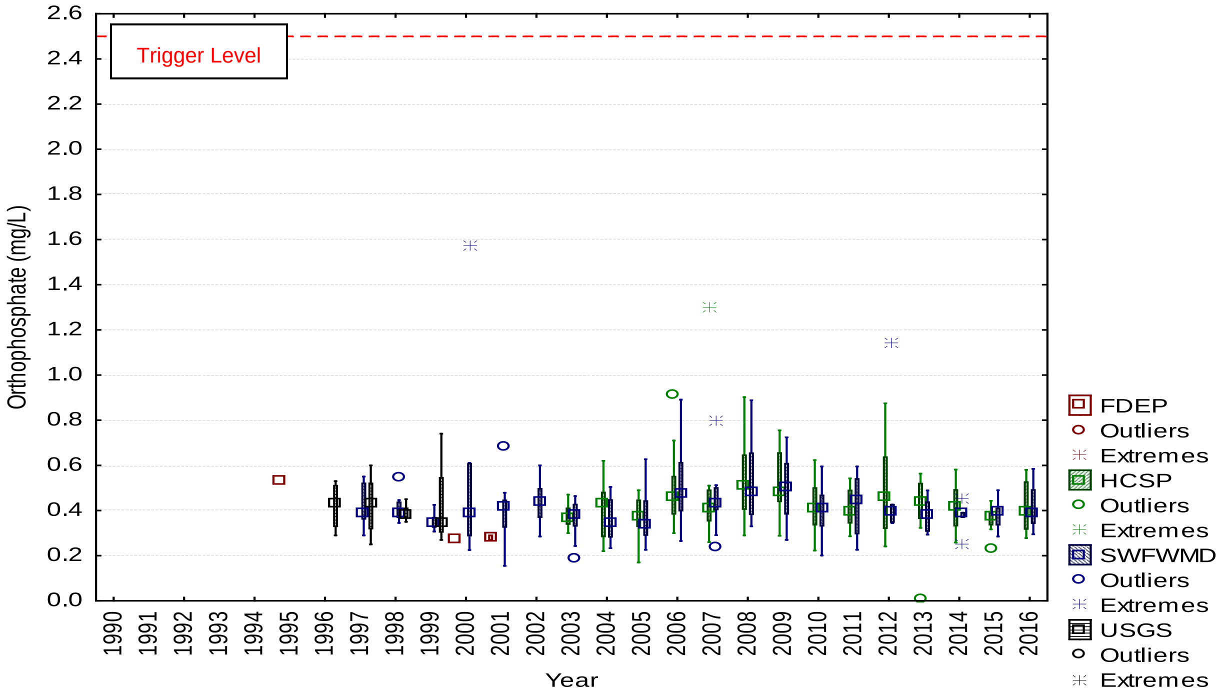


Figure C-39. HCSW-4 orthophosphate concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.

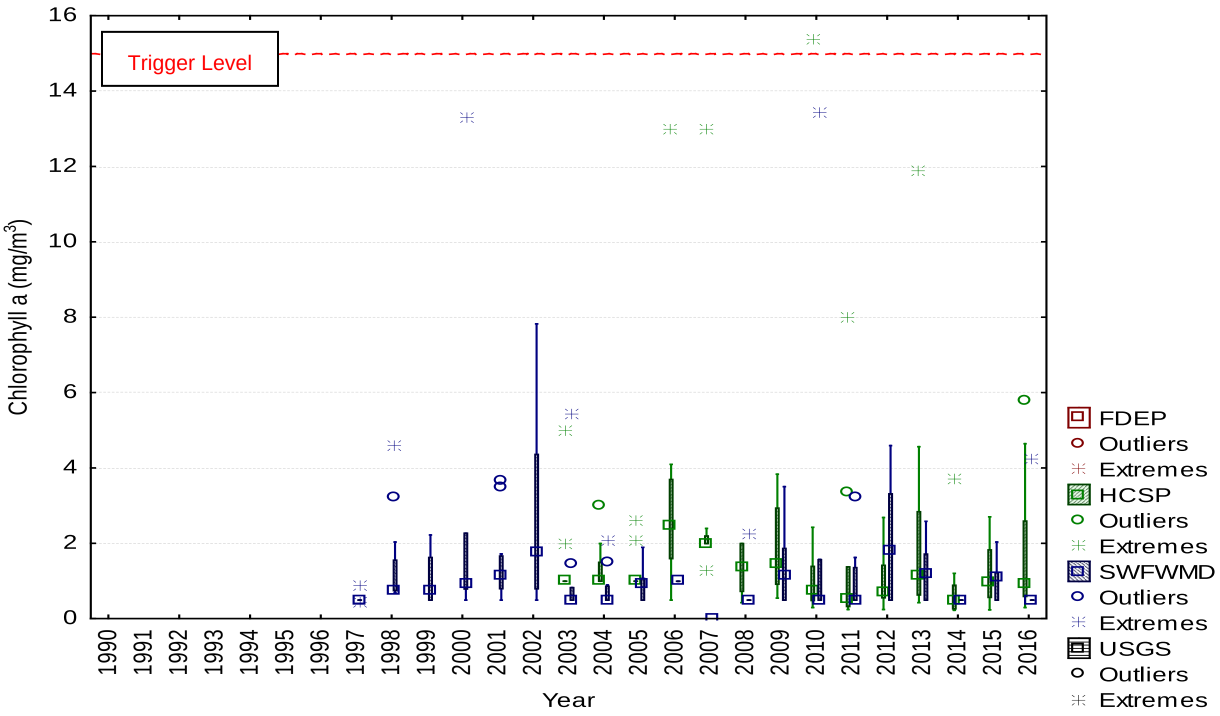


Figure C-40. **HCSW-1 chlorophyll-*a* concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

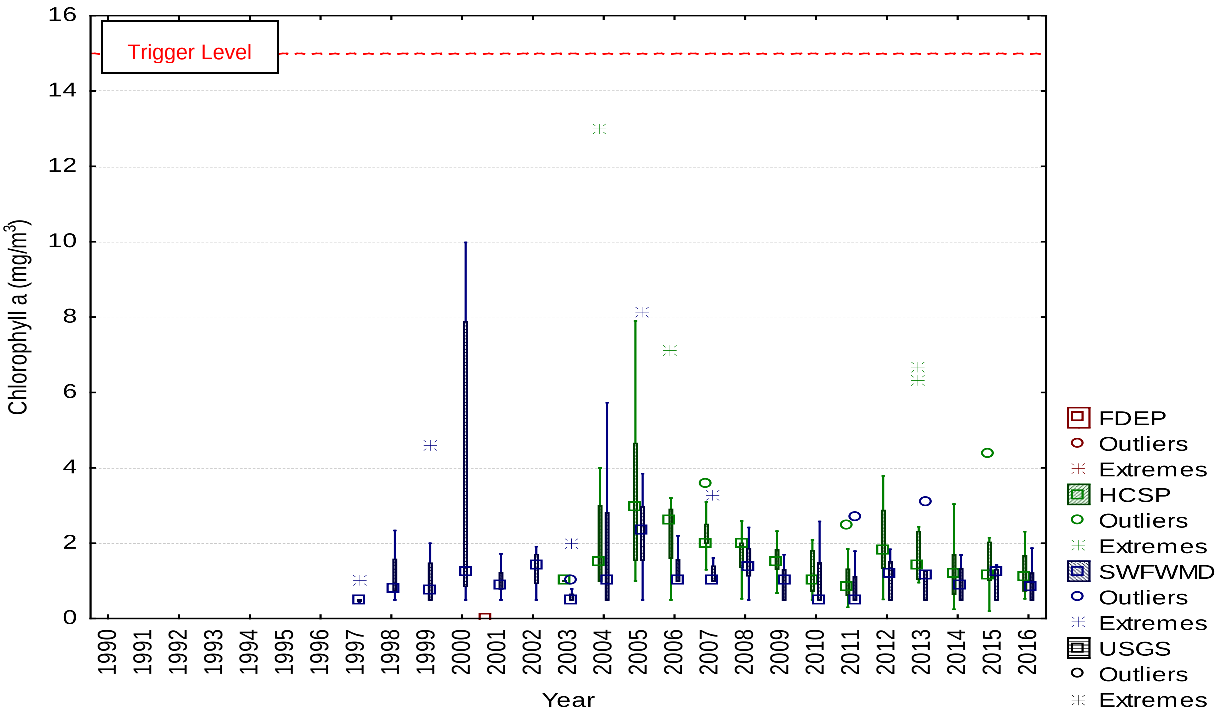


Figure C-41. **HCSW-4 chlorophyll-*a* concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

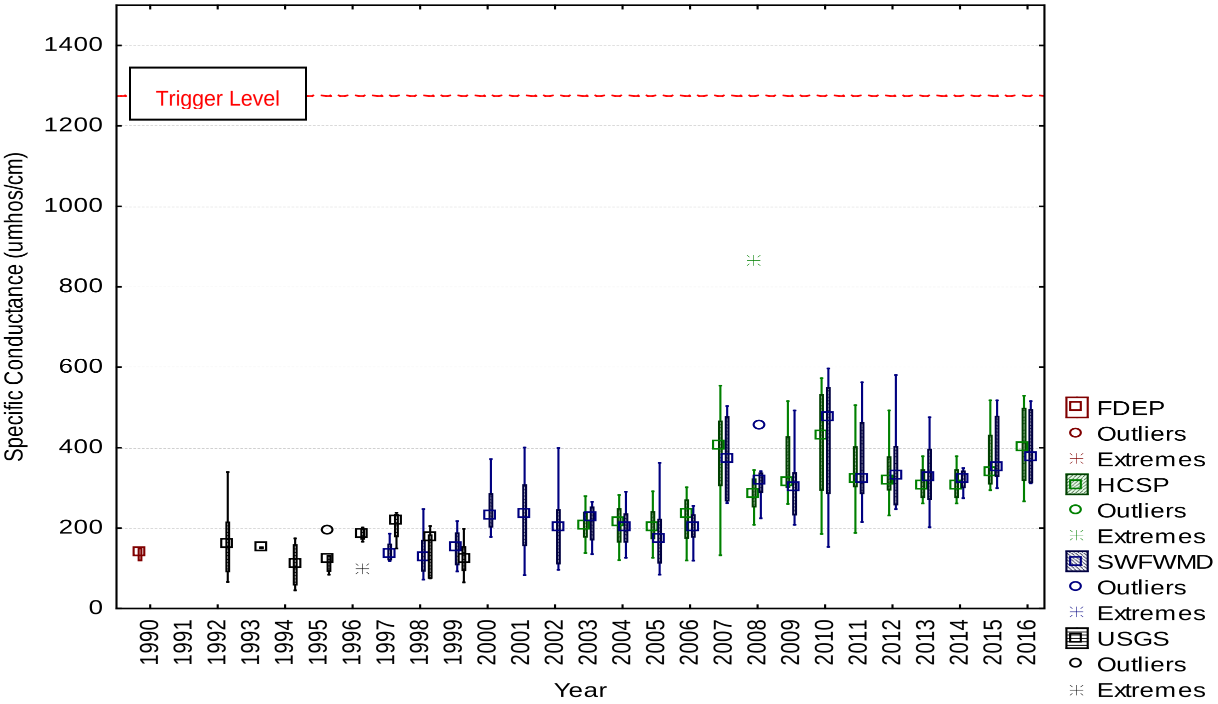


Figure C-42. **HCSW-1 values of SC obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

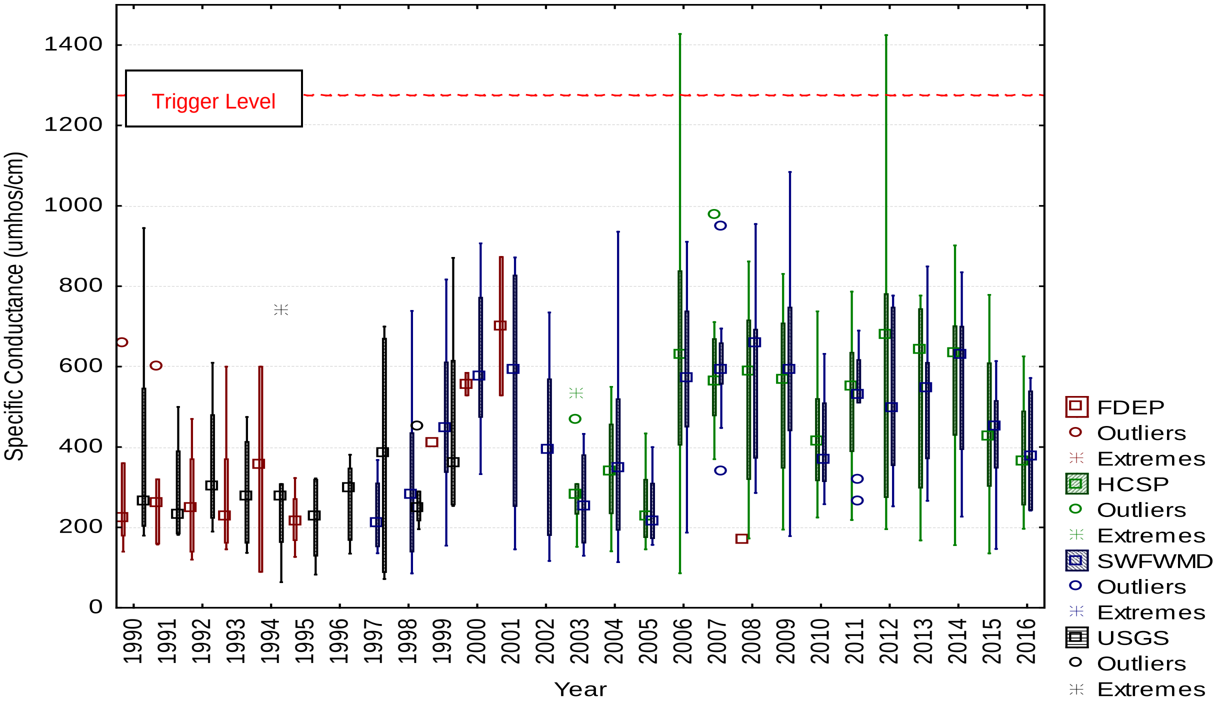


Figure C-43. **HCSW-4 values of SC obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

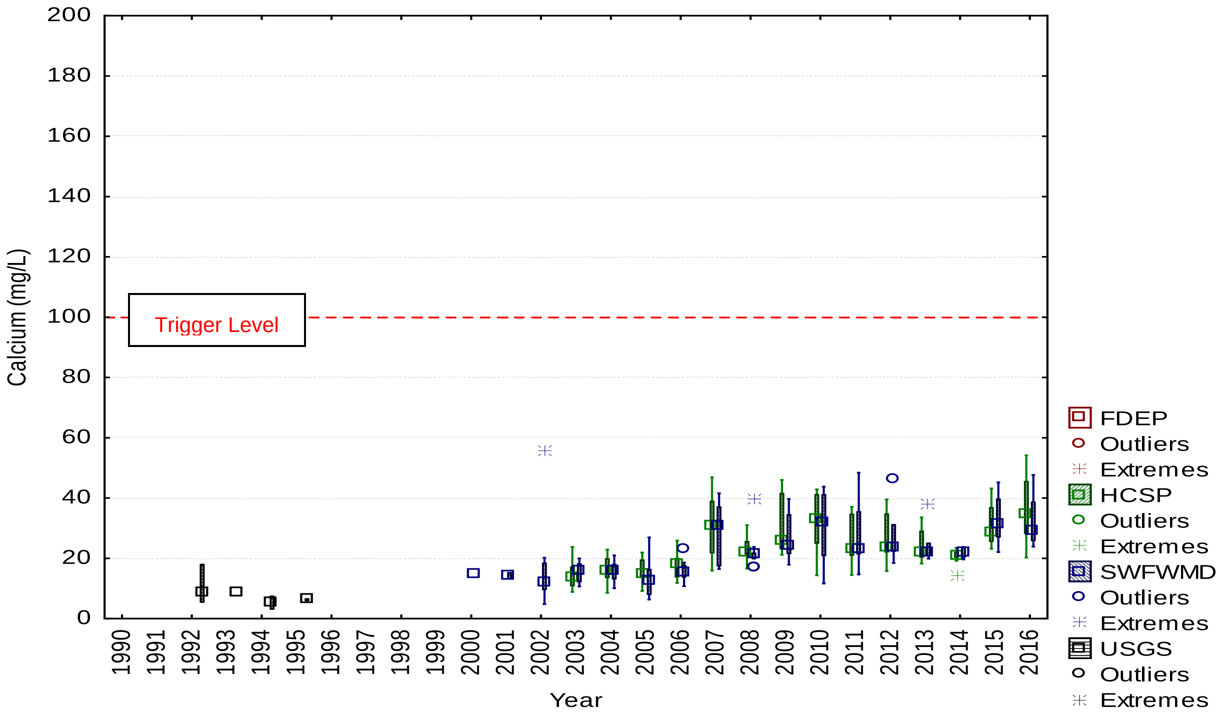


Figure C-44. **HCSW-1 calcium concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

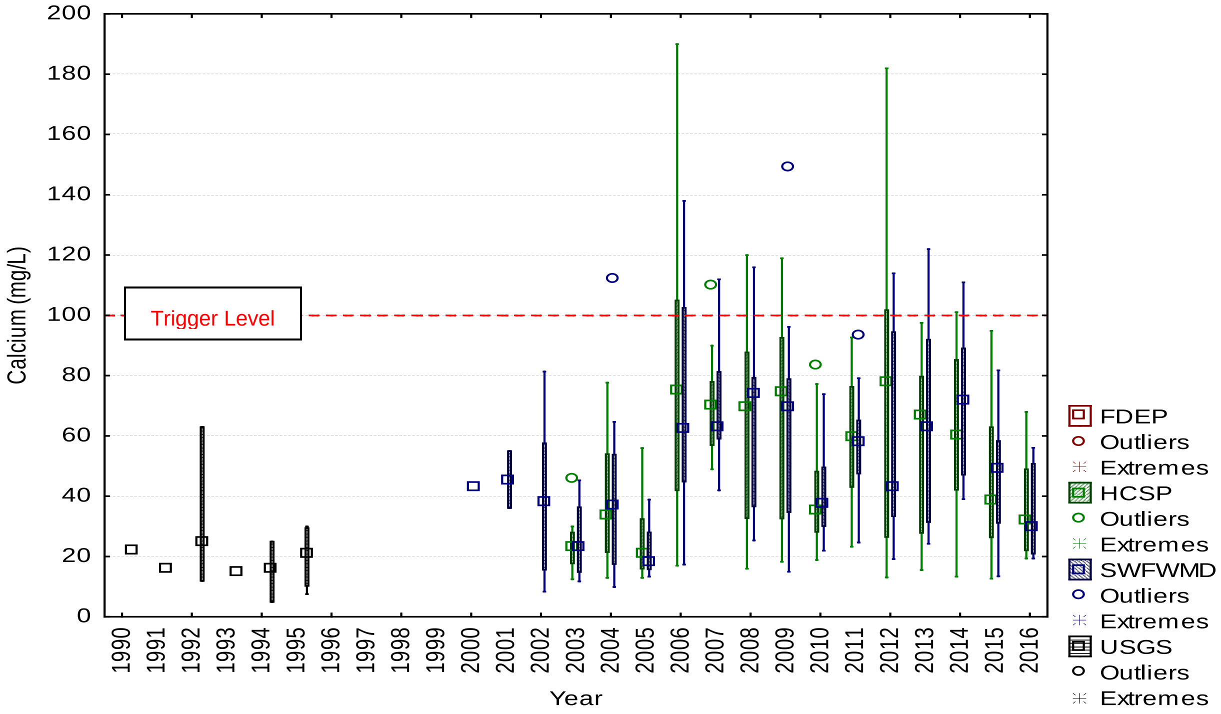


Figure C-45. **HCSW-4 calcium concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

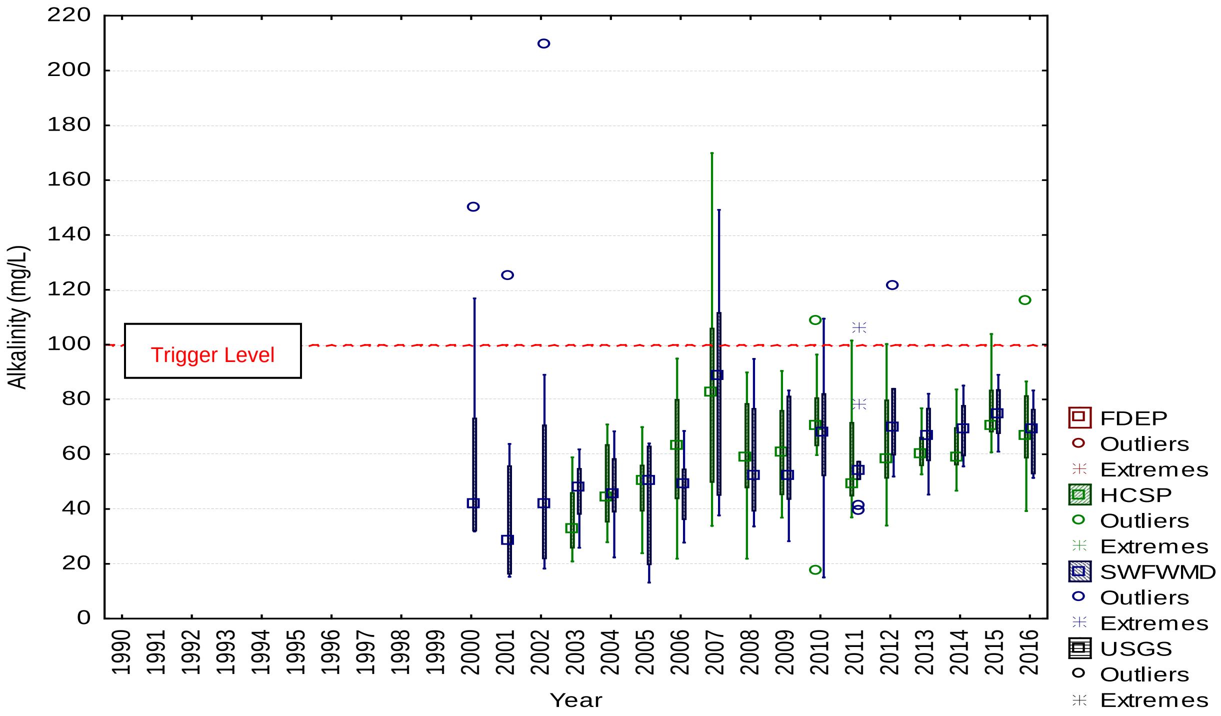


Figure C-46. **HCSW-1 alkalinity concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

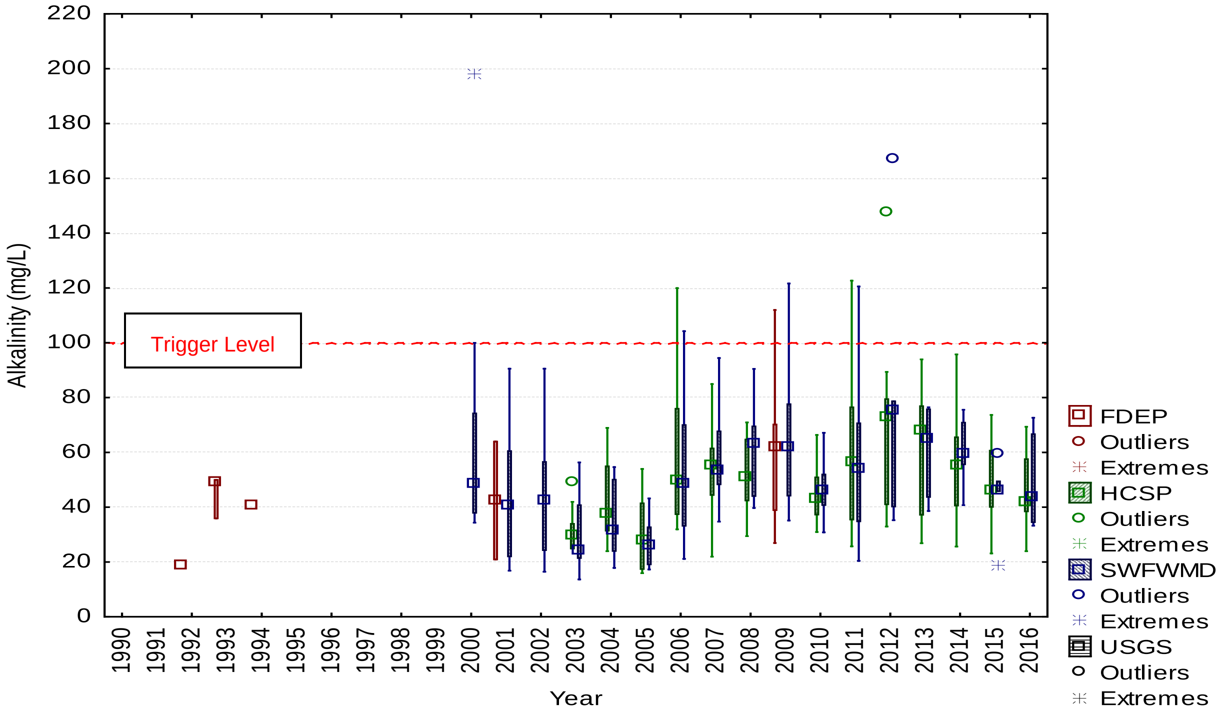


Figure C-47. **HCSW-4 alkalinity concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

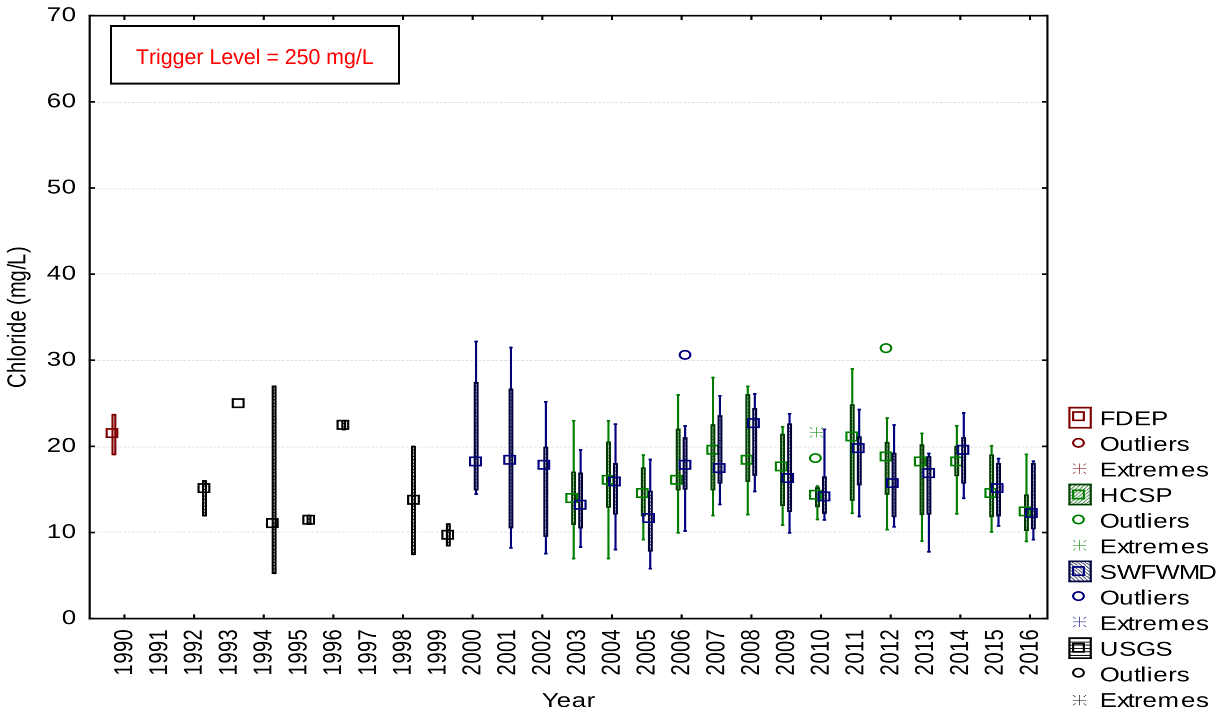


Figure C-48. HCSW-1 chloride concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.

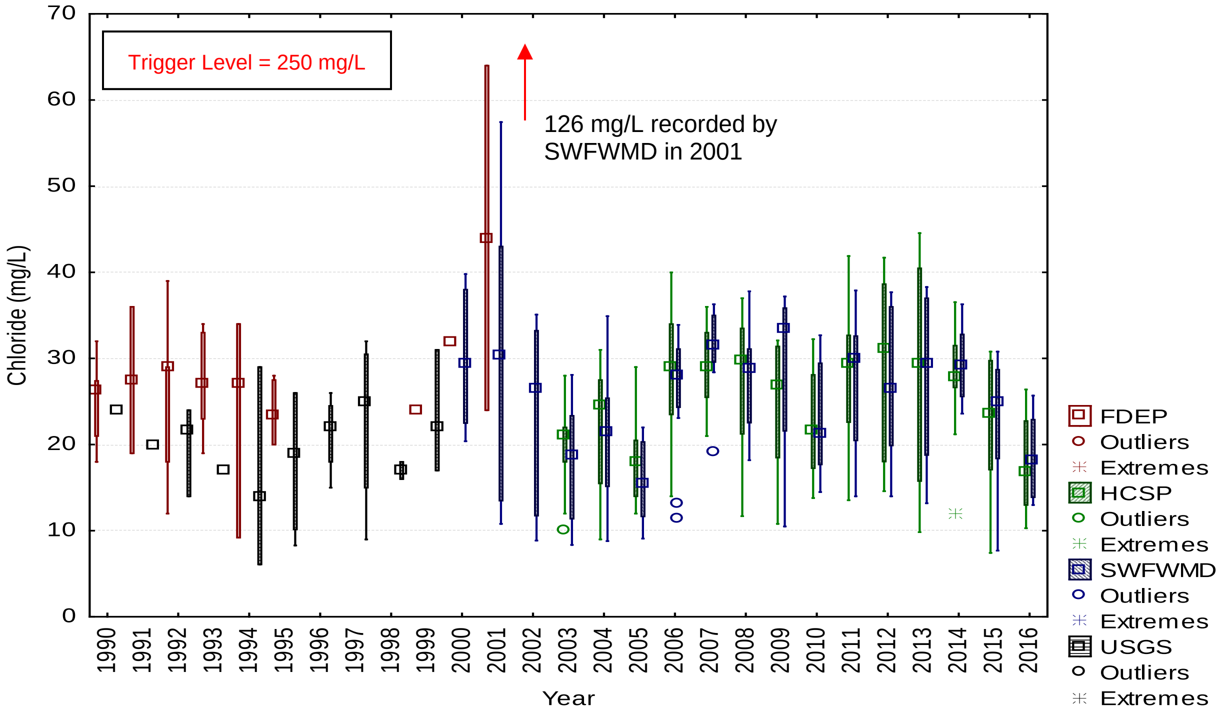


Figure C-49. HCSW-4 chloride concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.

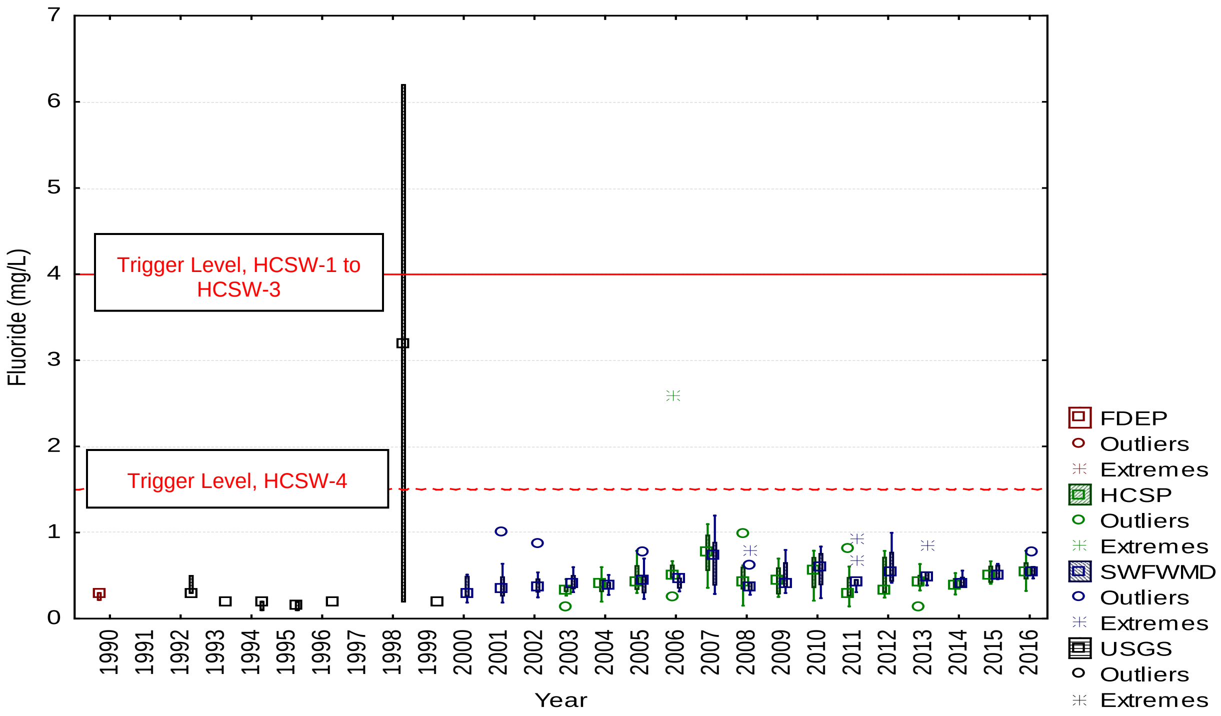


Figure C-50. **HCSW-1 fluoride concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

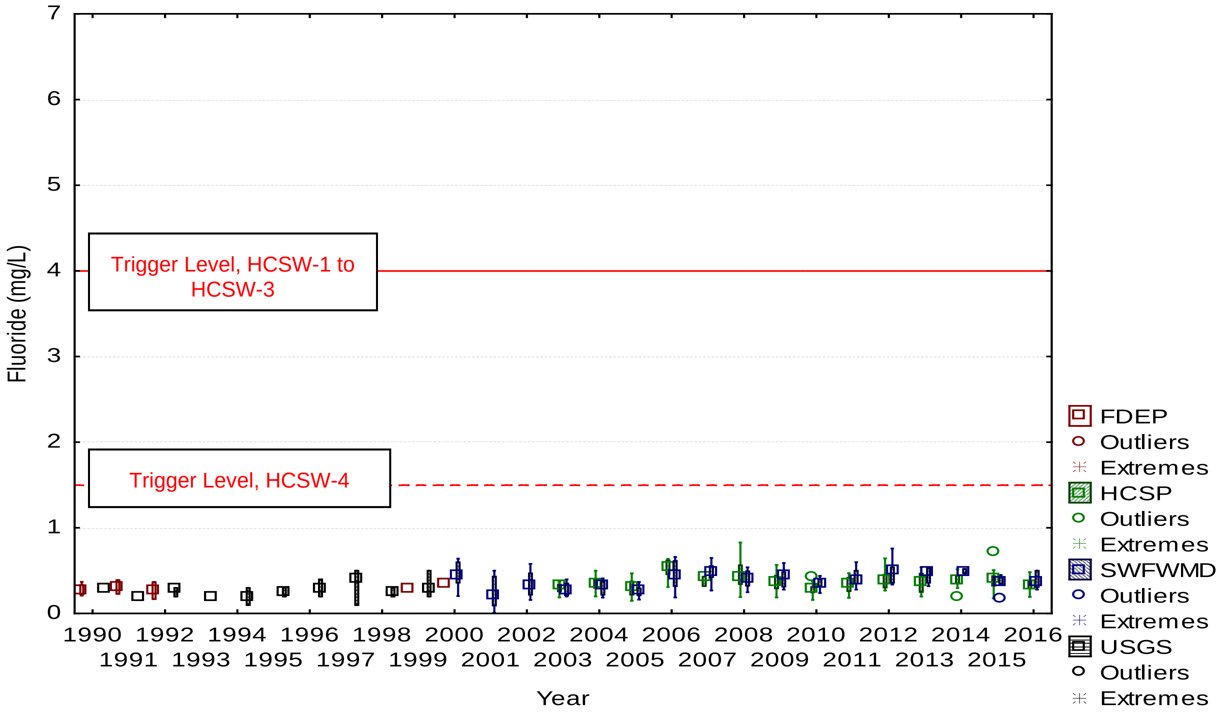


Figure C-51. **HCSW-4 fluoride concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

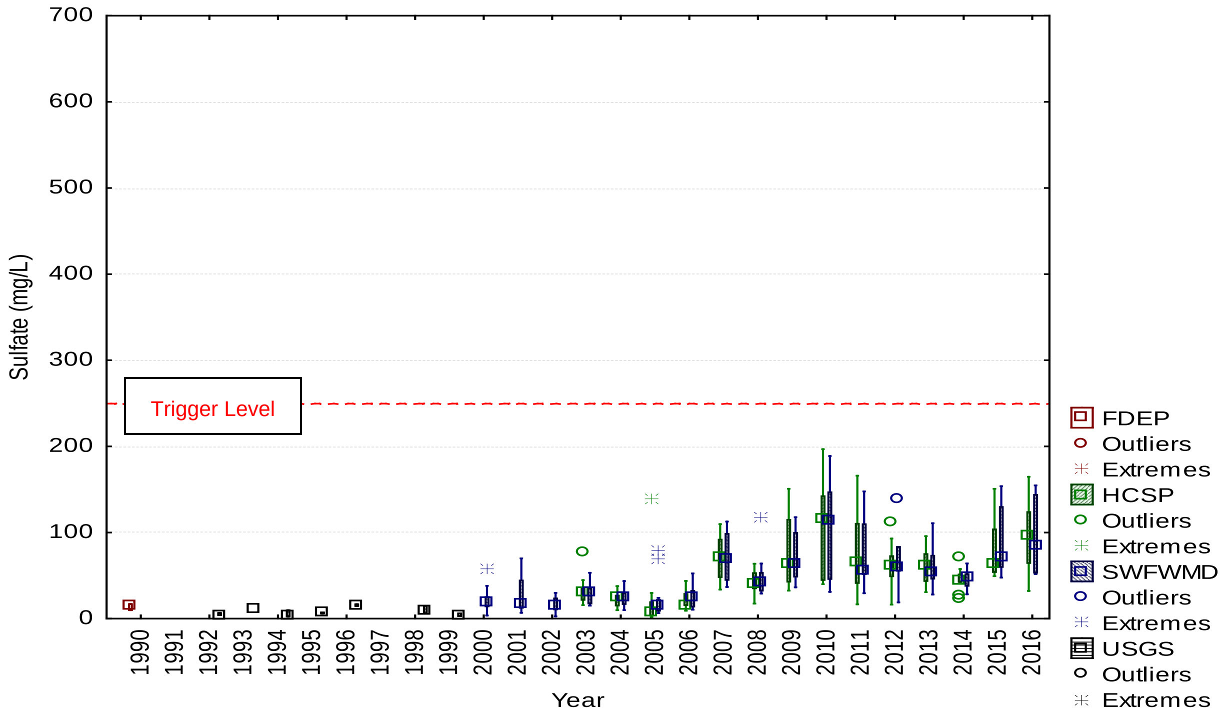


Figure C-52. **HCSW-1 sulfate concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

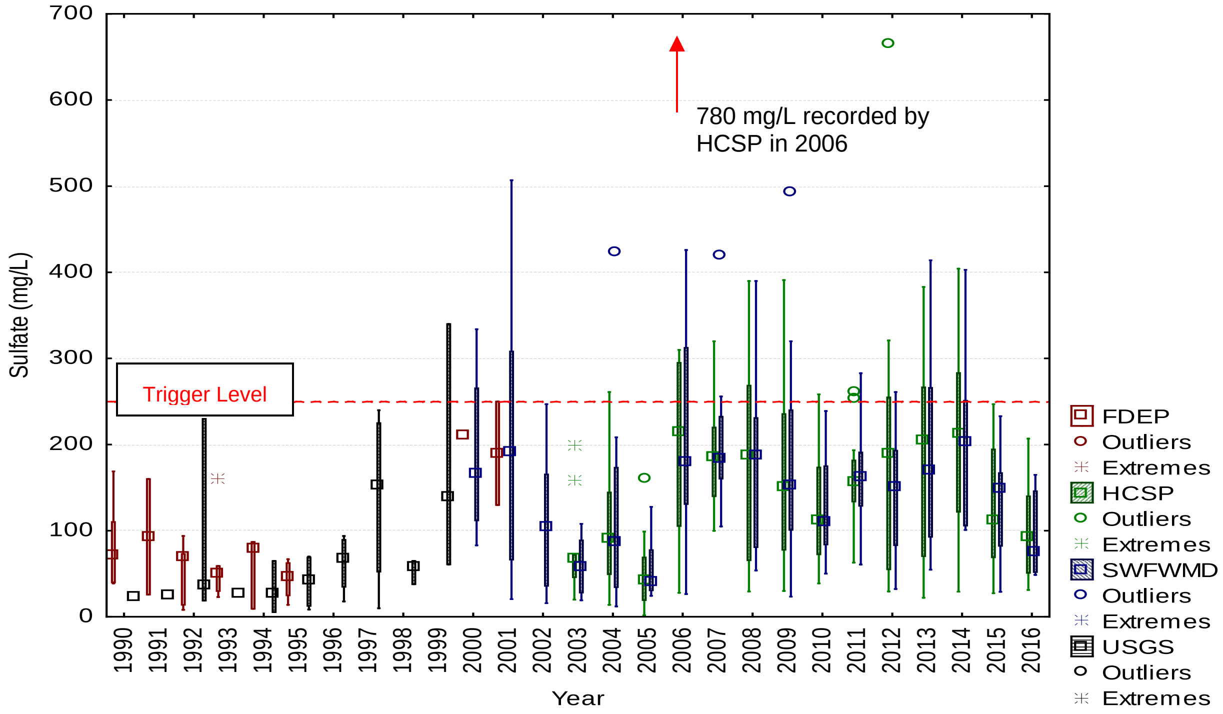


Figure C-53. **HCSW-4 sulfate concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

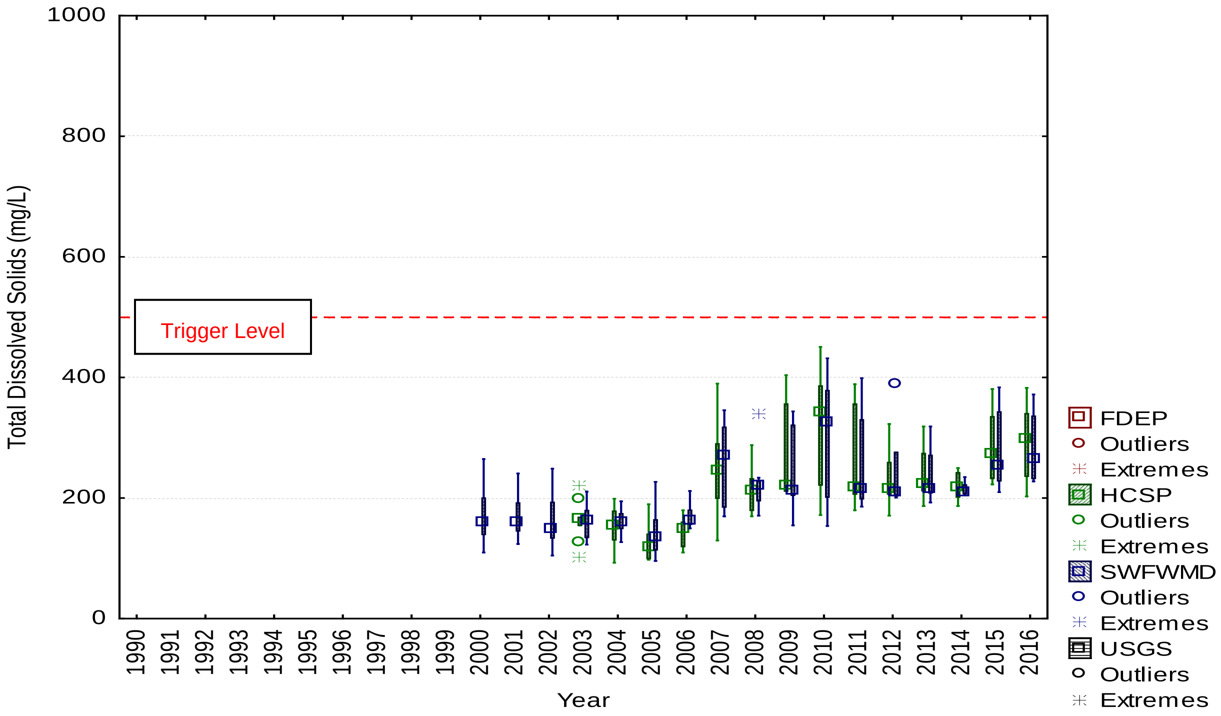


Figure C-54. **HCSW-1 TDS concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

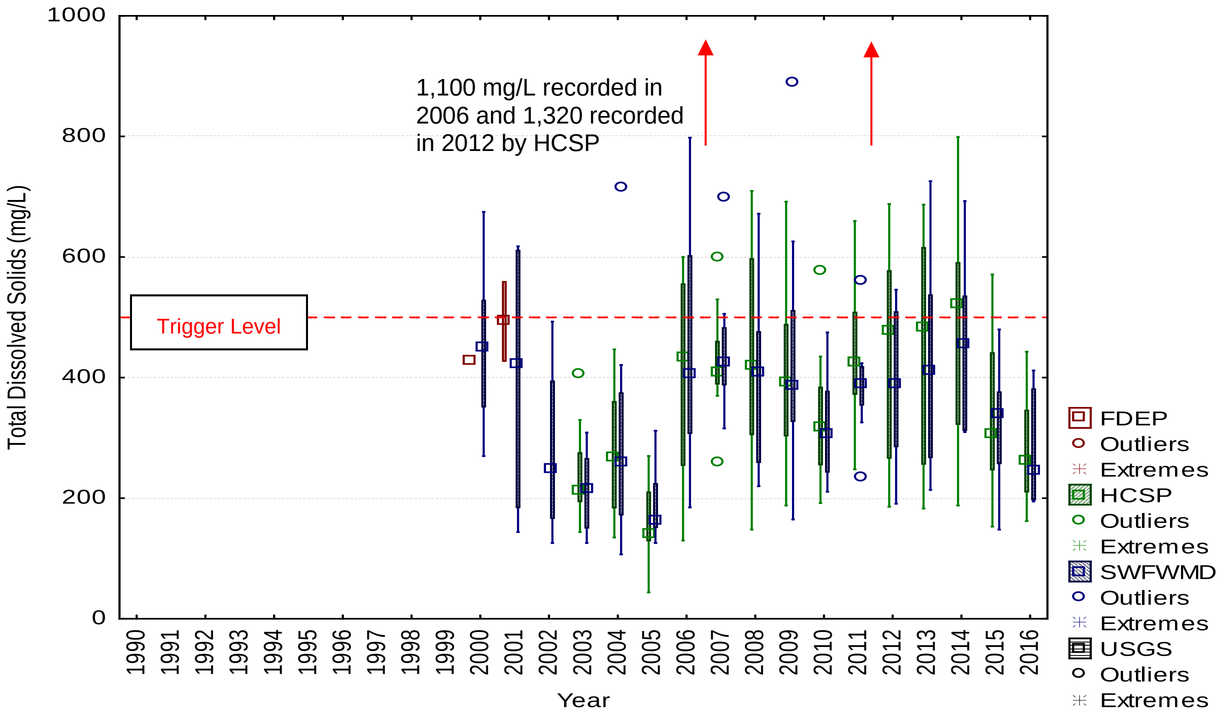


Figure C-55. **HCSW-4 TDS concentrations obtained from various data sources (FDEP, SWFWMD, and USGS Data from EPA STORET and HCSP) from 1990 to 2016.**

Horse Creek Stewardship
Program

APPENDIX

D

LITERATURE REVIEW OF STATISTICAL TREND ANALYSIS METHODS

Appendix D
Literature Review of Statistical Trend Analysis Methods

The following is a literature review of water quality data trend detection tests, intended to identify the best monotonic trend detection method for use in the Horse Creek Stewardship Program (HCSP). Based on information gleaned from a variety of source, including the USGS (United States Geological Survey), the Seasonal Kendall test was determined to be the best method for use in the HCSP. Because the method needs a minimum of five years of data collection, the 2008 HCSP Annual Report will be the first report to include this analysis. In this (2007) and previous annual reports (2003–2006), a variation of this test, the annual median Mann-Kendall, was used on the combined data from several data sources (HCSP, SWFWMD, USGS) for the period 1990 through 2007 to detect possible changes over time. Any changes over time detected using either method may result from a variety of causes, including changes in analytical methods, climatic variation, or anthropogenic causes; an impact assessment may be conducted to determine if the trend is caused by Mosaic mining activities. The following review describes both trend methods that have been or will be used in the HCSP.

Water quality monitoring data exhibits several characteristics that make trend analysis with traditional parametric statistics methods difficult. Water quality datasets often violate the assumptions of parametric statistics, such as the need for independent observations, normal distributions, and constant variance (Berryman et al. 1988, Lettenmaier 1988). In addition, water quality data may be seasonally cyclical or flow-dependent, and datasets may contain missing, censored, or truncated data. Although many methods have been proposed for trend detection, nonparametric methods are the most recommended for detecting trends in water quality data (Berryman et al. 1988, Lettenmaier 1988, Hirsch et al. 1982).

Trend detection methods include graphical methods, time series analysis, parametric statistical tests, and nonparametric statistical tests (Berryman et al. 1988). Graphical methods of trend analysis involve visual interpretation of the data, with no explicit test for trends. This method is often used for exploratory data analysis before other trend detection methods are applied. In time series analysis, a time series is broken down into components (base level, trend, cycle, etc.) using equations. These equations can be combined into a predictive model that can be used to estimate future water quality. Although trends can be modeled using time series analysis, the method does not determine the trend significance, or the chance that the trend is not-random. Statistical tests may be used on the results of the time series analysis to detect trends, but it is considered more appropriate and efficient to use other statistical methods directly. In addition, time series analysis is not appropriate for datasets with irregularly spaced observations or truncated data (observations below method detection limit) (Berryman et al. 1988).

Statistical tests detect trends by applying a rule that the magnitude of the trend is large compared to the variance. Statistical tests may be parametric (based on a normal distribution) or nonparametric. Parametric methods assume that the data is normally distributed, independent, and of constant variance. Although parametric methods are robust against data that violates these assumptions, the power of the test to detect trends is reduced. When these assumptions are violated, as with most water quality data, nonparametric methods are preferred. Because nonparametric methods are based on ranks of observations rather than magnitudes, they can be used on datasets with non-normal distributions or truncated data (Berryman et al. 1988, Lettenmaier 1988, Hirsch et al. 1982). Nonparametric methods can also be adapted for data that is not independent with corrections for seasonality or serial autocorrelation (Berryman et al. 1988, Hirsch et al. 1982, Harcum et al. 1992).

Nonparametric tests may be used to detect monotonic trends, step trends, or multi-step trends (Berryman et al. 1988). Monotonic trends are gradual and unidirectional, but step trends may occur suddenly, be restricted to a limited time period, and may reverse direction over time. Nonparametric methods used to detect step trends include the Mann-Whitney (single step), Kolmogorov-Smirov (single step), and Kruskal-Wallis (multi-step) tests. For each of these tests, the mean ranks before and after a designated time-step are compared, similar to parametric t-tests or ANOVA.

In the absence of *a priori* knowledge of a time-specific potential impact that could affect water quality, monotonic trends are typically the most common trends examined. Nonparametric methods that detect monotonic trends include the Mann-Kendall, Spearman, Cox-Stuart, and Friedman's tests. The Spearman and Kendall are considered the most powerful; these methods detect trends by a significant correlation between the parameter values and time (Berryman et al. 1988). Several of these methods have been adapted for use with seasonally cyclic data; the most commonly used seasonally-adjusted method for water quality trend analysis is the Seasonal Kendall method (Lettenmaier 1988, Hirsch et al. 1982, Harcum et al. 1992, Helsel et al. 2006).

The Seasonal Kendall method is a frequently recommended method for detecting trends in water quality data (Lettenmaier 1988, Hirsch et al. 1982, Harcum et al. 1992, Helsel et al. 2006). The Seasonal Kendall was developed by and is now the method of choice for the United States Geological Survey (USGS) (Hirsch et al. 1982, Helsel et al. 2006). Other agencies that have used the Seasonal Kendall include the United States Environmental Protection Agency, South Florida Water Management District, Departments of Environmental Protection in Virginia and Oregon, Charlotte Harbor National Estuary Program, National Institute of Water and Atmospheric Research, and many universities.

The Seasonal Kendall test determines water quality trends after correcting for seasonality by only comparing values between similar seasons over time (Schertz et al. 1991). The Seasonal Kendall test selects one value for each season (average, median, or subsample) and makes all pair-wise comparisons between time-ordered seasonal values (Harcum et al. 1992). A test statistic (Tau) is computed by comparing the number of times a later value is larger than an earlier value in the data set, and vice-versa (Schertz et al. 1991). Results for the Seasonal Kendall include the magnitude of the statistic Tau, its significance (p), its slope (Sen slope estimator), and the direction of significant trends. The trend (Sen) slope is the median slope of all pairwise comparisons. The direction of this slope (positive or negative) is more resistant to the effects of observations below minimum detection limits and missing data than the magnitude of the slope. The slope is a measure of the monotonic trend; the actual temporal variation may include step trends or trend reversals. If alternate seasons exhibit trends in opposite directions, the Seasonal Kendall test will not detect an overall trend (Lettenmaier 1988).

The power of the Seasonal Kendall test to detect trends in water quality data depends on sample size, season size, significance level, and the magnitude of trend to be detected (Harcum et al. 1992, Hirsch et al. 1982). Collapsing monthly data into quarters or years will reduce the power of the test to detect trends. If monthly data exhibits serial autocorrelation (dependence between adjacent months), however, collapsing is necessary to preserve an accurate significance level (p). Serial autocorrelation may make the actual p value much higher than expected (i.e. $p = 0.15$ instead of $p = 0.05$), leading to a very liberal interpretation of the significance level of potential trends. The loss of power caused by collapsing the data into quarters ceases to matter as sample size increases or the desired trend magnitude increases (Table 1, Harcum et al. 1992). The power difference between monthly and quarterly data disappears in 10-year datasets when the desired trend magnitude is 0.02 units/year, and in 5-year datasets when the trend magnitude is between 0.05 and 0.20 units/year.

Table 1. Power comparison for monthly and quarterly (median) data for five and ten years of data (adapted from figures in Harcum et al. 1992).

Years of Data	Trend slope (units/yr)	Power (Monthly Data)	Power (Quarterly Data)
5	0.002	0.05	0.05
5	0.005	0.09	0.06
5	0.02	0.6	0.31
5	0.05	0.97	0.83
5	0.2	1	1
5	0.5	1	1
10	0.002	0.12	0.1
10	0.005	0.45	0.32
10	0.02	0.98	0.95
10	0.05	0.99	0.99
10	0.2	1	1
10	0.5	1	1

The USGS recommends at least five years of data with less than five percent truncated observations for the Seasonal Kendall test. Trends detected in datasets with more than five percent of the observations below the method detection limit will have an accurate direction, but the slope magnitude will be a poor estimate (Schertz et al. 1991).

Based on this literature review on tests for water quality data trend detection, the best monotonic trend detection method for use in the Horse Creek Stewardship Program (HCSP) is the Seasonal Kendall. Because the USGS recommends a minimum of five years of data collection before applying the Seasonal Kendall test (Schertz et al. 1991), the 2008 Annual Report will be the first report to include this analysis.

When the Seasonal Kendall test is applied to data in the 2008 HCSP Annual Report, trend detection will be limited by several factors. With only five years of data, the power of the test to detect trends of small magnitude will be limited (Table 1, Harcum et al. 1992, Hirsch et al. 1982). In addition, the monthly data collected as part of the HCSP exhibits serial autocorrelation, meaning that adjacent monthly observations are not independent. Because the dependence in data for some parameters extends to observations made two months apart, collapsing the data into quarterly values is recommended (Harcum et al. 1992). This will reduce the power of the test by an additional margin (Table 1). Finally, data for parameters whose method detection limits have changed several times over the HCSP (fluoride, nitrate-nitrite) will have to be truncated to the highest detection limit, thereby reducing the available data for the test. As a result, trends will be harder to detect, and only the direction of the trend, not the magnitude of the trend, will be valid (Schertz et al. 1991). Despite these limitations, the Seasonal Kendall test is still the most appropriate to detect monotonic trends in HCSP water quality data, once five years of measurements have been collected.

In this (2007) and previous annual reports (2003–2006), the dataset collected by the HCSP was not of sufficient length for the Seasonal Kendall analysis. Instead, those reports included a variation of this test, the Mann-Kendall, where the data from several data sources (HCSP, SWFWMD, USGS) were collapsed into annual median values to detect possible changes over time for years 1990 to the present. Although collapsing the data into annual medians results in a loss of power to detect changes, it is a valid method for water quality trend detection (Harcum et al. 1992). The combined data set used in the HCSP reports includes data collected from 1990 to 2007 by FDEP, USGS, SWFWMD, and HCSP with various analytical methods, sampling frequencies, and method detection limits that may bias the results. The annual median Mann-Kendall was chosen over the Seasonal Kendall as a more conservative approach. All trend analysis methods are heavily influenced by the observations at the beginning and end of a dataset, so the effects of the recent drought years should also be considered when examining potential changes.

Because of all of the potential sources of bias in the combined dataset (changes in methods, different agency sources, different sampling frequencies, climatic variation, etc.), a statistically significant Mann-Kendall test may be caused by factors other than anthropogenic sources. Any changes over time detected using either the annual median Mann-Kendall or Seasonal Kendall test should be further examined to determine if the perceived change is caused by a data bias, if its magnitude is ecologically significant, and if the cause of the trend is related to Mosaic mining activities. If warranted, an impact analysis can be performed on statistically significant trends to determine if trends are caused by Mosaic mining activities and if a corrective action by Mosaic is necessary.

Literature Cited

Berryman, D., B. Bobee, D. Cluis, and J. Haemmerli. 1988. Nonparametric tests for trend detection in water quality time series. Water Resources Bulletin of American Water Resources Association. 24(3): 545 – 556.

Harcum, J. B., J. C. Loftis, and R. C. Ward. 1992. Selecting trend tests for water quality series with serial correlation and missing values. Water Resources Bulletin of American Water Resources Association. 28(3): 469 – 478.

Helsel, D. R., D. K. Mueller, and J. R. Slack. 2006. Computer program for the Kendall family of trend tests. U.S. Geological Survey Scientific Investigations Report: 2005-5275. 4 p.

Hirsch, R. M., J. R. Slack, and R. A. Smith. 1982. Techniques of trend analysis for monthly water quality data. Water Resources Research 18(1): 107 – 121.

Lettenmaier, D. P. 1988. Multivariate nonparametric tests for trend in water quality. Water Resources Bulletin of American Water Resources Association. 24(3): 505 – 512.

Schertz, T. L., R. B. Alexander, and D. J. Ohe. 1991. The computer program EStimate TREND (ESTREND), a system for the detection of trends in water-quality data: U.S. Geological Survey Water-Resources Investigations Report 91-4040. 63 p.

Horse Creek Stewardship
Program

APPENDIX

E

TAG MEETING SUMMARY

Appendix E
TAG Meeting Summary

Horse Creek Stewardship Program
Technical Advisory Group
Meeting Summary for October 17, 2018

Draft 2015 and 2016 Annual Reports

TAG Panel

Julian DeLeon	DeSoto County
Mandy Hines	DeSoto County
Rob Brown	Manatee County
Alissa Powers	Manatee County
John Ryan	Sarasota County

Presenters

Kristan Robbins	Brown and Caldwell
Sheri Huelster	Cardno

Attendees

Sam Stone	PRMRWSA
Ryan Tickles	Mosaic
Keith Nadaskay	Mosaic
Shelley Thornton	Mosaic
Eesa Ali	Flatwoods Consulting Group

1. Report Overview

Sheri Huelster of Cardno provided a technical summary of biological data present in the 2015 and 2016 HCSP Annual Reports. Kristan Robbins of Brown and Caldwell provided a technical summary and overview of Program water quantity and quality data presented in the 2015 and 2016 HCSP Annual Reports, including a summary of the impact assessment for pH and specific conductivity.

Similar to the previous Annual Reports, potential trends were identified for various water quality parameters in the 2015 and 2016 annual reports. For four parameters in 2015 (DO saturation, color, ammonia, and iron) and five parameters in 2016 (DO saturation and concentration, color, ammonia, and iron), the direction or the magnitude of the potential trends are small and/or not adverse. Five of the parameters in both 2015 and 2016 with increasing trends (calcium, alkalinity, fluoride, sulfate, and TDS) are related to specific conductivity, so the discussion focused on specific conductivity as the best surrogate for all dissolved ions showing potential trends. The majority of the trend discussion focused on pH and specific conductivity changes over time.

A Seasonal and Annual Kendall Tau analysis of the pH data indicates that there is a slight increasing trend over the longer time period and when using data collected by SWFWMD. However, when change-point analysis was used, it was evident that there was no consistent, continuing increase in pH at HCSW-

1 over time. Specific conductivity showed an increasing trend for the HCSP and when additional years were included. A change-point analysis indicated that there are step changes rather than a persistent increase from year to year. Analysis of other stations shows an influence from climatic and upstream conditions on conductivity at HCSW-1. While some isolated specific conductivity values at HCSW-1 may be related to increased groundwater influence from NPDES discharges, the majority of the increasing trend can be explained by upstream conditions and regional factors unrelated to NPDES discharge (see Appendix I of annual reports).

2. Action Items:

- TAG members will get any additional comments on the 2015 and 2016 annual reports to the Authority by October 31, 2018.
    - Last set of comments sent to Cardno by the Authority on October 30, 2018
- Cardno will provide a PDF version of the PowerPoint presentation to the TAG members.
    - Completed October 31, 2018
- Cardno will provide a Word document of all reviewers' questions/comments and responses to the Authority for transmittal to TAG members for the 2015 and 2016 annual reports.
    - Will be submitted when each report is finalized.
- Cardno and Brown and Caldwell will add a general description of the Horse Creek fish diversity to the annual report.
    - Added to finalized versions of 2015 and 2016 annual reports.
- Cardno will add the fish species accumulation curves back to the annual reports.
    - Added to finalized versions of 2015 and 2016 annual reports.

3. Timeline for 2015 and 2016 Annual Reports

The 2015 and 2016 final report could be sent to the Authority by December 28, 2018.

2015 Annual Report sent to the Authority and TAG members December 21, 2018.

2016 Annual Report sent to the Authority and TAG members January 30, 2019.

4. Timeline for the 2017 Annual Report

The draft 2017 report will be sent to the Authority and the TAG by November 30, 2018.

Draft report sent to Authority and TAG members November 30, 2018.

Horse Creek Stewardship
Program

APPENDIX

F

SUMMARY OF TRIGGER EXCEEDANCES FROM 2003 TO 2016

Appendix F

Summary of Trigger Exceedances from 2003 to 2016

Table F-1. List of exceedances for monitored parameters from 2003 to present for current trigger levels.

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at State Road 64	HCSW-1	1/23/2007	pH (SU)	8.83	8.5
Horse Creek at State Road 64	HCSW-1	1/4/2011	pH (SU)	4.8	6
Horse Creek at Goose Pond Road	HCSW-2	7/27/2006	pH (SU)	5.95	6
Horse Creek at Goose Pond Road	HCSW-2	10/19/2006	pH (SU)	5.99	6
Horse Creek at Goose Pond Road	HCSW-2	10/10/2012	pH (SU)	5.96	6
Horse Creek at State Road 70	HCSW-3	7/27/2005	pH (SU)	5.9	6
Horse Creek at State Road 72	HCSW-4	1/23/2007	pH (SU)	8.85	8.5
Horse Creek at State Road 72	HCSW-4	12/3/2015	pH (SU)	5.95	6
Horse Creek at State Road 72	HCSW-4	6/5/2012	Specific Conductance (µmhos/cm)	1,425	1,275
Horse Creek at Goose Pond Road	HCSW-2	7/2/2013	Dissolved Oxygen (%Saturation)	24.8	41.7
Horse Creek at Goose Pond Road	HCSW-2	8/1/2013	Dissolved Oxygen (%Saturation)	25.9	41.1
Horse Creek at Goose Pond Road	HCSW-2	9/4/2013	Dissolved Oxygen (%Saturation)	31.1	40.7
Horse Creek at Goose Pond Road	HCSW-2	10/1/2013	Dissolved Oxygen (%Saturation)	36.7	36.9
Horse Creek at Goose Pond Road	HCSW-2	2/3/2014	Dissolved Oxygen (%Saturation)	30.8	42.4
Horse Creek at Goose Pond Road	HCSW-2	8/6/2014	Dissolved Oxygen (%Saturation)	18.1	41.8
Horse Creek at Goose Pond Road	HCSW-2	9/3/2014	Dissolved Oxygen (%Saturation)	25.8	38.8
Horse Creek at Goose Pond Road	HCSW-2	10/6/2014	Dissolved Oxygen (%Saturation)	20.2	38.6
Horse Creek at Goose Pond Road	HCSW-2	11/4/2014	Dissolved Oxygen (%Saturation)	30.4	39.8
Horse Creek at Goose Pond Road	HCSW-2	12/2/2014	Dissolved Oxygen (%Saturation)	35.3	40.1
Horse Creek at Goose Pond Road	HCSW-2	3/5/2015	Dissolved Oxygen (%Saturation)	26	38.3
Horse Creek at Goose Pond Road	HCSW-2	7/6/2015	Dissolved Oxygen (%Saturation)	11.3	40.4
Horse Creek at Goose Pond Road	HCSW-2	8/6/2015	Dissolved Oxygen (%Saturation)	11.7	40.9
Horse Creek at Goose Pond Road	HCSW-2	9/22/2015	Dissolved Oxygen (%Saturation)	20.4	38.8
Horse Creek at Goose Pond Road	HCSW-2	10/5/2015	Dissolved Oxygen (%Saturation)	18.9	40.9
Horse Creek at Goose Pond Road	HCSW-2	11/3/2015	Dissolved Oxygen (%Saturation)	20.5	38.6
Horse Creek at Goose Pond Road	HCSW-2	2/23/2016	Dissolved Oxygen (%Saturation)	37.0	43.0
Horse Creek at Goose Pond Road	HCSW-2	3/7/2016	Dissolved Oxygen (%Saturation)	34.8	39.7
Horse Creek at Goose Pond Road	HCSW-2	4/6/2016	Dissolved Oxygen (%Saturation)	34.2	42.5
Horse Creek at Goose Pond Road	HCSW-2	5/5/2016	Dissolved Oxygen (%Saturation)	23.6	43.0
Horse Creek at Goose Pond Road	HCSW-2	6/7/2016	Dissolved Oxygen (%Saturation)	20.6	42.0
Horse Creek at Goose Pond Road	HCSW-2	7/7/2016	Dissolved Oxygen (%Saturation)	13.6	42.0
Horse Creek at Goose Pond Road	HCSW-2	8/4/2016	Dissolved Oxygen (%Saturation)	26.8	40.9
Horse Creek at Goose Pond Road	HCSW-2	9/8/2016	Dissolved Oxygen (%Saturation)	20.8	39.2
Horse Creek at Goose Pond Road	HCSW-2	10/18/2016	Dissolved Oxygen (%Saturation)	19.1	39.2
Horse Creek at Goose Pond Road	HCSW-2	11/7/2016	Dissolved Oxygen (%Saturation)	25.0	42.0
Horse Creek at Goose Pond Road	HCSW-2	12/13/2016	Dissolved Oxygen (%Saturation)	24.8	41.3
Horse Creek at State Road 70	HCSW-3	8/1/2013	Dissolved Oxygen (%Saturation)	38.4	39.9
Horse Creek at State Road 70	HCSW-3	8/6/2015	Dissolved Oxygen (%Saturation)	39.1	39.2

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at State Road 64	HCSW-1	4/27/2006	Color (PCU)	20	25
Horse Creek at State Road 70	HCSW-3	4/27/2006	Color (PCU)	15	25
Horse Creek at State Road 70	HCSW-3	6/29/2006	Color (PCU)	15	25
Horse Creek at Goose Pond Road	HCSW-2	1/30/2008	Total Nitrogen (mg/L)	4.8	3
Horse Creek at State Road 70	HCSW-3	9/27/2006	Total Nitrogen (mg/L)	6.7	3
Horse Creek at State Road 70	HCSW-3	6/20/2007	Total Nitrogen (mg/L)	9.68	3
Horse Creek at State Road 70	HCSW-3	2/23/2016	Total Nitrogen (mg/L)	3.5	3.0
Horse Creek at Goose Pond Road	HCSW-2	7/31/2008	Total Ammonia (mg/L)	0.41	0.3
Horse Creek at State Road 70	HCSW-3	7/31/2008	Total Ammonia (mg/L)	0.32	0.3
Horse Creek at State Road 70	HCSW-3	5/3/2011	Total Ammonia (mg/L)	0.31	0.3
Horse Creek at State Road 72	HCSW-4	7/31/2008	Total Ammonia (mg/L)	0.31	0.3
Horse Creek at State Road 64	HCSW-1	2/2/2010	Chlorophyll a (mg/m3)	15.4	15
Horse Creek at Goose Pond Road	HCSW-2	4/14/2004	Chlorophyll a (mg/m3)	16	15
Horse Creek at Goose Pond Road	HCSW-2	5/26/2004	Chlorophyll a (mg/m3)	21	15
Horse Creek at Goose Pond Road	HCSW-2	8/30/2004	Chlorophyll a (mg/m3)	35	15
Horse Creek at Goose Pond Road	HCSW-2	5/27/2005	Chlorophyll a (mg/m3)	17	15
Horse Creek at Goose Pond Road	HCSW-2	11/17/2005	Chlorophyll a (mg/m3)	17	15
Horse Creek at Goose Pond Road	HCSW-2	2/23/2006	Chlorophyll a (mg/m3)	23	15
Horse Creek at Goose Pond Road	HCSW-2	3/28/2006	Chlorophyll a (mg/m3)	30	15
Horse Creek at Goose Pond Road	HCSW-2	5/25/2006	Chlorophyll a (mg/m3)	32	15
Horse Creek at Goose Pond Road	HCSW-2	6/29/2006	Chlorophyll a (mg/m3)	45	15
Horse Creek at Goose Pond Road	HCSW-2	8/21/2006	Chlorophyll a (mg/m3)	20	15
Horse Creek at Goose Pond Road	HCSW-2	5/16/2007	Chlorophyll a (mg/m3)	25	15
Horse Creek at Goose Pond Road	HCSW-2	6/20/2007	Chlorophyll a (mg/m3)	110	15
Horse Creek at Goose Pond Road	HCSW-2	7/18/2007	Chlorophyll a (mg/m3)	17	15
Horse Creek at Goose Pond Road	HCSW-2	7/31/2008	Chlorophyll a (mg/m3)	22.6	15
Horse Creek at Goose Pond Road	HCSW-2	1/5/2009	Chlorophyll a (mg/m3)	24.9	15
Horse Creek at Goose Pond Road	HCSW-2	4/1/2009	Chlorophyll a (mg/m3)	21.7	15
Horse Creek at Goose Pond Road	HCSW-2	5/3/2011	Chlorophyll a (mg/m3)	17.5	15
Horse Creek at Goose Pond Road	HCSW-2	2/2/2012	Chlorophyll a (mg/m3)	75.1	15
Horse Creek at Goose Pond Road	HCSW-2	4/2/2012	Chlorophyll a (mg/m3)	35.9	15
Horse Creek at Goose Pond Road	HCSW-2	5/2/2012	Chlorophyll a (mg/m3)	34.1	15
Horse Creek at Goose Pond Road	HCSW-2	12/5/2012	Chlorophyll a (mg/m3)	17.9	15
Horse Creek at Goose Pond Road	HCSW-2	5/1/2013	Chlorophyll a (mg/m3)	53.2	15
Horse Creek at Goose Pond Road	HCSW-2	11/4/2013	Chlorophyll a (mg/m3)	17	15
Horse Creek at Goose Pond Road	HCSW-2	4/8/2015	Chlorophyll a (mg/m3)	28.6	15
Horse Creek at Goose Pond Road	HCSW-2	5/11/2015	Chlorophyll a (mg/m3)	26.7	15
Horse Creek at State Road 70	HCSW-3	8/30/2004	Chlorophyll a (mg/m3)	38	15
Horse Creek at State Road 70	HCSW-3	4/27/2006	Dissolved Calcium (mg/L)	110	100
Horse Creek at State Road 70	HCSW-3	6/29/2006	Dissolved Calcium (mg/L)	110	100
Horse Creek at State Road 70	HCSW-3	4/25/2007	Dissolved Calcium (mg/L)	110	100
Horse Creek at State Road 70	HCSW-3	5/16/2007	Dissolved Calcium (mg/L)	110	100
Horse Creek at State Road 70	HCSW-3	6/20/2007	Dissolved Calcium (mg/L)	140	100
Horse Creek at State Road 70	HCSW-3	4/2/2012	Dissolved Calcium (mg/L)	114	100

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at State Road 70	HCSW-3	4/2/2013	Dissolved Calcium (mg/L)	123	100
Horse Creek at State Road 70	HCSW-3	5/1/2013	Dissolved Calcium (mg/L)	105	100
Horse Creek at State Road 72	HCSW-4	5/25/2006	Dissolved Calcium (mg/L)	110	100
Horse Creek at State Road 72	HCSW-4	6/29/2006	Dissolved Calcium (mg/L)	190	100
Horse Creek at State Road 72	HCSW-4	12/13/2006	Dissolved Calcium (mg/L)	110	100
Horse Creek at State Road 72	HCSW-4	6/20/2007	Dissolved Calcium (mg/L)	110	100
Horse Creek at State Road 72	HCSW-4	3/27/2008	Dissolved Calcium (mg/L)	120	100
Horse Creek at State Road 72	HCSW-4	5/29/2008	Dissolved Calcium (mg/L)	110	100
Horse Creek at State Road 72	HCSW-4	2/2/2009	Dissolved Calcium (mg/L)	106	100
Horse Creek at State Road 72	HCSW-4	6/3/2009	Dissolved Calcium (mg/L)	119	100
Horse Creek at State Road 72	HCSW-4	4/2/2012	Dissolved Calcium (mg/L)	117	100
Horse Creek at State Road 72	HCSW-4	5/2/2012	Dissolved Calcium (mg/L)	109	100
Horse Creek at State Road 72	HCSW-4	6/5/2012	Dissolved Calcium (mg/L)	182	100
Horse Creek at State Road 72	HCSW-4	2/3/2014	Dissolved Calcium (mg/L)	101	100
Horse Creek at Goose Pond Road	HCSW-2	7/27/2006	Dissolved Iron (mg/L)	1.2	1
Horse Creek at Goose Pond Road	HCSW-2	6/3/2009	Dissolved Iron (mg/L)	1.03	1
Horse Creek at State Road 72	HCSW-4	5/27/2003	Dissolved Iron (mg/L)	0.4	0.3
Horse Creek at State Road 72	HCSW-4	6/19/2003	Dissolved Iron (mg/L)	0.6	0.3
Horse Creek at State Road 72	HCSW-4	7/14/2003	Dissolved Iron (mg/L)	0.7	0.3
Horse Creek at State Road 72	HCSW-4	8/28/2003	Dissolved Iron (mg/L)	0.7	0.3
Horse Creek at State Road 72	HCSW-4	9/25/2003	Dissolved Iron (mg/L)	0.6	0.3
Horse Creek at State Road 72	HCSW-4	10/29/2003	Dissolved Iron (mg/L)	0.4	0.3
Horse Creek at State Road 72	HCSW-4	12/16/2003	Dissolved Iron (mg/L)	0.32	0.3
Horse Creek at State Road 72	HCSW-4	7/27/2004	Dissolved Iron (mg/L)	0.5	0.3
Horse Creek at State Road 72	HCSW-4	8/30/2004	Dissolved Iron (mg/L)	0.7	0.3
Horse Creek at State Road 72	HCSW-4	9/29/2004	Dissolved Iron (mg/L)	0.4	0.3
Horse Creek at State Road 72	HCSW-4	10/27/2004	Dissolved Iron (mg/L)	0.4	0.3
Horse Creek at State Road 72	HCSW-4	3/30/2005	Dissolved Iron (mg/L)	0.45	0.3
Horse Creek at State Road 72	HCSW-4	4/27/2005	Dissolved Iron (mg/L)	0.4	0.3
Horse Creek at State Road 72	HCSW-4	5/25/2005	Dissolved Iron (mg/L)	0.45	0.3
Horse Creek at State Road 72	HCSW-4	6/22/2005	Dissolved Iron (mg/L)	0.77	0.3
Horse Creek at State Road 72	HCSW-4	7/27/2005	Dissolved Iron (mg/L)	0.74	0.3
Horse Creek at State Road 72	HCSW-4	8/23/2005	Dissolved Iron (mg/L)	0.58	0.3
Horse Creek at State Road 72	HCSW-4	9/29/2005	Dissolved Iron (mg/L)	0.44	0.3
Horse Creek at State Road 72	HCSW-4	11/17/2005	Dissolved Iron (mg/L)	0.49	0.3
Horse Creek at State Road 72	HCSW-4	7/27/2006	Dissolved Iron (mg/L)	0.5	0.3
Horse Creek at State Road 72	HCSW-4	8/21/2006	Dissolved Iron (mg/L)	0.7	0.3
Horse Creek at State Road 72	HCSW-4	9/27/2006	Dissolved Iron (mg/L)	1	0.3
Horse Creek at State Road 72	HCSW-4	10/19/2006	Dissolved Iron (mg/L)	0.6	0.3
Horse Creek at State Road 72	HCSW-4	7/18/2007	Dissolved Iron (mg/L)	0.42	0.3
Horse Creek at State Road 72	HCSW-4	7/31/2008	Dissolved Iron (mg/L)	0.81	0.3
Horse Creek at State Road 72	HCSW-4	8/26/2008	Dissolved Iron (mg/L)	0.96	0.3
Horse Creek at State Road 72	HCSW-4	9/30/2008	Dissolved Iron (mg/L)	0.59	0.3
Horse Creek at State Road 72	HCSW-4	10/16/2008	Dissolved Iron (mg/L)	0.64	0.3
Horse Creek at State Road 72	HCSW-4	7/8/2009	Dissolved Iron (mg/L)	0.483	0.3
Horse Creek at State Road 72	HCSW-4	8/5/2009	Dissolved Iron (mg/L)	0.567	0.3
Horse Creek at State Road 72	HCSW-4	9/2/2009	Dissolved Iron (mg/L)	0.603	0.3

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at State Road 72	HCSW-4	10/7/2009	Dissolved Iron (mg/L)	0.527	0.3
Horse Creek at State Road 72	HCSW-4	4/6/2010	Dissolved Iron (mg/L)	0.615	0.3
Horse Creek at State Road 72	HCSW-4	7/12/2010	Dissolved Iron (mg/L)	0.719	0.3
Horse Creek at State Road 72	HCSW-4	8/3/2010	Dissolved Iron (mg/L)	0.321	0.3
Horse Creek at State Road 72	HCSW-4	9/8/2010	Dissolved Iron (mg/L)	0.421	0.3
Horse Creek at State Road 72	HCSW-4	8/16/2011	Dissolved Iron (mg/L)	0.325	0.3
Horse Creek at State Road 72	HCSW-4	9/7/2011	Dissolved Iron (mg/L)	0.506	0.3
Horse Creek at State Road 72	HCSW-4	10/24/2011	Dissolved Iron (mg/L)	0.36	0.3
Horse Creek at State Road 72	HCSW-4	7/5/2012	Dissolved Iron (mg/L)	0.779	0.3
Horse Creek at State Road 72	HCSW-4	8/2/2012	Dissolved Iron (mg/L)	0.531	0.3
Horse Creek at State Road 72	HCSW-4	9/5/2012	Dissolved Iron (mg/L)	0.604	0.3
Horse Creek at State Road 72	HCSW-4	10/10/2012	Dissolved Iron (mg/L)	0.508	0.3
Horse Creek at State Road 72	HCSW-4	7/2/2013	Dissolved Iron (mg/L)	0.433	0.3
Horse Creek at State Road 72	HCSW-4	8/1/2013	Dissolved Iron (mg/L)	0.378	0.3
Horse Creek at State Road 72	HCSW-4	9/4/2013	Dissolved Iron (mg/L)	0.351	0.3
Horse Creek at State Road 72	HCSW-4	10/1/2013	Dissolved Iron (mg/L)	0.569	0.3
Horse Creek at State Road 72	HCSW-4	10/6/2014	Dissolved Iron (mg/L)	0.592	0.3
Horse Creek at State Road 72	HCSW-4	8/6/2015	Dissolved Iron (mg/L)	0.5	0.3
Horse Creek at State Road 72	HCSW-4	9/2/2015	Dissolved Iron (mg/L)	0.495	0.3
Horse Creek at State Road 72	HCSW-4	10/5/2015	Dissolved Iron (mg/L)	0.345	0.3
Horse Creek at State Road 72	HCSW-4	7/7/2016	Dissolved Iron (mg/L)	0.318	0.3
Horse Creek at State Road 72	HCSW-4	8/4/2016	Dissolved Iron (mg/L)	0.354	0.3
Horse Creek at State Road 72	HCSW-4	9/8/2016	Dissolved Iron (mg/L)	0.439	0.3
Horse Creek at State Road 64	HCSW-1	4/25/2007	Alkalinity (mg/L)	120	100
Horse Creek at State Road 64	HCSW-1	5/16/2007	Alkalinity (mg/L)	170	100
Horse Creek at State Road 64	HCSW-1	6/20/2007	Alkalinity (mg/L)	140	100
Horse Creek at State Road 64	HCSW-1	1/5/2010	Alkalinity (mg/L)	109	100
Horse Creek at State Road 64	HCSW-1	10/24/2011	Alkalinity (mg/L)	102	100
Horse Creek at State Road 64	HCSW-1	11/6/2012	Alkalinity (mg/L)	100.3	100
Horse Creek at State Road 64	HCSW-1	12/3/2015	Alkalinity (mg/L)	104	100
Horse Creek at State Road 64	HCSW-1	12/13/2016	Alkalinity (mg/L)	116	100
Horse Creek at State Road 72	HCSW-4	5/25/2006	Alkalinity (mg/L)	120	100
Horse Creek at State Road 72	HCSW-4	5/4/2009	Alkalinity (mg/L)	112	100
Horse Creek at State Road 72	HCSW-4	6/8/2011	Alkalinity (mg/L)	1223	100
Horse Creek at State Road 72	HCSW-4	5/2/2012	Alkalinity (mg/L)	147.5	100
Horse Creek at State Road 72	HCSW-4	1/23/2007	Fluoride (mg/L)	2.5	1.5
Horse Creek at State Road 72	HCSW-4	2/14/2007	Fluoride (mg/L)	2.5	1.5
Horse Creek at State Road 72	HCSW-4	3/14/2007	Fluoride (mg/L)	5	1.5
Horse Creek at State Road 70	HCSW-3	3/28/2006	Sulfate (mg/L)	300	250
Horse Creek at State Road 70	HCSW-3	4/27/2006	Sulfate (mg/L)	420	250
Horse Creek at State Road 70	HCSW-3	6/29/2006	Sulfate (mg/L)	430	250
Horse Creek at State Road 70	HCSW-3	5/16/2007	Sulfate (mg/L)	360	250
Horse Creek at State Road 70	HCSW-3	6/20/2007	Sulfate (mg/L)	440	250
Horse Creek at State Road 70	HCSW-3	6/26/2008	Sulfate (mg/L)	251	250
Horse Creek at State Road 70	HCSW-3	2/2/2009	Sulfate (mg/L)	280	250

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at State Road 70	HCSW-3	4/1/2009	Sulfate (mg/L)	293	250
Horse Creek at State Road 70	HCSW-3	6/3/2009	Sulfate (mg/L)	251	250
Horse Creek at State Road 70	HCSW-3	2/2/2012	Sulfate (mg/L)	254	250
Horse Creek at State Road 70	HCSW-3	3/5/2012	Sulfate (mg/L)	287	250
Horse Creek at State Road 70	HCSW-3	4/2/2012	Sulfate (mg/L)	365	250
Horse Creek at State Road 70	HCSW-3	6/5/2012	Sulfate (mg/L)	304	250
Horse Creek at State Road 70	HCSW-3	3/6/2013	Sulfate (mg/L)	319	250
Horse Creek at State Road 70	HCSW-3	4/2/2013	Sulfate (mg/L)	400	250
Horse Creek at State Road 70	HCSW-3	5/1/2013	Sulfate (mg/L)	373	250
Horse Creek at State Road 70	HCSW-3	6/4/2013	Sulfate (mg/L)	363	250
Horse Creek at State Road 70	HCSW-3	1/2/2014	Sulfate (mg/L)	282	250
Horse Creek at State Road 70	HCSW-3	6/3/2015	Sulfate (mg/L)	316	250
Horse Creek at State Road 72	HCSW-4	6/29/2004	Sulfate (mg/l)	261	250
Horse Creek at State Road 72	HCSW-4	3/28/2006	Sulfate (mg/L)	300	250
Horse Creek at State Road 72	HCSW-4	5/25/2006	Sulfate (mg/L)	310	250
Horse Creek at State Road 72	HCSW-4	6/29/2006	Sulfate (mg/L)	780	250
Horse Creek at State Road 72	HCSW-4	12/13/2006	Sulfate (mg/L)	290	250
Horse Creek at State Road 72	HCSW-4	6/20/2007	Sulfate (mg/L)	320	250
Horse Creek at State Road 72	HCSW-4	3/27/2008	Sulfate (mg/L)	390	250
Horse Creek at State Road 72	HCSW-4	5/29/2008	Sulfate (mg/L)	290	250
Horse Creek at State Road 72	HCSW-4	6/26/2008	Sulfate (mg/L)	287	250
Horse Creek at State Road 72	HCSW-4	2/2/2009	Sulfate (mg/L)	290	250
Horse Creek at State Road 72	HCSW-4	6/3/2009	Sulfate (mg/L)	391	250
Horse Creek at State Road 72	HCSW-4	12/2/2009	Sulfate (mg/L)	279	250
Horse Creek at State Road 72	HCSW-4	11/3/2010	Sulfate (mg/L)	258	250
Horse Creek at State Road 72	HCSW-4	1/4/2011	Sulfate (mg/L)	262	250
Horse Creek at State Road 72	HCSW-4	7/5/2011	Sulfate (mg/L)	253	250
Horse Creek at State Road 72	HCSW-4	3/5/2012	Sulfate (mg/L)	267	250
Horse Creek at State Road 72	HCSW-4	4/2/2012	Sulfate (mg/L)	321	250
Horse Creek at State Road 72	HCSW-4	6/5/2012	Sulfate (mg/L)	665	250
Horse Creek at State Road 72	HCSW-4	2/7/2013	Sulfate (mg/L)	251	250
Horse Creek at State Road 72	HCSW-4	3/6/2013	Sulfate (mg/L)	267	250
Horse Creek at State Road 72	HCSW-4	5/1/2013	Sulfate (mg/L)	292	250
Horse Creek at State Road 72	HCSW-4	6/4/2013	Sulfate (mg/L)	383	250
Horse Creek at State Road 72	HCSW-4	12/3/2013	Sulfate (mg/L)	267	250
Horse Creek at State Road 72	HCSW-4	1/2/2014	Sulfate (mg/L)	333	250
Horse Creek at State Road 72	HCSW-4	2/3/2014	Sulfate (mg/L)	404	250
Horse Creek at State Road 72	HCSW-4	6/3/2014	Sulfate (mg/L)	389	250
Horse Creek at State Road 70	HCSW-3	4/27/2006	TDS (mg/L)	580	500
Horse Creek at State Road 70	HCSW-3	6/29/2006	TDS (mg/L)	590	500
Horse Creek at State Road 70	HCSW-3	4/25/2007	TDS (mg/L)	590	500
Horse Creek at State Road 70	HCSW-3	5/16/2007	TDS (mg/L)	530	500
Horse Creek at State Road 70	HCSW-3	6/20/2007	TDS (mg/L)	700	500
Horse Creek at State Road 70	HCSW-3	7/18/2007	TDS (mg/L)	520	500
Horse Creek at State Road 70	HCSW-3	6/26/2008	TDS (mg/L)	580	500
Horse Creek at State Road 70	HCSW-3	2/2/2009	TDS (mg/L)	520	500
Horse Creek at State Road 70	HCSW-3	4/1/2009	TDS (mg/L)	568	500

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at State Road 70	HCSW-3	6/3/2009	TDS (mg/L)	540	500
Horse Creek at State Road 70	HCSW-3	12/2/2009	TDS (mg/L)	524	500
Horse Creek at State Road 70	HCSW-3	1/4/2011	TDS (mg/L)	513	500
Horse Creek at State Road 70	HCSW-3	12/21/2011	TDS (mg/L)	543	500
Horse Creek at State Road 70	HCSW-3	1/12/2012	TDS (mg/L)	571	500
Horse Creek at State Road 70	HCSW-3	2/2/2012	TDS (mg/L)	532	500
Horse Creek at State Road 70	HCSW-3	3/5/2012	TDS (mg/L)	603	500
Horse Creek at State Road 70	HCSW-3	4/2/2012	TDS (mg/L)	714	500
Horse Creek at State Road 70	HCSW-3	6/5/2012	TDS (mg/L)	646	500
Horse Creek at State Road 70	HCSW-3	3/6/2013	TDS (mg/L)	643	500
Horse Creek at State Road 70	HCSW-3	4/2/2013	TDS (mg/L)	818	500
Horse Creek at State Road 70	HCSW-3	5/1/2013	TDS (mg/L)	648	500
Horse Creek at State Road 70	HCSW-3	6/4/2013	TDS (mg/L)	675	500
Horse Creek at State Road 70	HCSW-3	12/3/2013	TDS (mg/L)	528	500
Horse Creek at State Road 70	HCSW-3	6/3/2014	TDS (mg/L)	548	500
Horse Creek at State Road 70	HCSW-3	7/1/2014	TDS (mg/L)	518	500
Horse Creek at State Road 72	HCSW-4	3/28/2006	TDS (mg/L)	600	500
Horse Creek at State Road 72	HCSW-4	5/25/2006	TDS (mg/L)	560	500
Horse Creek at State Road 72	HCSW-4	6/29/2006	TDS (mg/L)	1100	500
Horse Creek at State Road 72	HCSW-4	11/9/2006	TDS (mg/L)	510	500
Horse Creek at State Road 72	HCSW-4	12/13/2006	TDS (mg/L)	550	500
Horse Creek at State Road 72	HCSW-4	6/20/2007	TDS (mg/L)	600	500
Horse Creek at State Road 72	HCSW-4	7/18/2007	TDS (mg/L)	530	500
Horse Creek at State Road 72	HCSW-4	1/30/2008	TDS (mg/L)	550	500
Horse Creek at State Road 72	HCSW-4	3/27/2008	TDS (mg/L)	660	500
Horse Creek at State Road 72	HCSW-4	5/29/2008	TDS (mg/L)	710	500
Horse Creek at State Road 72	HCSW-4	6/26/2008	TDS (mg/L)	644	500
Horse Creek at State Road 72	HCSW-4	2/2/2009	TDS (mg/L)	536	500
Horse Creek at State Road 72	HCSW-4	6/3/2009	TDS (mg/L)	692	500
Horse Creek at State Road 72	HCSW-4	12/2/2009	TDS (mg/L)	604	500
Horse Creek at State Road 72	HCSW-4	11/3/2010	TDS (mg/L)	577	500
Horse Creek at State Road 72	HCSW-4	1/4/2011	TDS (mg/L)	574	500
Horse Creek at State Road 72	HCSW-4	7/5/2011	TDS (mg/L)	660	500
Horse Creek at State Road 72	HCSW-4	12/21/2011	TDS (mg/L)	543	500
Horse Creek at State Road 72	HCSW-4	1/12/2012	TDS (mg/L)	569	500
Horse Creek at State Road 72	HCSW-4	2/2/2012	TDS (mg/L)	512	500
Horse Creek at State Road 72	HCSW-4	3/5/2012	TDS (mg/L)	585	500
Horse Creek at State Road 72	HCSW-4	4/2/2012	TDS (mg/L)	688	500
Horse Creek at State Road 72	HCSW-4	5/2/2012	TDS (mg/L)	536	500
Horse Creek at State Road 72	HCSW-4	6/5/2012	TDS (mg/L)	1,320	500
Horse Creek at State Road 72	HCSW-4	3/6/2013	TDS (mg/L)	660	500
Horse Creek at State Road 72	HCSW-4	4/2/2013	TDS (mg/L)	595	500
Horse Creek at State Road 72	HCSW-4	5/1/2013	TDS (mg/L)	614	500
Horse Creek at State Road 72	HCSW-4	6/4/2013	TDS (mg/L)	687	500
Horse Creek at State Road 72	HCSW-4	12/3/2013	TDS (mg/L)	617	500
Horse Creek at State Road 72	HCSW-4	1/2/2014	TDS (mg/L)	601	500
Horse Creek at State Road 72	HCSW-4	2/3/2014	TDS (mg/L)	799	500
Horse Creek at State Road 72	HCSW-4	4/1/2014	TDS (mg/L)	555	500

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at State Road 72	HCSW-4	5/1/2014	TDS (mg/L)	544	500
Horse Creek at State Road 72	HCSW-4	6/3/2014	TDS (mg/L)	715	500
Horse Creek at State Road 72	HCSW-4	7/1/2014	TDS (mg/L)	580	500
Horse Creek at State Road 72	HCSW-4	4/8/2015	TDS (mg/L)	521	500
Horse Creek at State Road 72	HCSW-4	5/11/2015	TDS (mg/L)	571	500
Horse Creek at State Road 72	HCSW-4	6/3/2015	TDS (mg/L)	504	500
Horse Creek at Goose Pond Road	HCSW-2	7/27/2004	Radium (pCi/l)	5.1	5

Note: Dissolved oxygen (% Saturation) is the new HCSP trigger parameter and it is the Class III water quality standard as of 2013. The standard listed for percent saturation in this table is adjusted for time-of-day.

Table F-2. List of exceedances for parameters no longer monitored or trigger levels no longer used for HCSP evaluation.

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at State Road 64	HCSW-1	8/30/2004	Dissolved Oxygen (mg/l)	4.3	5
Horse Creek at State Road 64	HCSW-1	9/29/2004	Dissolved Oxygen (mg/l)	4.5	5
Horse Creek at State Road 64	HCSW-1	4/27/2006	Dissolved Oxygen (mg/l)	3.1	5
Horse Creek at State Road 64	HCSW-1	8/1/2013	Dissolved Oxygen (mg/l)	4.56	5
Horse Creek at Goose Pond Road	HCSW-2	4/30/2003	Dissolved Oxygen (mg/l)	1	5
Horse Creek at Goose Pond Road	HCSW-2	5/27/2003	Dissolved Oxygen (mg/l)	1.3	5
Horse Creek at Goose Pond Road	HCSW-2	6/19/2003	Dissolved Oxygen (mg/l)	1.1	5
Horse Creek at Goose Pond Road	HCSW-2	7/14/2003	Dissolved Oxygen (mg/l)	1.7	5
Horse Creek at Goose Pond Road	HCSW-2	8/28/2003	Dissolved Oxygen (mg/l)	3	5
Horse Creek at Goose Pond Road	HCSW-2	9/25/2003	Dissolved Oxygen (mg/l)	1.3	5
Horse Creek at Goose Pond Road	HCSW-2	10/29/2003	Dissolved Oxygen (mg/l)	2.9	5
Horse Creek at Goose Pond Road	HCSW-2	11/20/2003	Dissolved Oxygen (mg/l)	2.8	5
Horse Creek at Goose Pond Road	HCSW-2	12/16/2003	Dissolved Oxygen (mg/l)	4.1	5
Horse Creek at Goose Pond Road	HCSW-2	1/29/2004	Dissolved Oxygen (mg/l)	5	5
Horse Creek at Goose Pond Road	HCSW-2	2/24/2004	Dissolved Oxygen (mg/l)	3.6	5
Horse Creek at Goose Pond Road	HCSW-2	3/16/2004	Dissolved Oxygen (mg/l)	3.7	5
Horse Creek at Goose Pond Road	HCSW-2	5/26/2004	Dissolved Oxygen (mg/l)	3.1	5
Horse Creek at Goose Pond Road	HCSW-2	6/29/2004	Dissolved Oxygen (mg/l)	1.6	5
Horse Creek at Goose Pond Road	HCSW-2	7/27/2004	Dissolved Oxygen (mg/l)	0.3	5
Horse Creek at Goose Pond Road	HCSW-2	8/30/2004	Dissolved Oxygen (mg/l)	0.14	5
Horse Creek at Goose Pond Road	HCSW-2	9/29/2004	Dissolved Oxygen (mg/l)	1.4	5
Horse Creek at Goose Pond Road	HCSW-2	10/27/2004	Dissolved Oxygen (mg/l)	0.7	5
Horse Creek at Goose Pond Road	HCSW-2	11/18/2004	Dissolved Oxygen (mg/l)	2.8	5
Horse Creek at Goose Pond Road	HCSW-2	12/15/2004	Dissolved Oxygen (mg/l)	4.7	5
Horse Creek at Goose Pond Road	HCSW-2	1/26/2005	Dissolved Oxygen (mg/l)	4.1	5
Horse Creek at Goose Pond Road	HCSW-2	2/24/2005	Dissolved Oxygen (mg/l)	3.5	5
Horse Creek at Goose Pond Road	HCSW-2	3/30/2005	Dissolved Oxygen (mg/l)	2.6	5
Horse Creek at Goose Pond Road	HCSW-2	5/27/2005	Dissolved Oxygen (mg/l)	2	5
Horse Creek at Goose Pond Road	HCSW-2	6/22/2005	Dissolved Oxygen (mg/l)	1.4	5
Horse Creek at Goose Pond Road	HCSW-2	7/27/2005	Dissolved Oxygen (mg/l)	1.1	5
Horse Creek at Goose Pond Road	HCSW-2	8/23/2005	Dissolved Oxygen (mg/l)	1.7	5
Horse Creek at Goose Pond Road	HCSW-2	9/29/2005	Dissolved Oxygen (mg/l)	2.3	5
Horse Creek at Goose Pond Road	HCSW-2	10/27/2005	Dissolved Oxygen (mg/l)	4.6	5
Horse Creek at Goose Pond Road	HCSW-2	11/17/2005	Dissolved Oxygen (mg/l)	2.8	5
Horse Creek at Goose Pond Road	HCSW-2	12/20/2005	Dissolved Oxygen (mg/l)	4.4	5
Horse Creek at Goose Pond Road	HCSW-2	2/23/2006	Dissolved Oxygen (mg/l)	3.4	5
Horse Creek at Goose Pond Road	HCSW-2	5/25/2006	Dissolved Oxygen (mg/l)	4.9	5
Horse Creek at Goose Pond Road	HCSW-2	7/27/2006	Dissolved Oxygen (mg/l)	0.5	5
Horse Creek at Goose Pond Road	HCSW-2	9/27/2006	Dissolved Oxygen (mg/l)	1.3	5
Horse Creek at Goose Pond Road	HCSW-2	10/19/2006	Dissolved Oxygen (mg/l)	1.6	5
Horse Creek at Goose Pond Road	HCSW-2	11/9/2006	Dissolved Oxygen (mg/l)	2.9	5
Horse Creek at Goose Pond Road	HCSW-2	12/13/2006	Dissolved Oxygen (mg/l)	3.8	5
Horse Creek at Goose Pond Road	HCSW-2	1/23/2007	Dissolved Oxygen (mg/l)	3.38	5
Horse Creek at Goose Pond Road	HCSW-2	3/14/2007	Dissolved Oxygen (mg/l)	4.06	5
Horse Creek at Goose Pond Road	HCSW-2	4/25/2007	Dissolved Oxygen (mg/l)	4.6	5
Horse Creek at Goose Pond Road	HCSW-2	8/27/2007	Dissolved Oxygen (mg/l)	2.03	5

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at Goose Pond Road	HCSW-2	9/26/2007	Dissolved Oxygen (mg/l)	0.86	5
Horse Creek at Goose Pond Road	HCSW-2	10/29/2007	Dissolved Oxygen (mg/l)	1.08	5
Horse Creek at Goose Pond Road	HCSW-2	11/29/2007	Dissolved Oxygen (mg/l)	1.53	5
Horse Creek at Goose Pond Road	HCSW-2	12/17/2007	Dissolved Oxygen (mg/l)	2.13	5
Horse Creek at Goose Pond Road	HCSW-2	1/30/2008	Dissolved Oxygen (mg/l)	3.34	5
Horse Creek at Goose Pond Road	HCSW-2	2/26/2008	Dissolved Oxygen (mg/l)	1.65	5
Horse Creek at Goose Pond Road	HCSW-2	3/27/2008	Dissolved Oxygen (mg/l)	4.21	5
Horse Creek at Goose Pond Road	HCSW-2	4/23/2008	Dissolved Oxygen (mg/l)	1.77	5
Horse Creek at Goose Pond Road	HCSW-2	5/29/2008	Dissolved Oxygen (mg/l)	2.33	5
Horse Creek at Goose Pond Road	HCSW-2	6/26/2008	Dissolved Oxygen (mg/l)	1.41	5
Horse Creek at Goose Pond Road	HCSW-2	7/31/2008	Dissolved Oxygen (mg/l)	0.74	5
Horse Creek at Goose Pond Road	HCSW-2	8/26/2008	Dissolved Oxygen (mg/l)	0.13	5
Horse Creek at Goose Pond Road	HCSW-2	9/30/2008	Dissolved Oxygen (mg/l)	1.27	5
Horse Creek at Goose Pond Road	HCSW-2	10/16/2008	Dissolved Oxygen (mg/l)	0.19	5
Horse Creek at Goose Pond Road	HCSW-2	11/12/2008	Dissolved Oxygen (mg/l)	1.29	5
Horse Creek at Goose Pond Road	HCSW-2	12/4/2008	Dissolved Oxygen (mg/l)	3.04	5
Horse Creek at Goose Pond Road	HCSW-2	1/5/2009	Dissolved Oxygen (mg/l)	2.29	5
Horse Creek at Goose Pond Road	HCSW-2	2/2/2009	Dissolved Oxygen (mg/l)	2.38	5
Horse Creek at Goose Pond Road	HCSW-2	3/4/2009	Dissolved Oxygen (mg/l)	3.35	5
Horse Creek at Goose Pond Road	HCSW-2	4/1/2009	Dissolved Oxygen (mg/l)	2.49	5
Horse Creek at Goose Pond Road	HCSW-2	7/8/2009	Dissolved Oxygen (mg/l)	0.61	5
Horse Creek at Goose Pond Road	HCSW-2	8/5/2009	Dissolved Oxygen (mg/l)	1.21	5
Horse Creek at Goose Pond Road	HCSW-2	9/2/2009	Dissolved Oxygen (mg/l)	1.5	5
Horse Creek at Goose Pond Road	HCSW-2	10/7/2009	Dissolved Oxygen (mg/l)	0.34	5
Horse Creek at Goose Pond Road	HCSW-2	11/3/2009	Dissolved Oxygen (mg/l)	1.78	5
Horse Creek at Goose Pond Road	HCSW-2	12/2/2009	Dissolved Oxygen (mg/l)	1.98	5
Horse Creek at Goose Pond Road	HCSW-2	2/2/2010	Dissolved Oxygen (mg/l)	2.67	5
Horse Creek at Goose Pond Road	HCSW-2	3/3/2010	Dissolved Oxygen (mg/l)	3.75	5
Horse Creek at Goose Pond Road	HCSW-2	4/6/2010	Dissolved Oxygen (mg/l)	1.42	5
Horse Creek at Goose Pond Road	HCSW-2	5/5/2010	Dissolved Oxygen (mg/l)	0.56	5
Horse Creek at Goose Pond Road	HCSW-2	6/2/2010	Dissolved Oxygen (mg/l)	0.6	5
Horse Creek at Goose Pond Road	HCSW-2	7/12/2010	Dissolved Oxygen (mg/l)	0.62	5
Horse Creek at Goose Pond Road	HCSW-2	8/3/2010	Dissolved Oxygen (mg/l)	0.56	5
Horse Creek at Goose Pond Road	HCSW-2	9/8/2010	Dissolved Oxygen (mg/l)	0.72	5
Horse Creek at Goose Pond Road	HCSW-2	10/6/2010	Dissolved Oxygen (mg/l)	0.93	5
Horse Creek at Goose Pond Road	HCSW-2	11/3/2010	Dissolved Oxygen (mg/l)	1.28	5
Horse Creek at Goose Pond Road	HCSW-2	1/4/2011	Dissolved Oxygen (mg/l)	3.02	5
Horse Creek at Goose Pond Road	HCSW-2	2/3/2011	Dissolved Oxygen (mg/l)	1.47	5
Horse Creek at Goose Pond Road	HCSW-2	3/2/2001	Dissolved Oxygen (mg/l)	1.95	5
Horse Creek at Goose Pond Road	HCSW-2	4/5/2011	Dissolved Oxygen (mg/l)	0.14	5
Horse Creek at Goose Pond Road	HCSW-2	5/3/2011	Dissolved Oxygen (mg/l)	1.78	5
Horse Creek at Goose Pond Road	HCSW-2	7/5/2011	Dissolved Oxygen (mg/l)	0.89	5
Horse Creek at Goose Pond Road	HCSW-2	8/16/2011	Dissolved Oxygen (mg/l)	0.59	5
Horse Creek at Goose Pond Road	HCSW-2	9/7/2011	Dissolved Oxygen (mg/l)	0.45	5
Horse Creek at Goose Pond Road	HCSW-2	10/24/2011	Dissolved Oxygen (mg/l)	1.11	5
Horse Creek at Goose Pond Road	HCSW-2	11/29/2011	Dissolved Oxygen (mg/l)	2.7	5
Horse Creek at Goose Pond Road	HCSW-2	3/5/2012	Dissolved Oxygen (mg/l)	4.55	5
Horse Creek at Goose Pond Road	HCSW-2	5/2/2012	Dissolved Oxygen (mg/l)	3.32	5

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at Goose Pond Road	HCSW-2	10/10/2012	Dissolved Oxygen (mg/l)	2.92	5
Horse Creek at Goose Pond Road	HCSW-2	11/6/2012	Dissolved Oxygen (mg/l)	3.95	5
Horse Creek at Goose Pond Road	HCSW-2	12/5/2012	Dissolved Oxygen (mg/l)	4.74	5
Horse Creek at Goose Pond Road	HCSW-2	1/9/2013	Dissolved Oxygen (mg/l)	4.15	5
Horse Creek at Goose Pond Road	HCSW-2	6/4/2013	Dissolved Oxygen (mg/l)	4.21	5
Horse Creek at Goose Pond Road	HCSW-2	7/2/2013	Dissolved Oxygen (mg/l)	2.01	5
Horse Creek at Goose Pond Road	HCSW-2	8/1/2013	Dissolved Oxygen (mg/l)	2	5
Horse Creek at Goose Pond Road	HCSW-2	9/4/2013	Dissolved Oxygen (mg/l)	2.48	5
Horse Creek at Goose Pond Road	HCSW-2	10/1/2013	Dissolved Oxygen (mg/l)	2.56	5
Horse Creek at Goose Pond Road	HCSW-2	11/4/2013	Dissolved Oxygen (mg/l)	3.97	5
Horse Creek at Goose Pond Road	HCSW-2	12/3/2013	Dissolved Oxygen (mg/l)	3.8	5
Horse Creek at State Road 70	HCSW-3	7/27/2004	Dissolved Oxygen (mg/l)	4.7	5
Horse Creek at State Road 70	HCSW-3	8/30/2004	Dissolved Oxygen (mg/l)	0.27	5
Horse Creek at State Road 70	HCSW-3	9/29/2004	Dissolved Oxygen (mg/l)	2.4	5
Horse Creek at State Road 70	HCSW-3	6/22/2005	Dissolved Oxygen (mg/l)	3.9	5
Horse Creek at State Road 70	HCSW-3	7/27/2005	Dissolved Oxygen (mg/l)	3.5	5
Horse Creek at State Road 70	HCSW-3	8/23/2005	Dissolved Oxygen (mg/l)	4.4	5
Horse Creek at State Road 70	HCSW-3	7/27/2006	Dissolved Oxygen (mg/l)	4.5	5
Horse Creek at State Road 70	HCSW-3	8/21/2006	Dissolved Oxygen (mg/l)	3.7	5
Horse Creek at State Road 70	HCSW-3	9/27/2006	Dissolved Oxygen (mg/l)	1.8	5
Horse Creek at State Road 70	HCSW-3	10/19/2006	Dissolved Oxygen (mg/l)	4.5	5
Horse Creek at State Road 70	HCSW-3	7/18/2007	Dissolved Oxygen (mg/l)	3.93	5
Horse Creek at State Road 70	HCSW-3	8/27/2007	Dissolved Oxygen (mg/l)	2.8	5
Horse Creek at State Road 70	HCSW-3	9/26/2007	Dissolved Oxygen (mg/l)	2.88	5
Horse Creek at State Road 70	HCSW-3	10/29/2007	Dissolved Oxygen (mg/l)	3.06	5
Horse Creek at State Road 70	HCSW-3	11/29/2007	Dissolved Oxygen (mg/l)	4.3	5
Horse Creek at State Road 70	HCSW-3	2/26/2008	Dissolved Oxygen (mg/l)	3.64	5
Horse Creek at State Road 70	HCSW-3	3/27/2008	Dissolved Oxygen (mg/l)	4.75	5
Horse Creek at State Road 70	HCSW-3	4/23/2008	Dissolved Oxygen (mg/l)	3.27	5
Horse Creek at State Road 70	HCSW-3	5/29/2008	Dissolved Oxygen (mg/l)	2.9	5
Horse Creek at State Road 70	HCSW-3	6/26/2008	Dissolved Oxygen (mg/l)	4.78	5
Horse Creek at State Road 70	HCSW-3	7/31/2008	Dissolved Oxygen (mg/l)	0.99	5
Horse Creek at State Road 70	HCSW-3	8/26/2008	Dissolved Oxygen (mg/l)	1.62	5
Horse Creek at State Road 70	HCSW-3	9/30/2008	Dissolved Oxygen (mg/l)	3.28	5
Horse Creek at State Road 70	HCSW-3	10/16/2008	Dissolved Oxygen (mg/l)	2.73	5
Horse Creek at State Road 70	HCSW-3	6/3/2009	Dissolved Oxygen (mg/l)	3.89	5
Horse Creek at State Road 70	HCSW-3	7/8/2009	Dissolved Oxygen (mg/l)	3.38	5
Horse Creek at State Road 70	HCSW-3	8/5/2009	Dissolved Oxygen (mg/l)	3.33	5
Horse Creek at State Road 70	HCSW-3	9/2/2009	Dissolved Oxygen (mg/l)	3.87	5
Horse Creek at State Road 70	HCSW-3	10/7/2009	Dissolved Oxygen (mg/l)	3.13	5
Horse Creek at State Road 70	HCSW-3	4/6/2010	Dissolved Oxygen (mg/l)	4.74	5
Horse Creek at State Road 70	HCSW-3	7/12/2010	Dissolved Oxygen (mg/l)	3.67	5
Horse Creek at State Road 70	HCSW-3	8/3/2010	Dissolved Oxygen (mg/l)	4.61	5
Horse Creek at State Road 70	HCSW-3	9/8/2010	Dissolved Oxygen (mg/l)	4.09	5
Horse Creek at State Road 70	HCSW-3	8/16/2011	Dissolved Oxygen (mg/l)	4.14	5
Horse Creek at State Road 70	HCSW-3	9/7/2011	Dissolved Oxygen (mg/l)	3.32	5
Horse Creek at State Road 70	HCSW-3	6/5/2012	Dissolved Oxygen (mg/l)	4.64	5
Horse Creek at State Road 70	HCSW-3	7/5/2012	Dissolved Oxygen (mg/l)	3.28	5

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at State Road 70	HCSW-3	8/2/2012	Dissolved Oxygen (mg/l)	3.05	5
Horse Creek at State Road 70	HCSW-3	9/5/2012	Dissolved Oxygen (mg/l)	3.8	5
Horse Creek at State Road 70	HCSW-3	10/10/2012	Dissolved Oxygen (mg/l)	4.66	5
Horse Creek at State Road 70	HCSW-3	7/2/2013	Dissolved Oxygen (mg/l)	4.65	5
Horse Creek at State Road 70	HCSW-3	8/1/2013	Dissolved Oxygen (mg/l)	3	5
Horse Creek at State Road 70	HCSW-3	9/4/2013	Dissolved Oxygen (mg/l)	4.4	5
Horse Creek at State Road 70	HCSW-3	10/1/2013	Dissolved Oxygen (mg/l)	4.5	5
Horse Creek at State Road 72	HCSW-4	8/30/2004	Dissolved Oxygen (mg/l)	0.58	5
Horse Creek at State Road 72	HCSW-4	9/29/2004	Dissolved Oxygen (mg/l)	2.9	5
Horse Creek at State Road 72	HCSW-4	6/22/2005	Dissolved Oxygen (mg/l)	4	5
Horse Creek at State Road 72	HCSW-4	7/27/2005	Dissolved Oxygen (mg/l)	4.1	5
Horse Creek at State Road 72	HCSW-4	9/24/2006	Dissolved Oxygen (mg/l)	4.1	5
Horse Creek at State Road 72	HCSW-4	7/31/2008	Dissolved Oxygen (mg/l)	3.1	5
Horse Creek at State Road 72	HCSW-4	8/26/2008	Dissolved Oxygen (mg/l)	2.2	5
Horse Creek at State Road 72	HCSW-4	9/30/2008	Dissolved Oxygen (mg/l)	4.77	5
Horse Creek at State Road 72	HCSW-4	7/8/2009	Dissolved Oxygen (mg/l)	4.2	5
Horse Creek at State Road 72	HCSW-4	8/5/2009	Dissolved Oxygen (mg/l)	3.36	5
Horse Creek at State Road 72	HCSW-4	9/2/2009	Dissolved Oxygen (mg/l)	4.89	5
Horse Creek at State Road 72	HCSW-4	10/7/2009	Dissolved Oxygen (mg/l)	4.48	5
Horse Creek at State Road 72	HCSW-4	7/12/2010	Dissolved Oxygen (mg/l)	4.31	5
Horse Creek at State Road 72	HCSW-4	4/5/2011	Dissolved Oxygen (mg/l)	4.89	5
Horse Creek at State Road 72	HCSW-4	9/7/2011	Dissolved Oxygen (mg/l)	4.29	5
Horse Creek at State Road 72	HCSW-4	7/5/2012	Dissolved Oxygen (mg/l)	2.23	5
Horse Creek at State Road 72	HCSW-4	9/5/2012	Dissolved Oxygen (mg/l)	4.12	5
Horse Creek at State Road 72	HCSW-4	7/2/2013	Dissolved Oxygen (mg/l)	4.16	5
Horse Creek at State Road 72	HCSW-4	8/1/2013	Dissolved Oxygen (mg/l)	4.46	5
Horse Creek at State Road 72	HCSW-4	9/4/2013	Dissolved Oxygen (mg/l)	4.74	5
Horse Creek at State Road 72	HCSW-4	10/1/2013	Dissolved Oxygen (mg/l)	4.3	5
Horse Creek at State Road 64	HCSW-1	6/20/2007	Total Fatty Acids (mg/L)	1.5	0.5
Horse Creek at Goose Pond Road	HCSW-2	11/18/2004	Total Fatty Acids (mg/L)	1.1	0.5
Horse Creek at Goose Pond Road	HCSW-2	3/30/2005	Total Fatty Acids (mg/L)	0.56	0.5
Horse Creek at Goose Pond Road	HCSW-2	4/27/2005	Total Fatty Acids (mg/L)	0.53	0.5
Horse Creek at Goose Pond Road	HCSW-2	12/13/2006	Total Fatty Acids (mg/L)	1.6	0.5
Horse Creek at Goose Pond Road	HCSW-2	6/20/2007	Total Fatty Acids (mg/L)	1.6	0.5
Horse Creek at Goose Pond Road	HCSW-2	7/18/2007	Total Fatty Acids (mg/L)	0.87	0.5
Horse Creek at Goose Pond Road	HCSW-2	12/17/2007	Total Fatty Acids (mg/L)	0.88	0.5
Horse Creek at Goose Pond Road	HCSW-2	12/4/2008	Total Fatty Acids (mg/L)	0.97	0.5

Note: Dissolved oxygen (mg/L) is listed for comparison purposes because it was the trigger level from 2003-2013. Total fatty acid monitoring stopped in September 2009 when the new Brushy Creek (BCSW-1) monitoring location was added.

Horse Creek Stewardship
Program

APPENDIX

G

SUMMARY OF IMPACT ASSESSMENTS FROM 2003 TO 2016

Appendix G

Summary of Impact Assessments from 2003 to 2016

Station	Date	Exceedance	Action Taken	Conclusions
HCSW-4	7/14/2003	Dissolved Iron	A special sampling program was carried out in August 2003 where samples were collected from three locations on Horse Creek and two tributaries, but flow conditions were very high. In October 2003, eleven stations were sampled while flow was closer to normal.	Readings appear normal for the basin, the lower trigger level at this location caused the exceedance due to differences in water class. The trigger value may be set too low at this location.
HCSW-2	8/28/2003	Dissolved Oxygen	A sampling program was attempted in August 2003 in the northern portion of the stream, but flow conditions were very high. Instead six locations including tributaries were sampled at the end of October 2003.	Low DO levels persisted at HCSW-2 due to generally low streamflow levels and a greater amount of organics than the other stations. The low levels are not due to mining upstream.
HCSW-2	4/14/2004	Chlorophyll a	A special sampling program was carried out in May 2004 where samples were taken from four upstream locations in Horse Creek (due to dry conditions of tributaries).	Elevated chlorophyll a concentrations were caused by low streamflow and the physical nature of the stream channel and not mining activities.
HCSW-4	6/29/2004	Sulfate	A special sampling program was carried out where samples were taken from nearby tributaries as well as the HCSP stations during July 2004.	Nearby tributary basins have high amounts of agricultural activity (requiring irrigation) and streamflow was very low at this time which led to the elevated sulfate concentration in June 2004.

Station	Date	Exceedance	Action Taken	Conclusions
HCSW-2	7/27/2004	Total Radium	None	Blank sample results had high values, making other values suspect. No impact assessment required for July 2004, but future results should be monitored.
HCSW-1	8/30/2004	Dissolved Oxygen	None	Impact assessment deferred until the streamflows in Horse Creek are near normal for the time period the exceedance occurred (multiple hurricanes passing through region dramatically increased streamflow).
HCSW-2	8/30/2004	Dissolved Oxygen	None	Impact assessment deferred until the streamflows in Horse Creek are near normal for the time period the exceedance occurred (multiple hurricanes passing through region dramatically increased streamflow).
HCSW-3	8/30/2004	Dissolved Oxygen	None	Impact assessment deferred until the streamflows in Horse Creek are near normal for the time period the exceedance occurred (multiple hurricanes passing through region dramatically increased streamflow).
HCSW-4	8/30/2004	Dissolved Oxygen	None	Impact assessment deferred until the streamflows in Horse Creek are near normal for the time period the exceedance occurred (multiple hurricanes passing through region dramatically increased streamflow).
HCSW-2	8/30/2004	Chlorophyll a	None	Impact assessment deferred until the streamflows in Horse Creek are near normal for the time period the exceedance occurred (multiple hurricanes passing through region dramatically increased streamflow).

Station	Date	Exceedance	Action Taken	Conclusions
HCSW-3	8/30/2004	Chlorophyll a	None	Impact assessment deferred until the streamflows in Horse Creek are near normal for the time period the exceedance occurred (multiple hurricanes passing through region dramatically increased streamflow).
HCSW-2	11/18/2004	Total Fatty Acids	A special sampling program was carried out in January 2005, where three Horse Creek locations and a tributary (Brushy Creek) were sampled.	Nearby Horse Creek Prairie is likely to contribute to the elevated levels since all other stations had undetected values for fatty acids. Low streamflow and high organics in this region, not mining, were likely contributing factors.
HCSW-2	4/27/2005	Total Fatty Acids	A special sampling program was carried out in June 2005, where three Horse Creek locations and a tributary were sampled.	The exceedance is most likely caused by the surrounding habitat conditions and not impacted by mining.
HCSW-2	7/27/2006	Iron	None	Nearby Horse Creek Prairie is likely to contribute to the elevated levels since all other stations had lower iron concentrations.
HCSW-1	1/23/2007	pH	Compared measurement to SWFWMD measurements for the months of January and February.	Not an actual exceedance but equipment malfunction
HCSW-4	1/23/2007	pH	Compared measurement to SWFWMD measurements for the months of January and February.	Not an actual exceedance but equipment malfunction

Station	Date	Exceedance	Action Taken	Conclusions
HCSW-1	4/25/2007	Alkalinity	Statistical analysis of HCSP alkalinity and SWFWMD measurements. When alkalinity compared to streamflow, there was a weak negative correlation between the two (high alkalinity during low flow).	No evidence that high alkalinity was caused by mining, but was rather a seasonal pattern caused by lower water levels and flow. Once those recovered during the wet season, the alkalinity values decreased.
HCSW-1	6/20/2007	Total Fatty Acids	Used conclusions from the FIPR on the rate of biodegradation and soil leaching of organic compounds in a controlled environment.	It was unlikely that fatty acids from mining process water are responsible for the elevated levels seen. Instead it represents the variation in naturally-occurring fatty acids in Horse Creek.
HCSW-2	6/20/2007	Total Fatty Acids	Used conclusions from the FIPR on the rate of biodegradation and soil leaching of organic compounds in a controlled environment.	It was unlikely that fatty acids from mining process water are responsible for the elevated levels seen. Instead it represents the variation in naturally-occurring fatty acids in Horse Creek.
HCSW-2-FD	6/20/2007	Total Nitrogen	Compared to nitrate+nitrate and TKN values from April 2003 through August at HCSP.	Elevated measurements most likely due to lab analyst or instrument error. The total nitrogen levels recorded are not corroborated by measurements taken before or after the exceedance.
HCSW-3	6/20/2007	Total Nitrogen	Compared to nitrate+nitrate and TKN values from April 2003 through August at HCSP.	Elevated measurements most likely due to lab analyst or instrument error. The total nitrogen levels recorded are not corroborated by measurements taken before or after the exceedance.
HCSW-2	7/31/2008	Ammonia	None	Elevated concentrations are either due to laboratory method change or a seasonal fluctuation in the nitrogen cycle.
HCSW-3	7/31/2008	Ammonia	None	Elevated concentrations are either due to laboratory method change or a seasonal fluctuation in the nitrogen cycle.

Station	Date	Exceedance	Action Taken	Conclusions
HCSW-4	7/31/2008	Ammonia	None	Elevated concentrations are either due to laboratory method change or a seasonal fluctuation in the nitrogen cycle.
HCSW-4	5/4/2009	Alkalinity	Statistical analysis of HCSP alkalinity and SWFWMD measurements. When alkalinity compared to rainfall, there was a strong negative correlation between the two (high alkalinity during low flow).	No evidence that high alkalinity was caused by mining, but was rather a seasonal pattern caused by lower water levels, flow, and rainfall. Once those recovered during the wet season, the alkalinity values decreased.
HCSW-1	2/2/2010	Chlorophyll a	None	No connection with mining. May have been a sampling error since color, pH, and DO do not indicate a significant algal bloom causing an elevated chlorophyll a reading.
HCSW-1	1/4/2011	pH	Compared to SWFWMD measurements from December 2010 through March 2011.	Not an actual exceedance but equipment malfunction.
HCSW-3	5/3/2011	Ammonia	None	No connection with mining. Lab analyzing the data was getting back results that were ten-times higher than other labs. Split sampling conducted in October 2011, verified that it was lab error.
HCSW-1	11/6/2012	Alkalinity	None	Although NPDES discharge occurred prior to the November 2012 alkalinity exceedance, HCSW-1 alkalinity does not show a consistent pattern of exceeding the trigger level during periods of NPDES discharge.

Horse Creek Stewardship
Program

APPENDIX

H

SUMMARY OF TRENDS FROM THE 2008 TO 2015 HCSP ANNUAL REPORTS

Appendix H

Summary of Trends from the 2008 to 2015 HCSP Annual Reports

Station	Year	Parameter	Trend Noted	Addressing of Trend
HCSW-1	2008	Alkalinity	increasing trend with slope of 4.58	Alkalinity was higher in the dry season and lower during times of NDPES discharge. The trend was not shown to be linked to mining discharge. The trend is more likely linked to climate factors not completely accounted for in the LOESS smoothing with streamflow.
HCSW-1	2008	Specific Conductance	increasing trend with slope of 15.31	Conductivity was higher in the dry season and lower (or equal) during times of NDPES discharge. The trend was not shown to be linked to mining discharge. The trend is more likely linked to climate factors not completely accounted for in the LOESS smoothing with streamflow.
HCSW-1	2009	Alkalinity	increasing trend with slope of 4.71	As with specific conductivity, it is likely that this trend is strongly influenced by the dry conditions in 2006 to 2007, given that most of the highest alkalinity measurements are associated with periods without NPDES discharge. The estimated slopes for both stations are small compared to the historic HCSP MDL (≤ 1 mg/L) and/or the differences between primary and field duplicate samples (≤ 17 mg/L).
HCSW-1	2009	Dissolved Calcium	increasing trend with slope of 1.56	As with specific conductivity, it is likely that this trend is strongly influenced by the dry conditions in 2006 to 2007, given that most of the highest calcium measurements are associated with periods without NPDES discharge. The estimated slope of the trend for HCSW-1 is small compared to historic HCSP differences between primary and field duplicate samples (≤ 8.0 mg/L).
HCSW-1	2009	Chloride	slight increasing trend with slope of 0.50	As with the other dissolved ion parameters, the trend for HCSW-1 is small compared to the historic HCSP MDL (≤ 4.06 mg/L) and differences between primary and field duplicate samples (≤ 5.0 mg/L). The observed changes in chloride over time are probably related to the differences in rainfall over the course of the HCSP.
HCSW-1	2009	Orthophosphate	slight increasing trend with slope of 0.03	The slope is very small compared to historic HCSP values for laboratory Minimum Detection Limits (≤ 0.075 mg/L) or differences between primary and field duplicate samples (≤ 0.034 mg/L). Therefore, the trends at both stations are not of concern at this time, and could be related to extreme differences in rainfall and streamflow within the sampling period.
HCSW-1	2009	Specific Conductance	increasing trend with slope of 16.73	It is likely that this trend is strongly influenced by the dry conditions and subsequent higher than average conductivity in 2006 to 2007, given that conductivity is greatly influenced by rainfall and most of the highest conductivity measurements are associated with dryer years. The estimated slope of the trend for HCSW-1 is not of concern at this time because of the substantial variability in rainfall over the course of the HCSP.

Station	Year	Parameter	Trend Noted	Addressing of Trend
HCSW-1	2009	Total Dissolved Solids	increasing trend with slope of 9.46	As with the other dissolved ion parameters, the trend for HCSW-1 is small compared to differences between primary and field duplicate samples (≤ 44 mg/L). The observed changes in TDS over time are probably related to the differences in rainfall over the course of the HCSP.
HCSW-1	2010	pH	slight increasing trend with slope of 0.06	2010 Impact Assessment concluded that estimated slope was too small to be ecologically significant.
HCSW-1	2010	Fluoride	slight increasing trend with slope of 0.01	
HCSW-1	2010	Ammonia	slight decreasing trend with slope of -0.002	2010 Impact Assessment concluded that estimated slope was in the opposite direction of adverse change.
HCSW-1	2010	Orthophosphate	slight increasing trend with slope of 0.27	2010 Impact Assessment found that the evident trend was caused by a data bias, and extending the period of record before 2003 caused the trend to no longer be valid. Concentrations in 2008-2010 were similar to those before 2003.
HCSW-1	2010	Specific Conductance	increasing trend with slope of 16.68	2010 Impact Assessment found step-change in conductivity and dissolved ions likely caused by increased groundwater contributions from 2006-2008 drought and subsequent influence from Wingate dredge mining outfall discharge. Concentrations after 2008 remain relatively steady, with no evidence of biological impact.
HCSW-1	2010	Alkalinity	increasing trend with slope of 4.19	
HCSW-1	2010	Dissolved Calcium	increasing trend with slope of 1.60	
HCSW-1	2010	TDS	increasing trend with slope of 10.66	
HCSW-1	2011	pH	slight increasing trend with slope of 0.05	2011 Impact Assessment concluded that estimated slope was too small to be ecologically significant.
HCSW-1	2011	Fluoride	slight increasing trend with slope of 0.01	
HCSW-1	2011	Ammonia	slight decreasing trend with slope of -0.002	2011 Impact Assessment concluded that estimated slope was in the opposite direction of adverse change.
HCSW-1	2011	Dissolved Iron	slight decreasing trend with slope of -0.02	
HCSW-1	2011	Orthophosphate	slight increasing trend with slope of 0.02	2011 Impact Assessment found that the evident trend was caused by a data bias, and extending the period of record before 2003 caused the trend to no longer be valid. Concentrations in 2008-2011 were similar to those before 2003.
HCSW-1	2011	Specific Conductance	increasing trend with slope of 14.57	2011 Impact Assessment found step-change in conductivity and dissolved ions likely caused by increased groundwater contributions from 2006-2008 drought and subsequent influence from Wingate dredge mining outfall discharge. Concentrations after 2008 remain relatively steady, with no evidence of biological impact.
HCSW-1	2011	Alkalinity	increasing trend with slope of 3.91	
HCSW-1	2011	Dissolved Calcium	increasing trend with slope of 1.37	
HCSW-1	2011	Sulfate	Increasing trend with slope of 2.82	
HCSW-1	2011	Total Dissolved Solids	increasing trend with slope of 9.65	
HCSW-1	2012	pH	slight increasing trend with slope of 0.05	2012 Impact Assessment concluded that estimated slope was too small to be ecologically significant.
HCSW-1	2012	Color	slight increasing trend with slope of 5.25	
HCSW-1	2012	Ammonia	slight decreasing trend with slope of -0.0003	2012 Impact Assessment concluded that estimated slope was in the opposite direction of adverse change.
HCSW-1	2012	Dissolved Iron	slight decreasing trend with slope of -0.02	

Station	Year	Parameter	Trend Noted	Addressing of Trend
HCSW-1	2012	Orthophosphate	slight increasing trend with slope of 0.02	2012 Impact Assessment found that the evident trend was caused by a data bias, and extending the period of record before 2003 caused the trend to no longer be valid. Concentrations in 2008-2012 were similar to those before 2003.
HCSW-1	2012	Specific Conductance	increasing trend with slope of 10.6	2012 Impact Assessment found step-change in conductivity and dissolved ions likely caused by increased groundwater contributions from 2006-2008 drought and subsequent influence from Wingate dredge mining outfall discharge. Concentrations after 2008 remain relatively steady, with no evidence of biological impact.
HCSW-1	2012	Alkalinity	increasing trend with slope of 2.96	
HCSW-1	2012	Dissolved Calcium	increasing trend with slope of 1.05	
HCSW-1	2012	Sulfate	Increasing trend with slope of 2.27	
HCSW-1	2012	Total Dissolved Solids	increasing trend with slope of 6.64	
HCSW-1	2013	pH	slight increasing trend with slope of 0.05	Although the HCSP HCSW-1 pH data does show a step-change increase in 2007 during the drought period (which probably causes the statistically significant Seasonal Kendall Tau trend), there is no evidence that NPDES discharge is raising pH at HCSW-1. It is more likely that the step-change increase in pH may partially originate at stations upstream of HCSW-1 with no NPDES influence.
HCSW-1	2013	Fluoride	slight increasing trend with slope of 0.02	2013 Impact Assessment concluded that estimated slope was too small to be ecologically significant.
HCSW-1	2013	Ammonia	slight decreasing trend with slope of -0.002	2013 Impact Assessment concluded that estimated slope was in the opposite direction of adverse change.
HCSW-1	2013	Dissolved Iron	slight decreasing trend with slope of -0.01	
HCSW-1	2013	Specific Conductance	increasing trend with slope of 11.2	The conductivity increases in recent years were influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities. Any small portion of the change in specific conductivity that may have been affected by changes in NPDES water quality is likely to stay relatively constant at HCSW-1 in the near future given planned mining practices and the stable range of concentrations shown since Wingate mine began discharging to Horse Creek in 2008.
HCSW-1	2013	Alkalinity	increasing trend with slope of 2.50	
HCSW-1	2013	Dissolved Calcium	increasing trend with slope of 0.99	
HCSW-1	2013	Sulfate	Increasing trend with slope of 4.19	
HCSW-1	2013	Total Dissolved Solids	increasing trend with slope of 10.3	
HCSW-1	2014	pH	slight increasing trend with slope of 0.04	Although the HCSP HCSW-1 pH data does show a step-change increase in 2007 during the drought period (which probably causes the statistically significant Seasonal Kendall Tau trend), there is no evidence that NPDES discharge is raising pH at HCSW-1. It is more likely that the step-change increase in pH may partially originate at stations upstream of HCSW-1 with no NPDES influence.
HCSW-1	2014	Fluoride	slight increasing trend with slope of 0.01	2014 Impact Assessment concluded that estimated slope was too small to be ecologically significant.
HCSW-1	2014	DO Saturation	slight increasing trend with slope of 1.43	2014 Impact Assessment concluded that estimated slope was in the opposite direction of adverse change.
HCSW-1	2014	Ammonia	slight decreasing trend with slope of -0.001	
HCSW-1	2014	Dissolved Iron	slight decreasing trend with slope of -0.01	

Station	Year	Parameter	Trend Noted	Addressing of Trend
HCSW-1	2014	Specific Conductance	increasing trend with slope of 9.46	The conductivity increases in recent years were influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities. Any small portion of the change in specific conductivity that may have been affected by changes in NPDES water quality is likely to stay relatively constant at HCSW-1 in the near future given planned mining practices and the stable range of concentrations shown since Wingate mine began discharging to Horse Creek in 2008.
HCSW-1	2014	Alkalinity	increasing trend with slope of 2.28	
HCSW-1	2014	Dissolved Calcium	increasing trend with slope of 0.71	
HCSW-1	2014	Sulfate	Increasing trend with slope of 2.85	
HCSW-1	2014	Total Dissolved Solids	increasing trend with slope of 7.07	
HCSW-1	2015	pH	increasing trend with slope of 0.04	Although the HCSP HCSW-1 pH data does show a step-change increase in 2007 during the drought period (which probably causes the statistically significant Seasonal Kendall Tau trend), there is no evidence that NPDES discharge is raising pH at HCSW-1. It is more likely that the step-change increase in pH may partially originate at stations upstream of HCSW-1 with no NPDES influence
HCSW-1	2015	Dissolved Oxygen-%Sat	increasing trend with slope of 1.29	2015 Impact Assessment concluded that estimated slope was in the opposite direction of adverse change.
HCSW-1	2015	Ammonia	slight decreasing trend with slope of -0.001	
HCSW-1	2015	Dissolved Iron	slight decreasing trend with slope of -0.01	
HCSW-1	2015	Specific Conductance	increasing trend with slope of 10.2	The conductivity increases in recent years were influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities. Any small portion of the change in specific conductivity that may have been affected by changes in NPDES water quality is likely to stay relatively constant at HCSW-1 in the near future given planned mining practices and the stable range of concentrations shown since Wingate mine began discharging to Horse Creek in 2008.
HCSW-1	2015	Alkalinity	increasing trend with slope of 2.42	
HCSW-1	2015	Dissolved Calcium	increasing trend with slope of 0.86	
HCSW-1	2015	Fluoride	slight increasing trend with slope of 0.01	
HCSW-1	2015	Sulfate	Increasing trend with slope of 2.92	
HCSW-1	2015	Total Dissolved Solids	increasing trend with slope of 8.31	
HCSW-4	2008	Dissolved Oxygen	slight decreasing trend with slope of -0.40	May be influenced by climate or other land use in southern basin.
HCSW-4	2008	Orthophosphate	slight increasing trend with slope of 0.02 (data not correlated with streamflow)	Magnitude of trend not ecologically significant. May be influenced by climate or other land use in southern basin.
HCSW-4	2009	Alkalinity	increasing trend with slope of 1.90	As with specific conductivity, it is likely that this trend is strongly influenced by the dry conditions in 2006 to 2007, given that most of the highest alkalinity measurements are associated with periods without NPDES discharge. The estimated slopes for both stations are small compared to the historic HCSP MDL (≤ 1 mg/L) and/or the differences between primary and field duplicate samples (≤ 17 mg/L).

Station	Year	Parameter	Trend Noted	Addressing of Trend
HCSW-4	2009	Dissolved Oxygen	slight decreasing trend with slope of -0.42	It appears the declining trend stems from the difference between DO concentrations in 2006-2007 (dry years) compared to 2008-2009. When comparing DO overall annual and seasonal medians, DO concentrations in 2008-2009 are consistent with those in 2003-2005. Given this information and the fact that HCSW-1 does not show a significant trend, it is unlikely that mining activities are contributing to a perceived trend in dissolved oxygen concentrations at HCSW-4.
HCSW-4	2009	Orthophosphate	slight increasing trend with slope of 0.02 (data not correlated with streamflow)	The slope is very small compared to historic HCSP values for laboratory Minimum Detection Limits (≤ 0.075 mg/L) or differences between primary and field duplicate samples (≤ 0.034 mg/L). Therefore, the trends at both stations are not of concern at this time, and could be related to extreme differences in rainfall and streamflow within the sampling period.
HCSW-4	2010	Color	increasing trend with slope of 12.07	2010 Impact Assessment concluded that estimated slope was in the opposite direction of adverse change.
HCSW-4	2010	Orthophosphate	slight increasing trend with slope of 0.02	2010 Impact Assessment found that the evident trend was caused by a data bias, and extending the period of record before 2003 caused the trend to no longer be valid. Concentrations in 2008-2010 were similar to those before 2003.
HCSW-4	2010	Alkalinity	Increasing trend with slope of 1.62	2010 Impact Assessment found step-change in conductivity and dissolved ions likely caused by increased groundwater contributions from 2006-2008 drought and subsequent influence from Wingate dredge mining outfall discharge. Concentrations after 2008 remain relatively steady, with no evidence of biological impact.
HCSW-4	2011	Color	increasing trend with slope of 11.47	2011 Impact Assessment concluded that estimated slope was in the opposite direction of adverse change.
HCSW-4	2011	Dissolved Iron	slight decreasing trend with slope of -0.01	
HCSW-4	2011	Alkalinity	increasing trend with slope of 1.31	2011 Impact Assessment found step-change in conductivity and dissolved ions likely caused by increased groundwater contributions from 2006-2008 drought and subsequent influence from Wingate dredge mining outfall discharge. Concentrations after 2008 remain relatively steady, with no evidence of biological impact.
HCSW-4	2012	Color	increasing trend with slope of 10.6	2012 Impact Assessment concluded that estimated slope was in the opposite direction of adverse change.
HCSW-4	2012	Dissolved Iron	slight decreasing trend with slope of -0.01	
HCSW-4	2012	Alkalinity	increasing trend with slope of 1.66	2012 Impact Assessment found step-change in conductivity and dissolved ions likely caused by increased groundwater contributions from 2006-2008 drought and subsequent influence from Wingate dredge mining outfall discharge. Concentrations after 2008 remain relatively steady, with no evidence of biological impact.
HCSW-4	2013	Color	increasing trend with slope of 7.29	2013 Impact Assessment concluded that estimated slope was in the opposite direction of adverse change.
HCSW-4	2013	Dissolved Iron	slight decreasing trend with slope of -0.01	

Station	Year	Parameter	Trend Noted	Addressing of Trend
HCSW-4	2013	Alkalinity	increasing trend with slope of 1.37	The conductivity increases in recent years were influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities. Any small portion of the change in specific conductivity that may have been affected by changes in NPDES water quality is likely to stay relatively constant at HCSW-1 in the near future given planned mining practices and the stable range of concentrations shown since Wingate mine began discharging to Horse Creek in 2008.
HCSW-4	2013	Chloride	slight increasing trend with slope of 0.36	
HCSW-4	2013	Fluoride	Slight increasing trend with slope of 0.01	
HCSW-4	2014	Color	increasing trend with slope of 6.61	2014 Impact Assessment concluded that estimated slope was in the opposite direction of adverse change.
HCSW-4	2014	Dissolved Iron	slight decreasing trend with slope of -0.01	
HCSW-4	2014	Specific Conductance	increasing trend with slope of 9.01	The conductivity increases in recent years were influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities. Any small portion of the change in specific conductivity that may have been affected by changes in NPDES water quality is likely to stay relatively constant at HCSW-1 in the near future given planned mining practices and the stable range of concentrations shown since Wingate mine began discharging to Horse Creek in 2008.
HCSW-4	2014	Alkalinity	increasing trend with slope of 1.40	
HCSW-4	2014	Chloride	slight increasing trend with slope of 0.33	
HCSW-4	2014	Fluoride	slight increasing trend with slope of 0.01	
HCSW-4	2014	Sulfate	increasing trend with slope of 3.21	
HCSW-4	2014	TDS	increasing trend with slope of 12.2	
HCSW-4	2015	Color	increasing trend with slope of 6.32	2015 Impact Assessment concluded that estimated slope was in the opposite direction of adverse change.
HCSW-4	2015	Dissolved Iron	slight decreasing trend with slope of -0.01	
HCSW-4	2015	Specific Conductivity	increasing trend with slope of 7.47	The conductivity increases in recent years were influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities. Any small portion of the change in specific conductivity that may have been affected by changes in NPDES water quality is likely to stay relatively constant at HCSW-1 in the near future given planned mining practices and the stable range of concentrations shown since Wingate mine began discharging to Horse Creek in 2008.
HCSW-4	2015	Alkalinity	increasing trend with slope of 1.18	
HCSW-4	2015	Fluoride	Slight increasing trend with slope of 0.01	
HCSW-4	2015	Total Dissolved Solids	increasing trend with slope of 9.26	

Horse Creek Stewardship
Program

APPENDIX

I

2016 WATER QUALITY TREND IMPACT ASSESSMENT

Appendix I
2016 Water Quality Trend Impact Assessment

I.1 Introduction

This report was prepared as a component of the Horse Creek Stewardship Program (HCSP). As part of the HCSP, Mosaic monitors four locations on Horse Creek monthly for a number of water quality parameters and seasonally for biological indicators. At the end of each calendar year, an annual report is prepared that summarizes the collected information, including additional water quantity and quality data from public sources like the Southwest Florida Water Management District (SWFWMD) and United States Geological Service (USGS).

The HCSP plan document requires that an "impact assessment" be conducted for any trigger level exceedance or statistically significant water quality trends (in the direction of the trigger value) found while preparing the annual HCSP report. Impact assessments often include additional information that was not summarized in the annual report. If the impact assessment concludes that mining activities by Mosaic are the cause of the trigger level exceedance or statistically significant trend (in the direction of the trigger level), then Mosaic will need to take corrective action. The intensity of the corrective action will be based on the potential for short-term or long-term ecological harm to Horse Creek and/or the integrity of the downstream potable water supply.

In the 2016 Annual Report, of the twenty parameters examined using the Seasonal Kendall Tau analysis, thirteen had either no statistically significant trend from 2003 to 2016 detected or the detected trend was in the opposite direction of the trigger value (i.e. ammonia, color, DO saturation, and iron) (Table 1). Only seven parameters showed a statistically significant trend in the direction of the trigger values (pH, specific conductivity, alkalinity, calcium, fluoride, sulfate, and TDS), although only five of the parameters (all ions) had trend slopes of a high enough magnitude to be potentially ecologically significant. For this impact assessment, specific conductivity and pH were the two parameters that were focused on; other trends in dissolved ions were considered to be similar and sufficiently covered by the focus on specific conductivity, and therefore were not discussed here in detail.

In this impact assessment, the statistically significant trends are examined along with determining the potential impacts for Horse Creek ecology and the quality of the downstream potable water supply. This assessment consists of four parts: trend analysis of additional Horse Creek data, trend analysis of data from a non-mined stream, overview and timeline of Mosaic mining activities in the Horse Creek Basin, and an assessment of potential impacts on the biology of Horse Creek.

I.2 Analysis and Discussion

I.2.1 Trend Analysis with Additional Data

Trend Analysis

This impact assessment was developed because the 2016 HCSP Annual Report found statistically significant trends in some of the water quality parameters. In past HCSP annual reports, the Seasonal Kendall Tau method was determined to be the most appropriate method for monotonic trend detection. The Seasonal Kendall test determines water quality trends after correcting for seasonality by only comparing values between similar seasons over time. This test will produce a test statistic and median slope, which is a measure of a monotonic trend. The Seasonal Kendall Tau test can include LOESS smoothing for parameters that are influenced by streamflow or rainfall. The Annual Kendall Tau test is similar, but it is a nonparametric test for monotonic trends in which only annual median values are used.

The Seasonal Kendall Tau test is limited in several ways. The slope is a measure of the monotonic trend; the actual temporal variation may include step trends or trend reversals. If alternate seasons exhibit trends in opposite directions, the Seasonal Kendall test will not detect an overall trend. In addition, limited years of data will decrease the power of the test to detect trends of small magnitude. Any changes over time detected using the Seasonal Kendall test should be further examined to determine if the perceived change is caused by a data bias, if its magnitude is ecologically significant, or if the cause of the trend is related to Mosaic mining activities. For some parameters with significant Seasonal Kendall Tau trends, a change-point analysis was run to look for statistically significant step increases or decreases over time (Change-Point Analyzer 2012, Taylor 2000); additional information on the technical details of the change-point analyses are given in the final section of this impact assessment.

The results of the Seasonal Kendall Tau[2] for the 2016 Annual Report are given in Table I-1. Cells highlighted in yellow indicate 12 parameters where a statistically significant trend slope was found for at least one station; data collected by the HCSP for these parameters from 2003 to 2016 is shown in Figures I-1 to I-12. Although 11 water quality parameters had a statistically significant trend at HCSW-1 and six (6) parameters had a statistically significant trend at HCSW-4, several of the trends detected during the statistical analysis have an estimated slope that 1) was not in the direction of an adverse trend[3] (dissolved oxygen saturation, color, ammonia, and iron) or 2) was very small compared to the observed differences between primary and duplicate field samples (pH and fluoride). Specific conductivity and various dissolved ions had reported trends with higher estimated rates of change. The potential trends for pH and specific conductivity (with reference to other ions) are further discussed in this impact assessment, with a focus on the station closest to mining (HCSW-1). Specific conductivity, which has a longer period of record outside of the HCSP with more consistent data collection, is used as a surrogate[4] for the other dissolved ions (calcium, alkalinity, sulfate, fluoride, and TDS) in this impact assessment.

Tables I-2 and I-3 highlight parameters where trends have been identified in the 2003 to 2010, 2003 to 2011, 2003 to 2012, 2003 to 2013, 2003 to 2014, 2003 to 2015, and 2003 to 2016 data sets for HCSW-1 and HCSW-4. For some parameters, there has been relatively little if any change in the slope because it

---

[2] Beginning in the 2013 Annual Report, the LOESS smooth was conducted using log of streamflow rather than the raw streamflow values. Beginning in 2014, Kendall Tau analyses were performed in R (version 3.1.1) using the R function EnvStats:kendallTrendTest (Millard 2013). LOESS smoothing was done within the R function stats: loess (R Core Team 2014), with a smoothing factor (span) of 0.5, symmetric family, and degree of 1 for polynomials.

[3] From the HCSP Plan Document, Appendix A, p. A-3 to A-4: “Since the purpose of this monitoring is to detect trends toward the trigger values, should they be present, trend analyses and other statistical tests will generally focus only upon changes toward the trigger values.”

[4] From USEPA. Volunteer Stream Monitoring: A Methods Manual. Office of Water 4503F. EPA 841-B-97-003. November 1997, pg 179. “Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge).”

was already very small in magnitude (HCSW-1: ammonia, fluoride, pH, and iron; HCSW-4: fluoride, iron, and alkalinity). For other parameters, the current trend slope is less than what was shown in the 2010 to 2013 annual reports, and similar to the trend slopes in the 2014 and 2015 annual reports (HCSW-1: specific conductivity, calcium, alkalinity, sulfate, and TDS). The reduction of the trend slope for those parameters supports conclusions from the 2010 to 2014 annual reports that most of these parameters experienced a step-change over the 2003 to 2016 time period at HCSW-1, rather than a continuing, adverse, monotonic trend.

Table I-1. Summary of Seasonal Kendall-tau with LOESS (F=0.5) for HCSW-1 and HCSW-4 from 2003 to 2016 using HCSP data unless otherwise noted.

Parameter	HCSW-1				HCSW-4			
	tau	p-value	slope	2016 Median	tau	p-value	slope	2016 Median
pH	**0.49**	**0.00003**	**0.05**	7.65	0.17	0.15	N/A	7.53
Dissolved Oxygen (mg/L)	**0.24**	**0.04**	**0.06**	7.51	0.09	0.45	N/A	7.39
Dissolved Oxygen[1] (%Sat)	**0.28**	**0.002**	**0.74**	89.1	0.08	0.40	N/A	83.6
Turbidity	0.04	0.75	N/A	3.82	0.22	0.07	N/A	3.95
Color, total	0.06	0.61	N/A	157.5	**0.33**	**0.004**	**4.31**	165
Nitrogen, total	0.09	0.45	N/A	1.21	0.15	0.21	N/A	1.44
Nitrogen, total Kjeldahl	0.04	0.75	N/A	1.11	0.15	0.21	N/A	1.18
Nitrogen, nitrate-nitrite*	0.17	0.15	N/A	0.08	0.04	0.75	N/A	0.21
Nitrogen, ammonia*	**-0.37**	**0.002**	**-0.001**	0.04	0.01	0.95	N/A	0.05
Orthophosphate[2]	0.05	0.66	N/A	0.516	0.06	0.64	N/A	0.397
Chlorophyll-a[2]	0.03	0.85	N/A	0.92	-0.06	0.63	N/A	1.10
Specific Conductance	**0.55**	**0.000003**	**10.39**	403	**0.33**	**0.01**	**7.94**	365
Calcium, dissolved	**0.54**	**0.000004**	**1.05**	35.1	0.20	0.09	N/A	32.3
Iron, dissolved	**-0.49**	**0.00003**	**-0.02**	0.21	**-0.37**	**0.002**	**-0.01**	0.20
Alkalinity	**0.41**	**0.001**	**2.39**	67	**0.45**	**0.0001**	**1.08**	41.9
Chloride	-0.06	0.61	N/A	12.5	0.08	0.53	N/A	16.9
Fluoride*	**0.27**	**0.02**	**0.01**	0.54	**0.41**	**0.001**	**0.01**	0.33
Sulfate	**0.49**	**0.00003**	**3.67**	96.5	0.21	0.08	N/A	92.2
Total Dissolved Solids	**0.52**	**0.00001**	**8.56**	298	**0.24**	**0.04**	**6.02**	262
Radium, total	-0.16	0.16	N/A	1.3	-0.10	0.41	N/A	1.3

*SWFWMD data was used from April 2003 to December 2016. Sampling was reduced to every other month starting October 2011, making slope estimates approximate.

[1] Percent DO calculated from DO saturation (mg/L) and temperature. Temperature data was not available for samples prior to June 2006. Analysis period for DO % saturation is from June 2006 to December 2016.

[2] Data was not correlated with streamflow for either station; LOESS was not used.

Table I-2. Summary of Seasonal Kendall-tau with LOESS (F=0.5) at HCSW-1 for 2003-2010, 2003-2011, 2003-2012, 2003-2013, 2003-2014, 2003-2015, and 2003-2016 time periods using HCSP data unless otherwise noted.

Parameter	HCSW-1																											
	2003-2010				2003-2011				2003-2012				2003-2013				2003-2014				2003-2015				2003-2016			
	tau	p-value	slope	2010 Median	tau	p-value	slope	2011 Median	tau	p-value	slope	2012 Median	tau	p-value	slope	2013 Median	tau	p-value	slope	2014 Median	tau	p-value	slope	2015 Median	tau	p-value	slope	2016 Median
pH	0.29	0.10	N/A	7.25	0.28	0.08	N/A	7.3	0.38	**0.01**	**0.05**	7.62	0.36	**0.03**	**0.05**	7.31	0.39	**0.002**	**0.04**	7.38	0.40	**0.001**	**0.04**	7.26	0.49	**0.00003**	**0.05**	7.65
DO (mg/L)	-0.19	0.28	N/A	7.00	-0.04	0.86	N/A	7.83	-0.07	0.68	N/A	7.69	0.08	0.59	N/A	7.9	0.18	0.17	N/A	8.045	0.19	0.13	N/A	7.08	**0.24**	**0.04**	**0.06**	7.51
DO (%Saturation)																					0.51	**0.001**	**1.29**	89.4	**0.28**	**0.002**	**0.74**	89.1
Nitrogen, ammonia*	-0.52	**0.002**	**-0.002**	0.01	-0.52	**0.001**	**-0.002**	0.02	-0.47	**0.001**	**-0.002**	0.01	-0.43	**0.01**	**-0.002**	0.02	-0.39	**0.002**	**-0.0012**	0.02	-0.38	**0.002**	**-0.001**	0.0225	-0.37	**0.002**	**-0.001**	0.04
Orthophosphate	0.41	**0.02**	**0.03**	0.45	0.26	0.10	N/A	0.31	0.22	0.15	N/A	0.42	0.20	0.19	N/A	0.36	0.07	0.61	N/A	0.29	0.05	0.70	N/A	0.312	0.05	0.66	N/A	0.516
Specific Conductance	0.55	**0.001**	**16.5**	432	0.56	**0.0004**	**15.4**	323	0.53	**0.0003**	**13.4**	320	0.50	**0.01**	**11.2**	309	0.45	**0.0004**	**9.46**	290	0.50	**0.00004**	**10.20**	341	0.55	**0.000003**	**10.39**	403
Calcium, dissolved	0.62	**0.0003**	**1.88**	33.1	0.57	**0.0002**	**1.46**	23.1	0.53	**0.0003**	**1.21**	24	0.47	**0.01**	**0.99**	21.9	0.43	**0.001**	**0.71**	21.2	0.45	**0.0002**	**0.86**	29	0.54	**0.000004**	**1.05**	35.1
Iron, dissolved	-0.31	0.07	N/A	0.21	-0.37	**0.02**	**-0.02**	0.18	-0.36	**0.01**	**-0.02**	0.15	-0.35	**0.05**	**-0.01**	0.20	-0.36	**0.005**	**-0.01**	0.15	-0.40	**0.001**	**-0.01**	0.23	-0.49	**0.00003**	**-0.02**	0.21
Alkalinity	0.43	**0.01**	**3.64**	70.8	0.35	**0.03**	**3.07**	49.2	0.38	**0.01**	**2.87**	58.4	0.39	**0.01**	**2.50**	60.3	0.42	**0.001**	**2.28**	59.2	0.48	**0.0001**	**2.42**	70.4	0.41	**0.001**	**2.39**	67
Fluoride*	0.45	**0.01**	**0.02**	0.61	0.39	**0.01**	**0.02**	0.43	0.48	**0.001**	**0.02**	0.55	0.43	**0.01**	**0.02**	0.49	0.26	**0.04**	**0.01**	0.42	0.29	**0.02**	**0.01**	0.5	0.27	**0.02**	**0.01**	0.54
Sulfate	0.52	**0.002**	**6.43**	116	0.54	**0.001**	**6.43**	65.6	0.51	**0.0004**	**4.64**	62.5	0.50	**0.01**	**4.19**	61.1	0.42	**0.001**	**2.85**	44.7	0.47	**0.0001**	**2.92**	64.4	0.49	**0.00003**	**3.67**	96.5
Total Dissolved Solids	0.5	**0.003**	**16.9**	343	0.54	**0.001**	**13.2**	218	0.45	**0.002**	**11.1**	216	0.47	**0.01**	**10.3**	225	0.41	**0.001**	**7.07**	219	0.50	**0.00004**	**8.31**	274	0.52	**0.00001**	**8.56**	298

*SWFWMD data was used from April 2003 to December 2016.
Note: Trends and slopes presented in this table may be different than previous reports as LOESS smoothing used log flow (previous reports used flow).

Table I-3. Summary of Seasonal Kendall-tau with LOESS (F=0.5) at HCSW-4 for 2003-2010, 2003-2011, 2003-2012, 2003-2013, 2003-2014, 2003-2015, and 2003-2016 time periods using HCSP data unless otherwise noted.

Parameter	HCSW-4																											
	2003-2010				2003-2011				2003-2012				2003-2013				2003-2014				2003-2015				2003-2016			
	tau	p-value	slope	2010 Median	tau	p-value	slope	2011 Median	tau	p-value	slope	2012 Median	tau	p-value	slope	2013 Median	tau	p-value	slope	2014 Median	tau	p-value	slope	2015 Median	tau	p-value	slope	2016 Median
Color, total	0.41	**0.02**	**8.58**	150	0.46	**0.003**	**9.17**	140	0.44	**0.003**	**7.77**	80	0.42	**0.03**	**7.29**	130	0.35	**0.006**	**6.61**	115	0.37	**0.003**	**6.32**	150	0.33	**0.004**	**4.31**	165
Specific Conductance	0.05	0.83	N/A	414	0.17	0.31	N/A	552	0.14	0.35	N/A	682	0.22	0.11	N/A	641	0.30	**0.02**	**9.01**	634	0.32	**0.01**	**7.47**	426	0.33	**0.01**	**7.94**	365
Iron, dissolved	-0.21	0.22	N/A	0.2	-0.33	**0.04**	**-0.01**	0.13	-0.32	**0.03**	**-0.01**	0.08	-0.33	**0.05**	**-0.01**	0.15	-0.36	**0.005**	**-0.01**	0.16	-0.44	**0.0004**	**-0.01**	0.17	-0.37	**0.002**	**-0.01**	0.20
Alkalinity	0.24	0.17	N/A	43	0.33	**0.04**	**1.67**	56.7	0.41	**0.01**	**1.51**	73	0.42	**0.01**	**1.37**	68.4	0.47	**0.0002**	**1.40**	55.3	0.45	**0.0002**	**1.18**	46.5	0.45	**0.0001**	**1.08**	41.9
Chloride	0.12	0.52	N/A	21.8	0.20	0.21	N/A	29.4	0.20	0.18	N/A	31.2	0.27	**0.05**	**0.36**	29.4	0.31	**0.02**	**0.33**	27.9	0.14	0.27	N/A	23.7	0.08	0.53	N/A	16.9
Fluoride*	0.21	0.22	N/A	0.36	0.30	0.06	N/A	0.37	0.38	**0.01**	**0.01**	0.52	0.38	**0.03**	**0.01**	0.49	0.55	**0.00002**	**0.01**	0.48	0.45	**0.0002**	**0.01**	0.38	0.41	**0.001**	**0.01**	0.33
Sulfate	-0.05	0.83	N/A	112	0.11	0.51	N/A	157	0.07	0.68	N/A	189	0.16	0.24	N/A	205	0.26	**0.04**	**3.21**	213	0.21	0.08	N/A	112	0.21	0.08	N/A	92.2
Total Dissolved Solids	0.24	0.17	N/A	317	0.28	0.08	N/A	427	0.27	0.06	N/A	478	0.33	**0.02**	**10.6**	483	0.39	**0.002**	**12.2**	521	0.32	**0.01**	**9.3**	306	0.24	**0.04**	**6.02**	262

*SWFWMD data was used from April 2003 to December 2016.
Note: Trends and slopes presented in this table may be different than previous reports as LOESS smoothing used log flow (previous reports used flow).

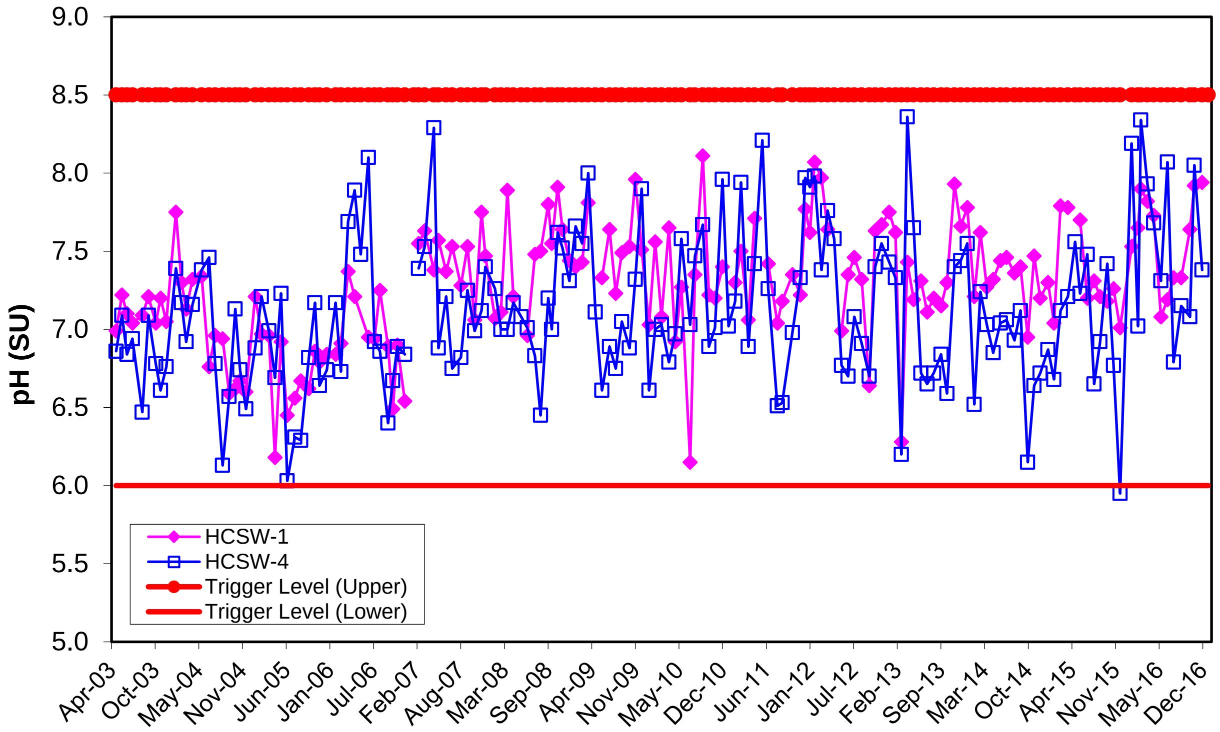


Figure I-1. Values of pH obtained during monthly HCSP water quality sampling from 2003 to 2016.

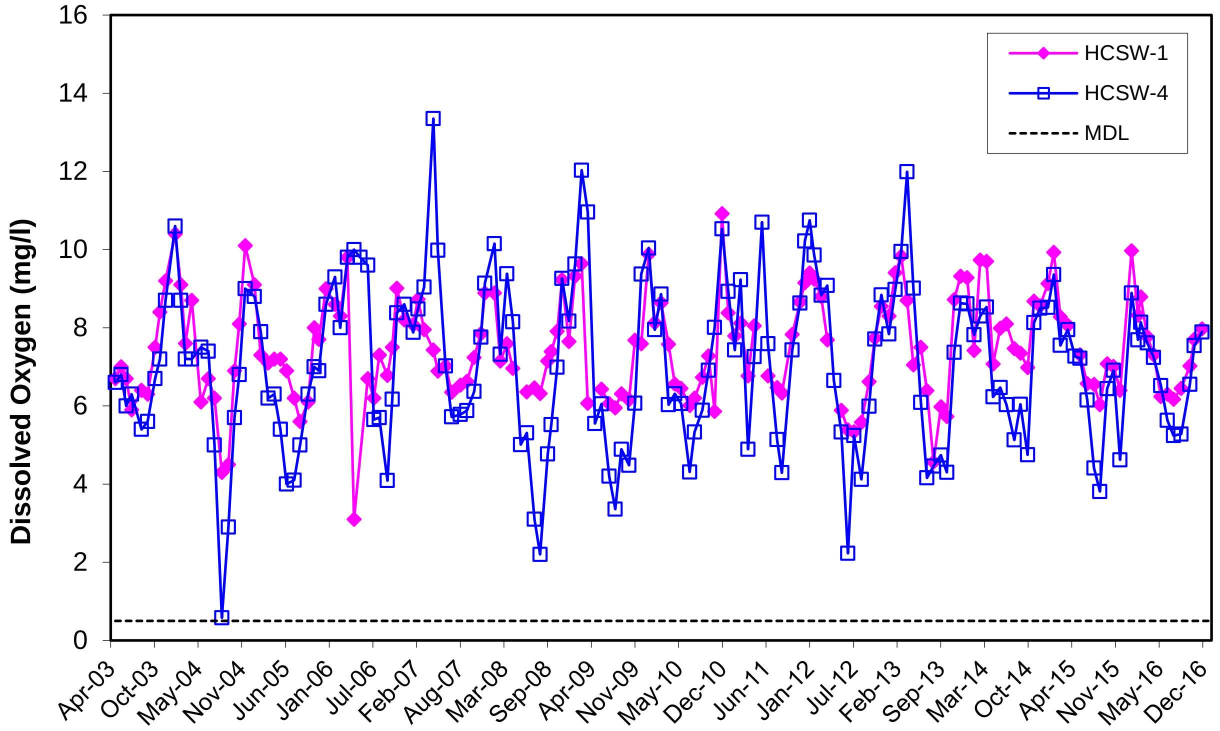


Figure I-2. Dissolved oxygen concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.

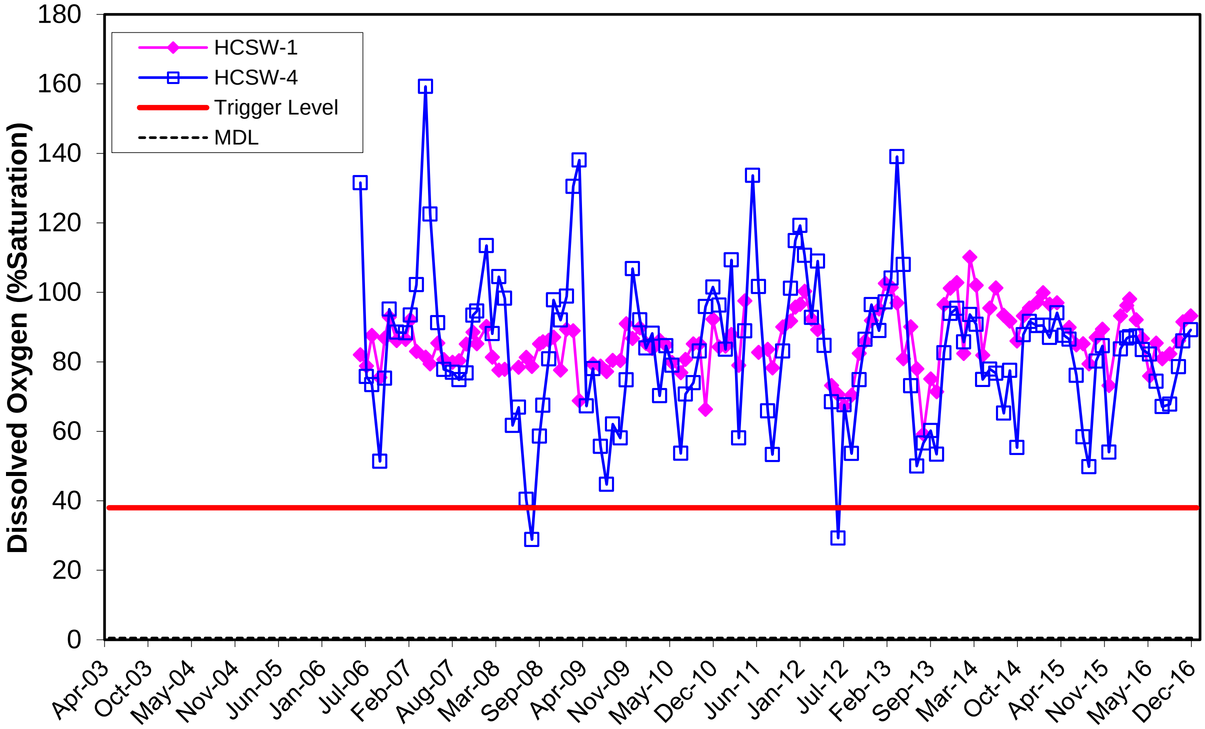


Figure I-3. **Dissolved oxygen saturations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

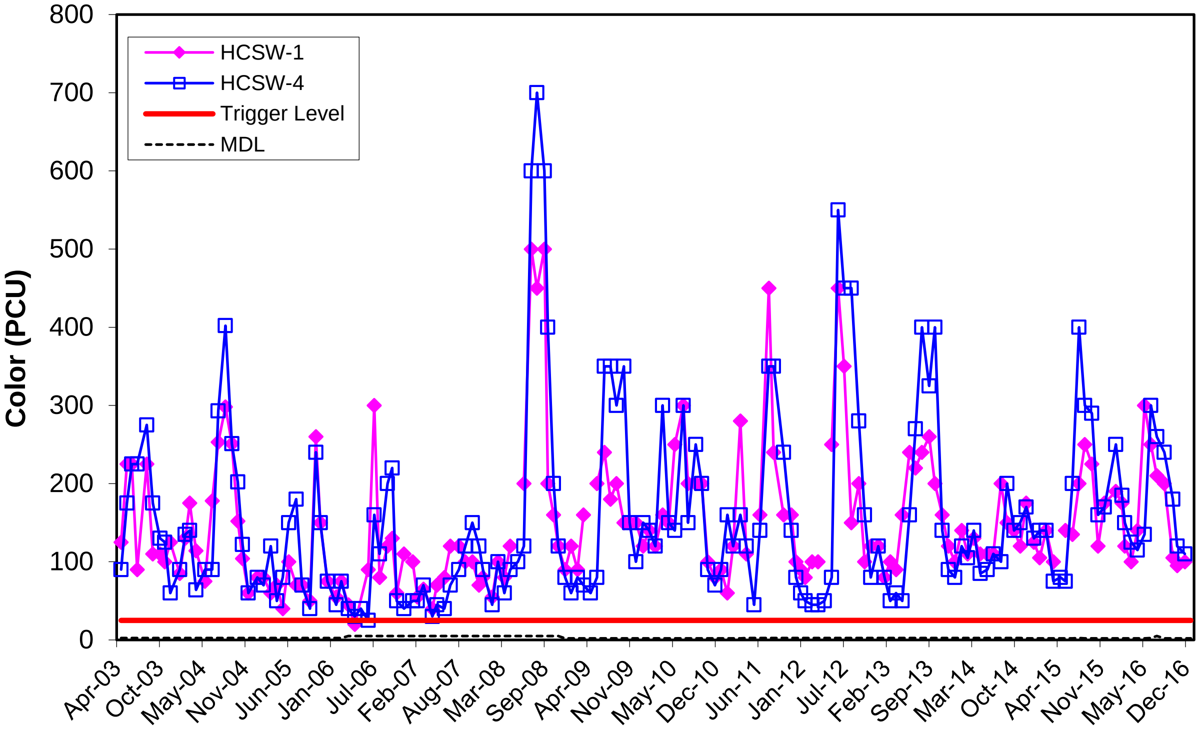


Figure I-4. **Color levels obtained during monthly HCSP water quality sampling from 2003 to 2016.**

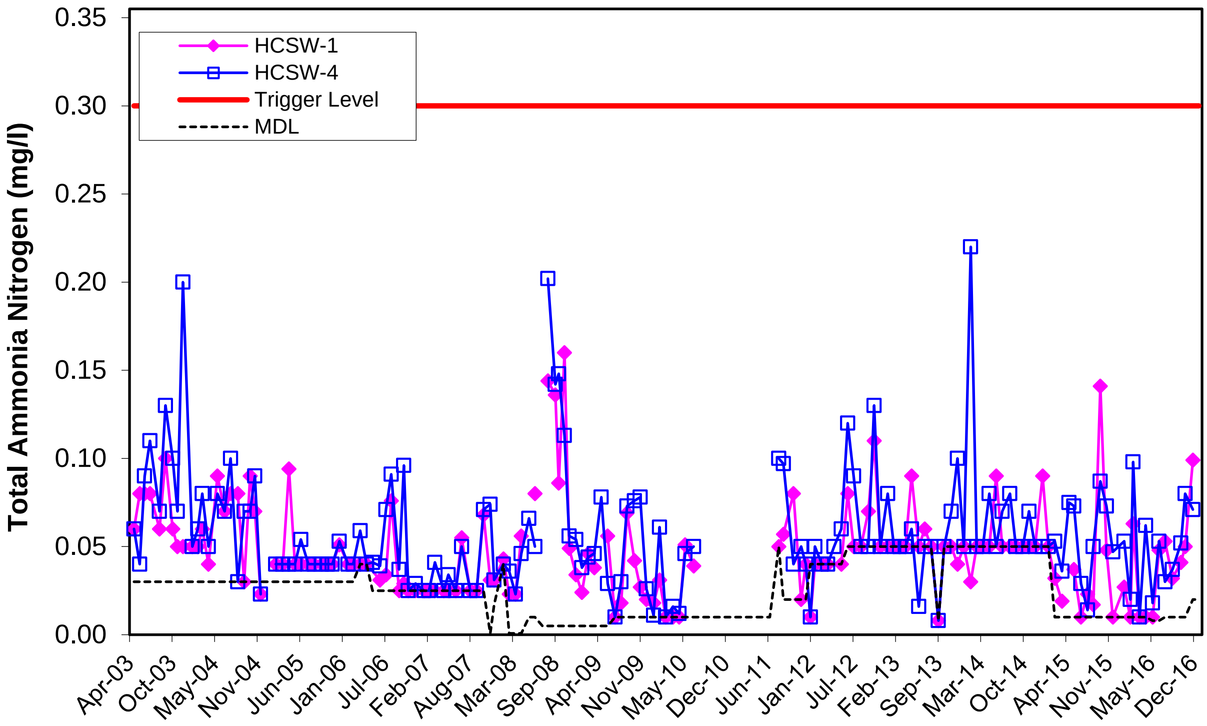


Figure I-5. **Total ammonia concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

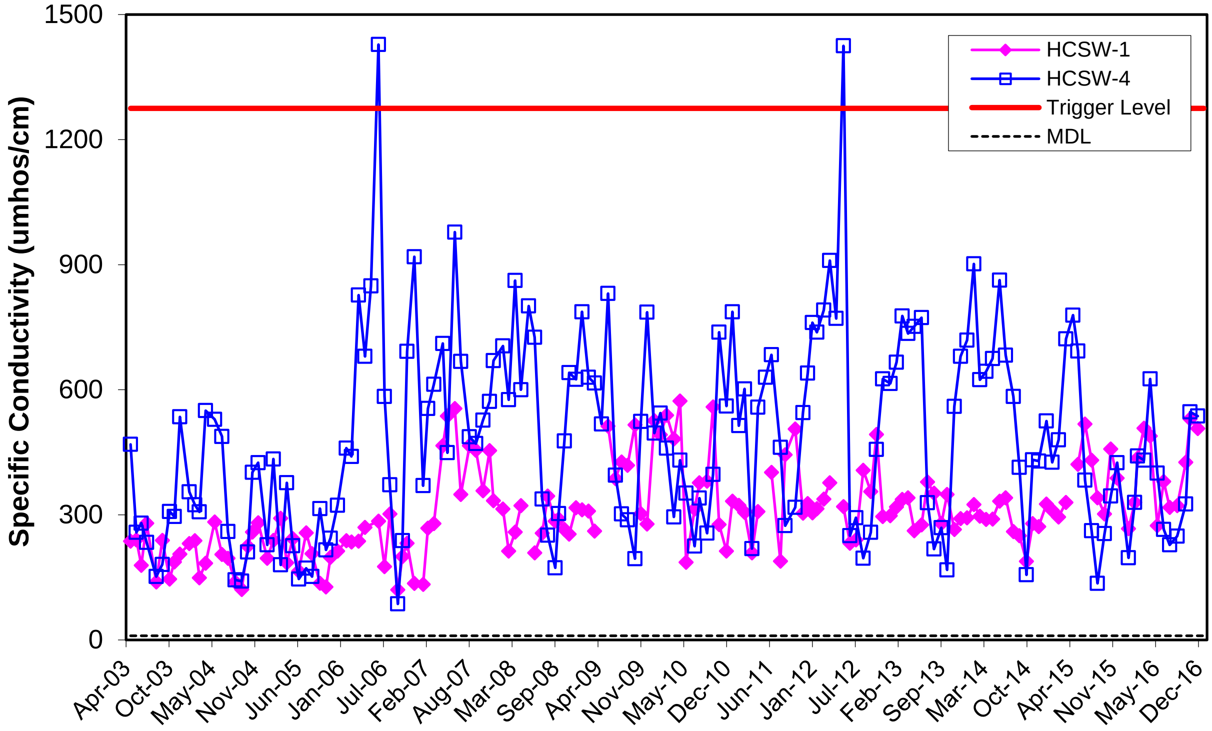


Figure I-6. **Specific conductivity values obtained during monthly HCSP water quality sampling from 2003 to 2016.**

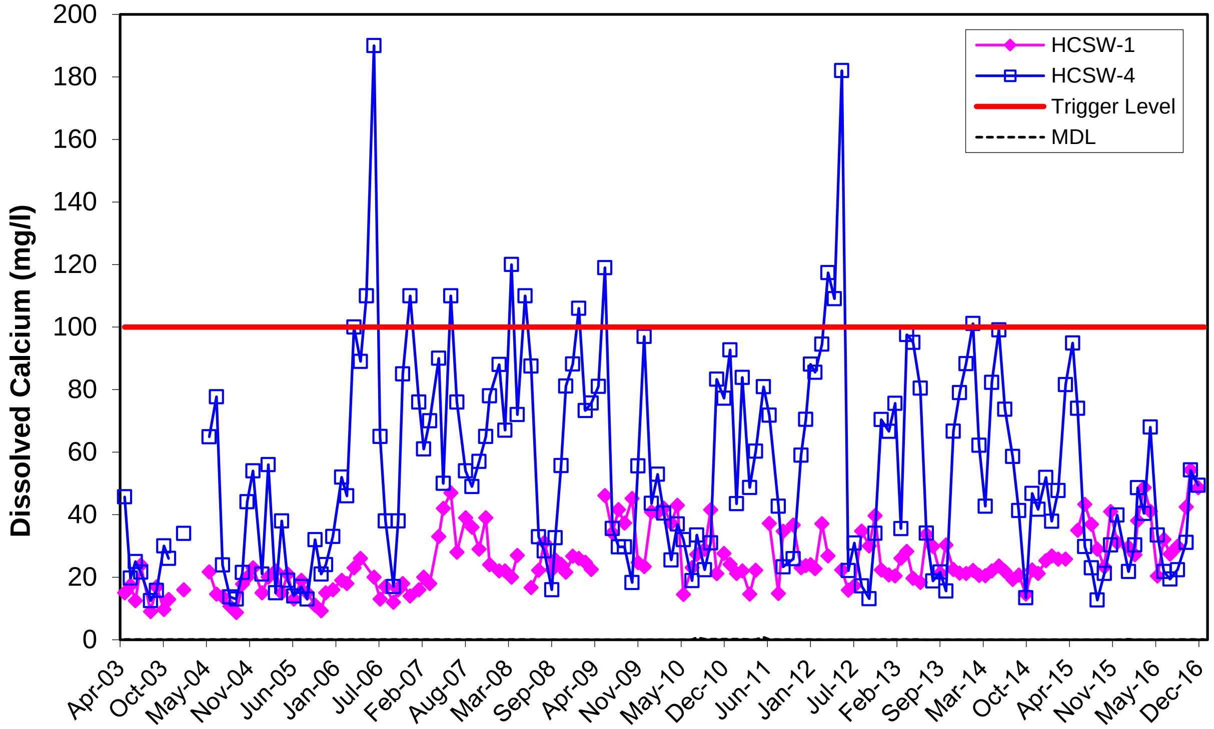


Figure I-7. **Dissolved calcium concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

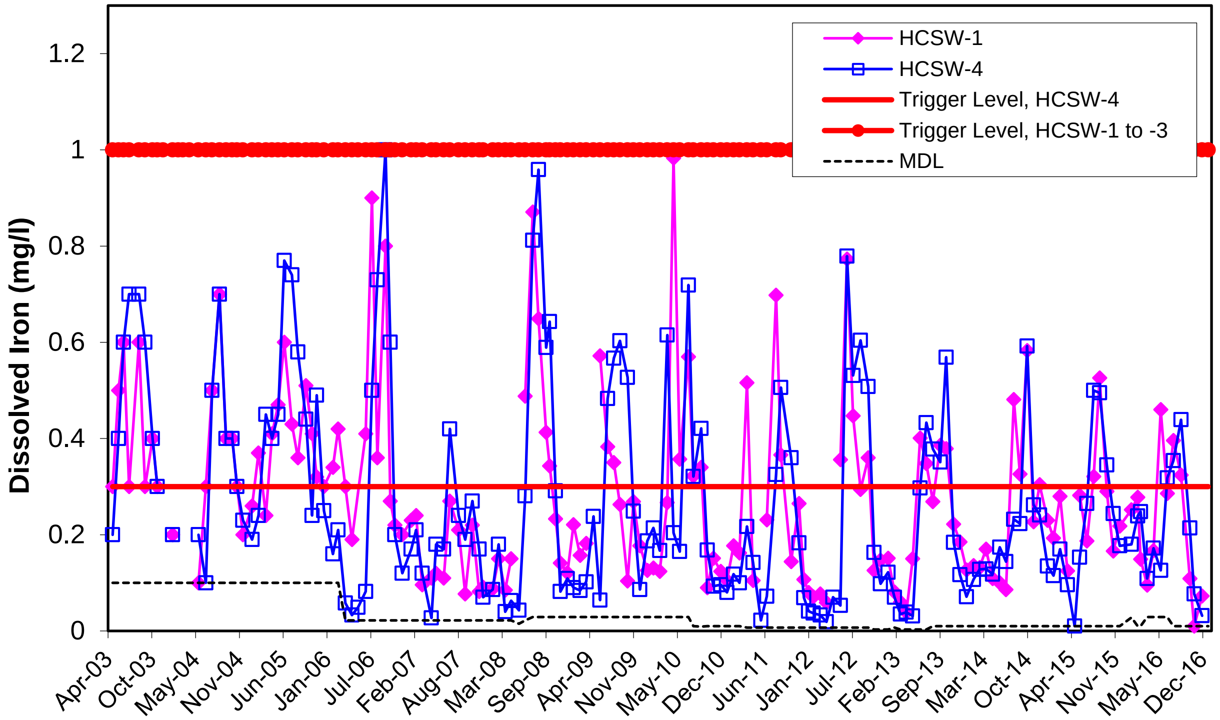


Figure I-8. **Dissolved iron concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

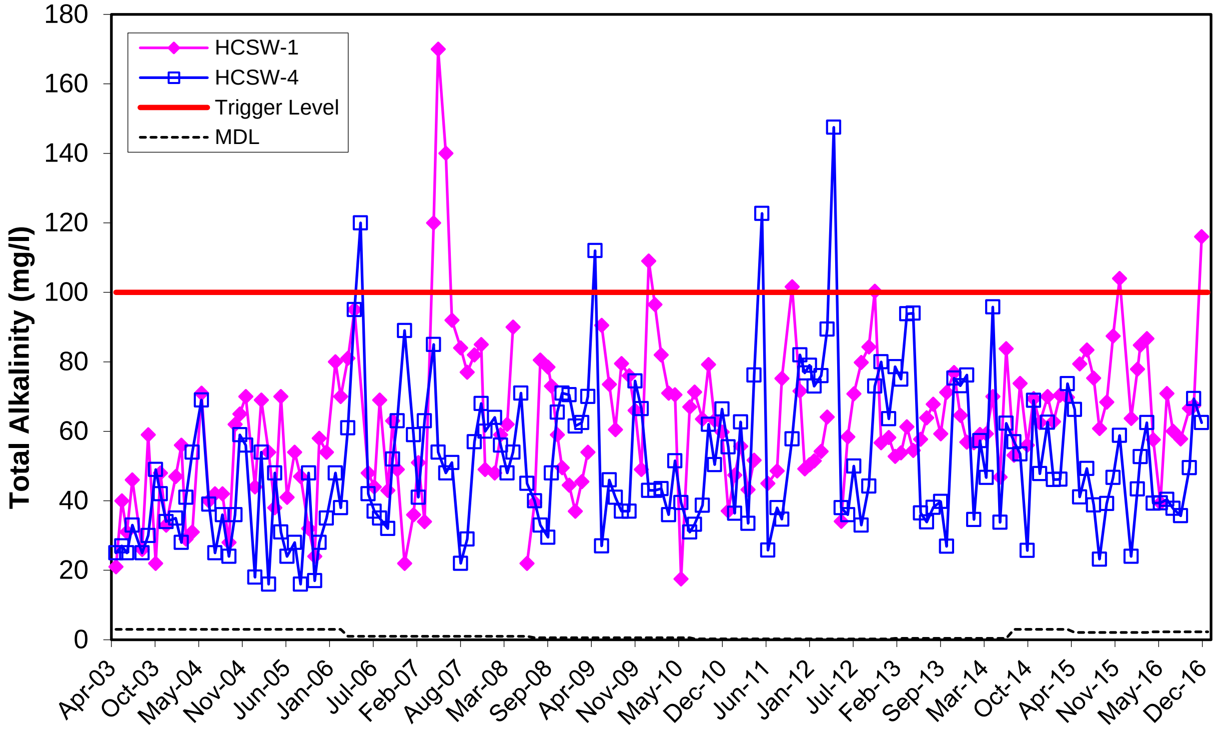


Figure I-9. **Total alkalinity concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

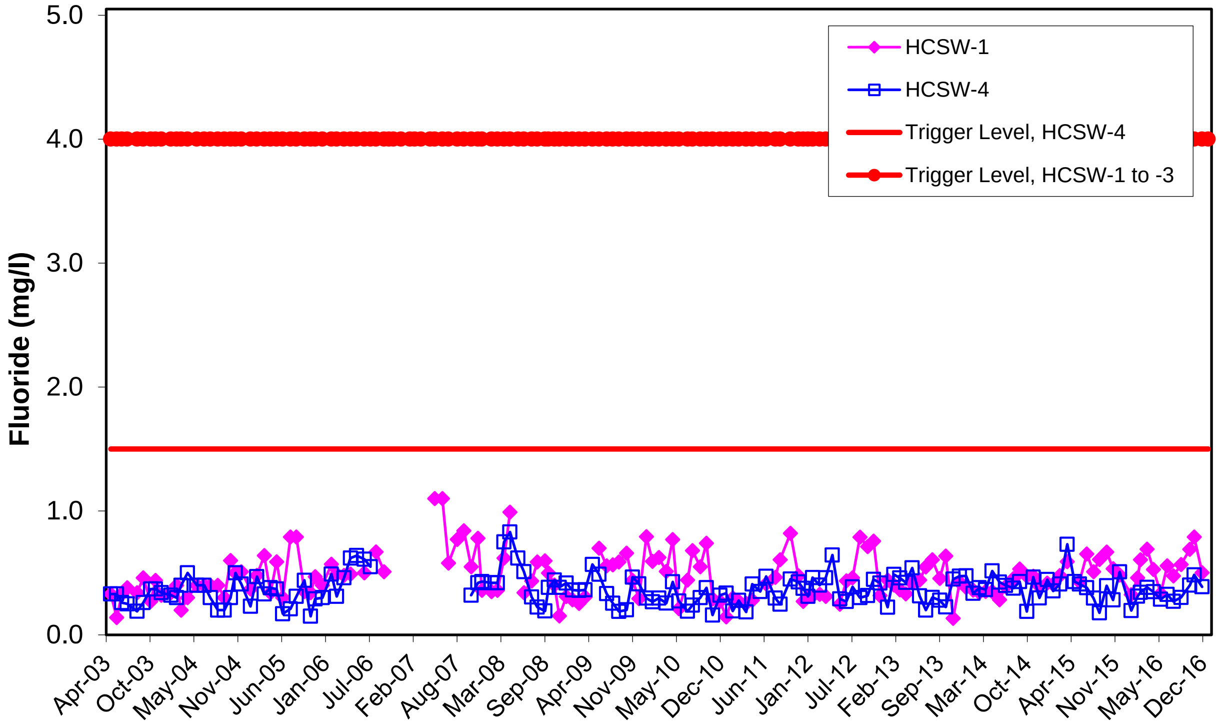


Figure I-10. **Fluoride concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.**

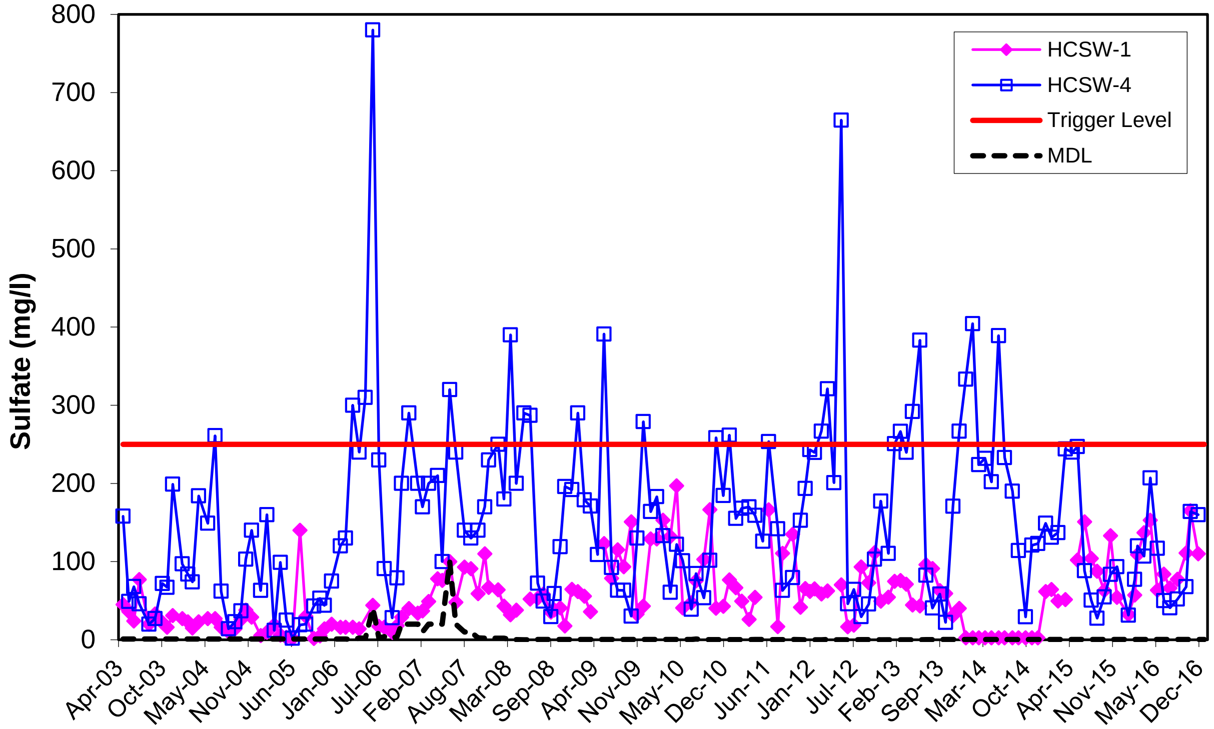


Figure I-11. Sulfate concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.

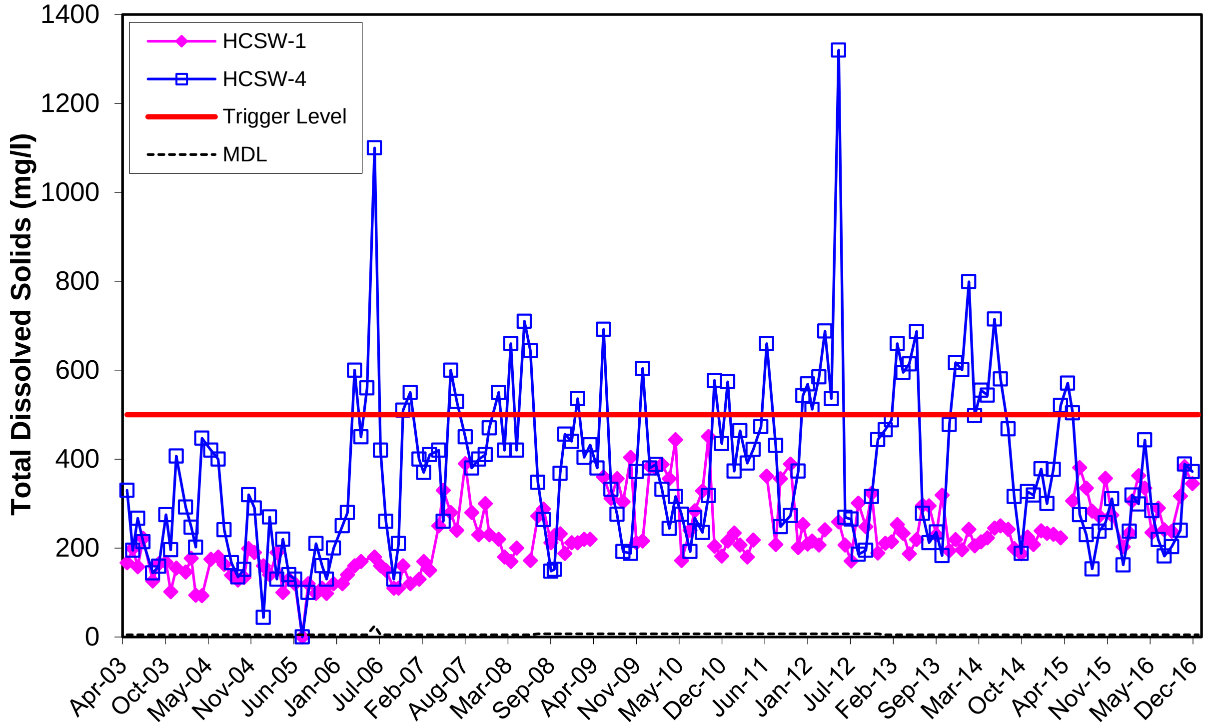


Figure I-12. Total dissolved solids concentrations obtained during monthly HCSP water quality sampling from 2003 to 2016.

Additional Data

Any statistical method for trend detection is inherently biased by the time period used in the analysis. For instance, many water quality parameters may be heavily influenced by climatic conditions that are dissimilar at the beginning and end of the time period under analysis. For the 2016 HCSP Annual Report trend analysis, the Seasonal Kendall Tau covered the time period from the beginning of the HCSP (2003) through 2016. In order to investigate if the time constraint resulted in some of the observed trends, pH and specific conductivity data collected by SWFWMD was used to expand the period of record into the past.

To ensure that the assumptions did not unduly influence this new trend analysis, multiple combinations of time periods, data sources, and types of Kendall Tau analysis were tried. For the scenarios with LOESS smoothing, the log of HCSW-1 USGS streamflow (same data as found in 2016 annual report) was used as our smoothing parameter.

For Seasonal Kendall Tau scenarios for the SWFWMD data, 1998 had the earliest consistently collected data for pH and specific conductivity. In October 2011, SWFWMD went from sampling monthly to every other month, making the 2012 to 2016 data frequency inconsistent with the rest of the period of record; this may bias Seasonal Kendall Tau analysis past 2011. Potential trends in the SWFWMD data were examined using the Seasonal Kendall Tau from 1998 to 2016 and 2003 to 2016 (time period of the HCSP). For the Annual Kendall Tau, data was available back to 1992 in the SWFWMD data; the time periods used were 1992 to 2016, 1998 to 2016, and 2003 to 2016. For the HCSP data, all analyses were from 2003 to 2016. Tables I-4 and I-5 present the results of the Seasonal and Annual Kendall Tau analyses of SWFWMD and HCSP pH and specific conductivity data, with statistically significant trends in bold and slopes highlighted in yellow.

For pH, the statistically significant increasing trend was observed in the seasonal analysis of 2003 to 2016 HCSP data, but not in the annual analysis (Table I-4, Figure I-13). For the SWFWMD data, annual Kendall Tau for 1992 to 2016 did show a significant increasing trend, but the other comparisons did not. Given that the increase in pH over time in the HCSP appears to be a step-change and is not a monotonic trend; the Seasonal Kendall Tau may not be an appropriate method to examine the magnitude of the change over time and change-point analysis was used to supplement the evaluation.

The statistically significant upward trend in specific conductivity in Horse Creek is apparent across multiple data time periods, data sources, and analysis methods (Table I-5, Figure I-16). The predicted median slope of these analyses indicated a potential increase in specific conductivity around 10 µmhos/cm/year (flow-adjusted concentration), if the assumption that specific conductivity is exhibiting a monotonic (or one directional) increasing trend is accepted. However, examining Figure I-16 in more detail provides evidence of several step-changes in conductivity at HCSW-1. Given that the increase in conductivity over time is not a monotonic trend; the Seasonal Kendall Tau may not be an appropriate method to examine the magnitude of the change over time (Figure I-16).

Change-point Analysis

Change-point analysis of the HCSP pH data at HCSW-1 shows a decline in 2004 (0.4 SU), an increase in 2007 (0.6 SU), and then a stable range from 2007 to 2016 (Figure I-14); those change-points correspond to a wet year with several hurricanes (2004) and a very dry time period (2006 to 2008). The SWFWMD data from 1998 to 2016 does not show a statistically significant change-point (Figure I-15). The differences in the SWFWMD and HCSP pH data, including the lack of a trend over the same 2003 to 2016 time period in the SWFWMD data, may indicate a sampling bias between the two entities. The change-point analysis for the HCSP data also shows that the apparent increase in pH at HCSW-1 since the beginning of the HCSP may be a single increase around the drought time period, with stable levels since that time. This is supported by the very small slope indicated by the Seasonal Kendall Tau test. The range of SWFWMD pH data for 2016 is well within the range previously observed by SWFWMD at

HCSW-1 well before the beginning of the HCSP (Figure I-13). Therefore, pH is not having an ecologically significant increase at HCSW-1 over the course of the HCSP program, and it is not of concern for this impact assessment.

Change-point analysis of HCSP specific conductivity data at HCSW-1 shows an increase in 2007 (190 µmhos/cm) corresponding to the drought period (Figure I-17); furthermore, the analysis also found a decreasing change-point around 2010 to 2012 (80 µmhos/cm), when rainfall began increasing; followed by an increase in 2015 (90 µmhos/cm) to approximately the same level as seen in 2007 to 2010. A change-point analysis of the SWFWMD data for HCSW-1 shows two change-point increases around drought periods (1999 and 2007), that are followed by relatively stable concentrations until the next change-point (Figure I-18). Regardless of the potential ups and downs over time, the specific conductivity at HCSW-1 has not increased above levels seen in 2007, and there is no consistent monotonic adverse trend.

Other ions at HCSW-1 with significant Seasonal Kendall Tau trends (Table I-1) have similar change-point analysis results as specific conductivity (shown for HCSP data only, except for fluoride which uses SWFWMD data), confirming that specific conductivity is an appropriate surrogate parameter for these ions. Alkalinity, calcium, fluoride, sulfate, and TDS show increases around 2007 that correspond with the drought period (Figures I-19 to I-23). Alkalinity and fluoride have no other change-points from 2007 to 2016 (Figures I-19 and I-21). Calcium, sulfate, and TDS show a cyclical pattern of changes, with higher concentrations in 2007, 2009 to 2010, and 2015 to 2016, and lower concentrations in 2008 to 2009 and 2011 to 2014 (Figures I-20, I-22, and I-23). The change-point analysis for specific conductivity is very similar to calcium, sulfate, and TDS, and it calls out all but one of the same step-changes, with a specific conductivity outlier in 2008 preventing that period from registering as different than the adjacent time periods.

Change-point analysis of HCSP specific conductivity at HCSW-4 showed a similar step-change increase in 2006 (Figure I-24), confirming that the decision to discuss a detailed analysis of changes at HCSW-1 instead of both stations is appropriate; other ions (alkalinity, calcium, fluoride, sulfate, TDS) at HCSW-4 also showed an increasing step-change increase in 2006, similar to the HCSW-1 results. Any of the smaller step-changes that may be occurring at HCSW-1 since the 2006-2007 drought period are not affecting the downstream station HCSW-4 or the Peace River.

These change-point analyses show that conductivity levels in Horse Creek, though higher in 2007 to 2016 than from 2003 to 2007, are relatively stable at this time. The effects of historical periods of low streamflow (1997, 1999 to 2000, and 2006 to 2008) can be seen in Figure I-16 as elevated conductivity compared to wetter years. From the 2010 annual report to this 2016 annual report, the estimated conductivity slope was reduced from 16.5 µmhos/cm/yr (2003 to 2010) to 10.4 µmhos/cm/yr (2003 to 2016) as more data is collected past the 2007 change-point and concentrations remain stable (Table I-2).

Table I-4. Period of record seasonal and annual Kendall-tau analysis for pH in Horse Creek samples collected by SWFWMD and HCSP.

LOESS Smooth Parameter	Stat	SWFWMD – Horse Creek Near Myakka Head					HCSP – HCSW-1	
		Seasonal 1998-2016	Seasonal 2003-2016	Annual 1992-2016	Annual 1998-2016	Annual 2003-2016	Seasonal 2003-2016	Annual 2003-2016
None	p-value	0.50	0.85	**0.03**	0.25	0.58	**0.01**	0.08
	slope	N/A	N/A	**0.01**	N/A	N/A	**0.04**	N/A
Logged Flow at HCSW-1	p-value	0.28	0.95	**0.03**	0.14	0.38	**0.001**	0.10
	slope	N/A	N/A	**0.01**	N/A	N/A	**0.05**	N/A

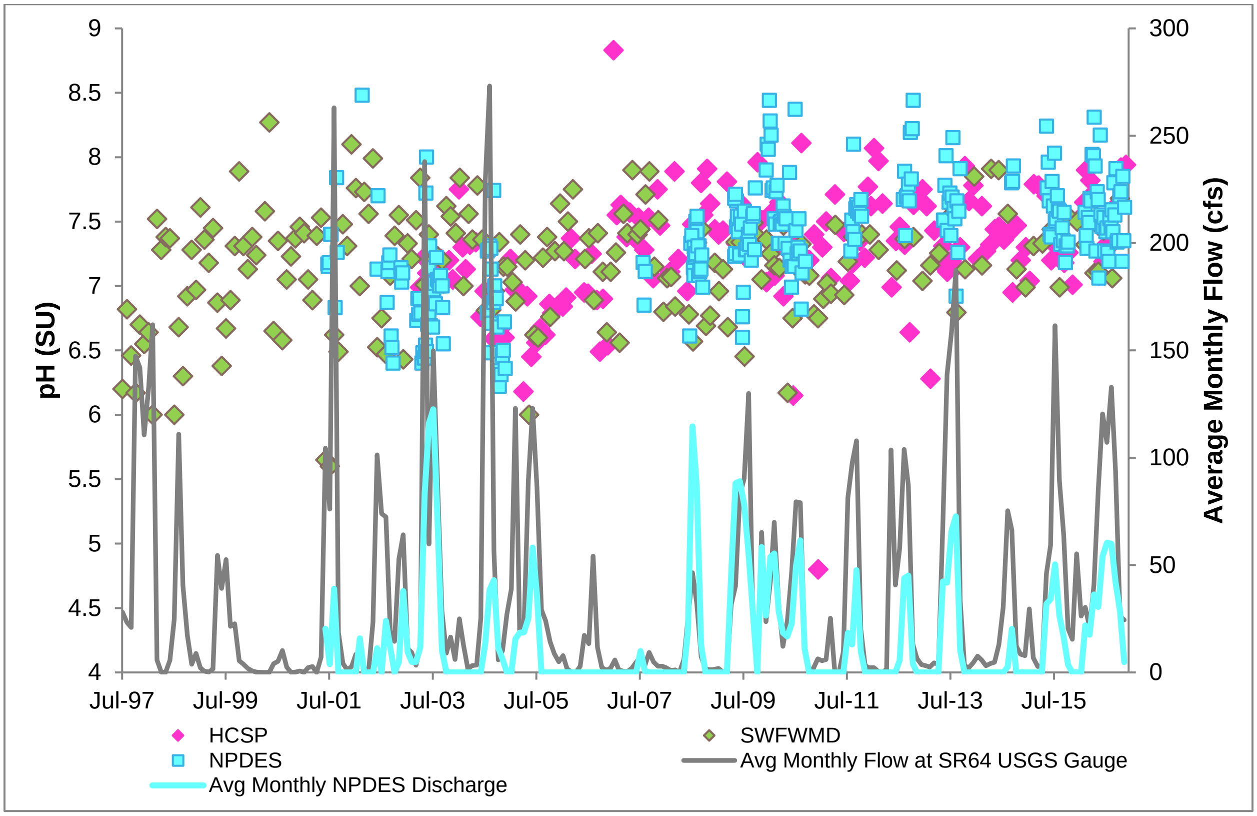


Figure I-13. HCSW-1 pH results obtained during monthly HCSP and SWFWMD water quality sampling, NPDES outfall pH results, and average monthly streamflow from USGS gauge at HCSW-1 and NPDES discharge.

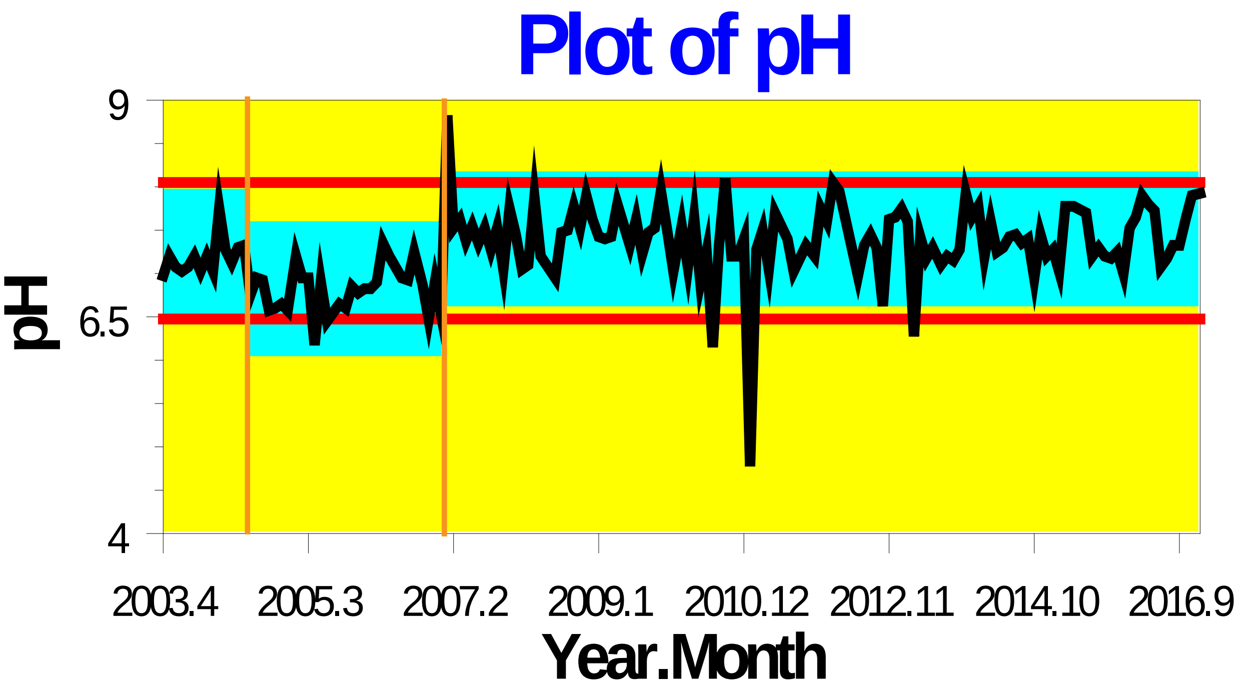
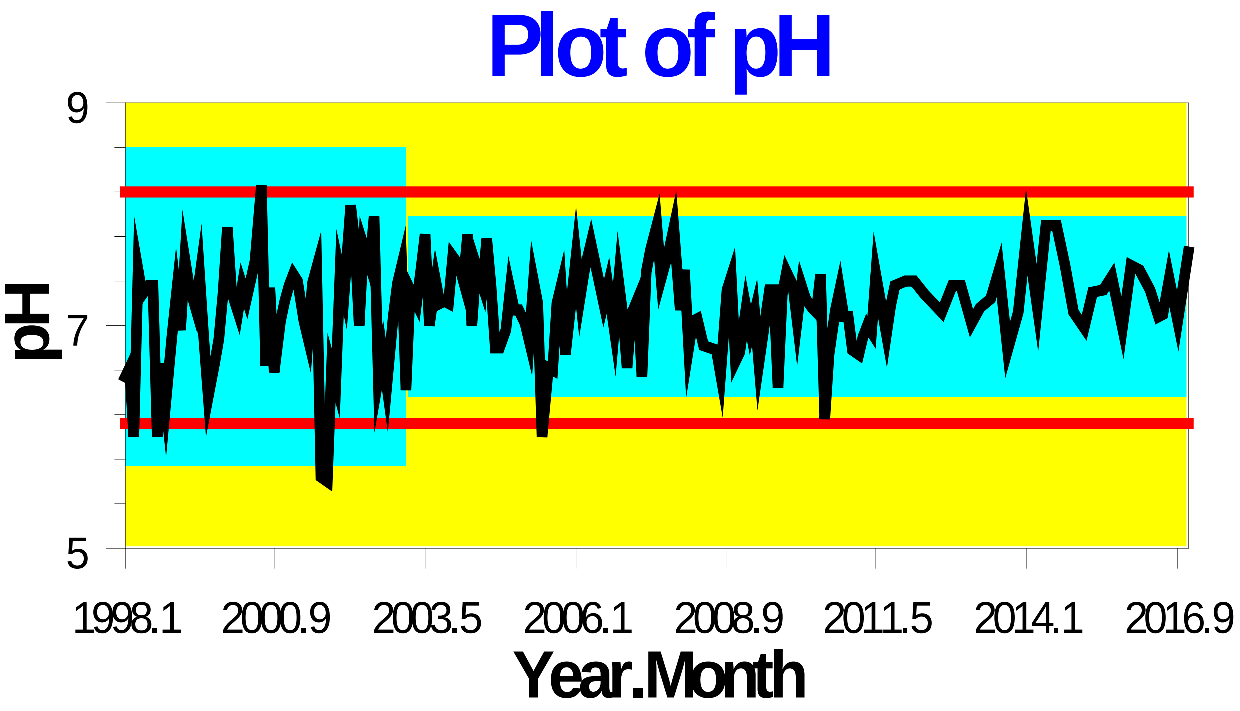


Table of Significant Changes for pH

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%,
Bootstraps = 1000, Without Replacement, MSE Estimates

Year.Month	Confidence Interval	Conf. Level	From	To	Level
2004.6	(2004.5, 2004.12)	100%	7.1986	6.8153	2 🟥
2007.1	(2006.11, 2007.10)	100%	6.8153	7.4064	1 🟥🟥

Figure I-14. **Change-point analysis graph and results table for pH at HCSW-1 collected by the HCSP from April 2003 to December 2016.**



No Significant Changes for pH

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%,
Bootstraps = 1000, Without Replacement, MSE Estimates

Estimated Average = 7.1677039

Figure I-15. **Change-point analysis graph and results table for pH at HCSW-1 collected by the SWFWMD from January 1998 to November 2016.**

Table I-5. **Period or record seasonal and annual Kendall-tau analysis for specific conductivity in Horse Creek Samples collected by SWFWMD and HCSP.**

LOESS Smooth Parameter	Stat	SWFWMD – Horse Creek Near Myakka Head					HCSP – HCSW-1	
		Seasonal 1998-2016	Seasonal 2003-2016	Annual 1992-2016	Annual 1998-2016	Annual 2003-2016	Seasonal 2003-2016	Annual 2003-2016
None	p-value	<0.0001	<0.0001	<0.0001	0.001	0.05	<0.0001	0.02
	slope	12.4	12.4	9.8	11.5	11.5	10.6	11.5
Logged Flow at HCSW-1	p-value	<0.0001	<0.0001	<0.0001	0.0002	0.05	<0.0001	0.01
	slope	12.1	12.9	9.5	10.1	7.1	10.4	7.8

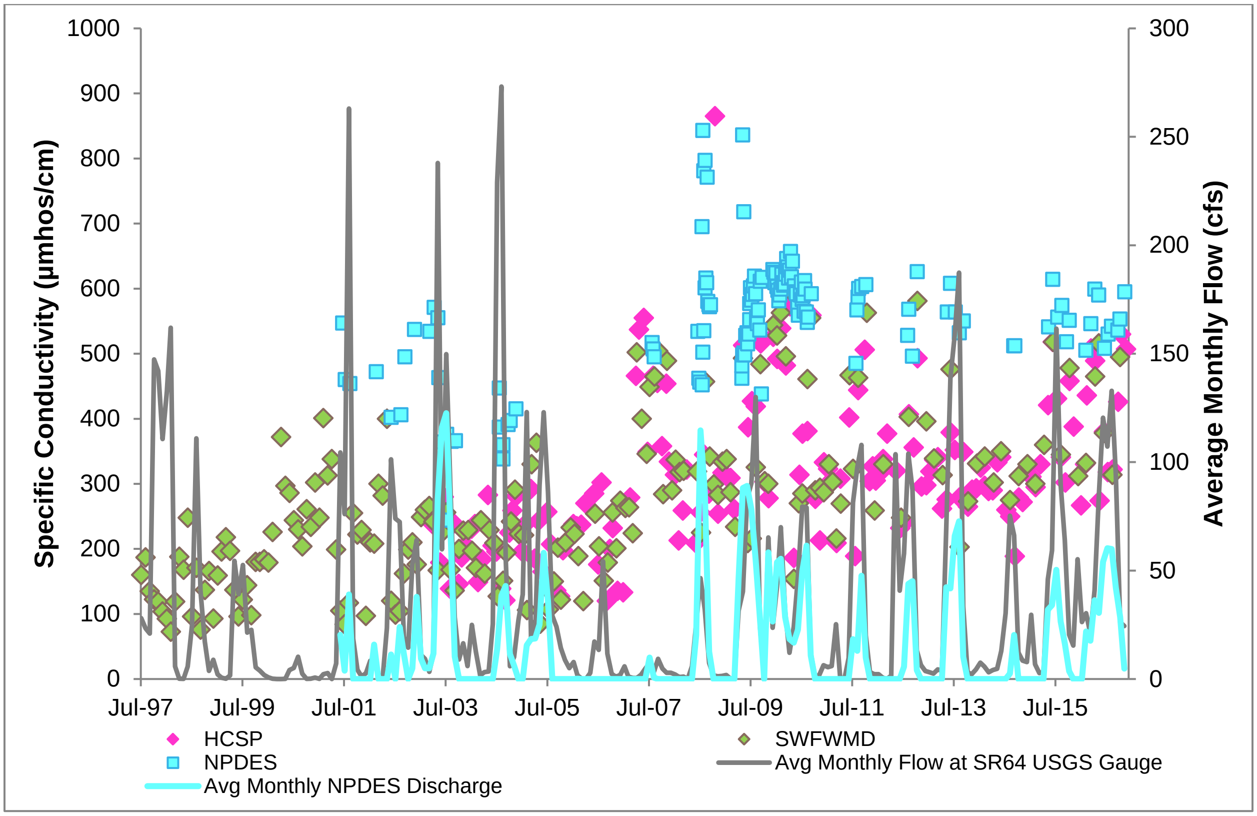


Figure I-16. **HCSW-1 specific conductivity measurements obtained during monthly HCSP and SWFWMD water quality sampling, NPDES outfall specific conductivity measurements, and average monthly streamflow from USGS gauge at HCSW-1 and NPDES discharge.**

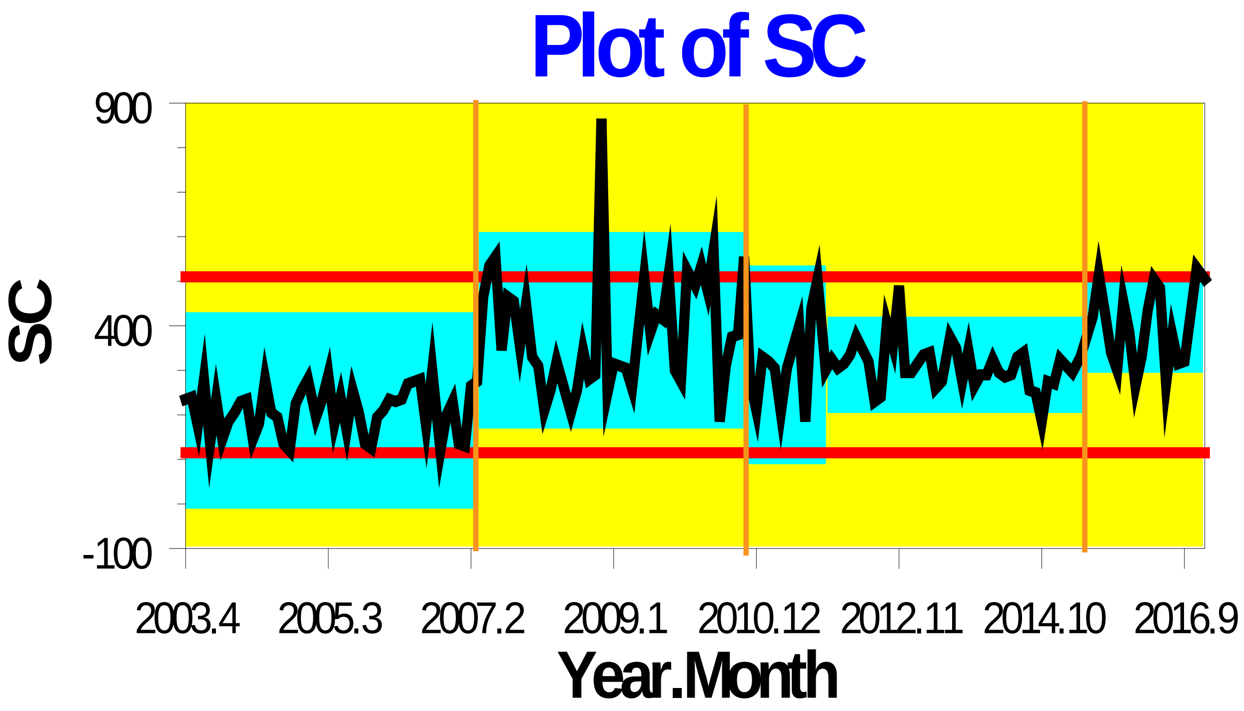


Table of Significant Changes for SC

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%,
Bootstraps = 1000, Without Replacement, MSE Estimates

Year.Month	Confidence Interval	Conf. Level	From	To	Level
2007.4	(2007.4, 2007.9)	100%	211.34	391.64	1 🟥
2010.11	(2007.5, 2011.5)	99%	391.64	312.45	4 🟥
2015.6	(2014.10, 2016.2)	99%	312.45	402.42	3 🟥

Figure I-17. **Change-point analysis graph and results table for specific conductivity at HCSW-1 collected by the HCSP from April 2003 to December 2016.**

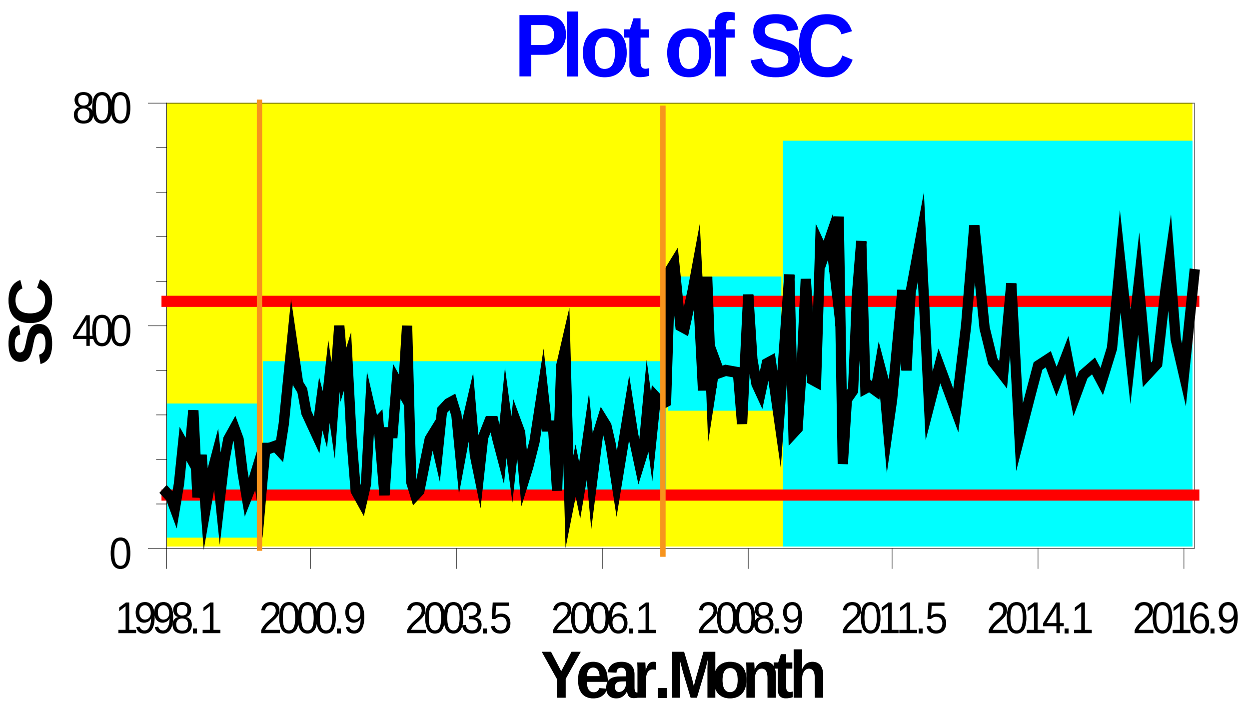


Table of Significant Changes for SC

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%,
Bootstraps = 1000, Without Replacement, MSE Estimates

Year.Month	Confidence Interval	Conf. Level	From	To	Level
1999.11	(1999.7, 2001.2)	100%	140.82	213.64	2 🟥
2007.4	(2007.2, 2007.10)	100%	213.64	367.57	1 🟥

Figure I-18. **Change-point analysis graph and results table for specific conductivity at HCSW-1 collected by the SWFWMD from January 1998 to November 2016.**

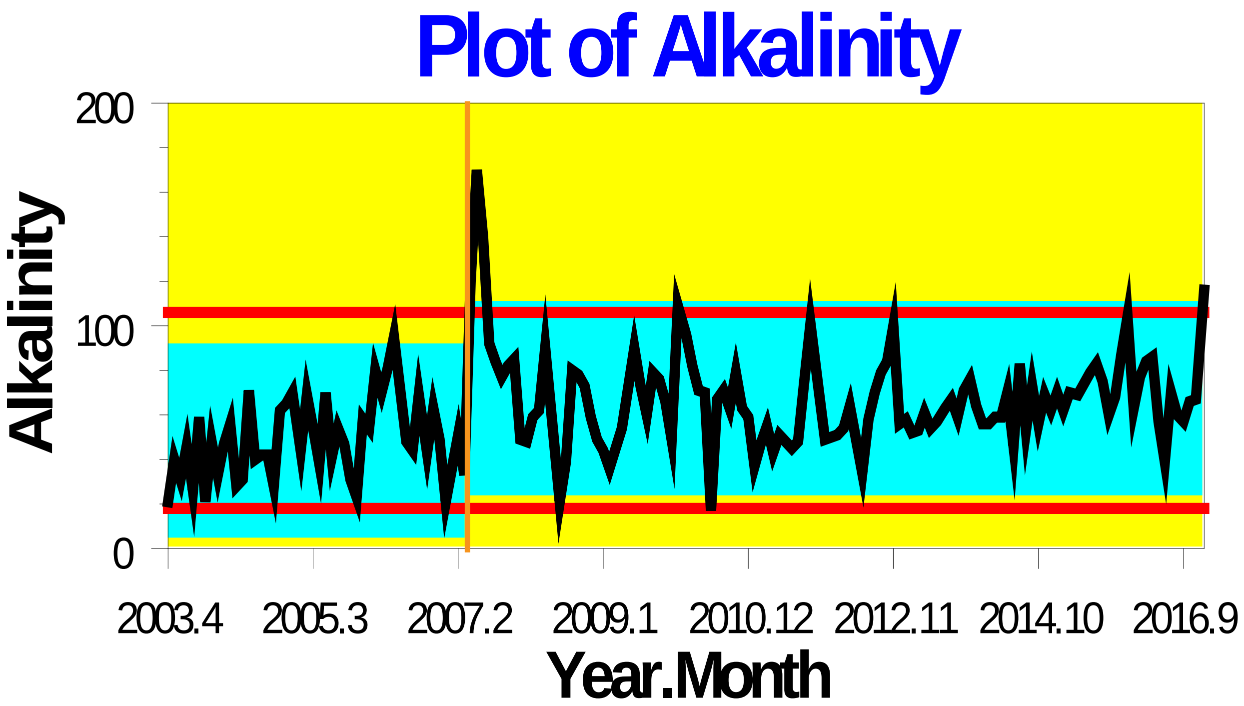


Table of Significant Changes for Alkalinity

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%,
Bootstraps = 1000, Without Replacement, MSE Estimates

Year.Month	Confidence Interval	Conf. Level	From	To	Level
2007.4	(2006.7, 2008.8)	100%	48.489	67.744	2 🟥

Figure I-19. **Change-point analysis graph and results table for alkalinity at HCSW-1 collected by the HCSP from April 2003 to December 2016.**

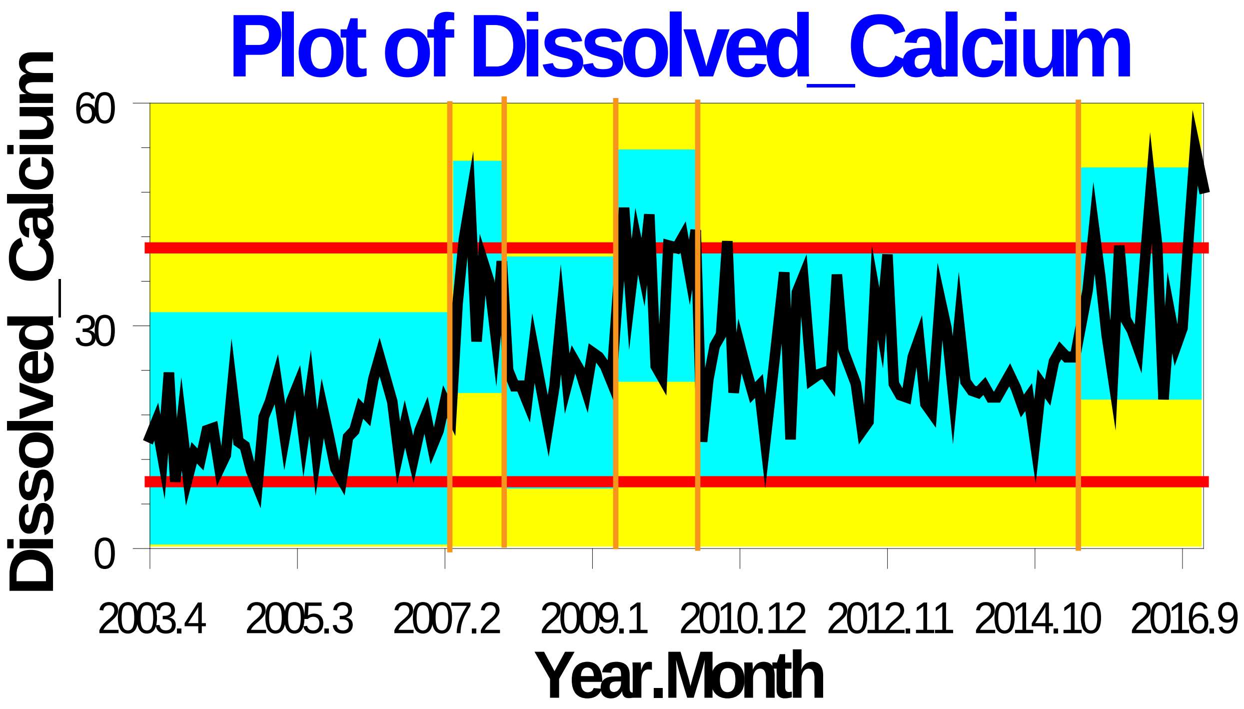


Table of Significant Changes for Dissolved_Calcium

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%, Bootstraps = 1000, Without Replacement, MSE Estimates

Year.Month	Confidence Interval	Conf. Level	From	To	Level
2007.4	(2007.4, 2007.4)	100%	16.111	36.625	1 🟥
2007.12	(2007.9, 2008.1)	100%	36.625	23.669	3 🟥
2009.6	(2009.4, 2009.9)	100%	23.669	38.042	6 🟥
2010.6	(2010.3, 2010.9)	100%	38.042	24.514	5 🟥
2015.6	(2015.1, 2015.12)	100%	24.514	35.763	4 🟥

Figure I-20. Change-point analysis graph and results table for calcium at HCSW-1 collected by the HCSP from April 2003 to December 2016.

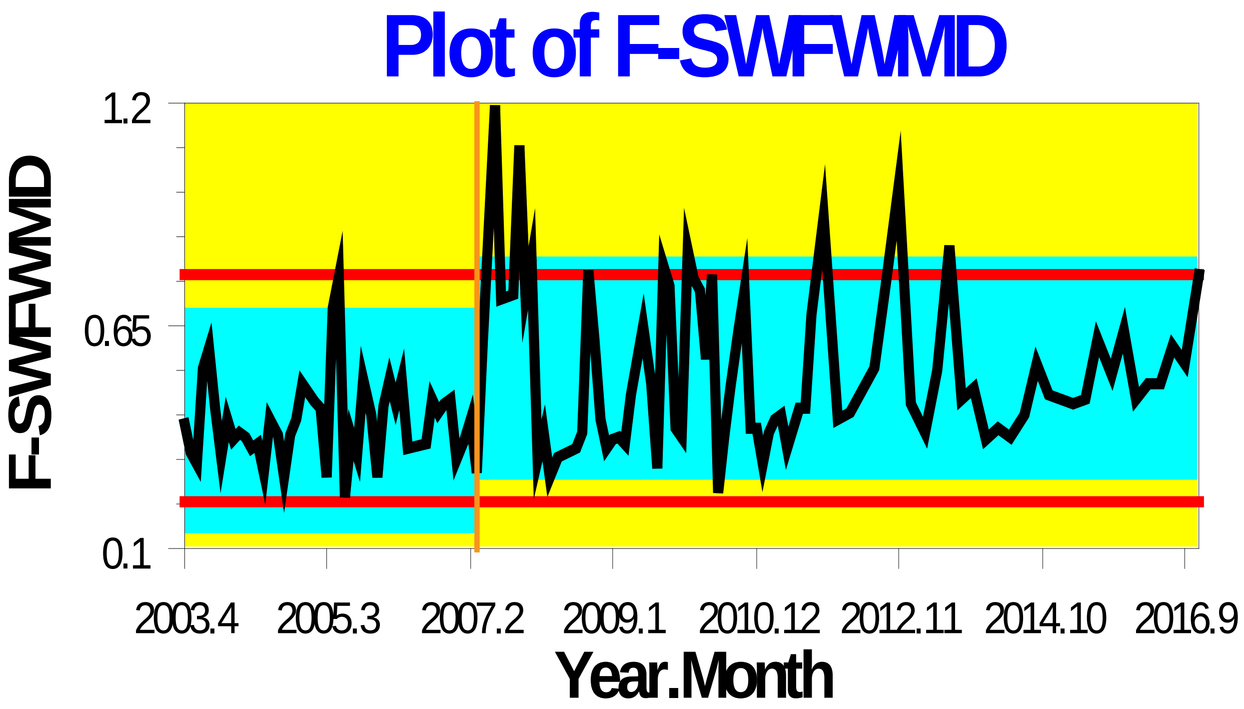


Table of Significant Changes for F-SWFWMD

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%, Bootstraps = 1000, Without Replacement, MSE Estimates

Year.Month	Confidence Interval	Conf. Level	From	To	Level
2007.4	(2006.9, 2010.12)	100%	0.41696	0.54576	1 🟥

Figure I-21. **Change-point analysis graph and results table for fluoride at HCSW-1 collected by the SWFWMD from April 2003 to November 2016.**

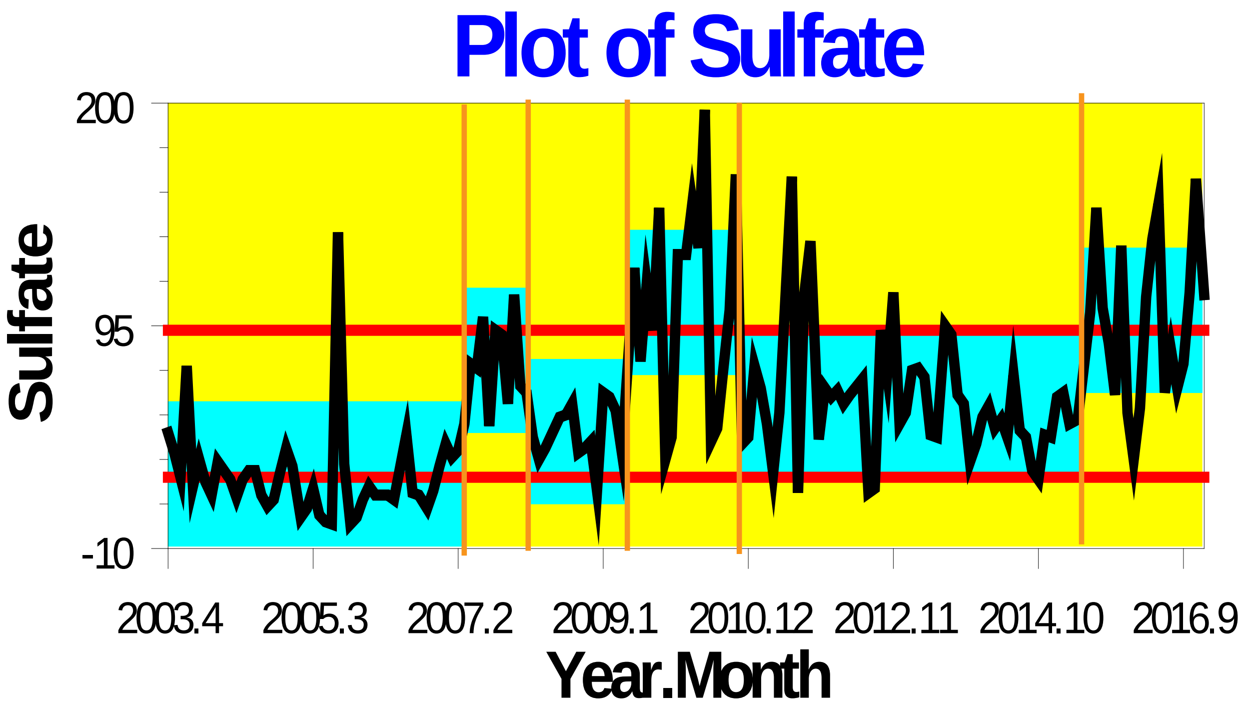


Table of Significant Changes for Sulfate

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%,
Bootstraps = 1000, Without Replacement, MSE Estimates

Year.Month	Confidence Interval	Conf. Level	From	To	Level
2007.4	(2007.1, 2007.5)	100%	25.313	78.6	1 🟥
2008.2	(2007.10, 2008.3)	100%	78.6	44.736	5 🟥
2009.6	(2009.6, 2009.12)	99%	44.736	106.45	4 🟥
2010.11	(2010.1, 2011.3)	99%	106.45	59.481	3 🟥
2015.6	(2014.10, 2016.3)	99%	59.481	97.932	2 🟥

Figure I-22. Change-point analysis graph and results table for sulfate at HCSW-1 collected by the HCSP from April 2003 to December 2016.

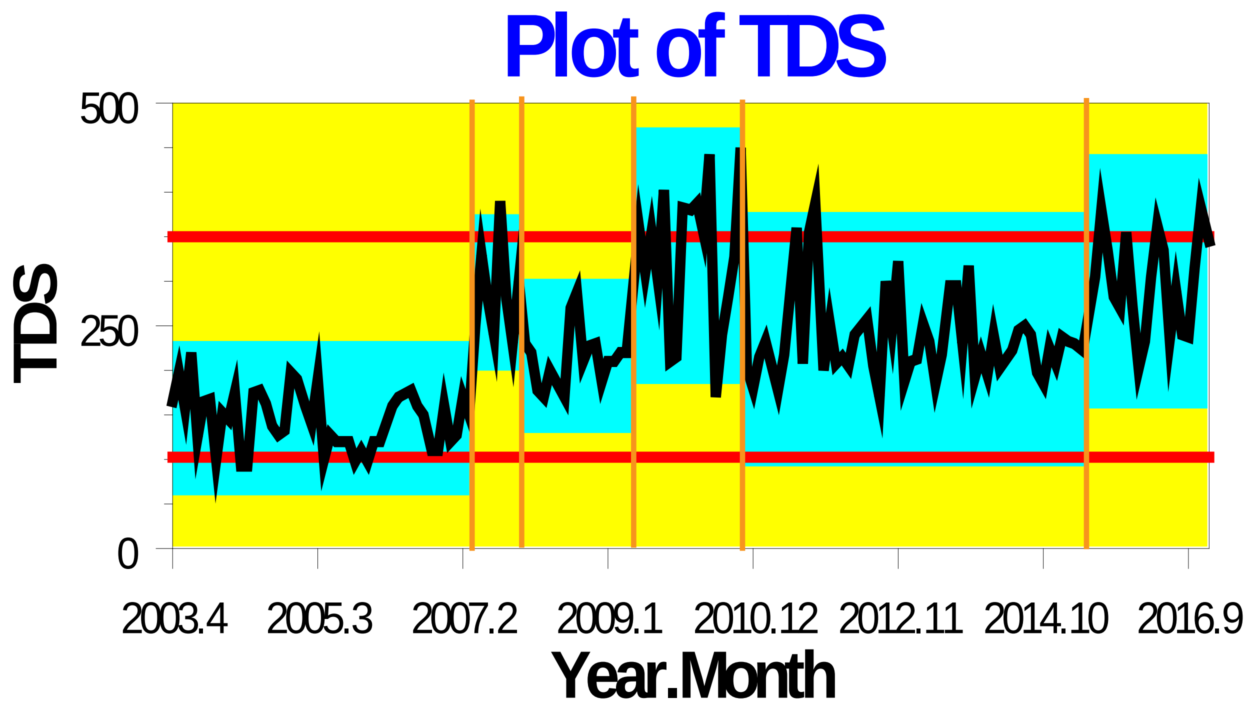


Table of Significant Changes for TDS

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%, Bootstraps = 1000, Without Replacement, MSE Estimates

Year.Month	Confidence Interval	Conf. Level	From	To	Level
2007.4	(2007.4, 2007.4)	100%	145.57	287.5	1 🟥
2007.12	(2007.7, 2008.2)	98%	287.5	216	5 🟥
2009.6	(2009.4, 2009.12)	100%	216	328.94	4 🟥
2010.11	(2010.5, 2011.2)	100%	328.94	234.87	3 🟥
2015.6	(2014.9, 2015.12)	99%	234.87	299.89	2 🟥

Figure I-23. **Change-point analysis graph and results table for TDS at HCSW-1 collected by the HCSP from April 2003 to December 2016.**

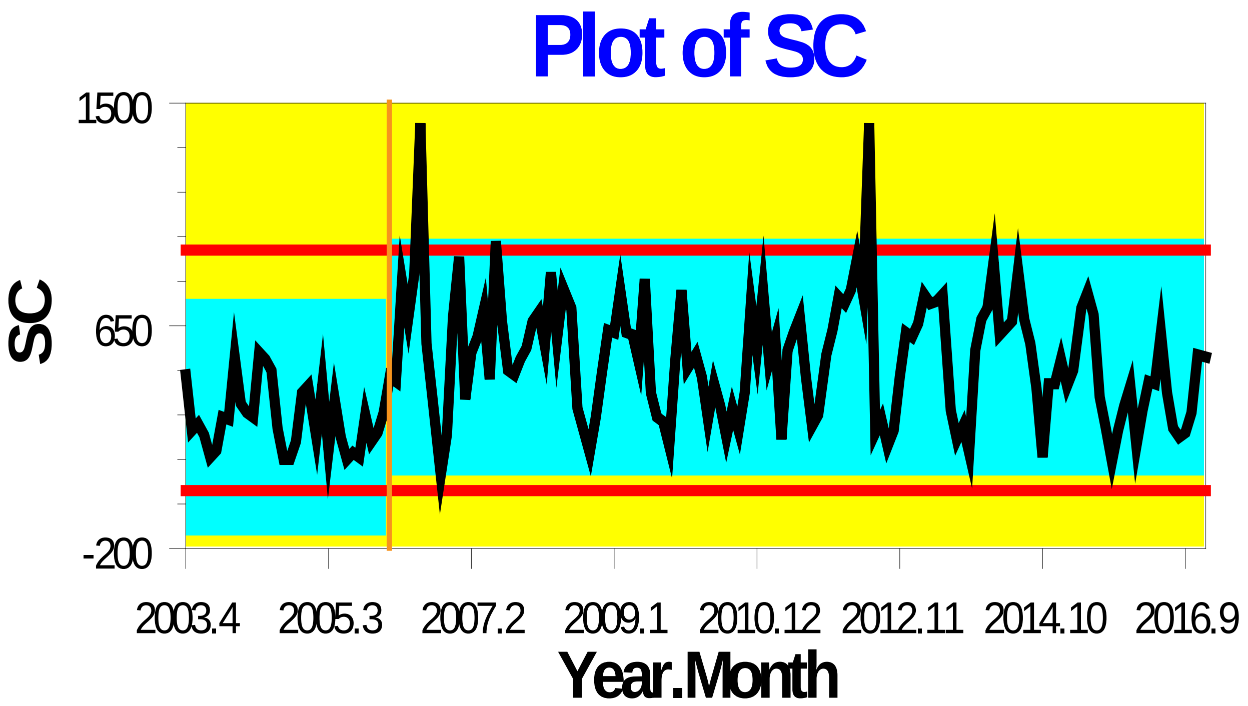


Table of Significant Changes for SC

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%, Bootstraps = 1000, Without Replacement, MSE Estimates

Year.Month	Confidence Interval	Conf. Level	From	To	Level
2006.1	(2005.10, 2007.4)	100%	298.85	530.87	1 🟥

Figure I-24. **Change-point analysis graph and results table for specific conductivity at HCSW-4 collected by the HCSP from April 2003 to December 2016.**

I.2.2 Other Streams

To put the Horse Creek results into a regional perspective, potential trends at Charlie Creek, a stream elsewhere in Peace River basin that has not had phosphate mining in its watershed, were examined.

Charlie Creek, like Horse Creek, is a part of the Peace River basin. Unlike Horse Creek, the Charlie Creek basin is not influenced by phosphate mining, and thus can provide some insight into potential ways that climate and/or other land uses may influence water quality in the Peace River system. For the Charlie Creek analysis, data collected by FDEP, USGS, and SWFWMD was used to examine potential trends in pH and specific conductivity over similar time periods as those used in our Horse Creek analysis in Tables I-4 and I-5. Tables I-6 and I-7 present the results of the Seasonal and Annual Kendall Tau analyses with and without LOESS smoothing by Charlie Creek USGS log streamflow. For the Seasonal Kendall Tau analyses, relatively consistent monthly sampling began in 1999, trends from 1999 to 2016 and 2003 to 2016 were examined. For the Annual Kendall Tau, data matched the Horse Creek analysis time periods (Table I-4) more exactly.

The pH measurements show a small, statistically significant downward trend in seasonal raw and log flow-adjusted values for the 1999 to 2016 time period, as well as for annual log flow-adjusted values for the 1998 to 2016 time period; there were no other trends over time either seasonally or annually when using log flow-adjusted values (Table I-6, Figures I-25 and I-26). Change-point analysis for Charlie Creek pH also indicates a minor decreasing step-change at the beginning of 2015 (Figure I-27); pH at HCSW-1 had minor step changes (down in 2004 and up in 2007, Figure I-14) during different years than Charlie Creek. In addition to the trend and change-point analysis for Charlie Creek, Charlie Creek and Horse Creek pH was compared over time. When compared to the 95% prediction intervals of pH at Charlie Creek (Figure I-28), the pH values at HCSW-1 are almost all within the range of the non-mined stream, including during times of NPDES discharge; only 13 measurements from HCSW-1 were outside of the Charlie Creek 95% prediction intervals, with only four (4) occurring during times of NPDES discharge.

Specific conductivity for Charlie Creek does not show statistically significant trends seasonally or annually when the trend analysis time period ends in 2016, although previous HCSP annual reports, including the 2015 annual report, showed statistically significant upward trends flow-adjusted concentrations for Charlie Creek (Table I-7, Figures I-29 and I-30); trend analysis is not the best statistical method for SC because the changes over time are step-changes rather than a monotonic trend. A change-point analysis of the Charlie Creek data indicates change-point increases around drought periods (2000 and 2006) and change-point decreases at the beginning of wetter periods (2001 and 2013), with the change-points followed by relatively stable concentrations until the next change-point (Figure I-31); the years of the Charlie Creek major increasing changes were similar to increasing changes from the Horse Creek SWFWMD and HCSP data (1999, 2007, Figures I-17 and I-18). These results indicate that Charlie Creek had step-change increases and decreases in specific conductivity over time that are unrelated to mining.

In addition to the trend and change-point analysis for Charlie Creek, Charlie Creek and Horse Creek specific conductivity was compared over time. When compared to the 95% prediction intervals of specific conductivity at Charlie Creek (Figure I-32), the specific conductivity values at HCSW-1 are almost all within the range of the non-mined stream, including during times of NPDES discharge; only 11 measurements from HCSW-1 were outside of the Charlie Creek 95% prediction intervals, with eight (8) measurements occurring during times of NPDES discharge.

The step-changes seen in the HCSW-1 specific conductivity data are similar to those in the Charlie Creek data, showing that there may be similar regional influences on both streams unrelated to mining. It is possible that whatever is influencing changes in Charlie Creek, whether it is climate, changes in land use, agriculture irrigation run off, etc., may also be part of what caused concentrations in Horse Creek to rise.

Table I-6. **Period of record seasonal and annual Kendall-tau analysis for pH in Charlie Creek samples collected by FDEP, SWFWMD, and USGS.**

LOESS Smooth Parameter	Statistics	SWFWMD and FDEP Data		USGS, SWFWMD, and FDEP Data		
		Seasonal 1999-2016	Seasonal 2003-2016	Annual 1992-2016	Annual 1998-2016	Annual 2003-2016
None	p-value	**0.002**	0.12	0.07	0.42	0.32
	slope	**-0.02**	N/A	N/A	N/A	N/A
USGS Flow	p-value	**0.002**	0.08	0.59	**0.03**	0.66
	slope	**-0.01**	N/A	N/A	**-0.01**	N/A

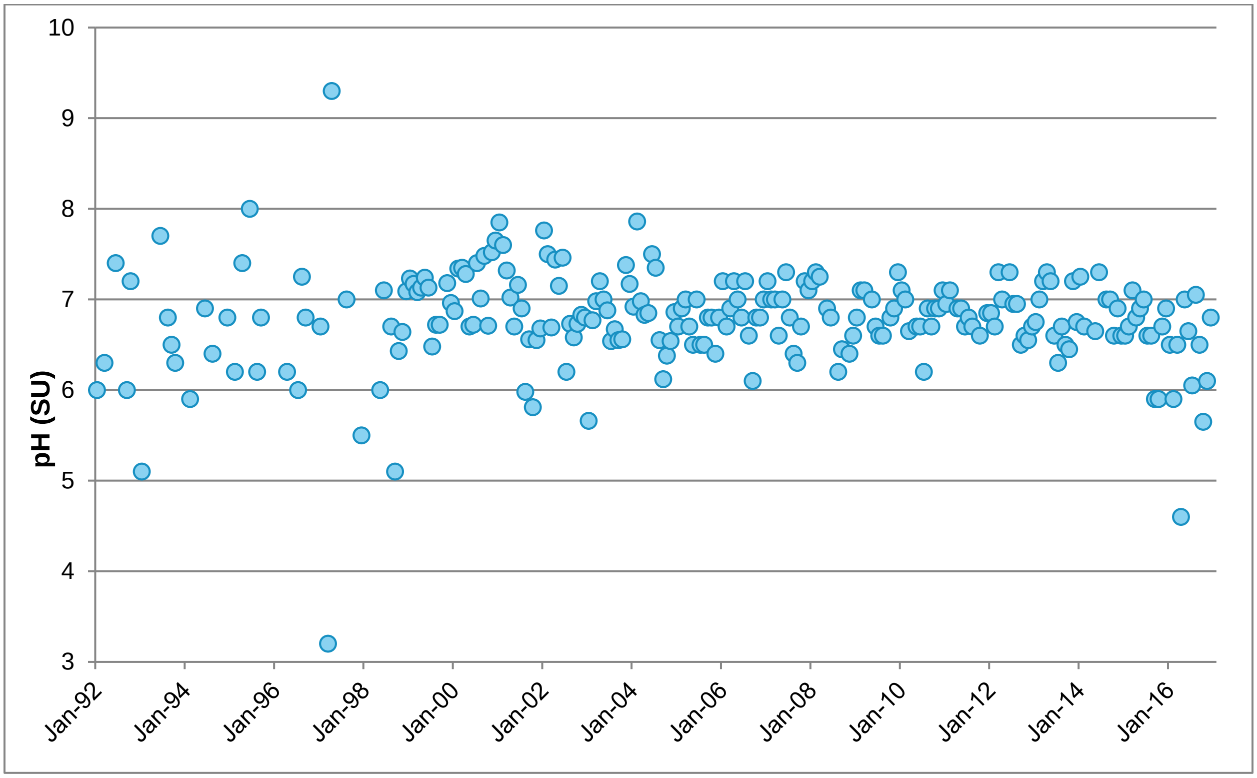


Figure I-25. **Charlie Creek monthly average pH collected by USGS, SWFWMD, and FDEP water quality sampling from 1992 to 2016.**

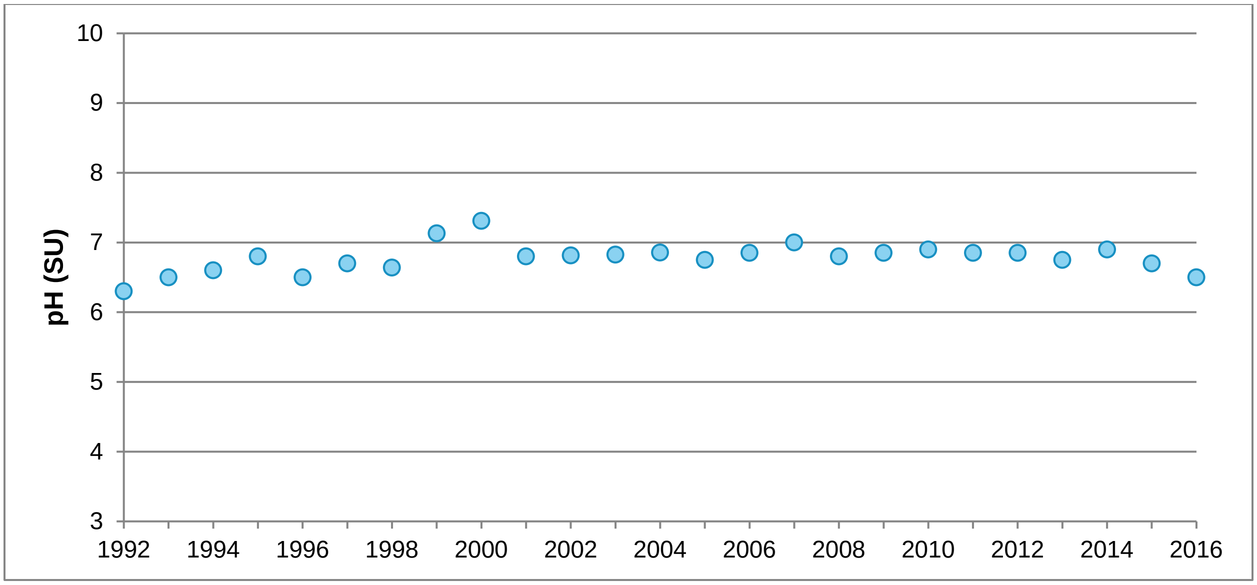


Figure I-26. Charlie Creek annual median pH collected by USGS, SWFWMD, and FDEP water quality sampling from 1992 to 2016.

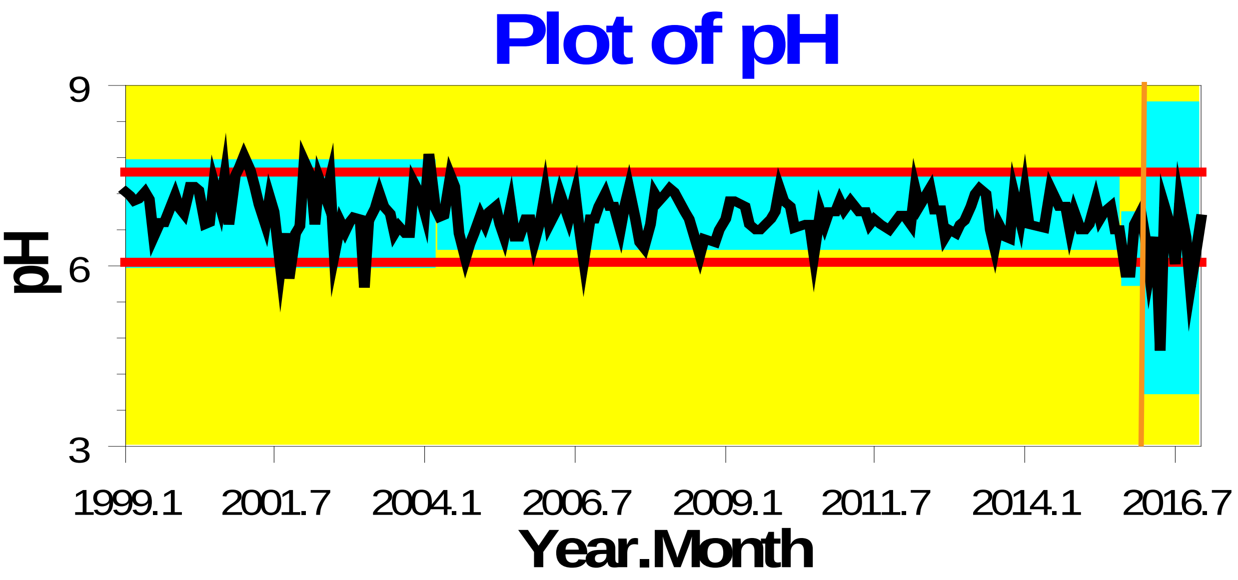


Table of Significant Changes for pH

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%, Bootstraps = 1000, Without Replacement, MSE Estimates

Year.Month	Confidence Interval	Conf. Level	From	To	Level
2015.9	(2015.4, 2016.11)	97%	6.8746	6.2937	1 🟥

Figure I-27. Change-point analysis graph and results table for pH at Charlie Creek collected by the SWFWMD and FDEP from January 1999 to December 2016.

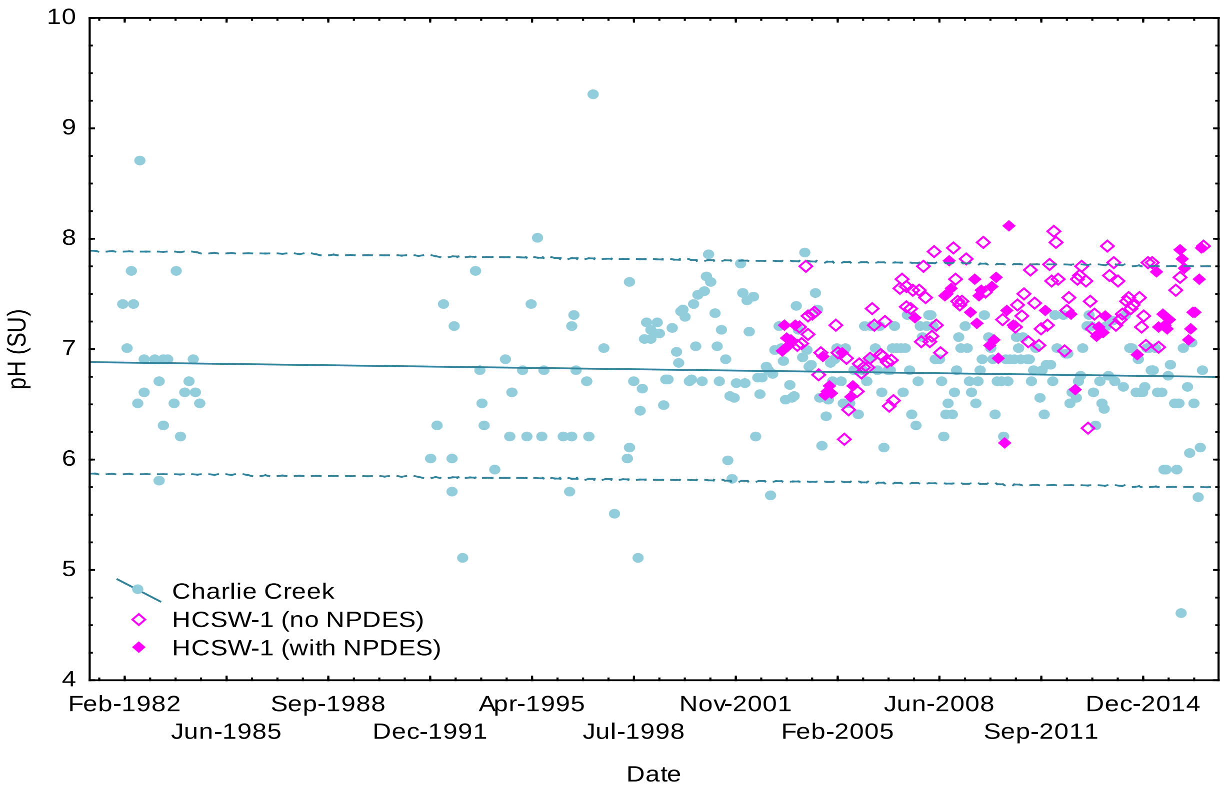


Figure I-28. HCSW-1 pH from the HCSP during periods with and without NPDES discharge, shown with 95% prediction intervals of pH at Charlie Creek.

Table I-7. Period of record seasonal and annual Kendall-Tau analysis for specific conductivity in Charlie Creek samples collected by FDEP, SWFWMD, and USGS.

LOESS Smooth Parameter	Statistics	SWFWMD and FDEP Data		USGS, SWFWMD, and FDEP Data		
		Seasonal 1999-2016	Seasonal 2003-2016	Annual 1992-2016	Annual 1998-2016	Annual 2003-2016
None	p-value	0.90	0.68	0.50	0.67	1.00
	slope	N/A	N/A	N/A	N/A	N/A
USGS Log Flow	p-value	0.46	0.90	0.27	0.67	0.58
	slope	N/A	N/A	N/A	N/A	N/A

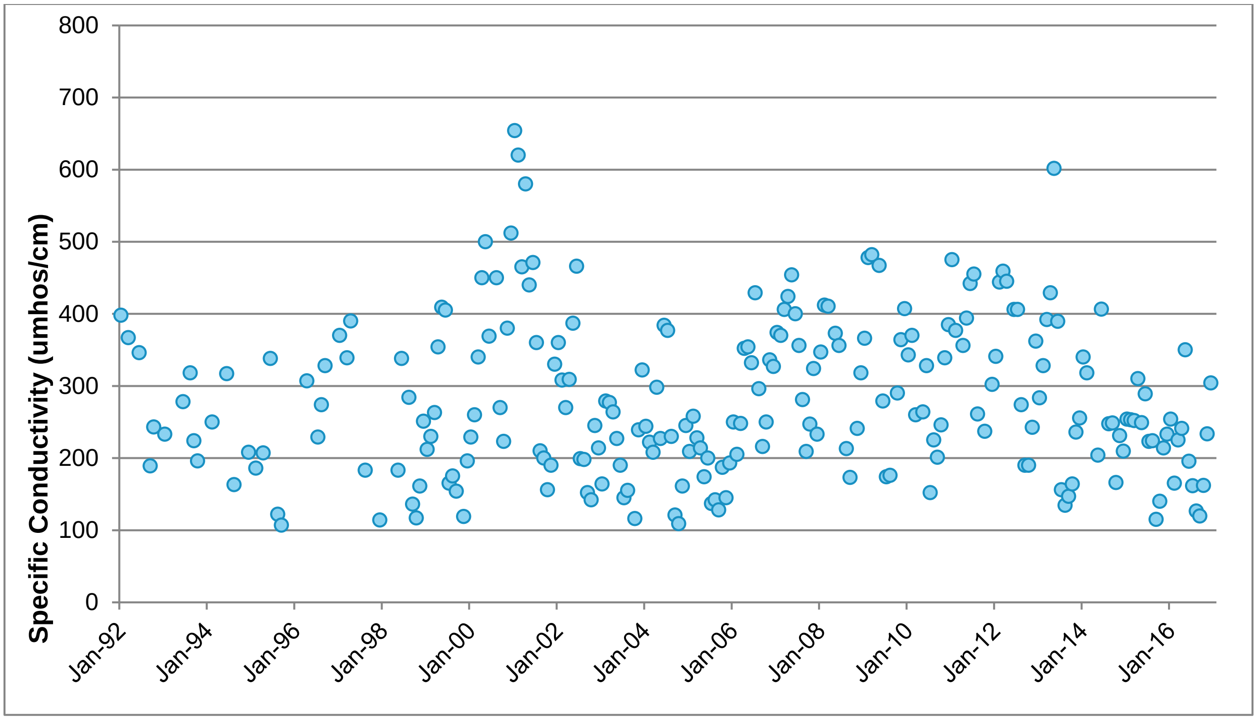


Figure I-29. Charlie Creek monthly average specific conductivity collected by the USGS, SWFWMD, and FDEP water quality sampling from 1992 to 2016.

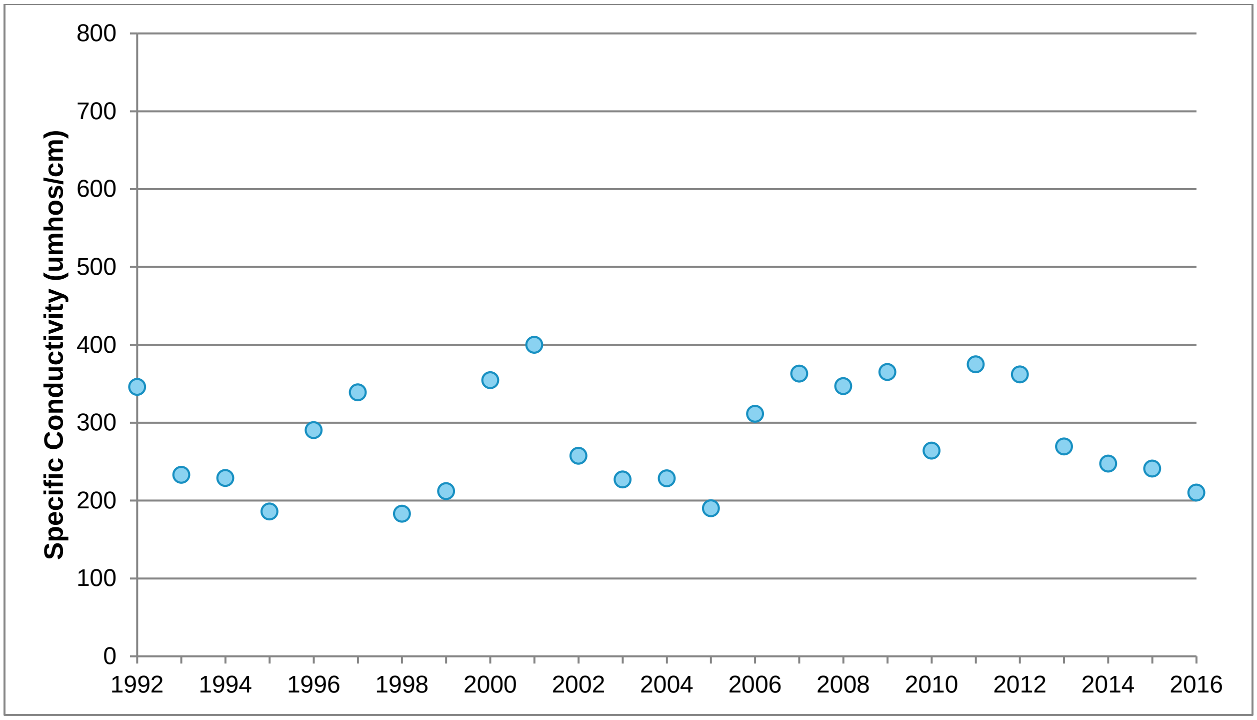


Figure I-30. Charlie Creek annual median specific conductivity collected by USGS, SWFWMD, and FDEP water quality sampling from 1992 to 2016.

Plot of SC

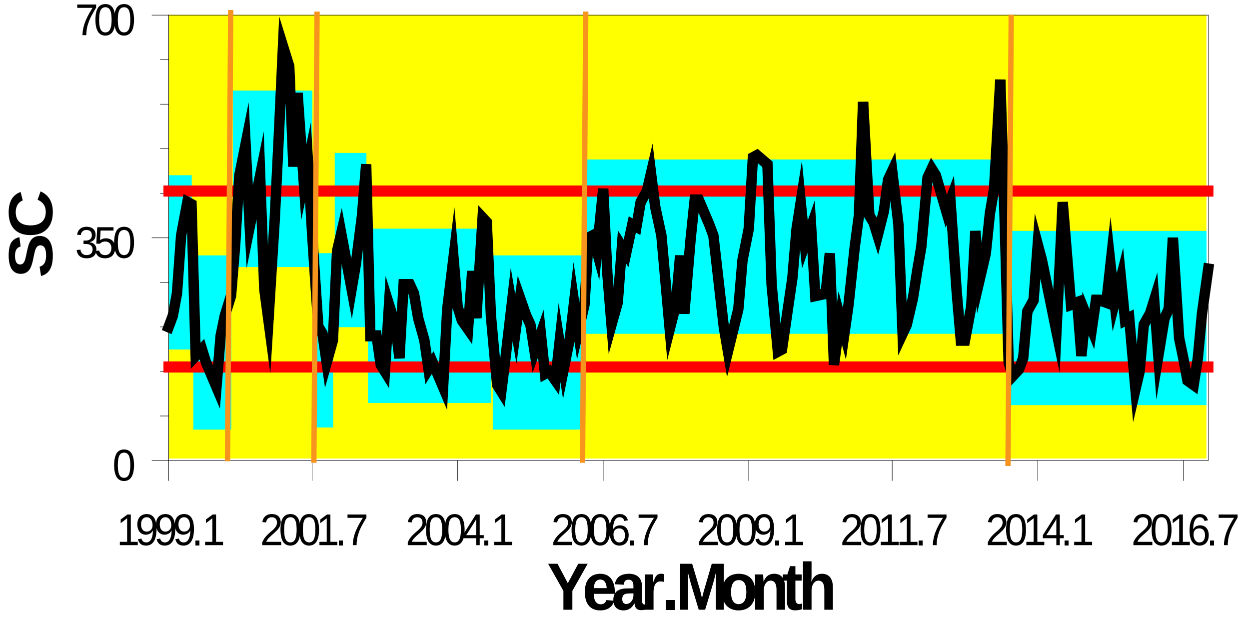


Table of Significant Changes for SC

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%,
Bootstraps = 1000, Without Replacement, MSE Estimates

Year.Month	Confidence Interval	Conf. Level	From	To	Level
1999.7	(1999.3, 1999.8)	97%	312.17	185.43	5 🟥
2000.3	(2000.3, 2000.5)	100%	185.43	442.75	4 🟥
2001.8	(2001.5, 2001.8)	98%	442.75	189	5 🟥
2001.12	(2001.12, 2002.1)	96%	189	347.14	6 🟥
2002.7	(2002.5, 2002.12)	100%	347.14	228.72	3 🟥
2004.9	(2002.8, 2005.7)	96%	228.72	187.05	4 🟥
2006.4	(2006.4, 2006.9)	100%	187.05	336.24	2 🟥
2013.7	(2012.9, 2013.10)	100%	336.24	224.55	2 🟥

Figure I-31. **Change-point analysis graph and results table for specific conductivity at Charlie Creek collected by the SWFWMD and FDEP from January 1999 to December 2016.**

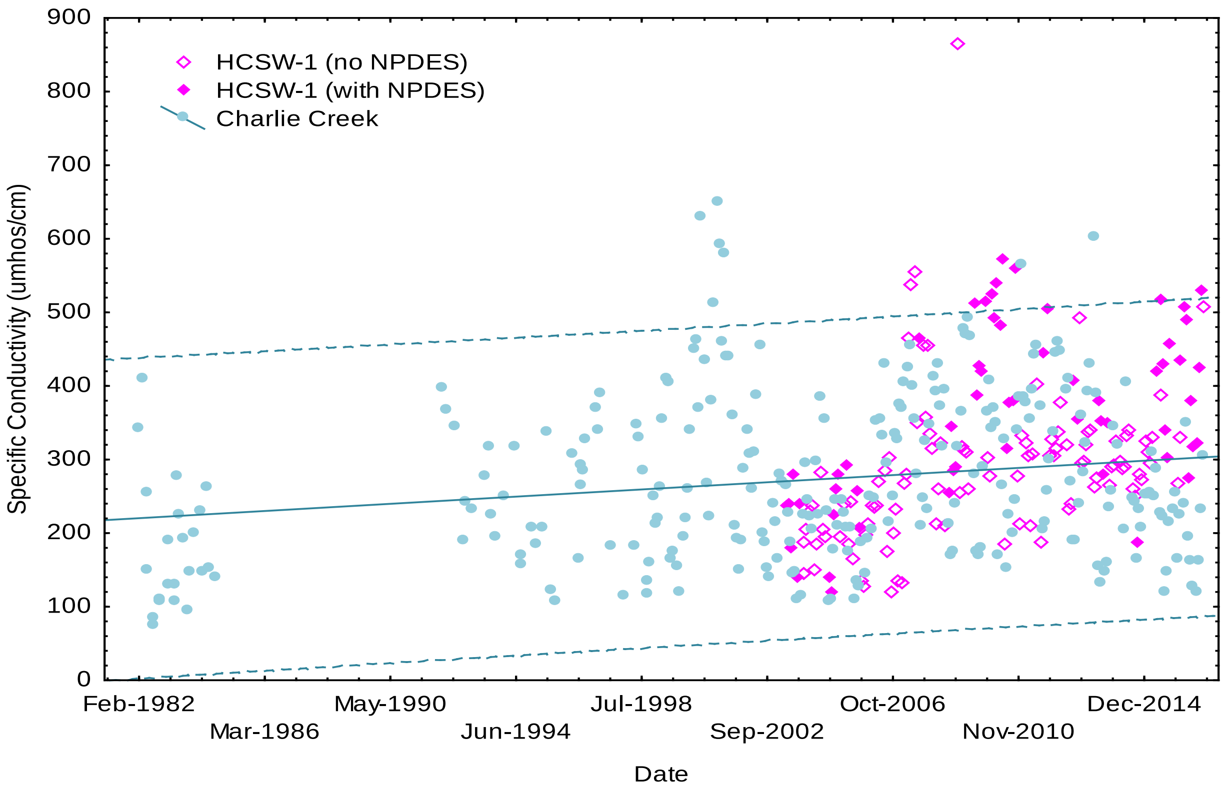


Figure I-32. HCSW-1 specific conductivity from the HCSP during periods with and without NPDES discharge, shown with 95% prediction intervals of specific conductivity at Charlie Creek.

I.2.3 Upstream Horse Creek and Mining Milestones

In order to evaluate whether Mosaic's mining activities have influenced the increasing trend in specific conductivity (and possibly pH) at HCSW-1, the history of mining changes in the Horse Creek basin with respect to water quality was examined.

There are several stations on Horse Creek upstream of HCSW-1 (Figure I-33) that either are upstream of the FTG-003 and WIN-004 (previously named FTG-004) outfalls on the main stem (Horse Creek Inlet and Horse Creek at SR 37) or are located on the tributary West Fork Horse Creek (Manson Jenkins SW-1 and SW-5). Horse Creek at SR37 is located adjacent to several clay settling areas and has a limited watershed, as it is located in the headwaters of Horse Creek. Horse Creek Inlet is located downstream of Horse Creek at SR37 and upstream of the NPDES outfalls, and its watershed includes mined and reclaimed lands and natural rangeland and wetlands. Manson Jenkins SW-1 is downstream of an area of row crops on West Fork Horse Creek, and SW-5 is located further downstream on West Fork Horse Creek with reclaimed and reconnected lands in its watershed.

All four of the upstream stations were not affected by NPDES discharge. Figure I-35 and I-38 show how pH and specific conductivity are changing over time at each upstream station compared to HCSW-1, with annual Kendall Tau trend analysis shown in Table I-8; trend analysis was only preformed for annual medians with no smoothing because streamflow was not available for the upstream stations and monthly data collection was not consistent.

For pH, two upstream stations show statistically significant increasing trends with slopes that are similar or greater than the slope of the pH trend at HCSW-1 (Table I-8). There are change-point increases in 2005 to 2007 at all four upstream Horse Creek stations (change-point results not shown) that mirror the HCSP HCSW-1 data. Three of the four upstream stations show almost complete overlap in pH values as well (HC Inlet has had slightly lower values from 2014 to 2016, Figure I-35).

For specific conductivity, three of the four upstream stations show statistically significant increasing trends with slopes that are similar or greater than the trend slope for HCSW-1 (Table I-8). There are change-point increases in 2006 to 2007 at all four upstream Horse Creek stations (change-point results not shown) that mirror the HCSP HCSW-1 data. The specific conductivity for HCSW-1 (both HCSP and SWFMWD) very closely mirrors the values and trends shown for the West Fork Horse Creek stations since 2015, especially during dry seasons. Given that the Horse Creek stations upstream of the NPDES outfalls are showing statistically significant trends and change-points in pH and specific conductivity that are similar to HCSW-1 HCSP data, it is clear that a portion of potential increase in those parameters at HCSW-1 can be attributed to changes in the water quality of the upstream stations. In addition, the visual increases at the upstream stations begin well before the beginning of the HCSP program.

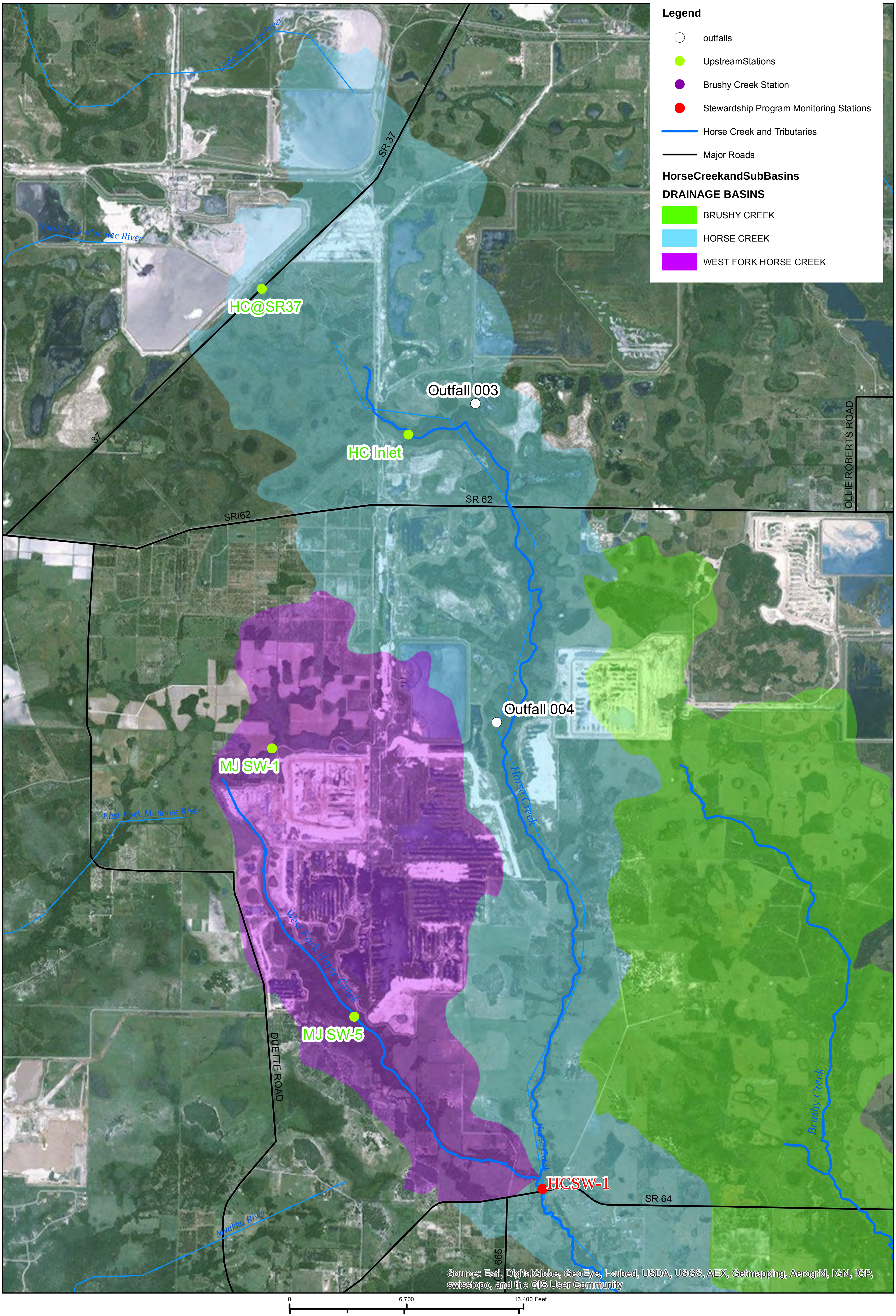
Since mining began in the Horse Creek basin in the late 1980s, mining practices have varied in several important ways. For several years prior to 2006, the NPDES outfalls that discharge into Horse Creek were connected to active clay settling areas that received clays from strip mining conducted in the Four Corners or Fort Green mines. In June 2006, the last clays from Fort Green beneficiation plant were sent to Clay Settling Areas FGH3 and FGH4, which discharge to Horse Creek via FTG-003 and FTG-004. After 2006, the outfalls were not used to release process water for several years because the clay settling areas were not being used to store new clay; in addition, extremely dry conditions during this time period resulted in very little stormwater discharge into Horse Creek via the FTG-003 and FTG-004 outfalls (Figure I-34). In October 2008, clays mined by dredge from the Wingate Mine began to be transported to facilities and settling areas (FM1) in the Horse Creek basin for processing and storage. Dredge mining (used at Wingate mine) is more influenced by groundwater than conventional mining at Fort Green/Four Corners. The HCSP sampling stations are located downstream of these two NPDES outfalls, but the HCSP stations also receive water from West Fork Horse Creek and reaches of Horse Creek upstream of the NPDES outfalls, as discussed above.

The changes in pH (Figure I-36) and specific conductivity (Figure I-39) at HCSW-1 are shown with references to the timing of changes in mining operations and mine water management. For pH, the SWFWMD HCSW-1 data from 2003 to 2016 shows no increasing trend that would correspond to recent changes in mining practices that could affect the NPDES discharges (Figure I-36). A comparison of the range of pH observations during periods with and without NPDES discharge (Figure I-36) shows no evidence of a NPDES-related effect on pH values. When compared to the 95% prediction intervals of pH at upstream stations (like HC Inlet and MJ SW-5 in Figure I-37), the pH values at HCSW-1 are almost all within the range of the upstream stations, including during times of NPDES discharge (four [4] measurements outside, one during NPDES at MJ SW-5 and eight [8] measurements outside, two [2] during NPDES at HC Inlet). Although the HCSP HCSW-1 pH data does show a step-change increase in 2007 during the drought period (which probably causes the statistically significant Seasonal Kendall Tau trend), there is no evidence that NPDES discharge is raising pH at HCSW-1. It is more likely that the step-change increase in pH may partially originate at stations upstream of HCSW-1 with no NPDES influence.

When the Horse Creek outfalls were receiving water from Fort Green/Four Corners, the specific conductivity ranged between 100 and 400 µmhos/cm (Figure I-39). From 2006 to 2008 (Figure I-39), when the outfalls were discharging only small quantities of surface water, specific conductivity started to increase to between 200 and 500 µmhos/cm; this increase was likely caused by an increased proportion of natural baseflow (groundwater influence) with less rain water dilution at HCSW-1 during those unusually dry years. When the Horse Creek outfalls began to discharge water again in 2008, the conductivity remained at these levels (200-600 µmhos/cm). Over the same time period, conductivity at stations upstream of the NPDES outfalls also increased (Figure I-38). The West Fork Horse Creek stations went from between 100 and 300 µmhos/cm in 2003 through 2005, to between 200 and 450 µmhos/cm after 2008. At Horse Creek at SR37, the conductivity range went from between 100 and 500 µmhos/cm in 2003 through 2005 to between 250 and 800 µmhos/cm from 2008 through July 2014, and has decreased from August 2014 to present with a range between 200 and 500 µmhos/cm. These changes are supported by the change-point analysis for HCSW-1 and upstream stations.

Given that upstream stations on Horse Creek experienced similar change-point increases in conductivity ranges around 2007 as those seen at HCSW-1, and that upstream stations also show statistically significant trends of similar magnitude as that of the trend at HCSW-1, it is likely that the changes seen in conductivity at HCSW-1 can be partially attributed to upstream conditions. Conductivity at one of the upstream stations (HC at SR37, Figure I-40) is well above concentrations typically seen at HSCW-1, and the higher mean concentration and increasing trend at that station could be a contributor to changes in conductivity at HCSW-1 downstream. When compared to another upstream station (MJ SW-5, Figure I-40), the majority of HCSW-1 observations fall within the 95% prediction interval of the upstream station. Only 11% of the observations at HCSW-1 are outside of the prediction intervals for MJ SW-5, and 10 out of 16 of those observations were during periods of NPDES discharge. Additionally, when compared to the 95% prediction interval for Charlie Creek (Figure I-32), only 11 observations from HCSW-1 were outside of the interval, with eight (8) collected during times of NPDES discharge. In recent years, the highest specific conductivity at HCSW-1 was recorded during the dry season when no NPDES discharge was occurring; during those periods, HCSW-1 conductivity was very similar to that of West Fork Horse Creek stations. Thus, while some isolated conductivity values at HCSW-1 may be related to increased groundwater influence at NPDES discharges, the majority of the increasing trend at HCSW-1 can be explained by conditions at upstream stations or regional factors unrelated to mining.

The conductivity increases in recent years were influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions (Figures I-38 and I-39), and increased influence of groundwater in current mining activities. Any small portion of the change in specific conductivity that may have been affected by changes in NPDES water quality is likely to stay relatively constant at HCSW-1 in the near future given planned mining practices and the stable range of concentrations shown since Wingate mine began discharging to Horse Creek in 2008.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure I-33. Aerial Photograph of the Horse Creek Basin and HCSP Sampling Locations, Including Mosaic Sampling Locations Upstream

Cardno
Shaping the Future
3905 Crescent Park Drive
Riverview, FL 33578-3625
ph. (813) 664-4500
fx (813) 664-0440
www.cardno.com

Coordinate System:
NAD 1983 UTM Zone 17N feet

Date: 12/19/11 Rev. Date: 10/01/15 PM: KMNR GIS Analyst: KMNR Map Document: horsecreek_aerial_2013_Figure2.mxd PDF Document: horsecreek_aerial_2013_Figure2.pdf Plot Size: 11 x 17

Table I-8. **Annual Kendall trend analysis results for pH and specific conductivity for stations upstream of HCSW-1.**

pH	HC at SR37	HC Inlet				MJ SW-1	MJ SW-5
	2003-2016	1988-2016	1992-2016	1998-2016	2003-2016	2003-2016	2003-2016
p-value	0.11	**<0.0001**	**<0.0001**	**0.01**	1.00	**0.05**	**0.02**
Slope	N/A	**0.07**	**0.07**	**0.05**	N/A	**0.03**	**0.04**
SC	**HC at SR37**	**HC Inlet**				**MJ SW-1**	**MJ SW-5**
	2003-2016	**1989-2016**	**1992-2016**	**1998-2016**	**2003-2016**	**2003-2016**	**2003-2016**
p-value	0.44	**<0.0001**	**<0.0001**	**0.001**	**0.05**	**0.003**	**<0.0001**
Slope	N/A	**4.29**	**4.71**	**3.93**	**3.28**	**8.8**	**16.1**

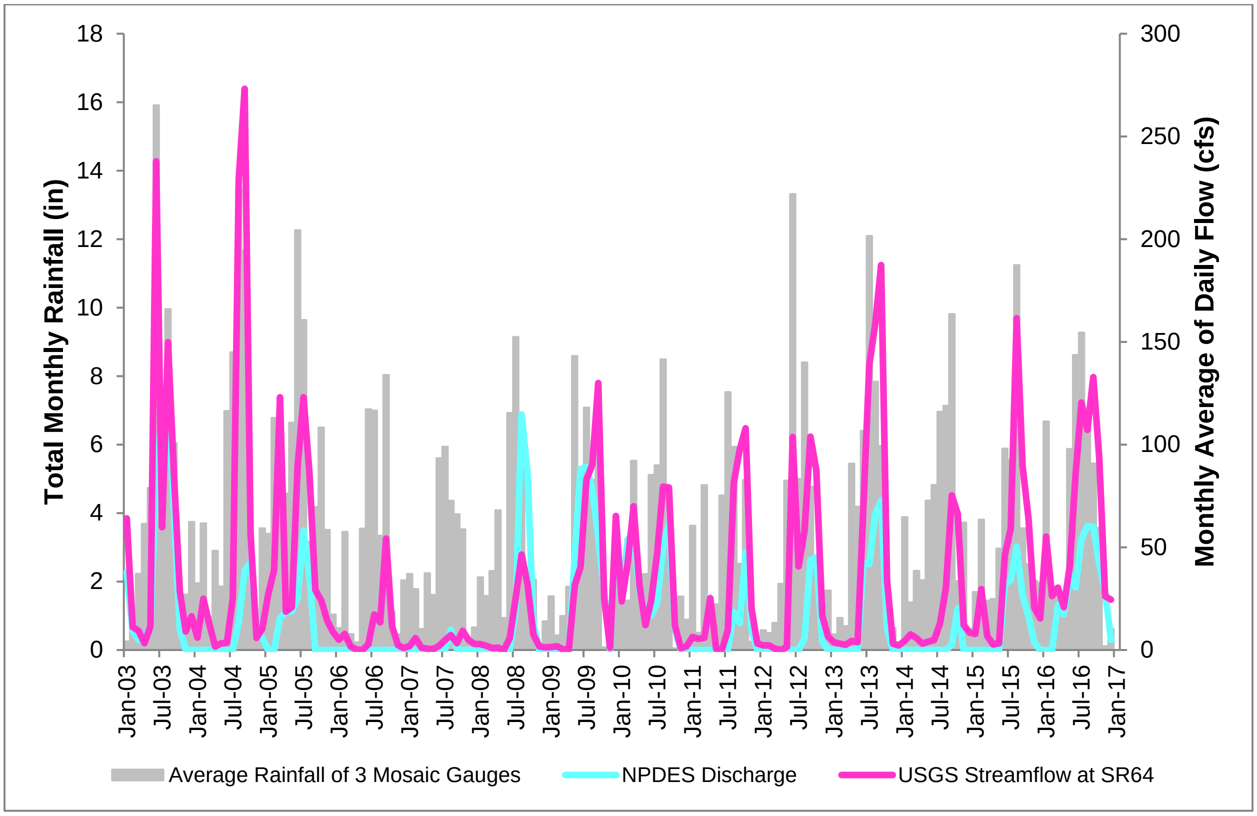


Figure I-34. **Mosaic rainfall, NPDES discharge, and USGS streamflow for HCSW-1 from 2003 to 2016.**

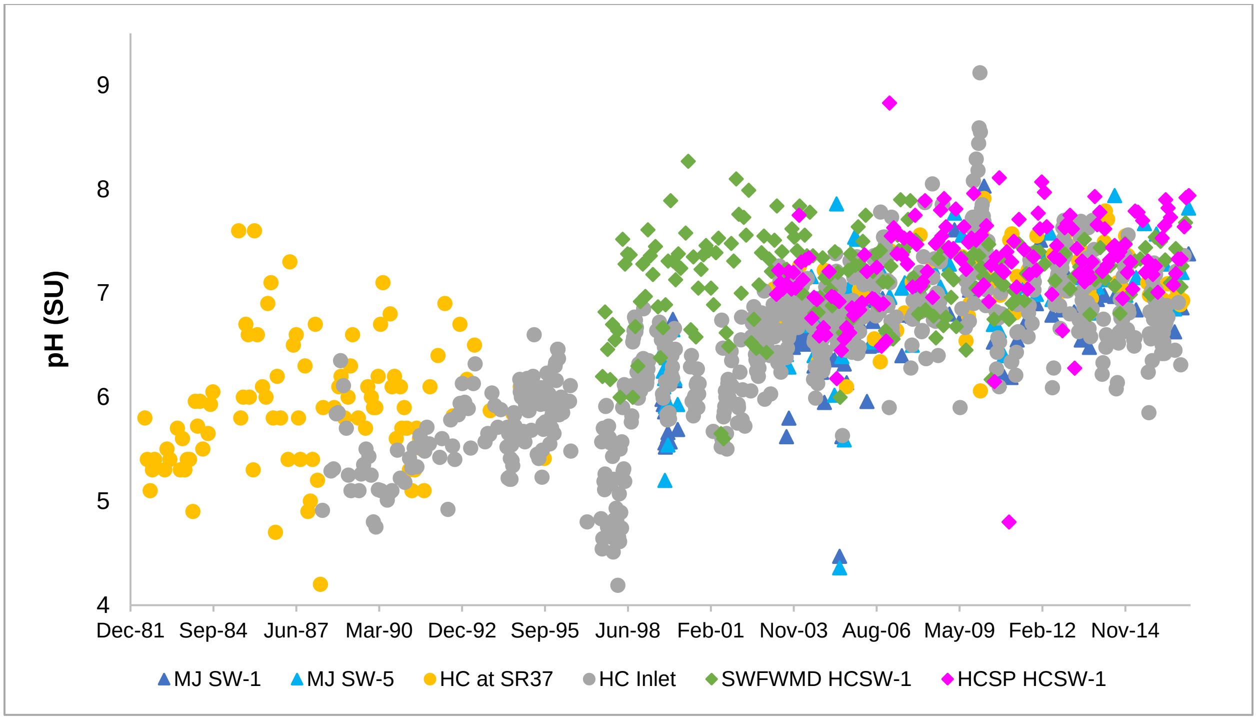


Figure I-35. Measurements of pH collected in West Fork Horse Creek (MJ SW-1 and SW-5), Horse Creek upstream of NPDES discharges (HC at SR37 and HC Inlet), and at HCSW-1 (HCSP and SWFWMD) from 1982 to 2016.

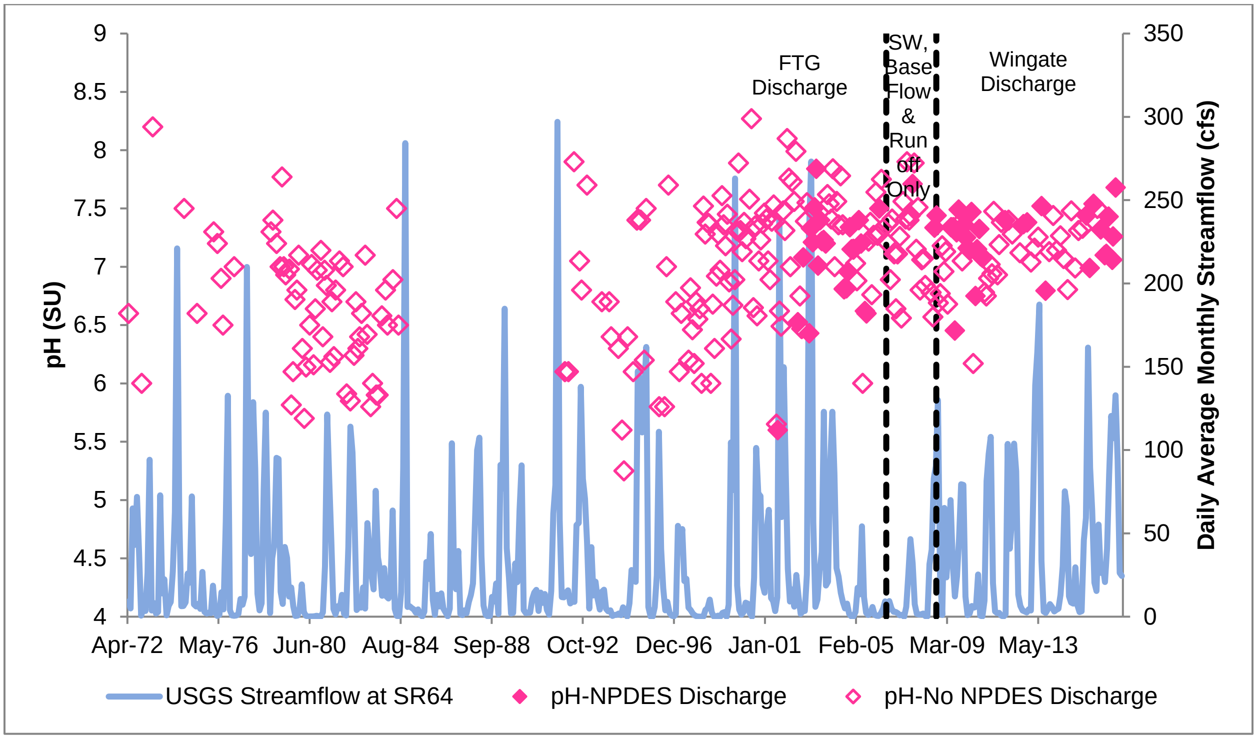


Figure I-36. Measurements of pH collected by FDEP, USGS, and SWFWMD water quality sampling from 1972 to 2016 at HCSW-1, with USGS streamflow for HCSW-1.

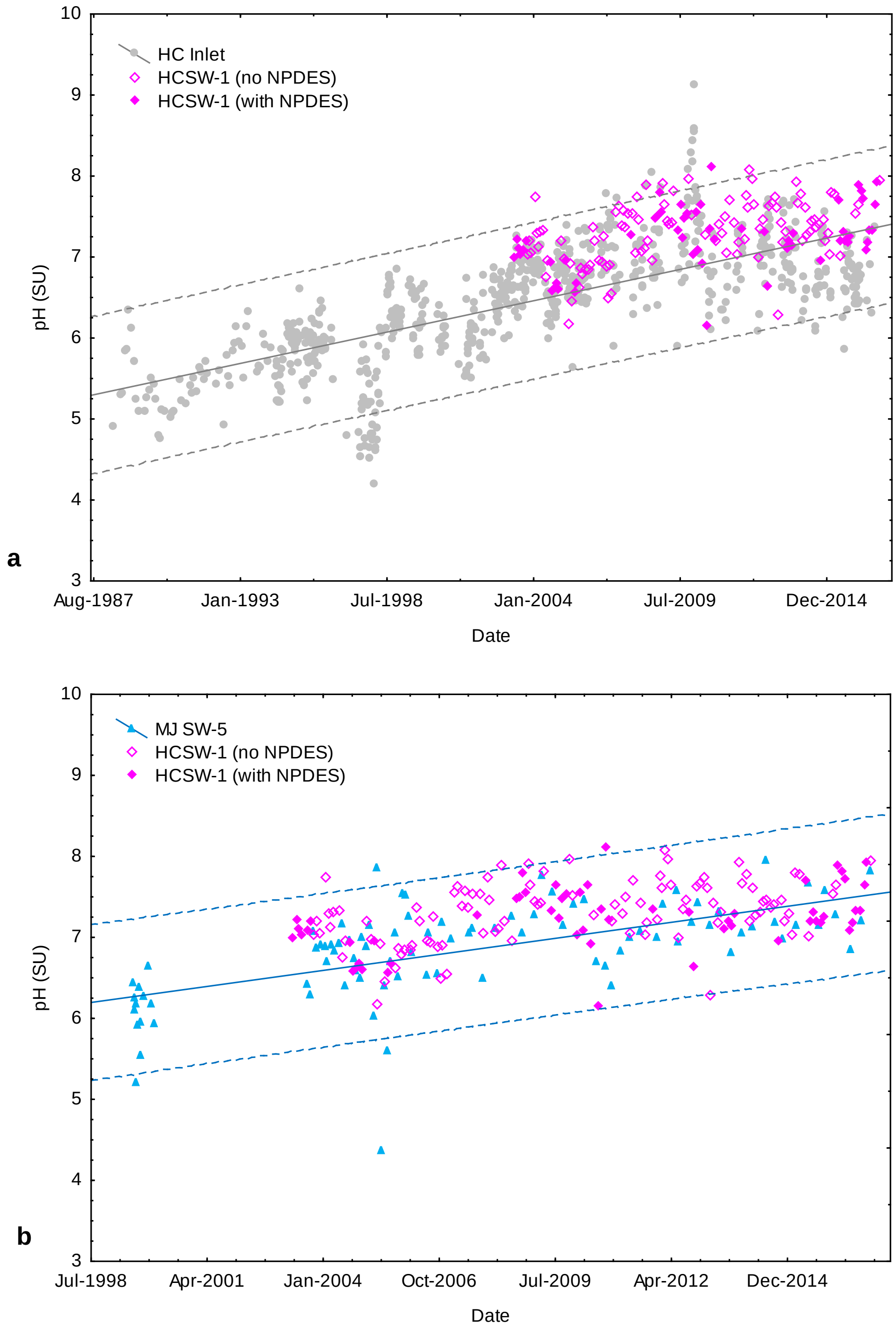


Figure I-37. **HCSW-1 pH from the HCSP during periods with and without NPDES discharge, shown with 95% prediction intervals of pH at HC Inlet (a) and MJ SW-5 (b).**

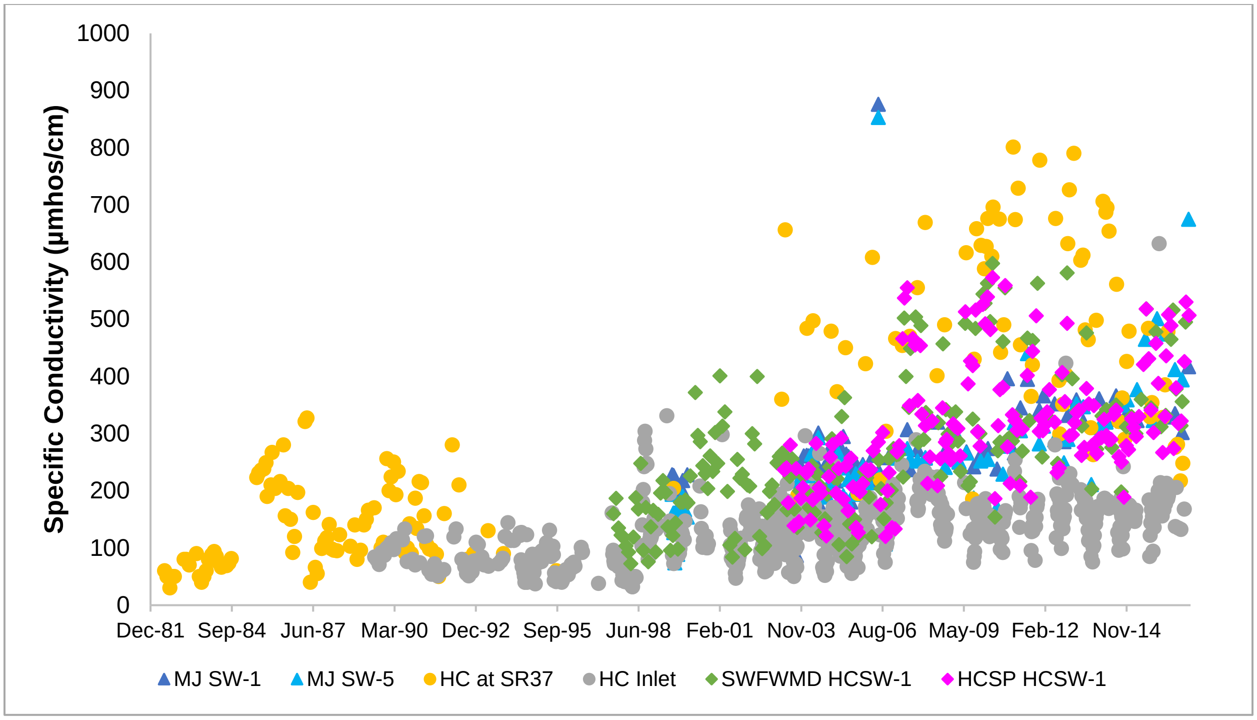


Figure I-38. **Specific conductivity collected in West Fork Horse Creek (MJ SW-1 and SW-5), Horse Creek upstream of NPDES discharges (HC at 37 and HC Inlet), and at HCSW-1 (HCSP and SWFWMD) from 1982 to 2016.**

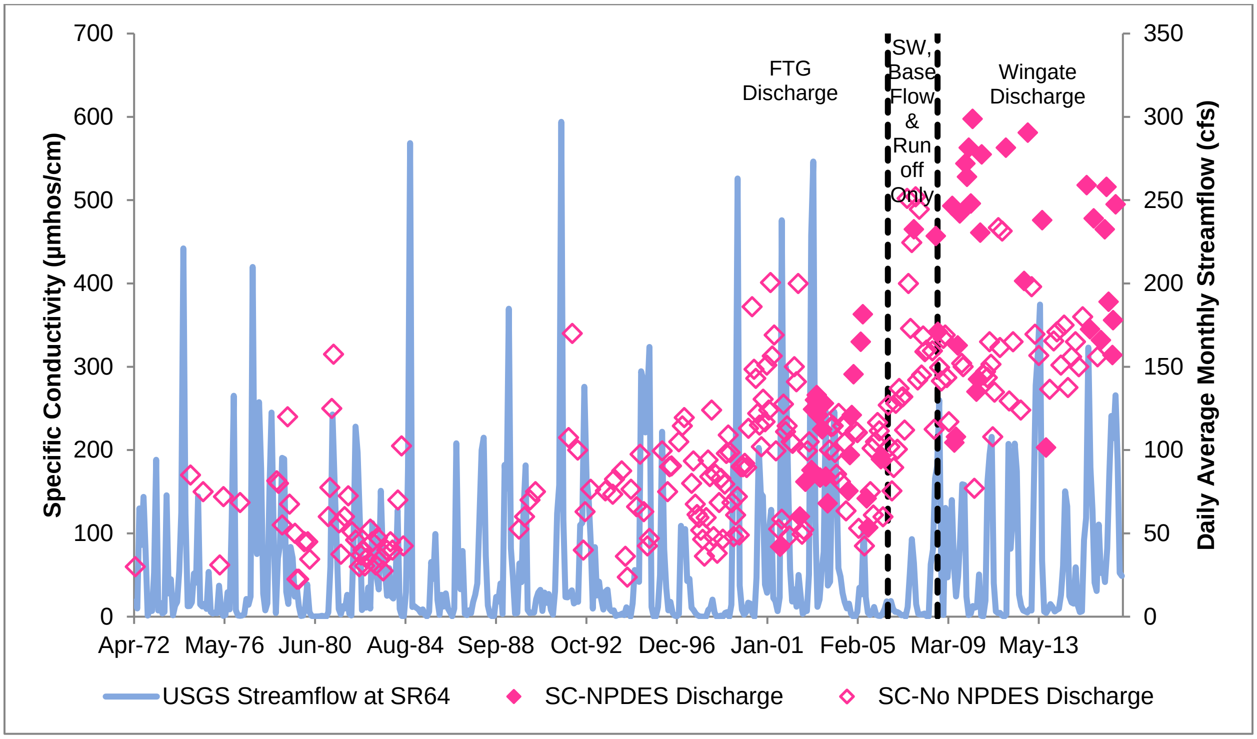


Figure I-39. **Specific conductivity collected by FDEP, USGS, and SWFWMD water quality sampling from 1972 to 2016 at HCSW-1, with USGS streamflow for HCSW-1.**

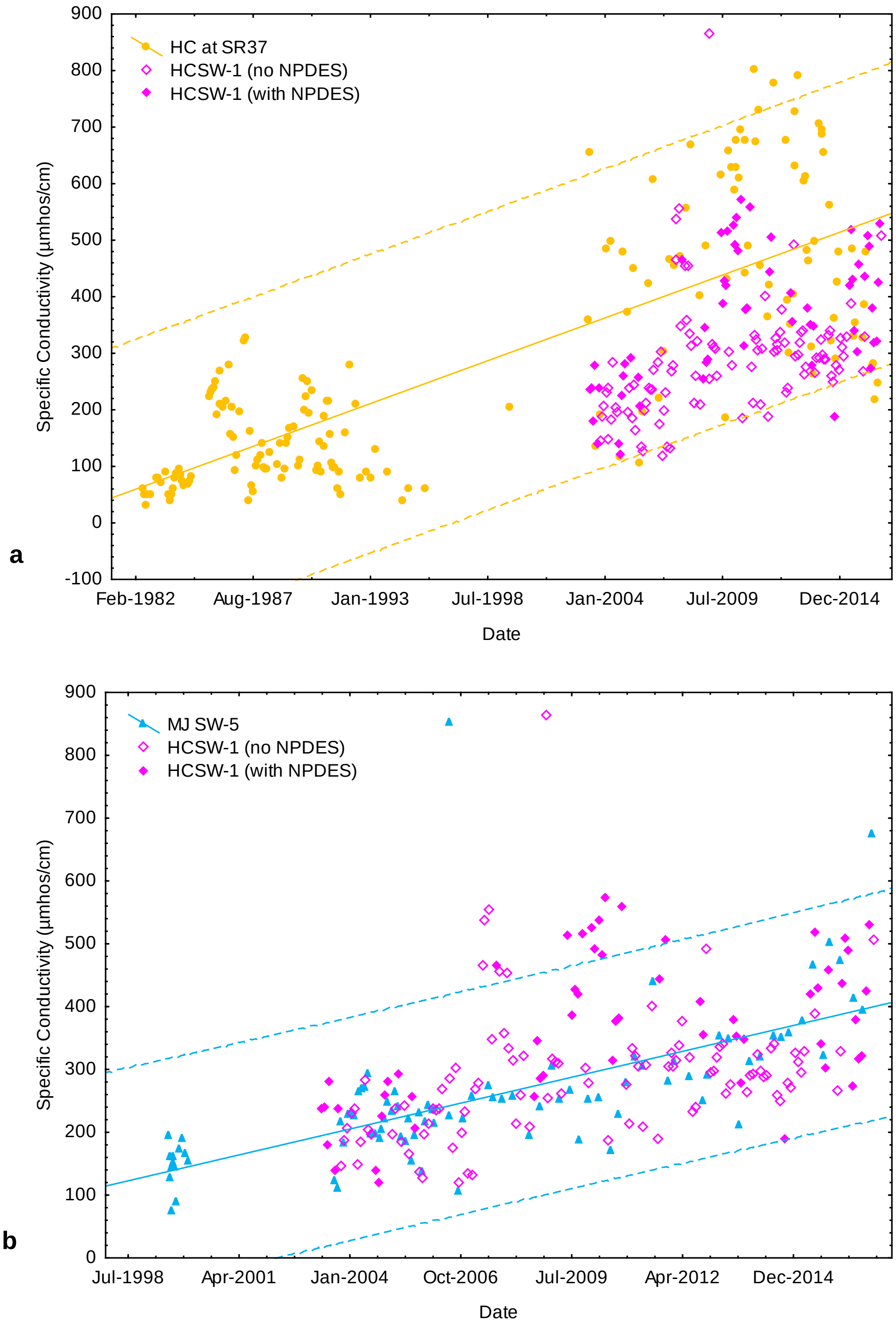


Figure I-40. **HCSW-1 specific conductivity from the HCSP during periods with and without NPDES discharge, shown with 95% prediction intervals of specific conductivity at HC at SR37 (a) and MJ SW-5 (b).**

I.2.4 Water Quality Standards and Biological Integrity

Although there is a statistically significant increasing trend and/or change-point in pH and specific conductivity (and some specific dissolved ions) in Horse Creek at HCSW-1, the magnitude of the increases are not of concern when compared to state drinking water or Class III surface water standards. For pH, fluoride, alkalinity, and specific conductivity (with significant trends in the 2016 Annual Report), all have been well below the applicable Florida Surface Water Class III Standards through 2016, with the exception of one or two exceedances over 14 years (Table I-9). Iron exhibited a negative potential trend in 2016 (Table I-1), indicating that any potential change is in the opposite direction of the HCSP trigger levels and water quality standards. When compared to water quality standards, HCSW-1 has met the Class III standard for iron through 2016. Therefore, the five parameters listed in Table I-9 do not pose a concern in regards to state water quality standards at this time.

Table I-9. HCSW-1 water quality concentrations compared to Florida drinking water and Class III surface water standards for dissolved ions.

Parameter	HCSP through 2016	Class III Standard
pH	Only 2 value above (8.07 and 8.11)	Not ≤ 6.0 SU, ≥ 8.5 SU
Fluoride	2.6 mg/L (Max)	Not > 10.0 mg/L
Alkalinity	Only 1 value below (17.5 mg/L)	Not < 20 mg/L (opposite direction as HCSP trigger value of Not > 100 mg/L)
Specific Conductance	573 µmhos/cm (Max)	Not > 1275 µmhos/cm
Iron	0.98 mg/L (Max)	Not > 1.0 mg/L

Although there were no nutrient parameters with statistically significant increasing trends in this impact assessment, the compliance of HCSW-1 with recently revised nutrient standards was examined to show that biological health criteria are being met. Under the recently approved state numeric nutrient standards, to avoid being listed as impaired for nutrients, a stream must pass a combination of biological and/or numerical criteria. According to 62-302 and 62-303 F.A.C., biological and nutrient data collected during the HCSP at HCSW-1 indicate no nutrient impairment. Table I-10 lists some of the ways that HCSW-1 passes nutrient criteria.

According to the FDEP NNC Implementation Document and 62-302.531(2)(c), streams without site-specific criteria have achieved the nutrient criteria from 62-302.530(47)(b), F.A.C. if:

- There is no imbalance in flora and fauna based on chlorophyll a levels, algal mats or bloom, nuisance macrophyte growth, or changes in algal species composition; AND EITHER
- The average score of two temporally independent (90 days) SCIs is ≥ 40, with neither of the two most recent SCIs < 35, OR
- The Nutrient Thresholds (0.49 mg/L TP and 1.65 mg/L TN for Horse Creek) expressed as annual geometric means are not exceeded more than once in a 3 year period.

As of December 2016, HCSW-1 meets the nutrient criteria set in 62-302.351(2)(c) and shows no imbalance of flora and fauna (chlorophyll-a, RPS, and LVS) and has healthy benthic macroinvertebrate conditions (SCI). HCSW-1 shows no evidence of persistent algal blooms, has annual geometric mean concentrations of chlorophyll < 3.2 µg/L, and has nine (9) passing Rapid Periphyton Surveys (RPS) and Linear Vegetation Surveys (LVS) from 2012 to 2016 (sampling events with less than 90 days between samples use the average score: October and December 2012, October and December 2013, September and November 2014, and October and December 2015). The HCSW-1 average of SCI scores is > 40, with neither of the two most recent scores < 35. HCSW-1 also meets the SCI portion of the Biological

Heath Assessment in 62-303.330 with the two most recent SCI scores > 35 and within 20 points of the historic maximum (if the historic maximum is above 64).

Table I-10. Selected criteria for Class III surface water nutrient standards compared to HCSW-1 results through 2016.

Parameter	Criteria for Passing	HCSW-1 Results
Numeric Nutrient Criteria: Floral Metrics (62-302.531(2)(c), F.A.C., FDEP NNC Implementation)	RPS rank 4-6 ≤ 25%; if 20%-25%, no dominant algal species are nutrient enrichment indicators	RPS and LVS sampling began in 2012 with only one independent sample collected during that year; from 2013 to 2016 there were 8 consecutive passing scores. No algal mats or blooms. All chlorophyll-a annual geomean < 3.2 µg/L. No trend in chlorophyll-a.
	LVS CofC score ≤ 2.5 and FLEPPC exotic taxa ≤25%	
	Annual geomean chlorophyll-a ≤ 3.2 µg/L; or not exceeding 20 ug/L more than once in 3 year period with site-specific evaluation	
Numeric Nutrient Criteria: SCI (62-302.531(2)(c), F.A.C.)	Avg SCI > 40 for at least 2 independent samples, with neither 2 most recent < 35	Avg SCI score > 40 with recent 2 > 35.
Numeric Nutrient Criteria: Nutrient Thresholds (62-302.531(2)(c), F.A.C.)	Annual Geometric Mean TP < 0.49 mg/L and TN < 1.65 mg/L, not exceeded more than once in 3 year period	TN < 1.65 mg/L, and TP < 0.49 mg/L. Passing NNC by nutrient and biological metrics.
Biological Health Assessment (62-303.330, F.A.C.) used for Planning and Verified Lists	2 recent SCI > 35 AND not 20 pts < Historic Max	Recent SCI scores > 35 and within 20 pts of Historic Max (65);
Chlorophyll for Planning List (62-303.351(3) and (4) F.A.C)	No algal mats or blooms and 2 of 3 Annual Geometric Mean Chlorophyll-a < 20 µg/L	No algal mats or blooms. All chlorophyll-a < 20 µg/L
Trends for Planning List, Study List, and Impaired List [62-303.351(5); 62-303.390(2)(a); 62-303.450(4) F.A.C.]	Statistically significant trend in annual geometric mean TP, TN, Chlorophyll-a using one-sided Mann's trend test with 95%. Planning list – 10 years of data. Study List – remove confounding variables and predicted impairment within 10 years. Verified list – trend on study list and predicted impairment within 5 years	No significant trends for TN, TP, and chlorophyll a from 2003 to 2016. No impairment.

Horse Creek fish population data and relevant literature were reviewed with respect to potential effects of specific conductivity; pH was not considered to be a concern to the biological community at this time because more than 95% of the measurements at HCSW-1 were within state water quality standards. Horse Creek fish populations at HCSW-1[5] and HCSW-4 show no evidence of declines during the HCSP study period through 2016 (Figures I-41 and I-42). Freshwater fish, or those species that are confined to freshwater, are part of the *Cyprinidae*, *Catostomidae*, *Ictaluridae*, *Centrarchidae*, and *Percidae* families (Peterson and Meador 1994). In general, a fish species is only as tolerant of changes in conductivity or salinity as their most sensitive life stage. The tolerance to salinity/conductivity at each life stage varies

---

[5] Fish richness and diversity at HCSW-1 in 2010 was affected by higher than usual streamflow and gauge height during sampling that resulted in few habitat refuges for fish at the HCSW-1 sampling location, as well as record cold temperatures that were responsible for increases in regional fish mortality.

with the species. The main stress caused by salinity changes is the demand of maintaining an osmotic balance (Nordilie and Mirandi 1996). However, salinity is not the only factor influencing the survival of freshwater species. Several factors, including habitat complexity, predation, and prey availability, also influence growth and consequently survival (Peterson and Meador 1994). Other considerations, such as water temperature and suitable habitat (woody debris or macrophytes) may affect the taxa richness and abundance of freshwater fish in Horse Creek.

Freshwater fish can be found in a range of conductivities, but tend to have a preferred range based on the species. Of the common species (Seminole killifish, shiner species, and brook silverside) and game species (bass, bluegill, redear sunfish, and spotted sunfish) that have been collected within the lower portion of Horse Creek, the ideal range of conductivities was from 200-500 µmhos/cm (Call et.al. 2011). More than 90% of the HCSP conductivity measurements at HCSW-1 are below 500 µmhos/cm from 2003 to 2016, suggesting that conditions at HCSW-1 are well within the preferred range of most freshwater species. Over that time period, there was no correlation between the specific conductivity and number of freshwater fish species collected at HCSW-1 (Spearman's rank correlation, $p > 0.05$, Figure I-42). At HCSW-4, specific conductivity concentrations were often above 500 µmhos/cm and conductivity concentrations found at HCSW-1, but a diverse suite of freshwater fish species were collected with no correlation with conductivity (Spearman's rank correlation, $p > 0.05$, Figure I-42).

Overall, Horse Creek macroinvertebrate communities at HCSW-1 and HCSW-4 are healthy according to the Florida SCI, with no evidence of declines over time during the HCSP study period (Figure I-43). Comparing the SCI scores for HCSW-1 and HCSW-4 to the three-month average[6] conductivity shows no directional relationship or step-change in SCI over the range of conductivity seen in Horse Creek (Figure I-44).

---

[6] Several conductivity values were tried for this analysis: conductivity at sampling, three-month average, three-month maximum, six-month average, and six-month maximum. The three-month average conductivity was representative of all of the potential relationships. Three months (or 90 days) is the minimum streamflow requirement for conducting SCI within a stream.

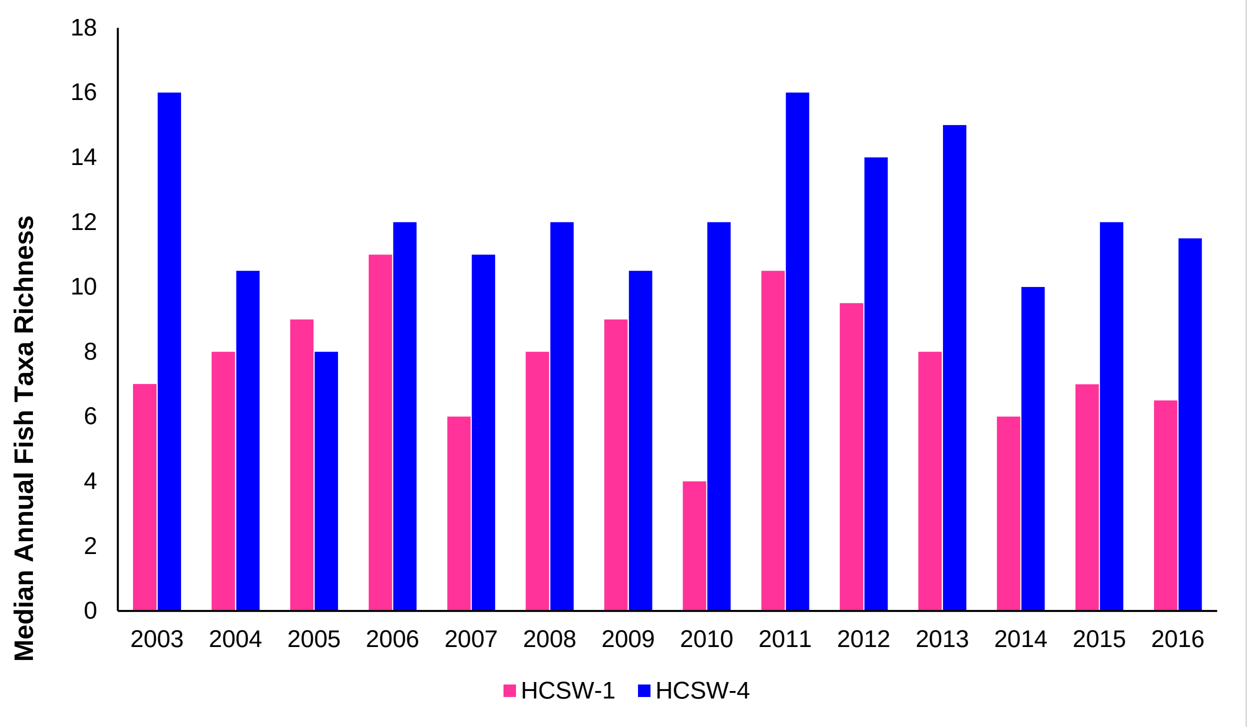


Figure I-41. Annual median fish taxa richness at HCSW-1 and HCSW-4 collected during the HCSP.

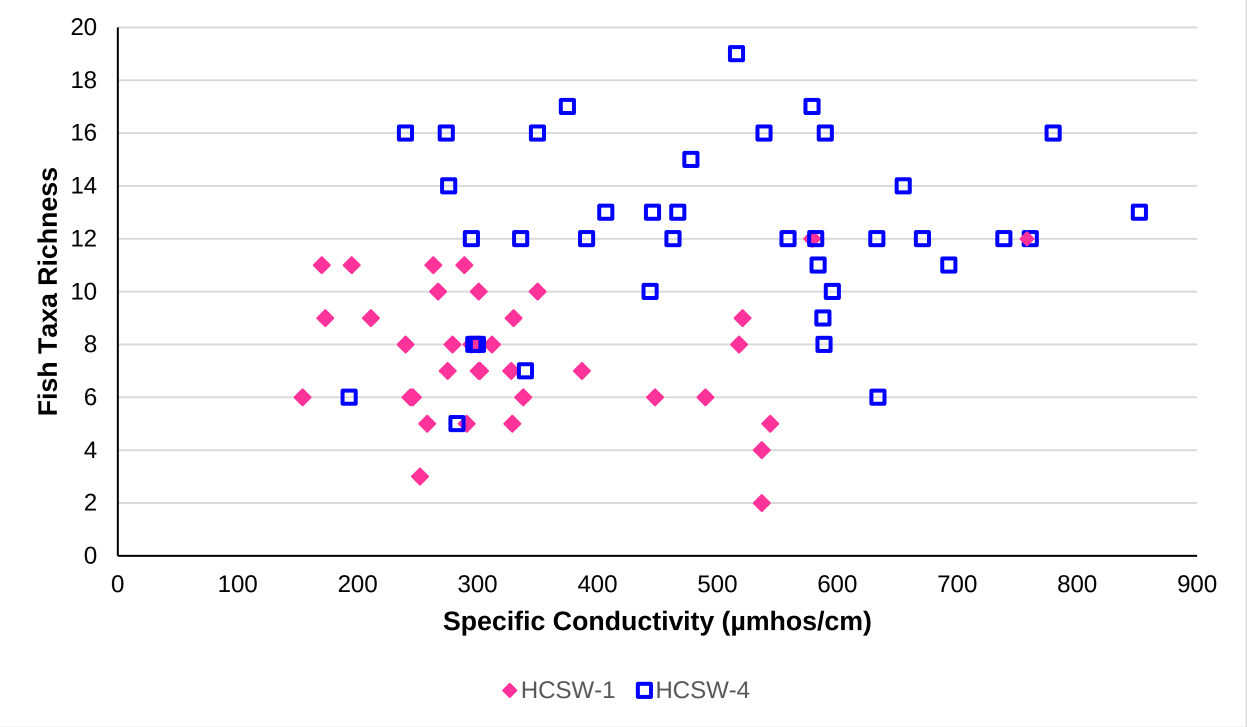


Figure I-42. Specific conductivity versus number of freshwater fish species at HCSW-1 and HCSW-4 collected during the HCSP from 2003 to 2016.

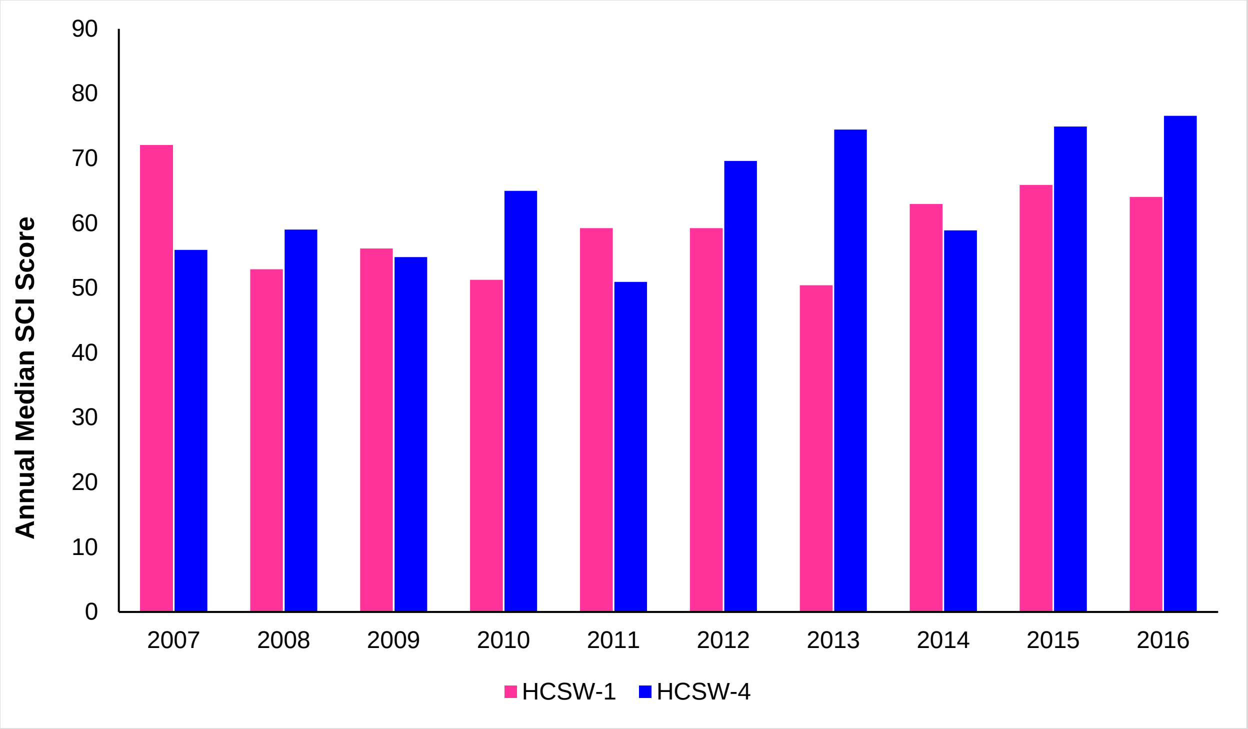


Figure I-43. Annual median SCI scores at HCSW-1 and HCSW-4 collected during the HCSP[7].

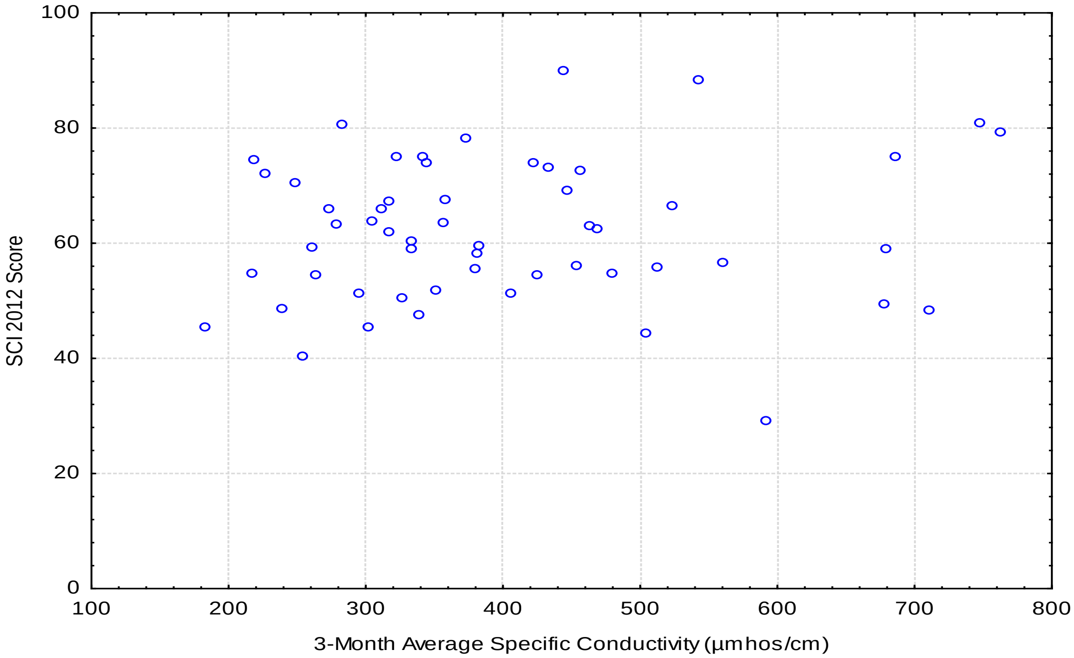


Figure I-44. Specific conductivity (3 month average) versus SCI 2012 scores at HCSW-1 and HCSW-4 collected during the HCSP from November 2006 through 2016.

---

[7] Changes in SCI SOP in 2007 may mean that 2007 to 2016 SCI scores are not directly comparable to those collected previously.

I.3 Conclusions

In the 2016 Annual Report, the Seasonal Kendall Tau procedure found statistically significant trends for some of the water quality parameters between 2003 and 2016. Twelve water quality parameters had a statistically significant trend (11 at HCSW-1 and six at HCSW-4, with five having trends at both stations). Trends detected during the statistical analysis in seven of the 12 water quality parameters have an estimated slope that 1) was not in the direction of an adverse trend (dissolved oxygen concentration and saturation, color, ammonia, and iron) or 2) was very small compared to the observed differences between primary and duplicate field samples (pH and fluoride). The potential trends for pH and specific conductivity (with reference to other ions) are further discussed in this impact assessment, with a focus on the station closest to mining (HCSW-1). Specific conductivity, which has a longer period of record with more consistent data collection, is used as a surrogate for other dissolved ions (calcium, alkalinity, sulfate, fluoride, and TDS) in this impact assessment.

For pH, the statistically significant increasing trend was observed in the seasonal analysis of 2003 to 2016 HCSP data, but not in the annual analysis. For the SWFWMD data, the pH measurements show a small, statistically significant downward trend in seasonal raw and log flow-adjusted values for the 1999 to 2016 time period, as well as for annual log flow-adjusted values for the 1998 to 2016 time period; there were no other trends over time either seasonally or annually when using log flow-adjusted values. Change-point analysis of the HCSP pH data at HCSW-1 shows a decline in 2004 (0.4 SU), an increase in 2007 (0.6 SU), and then a stable range from 2007 to 2016; those change-points correspond to a wet year with several hurricanes (2004) and a very dry time period (2006 to 2008). The SWFWMD data for 1998 to 2016 does not show a statistically significant change-point. The differences in the SWFWMD and HCSP pH data, including the lack of a trend over the same 2003 to 2016 time period in the SWFWMD data, may indicate a sampling bias between the two entities. The change-point analysis for the HCSP data also shows that the apparent increase in pH at HCSW-1 since the beginning of the HCSP may be a single increase around the drought time period, with stable levels since that time. This is supported by the very small slope indicated by the Seasonal Kendall Tau test. The range of SWFWMD pH data for 2016 is well within the range previously observed by SWFWMD at HCSW-1 well before the beginning of the HCSP.

Charlie Creek and Horse Creek pH was compared over time. When compared to the 95% prediction intervals of pH at Charlie Creek, the pH values at HCSW-1 are almost all within the range of the non-mined stream, including during times of NPDES discharge; only 13 measurements from HCSW-1 were outside of the Charlie Creek 95% prediction intervals, with only four (4) occurring during times of NPDES discharge.

For pH, the SWFWMD HCSW-1 data from 2003 to 2016 shows no increasing trend that would correspond to recent changes in mining practices that could affect the NPDES outfalls. A comparison of the range pH observations during periods with and without NPDES discharge shows no evidence of a NPDES-related effect on pH values. When compared to the 95% prediction intervals of pH at upstream stations, the pH values at HCSW-1 are almost all within the range of the upstream stations, including during times of NPDES discharge (four measurements outside, one during NPDES at MJ SW-5 and eight measurements outside, two during NPDES at HC Inlet). Although the HCSP HCSW-1 pH data does show a step-change increase in 2007 during the drought period (which probably causes the statistically significant Seasonal Kendall Tau trend), there is no evidence that NPDES discharge is raising pH at HCSW-1. It is more likely that the step-change increase in pH may partially originate at stations upstream of HCSW-1 with no NPDES influence. In conclusion, pH is not having an ecologically significant increase at HCSW-1 over the course of the HCSP program, and is not of concern for this impact assessment.

For specific conductivity, a significant increasing trend was detected at HCSW-1 even when the period of record was expanded, but an analysis of other stations shows the influence of climatic and upstream conditions. At least part of the increase may be caused by regional influences, as Charlie Creek (an unmined stream) and Horse Creek closely mirror each other. Specific conductivity for Charlie Creek does not show statistically significant trends seasonally or annually when the trend analysis time period ends in 2016, although previous HCSP annual reports, including the 2015 annual report, showed statistically significant upward trends flow-adjusted concentrations for Charlie Creek; trend analysis is not the best statistical method for SC because the changes over time are step-changes rather than a monotonic trend. When compared to the 95% prediction interval for Charlie Creek, only 11 measurements from HCSW-1 were outside of the prediction intervals, with eight measurements occurring during times of NPDES discharge.

In addition, specific conductivity at Horse Creek and West Fork Horse Creek stations upstream of the NPDES outfalls has also been increasing over the same time period. Specific conductivity at HCSW-1 began to rise during a very dry period from 2006 to 2008 when Mosaic had very little NPDES discharge into Horse Creek, and the stream was dominated by baseflow (surficial aquifer) contributions. Water resulting from Wingate dredge mining activities began to discharge from the two Horse Creek NPDES outfalls in late 2008; dredge mining is more influenced by groundwater than conventional mining. Although HCSW-1 specific conductivity remained at higher levels from 2008 to 2016, concentrations at Horse Creek stations upstream of the NPDES outfalls and from Charlie Creek (an unmined stream) also had a step-change increase around that time period.

Given that upstream stations on Horse Creek experienced similar change-point increases in conductivity ranges around 2007 as seen at HCSW-1, and that those upstream stations also show statistically significant trends of similar magnitude as that of the trend at HCSW-1, it is likely that the changes seen in conductivity at HCSW-1 can be partially attributed to upstream conditions. Conductivity at one of the upstream stations (HC at SR37) is well above concentrations typically seen at HSCW-1, and the higher mean concentration and increasing trend at that station could be a contributor to changes in conductivity at HCSW-1 downstream. When compared MJ SW-5, the majority of HCSW-1 (both HCSP and SWFMWD) observations fall within the 95% prediction interval of the upstream station. Only 11 percent of the observations at HCSW-1 are outside of the prediction intervals for MJ SW-5, and 10 out of 16 of those observations were during periods of NPDES discharge. Thus, while some isolated conductivity values at HCSW-1 may be related to increased groundwater influence at NPDES discharges, the majority of the increasing trend at HCSW-1 can be explained by conditions at upstream stations or regional factors unrelated to mining.

The trend for specific conductivity and other ions may have been influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities, but the current concentrations are stable and not biologically harmful. Any small portion of the change in specific conductivity that may have been affected by changes in NPDES water quality is likely to stay relatively constant at HCSW-1 in the near future given planned mining practices and the stable range of concentrations shown since Wingate mine began discharging to Horse Creek in 2008. This theory has been validated considering that the range and median specific conductivity from 2009 to 2016 has been very consistent with no expectation that it will increase from the recently observed range in the future.

Dissolved ion concentrations at HCSW-1 in recent years still meet all applicable state drinking water and Class III surface water standards, except where otherwise noted in previous monthly impact assessments. In addition, the current specific conductivity concentrations at HCSW-1 are within the preferred range of Horse Creek freshwater fish species, and the diversity and composition of fish populations have remained steady over the HCSP study period with no correlation with specific conductivity. SCI scores, an indicator of benthic macroinvertebrate community health, have remained steady over the HCSP study period and show no relationship with specific conductivity. In addition, data collected at HCSW-1 for biological health indicates that Horse Creek has no evidence of an imbalance of flora and fauna.

The HCSP plan document requires that an “impact assessment” be conducted for any trigger level exceedance or adverse water quality trends found while preparing the annual HCSP report. If the impact assessment indicates or suggests that mining activities by Mosaic are the cause of the adverse exceedance or trend, then Mosaic needs to take corrective action. The intensity of the corrective action will be based on the potential for short-term or long-term ecological harm to Horse Creek and/or the integrity of the downstream potable water supply. In this impact assessment, the conclusion is that some of the trends found in the 2016 Annual Report (ammonia and iron) are not adverse and require no corrective action. The apparent change in pH since 2003 is not a strong trend when compared to SWFWMD data collected at the same place, and is well within the range of pH values shown at upstream stations. The trend for specific conductivity and other ions may have been influenced by regional factors unrelated to mining activities, drought-period baseflow contributions, upstream conditions, and increased influence of groundwater in current mining activities, but the current concentrations are stable and not biologically harmful. The biological effects of this step-increase in conductivity should be minimal, given that more than 90% of the concentrations at HCSW-1, the station closest to mining, are within the preferred conductivity range of freshwater fish, and all recorded conductivities are within their tolerance. Invertebrate SCI scores also show no effect of conductivity changes at HCSW-1. At this time, there is no recommended corrective action beyond continued monitoring. This will ensure that existing biological quality is preserved in upper Horse Creek.

I.4 Literature Cited

Call, M.E., P.W. Stevens, D.A. Blewett, D.R. Sechler, S. Canter, and T.R. Champeau. 2011 (draft). Peace River Fish Community Assessment. Florida Fish and Wildlife Conservation Comission and Fish and Wildlife Research Institute. Prepared for State Wildlife Grants, Florida's Wildlife Legacy Initiative, Florida Fish and Wildlife Conservation Commission, and Southwest Florida Water Management District.

Change-Point Analyzer 2.3. 2012. Taylor Enterprises, Inc. Confidence Level for Changes = 95%, Confidence Interval = 95%, Bootstraps 1000 without replacement, MSE Estimates. http://www.variation.com/cpa/index.html

Florida Department of Environmental Protection (FDEP). 2013. Implementation of Florida's Numeric Nutrient Standards. Tallahassee, Fl.

Martin, S.B., A.T Hitch, K.M. Purcell, P.L. Klerks, and P.L. Leberg. 2009. Life history variation along salinity gradient in coastal marshes. Aquatic Biology, 8: 15-28.

Millard, S.P. 2013. EnvStats: An R Package for Environmental Statistics. Springer, New York.

Niu, X-F, S. C. Levings, K. Weaver., D. D. Whiting, and L. Wolfe. 2008. Two Statistical Approaches for Establishing the Specific Conductance Criterion for Florida Class I, III, and IV Fresh Waters. Technical Report Submitted to the Florida Department of Environmental Protection, Tallahassee, FL.

Nordlie, F.G. and A. Mirandi. 1996. Salinity relationships in a freshwater population of eastern mosquitofish. Journal of Fish Biology, 49: 1226-1232.

Peterson, M.S. and M.R. Meador. 1994. Effects of salinity on freshwater fishes in coastal plain drainages in the southeastern U.S. Reviews in Fisheries Science, 2(2): 95-121.

Pond, G. J., M. E. Passmore, F. A. Borsuk, L. Reynolds, and C. J. Rose. 2008. Downstream effects of mountaintop coal mining: comparing biological conditions using family- and genus-level Macroinvertebrate bioassessment tools. Freshwater Science, 27(3): 717-737.

R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Robbins, K.M.N., and S.A. Huelster. 2015. Horse Creek Stewardship Program: 2011 Annual Report. Prepared by Cardno ENTRIX for Mosaic Fertilizer, LLC.

Robbins, K.M.N., and S.A. Huelster. 2015. Horse Creek Stewardship Program: 2012 Annual Report. Prepared by Cardno for Mosaic Fertilizer, LLC.

Robbins, K.M.N., and S.A. Huelster. 2016. Horse Creek Stewardship Program: 2013 Annual Report. Prepared by Cardno for Mosaic Fertilizer, LLC.

Robbins, K.M.N., and S.A. Huelster. 2017. Horse Creek Stewardship Program: 2014 Annual Report. Prepared by Cardno for Mosaic Fertilizer, LLC.

Robbins, K.M.N., and S.A. Huelster. 2018. Horse Creek Stewardship Program: 2015 Annual Report. Prepared by Cardno and Brown & Caldwell for Mosaic Fertilizer, LLC.

Robbins, K.M.N., S.A. Huelster, and D.J. Durbin. 2014. Horse Creek Stewardship Program: 2010 Annual Report. Prepared by Cardno ENTRIX Mosaic Phosphates Company.

Taylor, Wayne A. (2000), "Change-Point Analysis: A Powerful New Tool For Detecting Changes," WEB: http://www.variation.com/cpa/tech/changepoint.html.

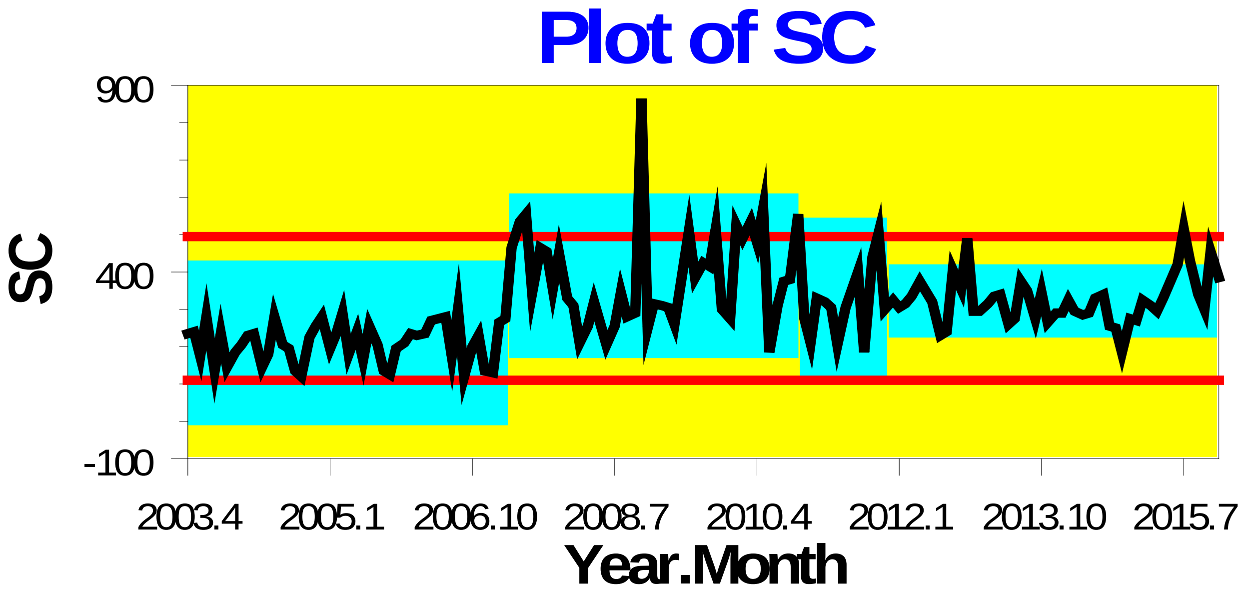
U.S. EPA. 2011. A Field-Based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-10/023F.

I.5 Additional Technical Information on Change-Point Analysis

Change-point analysis works by plotting the cumulative sum (CUSUM) over time of the differences between each observation and the average of all observations; changes in slope of the CUSUM plot indicate that a change in the mean of the observations has occurred. Bootstrapping the data is used to determine if the change in the CUSUM plot is statistically significant. The exact estimate of when the change occurred is given by moving the potential change point back and forth and minimizing the mean square error (MSE) of the two datasets on either side of the proposed change point. Once the change-points are defined (the first sampling event following the detected change), they are given a confidence level and confidence intervals (Taylor 2000). Change-point analysis has fewer assumptions about data gaps and distributions than trend analysis, but it does assume that there is no serial autocorrelation (dependence of sampling values over time). In change-point analysis, serial autocorrelation is dealt with by aggregating consecutive values (taking the mean, median, etc).

In the program Change-Point Analyzer (Taylor 2000), produces the following output for the data values and their variation: a graph of showing change-points, a table of the changes, and a plot of the CUSUM results. For the HCSP analysis, the graph and table of the change-points have been included. On the graph of the change-points, the black line is the plot of the water quality data that were analyzed and the blue boxes show time periods were changes may have occurred. Red lines are control limits, which are the maximum range of all the data if no change had occurred; control charting is another method to detected changes, but it is less sensitive than change-point analysis. The table of results lists the details of the analysis, including the number of bootstraps and the confidence levels used for identification of candidate changes, inclusion in the table, and calculation of the confidence interval; the HCSP analysis uses 95% confidence levels and 1000 bootstraps without replacement. The table also lists the detailed results for each change point detected, including the first month after the change occurred, a confidence interval for the time of the change, confidence level (certainty that the change actually occurred), the average values before and after the change, and the level of importance of the change compared to others that were detected. The CUSUM chart shows the cumulative sum of the differences between values and the overall average: lines sloping up represent a time when the data is above the overall average, lines sloping down represent a time when the data is below the overall average, flat lines represents a period when no change occurred, and a sudden change in the slope indicates a change-point. Finally, the analysis also checks for outliers and assumptions of serial independence.

The 2015 results for the HCSW-1 HCSP specific conductivity analysis are used as an example of interpreting the results (Figure I-45). The plot of values shows three candidate change-points, occurring in 2007, 2010, and 2011. The table of results and the CUSUM chart show that only two of those candidate changes (2007 and 2010) were found to be statistically significant. On the CUSUM chart, those change-points are when the slope changes from decreasing to increasing (2007), and then again when the line flattens (2010); the flattening of the line is a less distinct change in this case, so that change-point will be less certain. The table of results indicates that the 2007 change point occurred in April 2007, with a timing confidence interval of April 2007 to September 2007. The analysis indicates that there is 100% confidence that this change actually occurred, and it is the most “important” change for the dataset (Level 1). The change in mean was about +180 µmhos/cm between those time periods. The 2010 time period is less “important” (Level 2), and there is slightly less confidence that it happened (98%). The timing of the change-point is less certain because the confidence interval is much wider (November 2010 with a confidence interval of June 2007 to May 2011). The change in mean was about -80 µmhos/cm between those time periods. When reviewing all of the data, one can say with confidence that an increasing step-change did occur in mid-to-late June 2007 and that a smaller decreasing step-change did occur after the first, but the timing of the second step-change was sometime between mid-2007 and mid-2011.

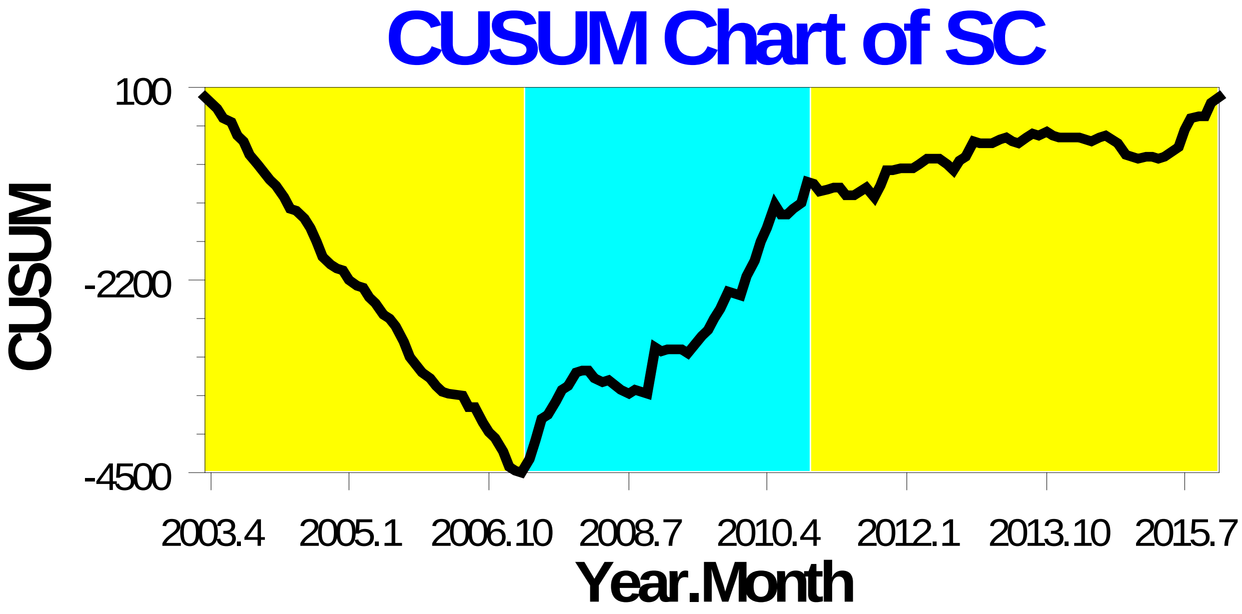


Plot of SC

Table of Significant Changes for SC

Confidence Level for Candidate Changes = 95%, Confidence Level for Inclusion in Table = 95%, Confidence Interval = 95%,
Bootstraps = 1000, Without Replacement, MSE Estimates

Year.Month	Confidence Interval	Conf. Level	From	To	Level
2007.4	(2007.4, 2007.9)	100%	211.34	391.64	1 🟥
2010.11	(2007.5, 2011.11)	100%	391.64	323.84	2 🟥



CUSUM Chart of SC

Figure I-45. **Change-point analysis graph and results table for specific conductivity at HCSW-1 collected by the HCSP from April 2003 to December 2016.**

Horse Creek Stewardship Program

APPENDIX

J

COMMENTS ON HCSP SCI DATA

Appendix J
Comments on HCSP SCI Data

Beginning with the 2010 annual report, the HCSP SCI data was reevaluated with strict interpretation of FDEP SOP guidance, including the upper and lower limits of the SOP target number of individuals, the SOP target of a minimum velocity of 0.05 m/sec 28 days prior to sampling, the SOP target of waiting at least 90 days after abatement of a stream desiccation event (i.e. no refugia for organisms), and the SOP target of less than a 0.5 m water level increase in the previous 28 days. As a result of this evaluation, some SCI scores have been removed from the analysis (in red italics). In addition, some SCI results with more than the target number of individuals were randomly resampled to provide an unbiased result.

Date	HCSW-1					HCSW-2					HCSW-3					HCSW-4				
	HA Score	2004 SCI Score	2007 SCI Score	2012 SCI Score	Comments	HA Score	2004 SCI Score	2007 SCI Score	2012 SCI Score	Comments	HA Score	2004 SCI Score	2007 SCI Score	2012 SCI Score	Comments	HA Score	2004 SCI Score	2007 SCI Score	2012 SCI Score	Comments
4/25/2003	*134*	*64*	NA	NA	Stream presumed dry earlier in month with no refugia for organisms; sample taken less than 90 days from when dry conditions abated	134	52	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	142	38	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	147	62	NA	NA	
7/29/2003	*141*	*55*	NA	NA	Greater than 0.5m water level increase over previous 28 days	*139*	*14*	NA	NA	Greater than 0.5m water level increase over previous 28 days	*151*	*27*	NA	NA	Less than SOP target number of individuals; Greater than 0.5m water level increase over previous 28 days	*146*	*61*	NA	NA	Less than SOP target number of individuals; Greater than 0.5m water level increase over previous 28 days
11/20/2003	133	65	NA	NA		121	35	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	131	60	NA	NA		135	61	NA	NA	
4/22/2004	138	37	NA	NA		134	27	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	138	*34*	NA	NA	Less than SOP target number of individuals	141	*57*	NA	NA	Less than SOP target number of individuals
11/3/2004	NA	*58*	NA	NA	Less than SOP target number of individuals	117	5	NA	NA		99	*24*	NA	NA	Less than SOP target number of individuals	111	33	NA	NA	
2/15/2005	131	48	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	117	62	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	112	51	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	113	54	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP
4/20/2005	126	18	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	117	40	NA	NA		124	59	NA	NA		121	67	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP
9/15/2005[1]	129	42	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	124	21	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	121	53	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	114	53	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP
12/15/2005	130	48	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	114	37	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	115	41	NA	NA		115	36	NA	NA	

Date	HCSW-1					HCSW-2					HCSW-3					HCSW-4				
	HA Score	2004 SCI Score	2007 SCI Score	2012 SCI Score	Comments	HA Score	2004 SCI Score	2007 SCI Score	2012 SCI Score	Comments	HA Score	2004 SCI Score	2007 SCI Score	2012 SCI Score	Comments	HA Score	2004 SCI Score	2007 SCI Score	2012 SCI Score	Comments
4/6/2006	110	46	NA	NA	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	98	25	NA	NA		103	60	NA	NA		105	46	NA	NA	
7/27/2006	*115*	*59*	NA	NA	Stream presumed dry at end of May with no refugia for organisms; sample taken less than 90 days from when dry conditions abated	106	26	NA	NA	Stream presumed dry in May with no refugia for organisms; sample taken less than 90 days from when dry conditions abated; Less than SOP target number of individuals	118	32	NA	NA	Stream presumed dry in May with no refugia for organisms; sample taken less than 90 days from when dry conditions abated	127	50	NA	NA	
11/28/2006[2]	115		40	45		93		34	36		121		43	47		113		42	48	
3/28/2007	115		65	72	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	100		32	37	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	117		55	60	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	113		50	56	
8/9/2007	123		65	71		-		-	-	Does not meet SOP minimum velocity requirements - no sample	121		29	34	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	130		41	48	
11/27/2007	116		65	73		108		22	25		116		65	72	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	124		61	66	
4/24/2008	*101*		47	54	Did not meet SOP minimum velocity requirements	109		23	27		114		48	53		104		52	59	
9/12/2008	122		45	51	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	104		9	11		121		7	10		119		33	40	
11/19/2008	115		48	55	Randomly subsampled because original sort had more than the recommended number of individuals from FDEP SOP	84		25	26		109		29	34		108		56	61	
4/22/2009	--		-	-	Does not meet SOP minimum velocity requirements - no sample	-		-	-	Does not meet SOP minimum velocity requirements - no sample	-		-	-	Does not meet SOP minimum velocity requirements - no sample	105		45	50	
10/22/2009	124		49	56		123		22	25		106		54	60		114		52	59	
4/20/2010	126		37	44		115		29	34		103		59	64		110		68	73	
9/28/2010	128		55	63		102		11	14		99		65	71		109		58	65	
11/4/2010 (or 11/11/10)	119		45	51		105		32	36		100		64	71		105		55	63	
4/18/2011	127		56	63		102		20	25		103		67	72		113		83	90	
8/9/2011	--		-		Severe thunderstorm with rising water levels – no sample	-		-	-	Suspected water level increase >0.5m and habitats less than 28 days inundated – no sample	112		-	-	Normal stream channel not accessible (flooded) according to SOP – no sample	122		26	29	

Date	HCSW-1					HCSW-2					HCSW-3					HCSW-4				
	HA Score	2004 SCI Score	2007 SCI Score	2012 SCI Score	Comments	HA Score	2004 SCI Score	2007 SCI Score	2012 SCI Score	Comments	HA Score	2004 SCI Score	2007 SCI Score	2012 SCI Score	Comments	HA Score	2004 SCI Score	2007 SCI Score	2012 SCI Score	Comments
10/26/2011	110		49	55		-		-	-	Normal stream channel not accessible (flooded) according to SOP - no sample	109		61	68		116		45	51	
3/30/2012	--		-	-	Low water levels - no samples collected	-		-	-	Dry - no samples collected	-		-	-	Does not meet SOP minimum velocity requirements - no sample	121		73	78	
10/26/2012	126		54	60		-		-	-	Normal stream channel not accessible (flooded) according to SOP – no sample	118		61	68		97		64	70	
12/12/2012	120		51	58		-		-	-	Does not meet SOP minimum velocity requirements - no sample	104		72	78		103		62	69	
3/20/2013	96		61	67		-		-	-	Does not meet SOP minimum velocity requirements - no sample	107		65	71		113		69	75	
10/28/2013	114		44	50		98		15	20		117		61	67		94		68	74	
12/16/2013	108		40	45		105		43	46		115		72	79		119		55	62	
3/18/2014	115		57	63		109		37	42		120		66	72		119		74	81	
9/3/2014	124		74	81		103		33	36		120		38	43		121		50	56	
11/10/2014	121		43	49		103		21	25		111		49	56		111		52	59	
4/3/2015	117		59	66		100		36	40		107		70	76		117		83	88	
10/27/2015	129		62	66		109		23	27		112		68	75		114		48	55	
12/15/2015	136		54	60		111		49	52		107		58	64		114		68	75	
3/17/2016	125		68	74		114		52	57		110		51	58		115		69	75	
11/16/2016	131		49	54		105		27	31		107		59	65		111		72	78	

[1] Sorting method change in FDEP SOP

[2] Sorting and calculation method change in FDEP SOP; two vial average

Horse Creek Stewardship Program

APPENDIX

K

SUMMARY OF MAJOR EVENTS, LAB CHANGES, AND POTENTIALLY ERRONEOUS DATA RECORDED DURING THE HCSP

Appendix K

Summary of Major Events, Lab Changes, and Potentially Erroneous Data Recorded during the HCSP

K.1 Events Timeline

April 2003 – HCSP began.

August 2004 – Hurricane Charley moves up the Horse Creek Basin. A few days later, there were odor complaints in the Peace River. As a response, monthly water sampling was increased to weekly sampling to aid in determining problems with water quality data, primarily dissolved oxygen in the Peace River watershed (including estuary and lower tributaries)[8]. In Horse Creek near Myakka Head (HCSW-1) water levels did not drop to hypoxic levels; however, at Horse Creek near Arcadia (HCSW-4) a drop was observed (it did see the fastest recovery to pre-hurricane conditions of sites tested)[7].

September 2004 – Hurricane Frances moves up the Horse Creek Basin.

September 2004 – Hurricane Jeanne moves up the Horse Creek Basin. The combined effects of the three hurricanes appear to be related to hypoxic conditions recorded in the Peace River watershed with areas within 20 km of the eyewall experiencing hypoxic condtions[7]. DO took approximately two to three months to recover to pre-hurricane levels at most locations.

August 2005 – Invertebrate sorting methodology change in FDEP SCI SOP. Target number of individuals between 100 and 120 per sample (SCI-2004).

October 2005 – USGS rain gauge discontinued at HCSW-1. Began using SWFWMD rain gauge 494 for annual reports.

June 2006 – The last clays from Fort Green beneficiation plant were sent to clay settling areas (CSAs) FGH3 and FGH4 which discharge to Horse Creek via FTG-003 and FTG-004.

November 2006 – Invertebrate sorting methodology change in FDEP SCI SOP. Two vials with a target number of individuals of 140 to 160 per sample are required (previous protocol had a target of 100 to 120 individuals with only a single vial per sample). The average SCI score of the two vials is used for reporting purposes (SCI-2007).

2006 – 2008 – Time period with lower than average streamflow and rainfall for the Horse Creek Basin.

July 2006 - September 2008 – Very little NPDES discharge (stormwater and baseflow only) from FTG-003 and FTG-004 due to extremely dry conditions.

October 2008 – Clays mined via dredge from the Wingate Mine began to be transported to facilities and FM1 in the Horse Creek basin for processing and storage. NPDES discharge was comprised mostly of groundwater from the Wingate mining process.

March 2009 – Added CSA FM-1 to existing monitoring program.

---

[8] Tomasko, D.A., C. Anastasiou, and C. Kovach. 2006. Dissolved oxygen dynamics in Charlotte Harbor and its contributing watershed, in response to Hurricanes Charley, Frances, and Jeanne – impacts and recovery. Estuaries and Coasts 29 (6A): 932-938.

September 2009 – discontinue monitoring FL-PRO, fatty acids, and total amines at all four Horse Creek locations. Sampling began in Brushy Creek (BCSW-1) minus trigger levels and impact assessments.

Winter 2009/2010 – Florida experienced one of the coldest winters on record (December-February the 10th coldest period in Tampa since records started in 1890). In Hillsborough County, overnight lows in early January were at or below freezing for 12 consecutive nights. Cold temperatures led to large fish kill in the area as a result.

December 2010 – Coldest December for the Tampa Bay area in recorded history (the daily average [53.2°C] was 10°C lower for the month than normal). Several areas throughout west-central and southwest Florida also set record lows.

October 2011 – SWFWMD reduced sampling frequency at HCSW-1 and HCSW-4 to every other month from monthly sampling.

November 2011 – SWFWMD rain gaugue 494 discontinued. Began using NOAA gauges.

January 2013 – Supplemented SWFWMD Flatfort Swamp rain gauge in additoin to NOAA gauges and Mosaic gauges in annual report tables and graphics.

July 2014 – New FDEP SOP for the SCI (SCI 1000) calculations along with newly estabished bioregions (Panhandle West, Big Bend, Northeast, and Peninsula) went into effect with the approval of the new QA rule. This new methodology is referred to as the SCI-2012 method in the report.

K.2 Lab Changes Timeline

April 2003 – November 2004: Various labs

December 2004 – May 2008: STL/Test America (all but Radiologicals)

April 2006 – July 2008: KNL Labs (Radiologicals only)

July 2008 – July 2010: Benchmark Analytical (all parameters except Radiologicals)

July 2008 – November 2014: Benchmark Analytical (color and chlorophyll-a only)

August 2008 – Present: Florida Radiochemistry (Radiologicals only)

August 2010 – Present: Mosaic’s Laboratory

December 2014 – Present: Mosaic’s Laboratory started analyzing color and chlorophyll-a

K.3 Major MDL Changes

January 2006 – July 2008: Nitrate-Nitrite highly variable

April 2003 – December 2011: Ammonia (around 0.03 mg/L through October 2007, variable through July 2008, stable through July 2011, then variable)

December 2007: Orthophosphate abnormally high value (0.75 mg/L)

April 2003 – December 2011: Dissolved iron started at 0.1 mg/L, reduced in March 2006 to 0.022 mg/L, stable from August 2010 at around 0.01 mg/L

March 2006 – February 2008: Chloride numerous changes ranging from 0.022-30 mg/L; stable since March 2008

March 2006 – February 2008: Fluoride numerous changes ranging from 0.017-5 mg/L; relatively stable since March 2008

March 2006 – February 2008: Sulfate numerous changes; stable since March 2008

K.4 Possible Outlier Data Identified but Remaining in Analysis

The data listed in the table below was identified in Decision Memo #1 as outlier data but remains in Appendix C graphs and data analysis.

Parameter	Date	HCSW-1	HCSW-2	HCSW-3	HCSW-4	Units	Explanation
TKN	9/27/2006			6.6		mg/L	Outlier based on adjacent sampling events and SWFWMD data from the same month. Likely lab error. Was not removed from analysis.
TN	9/27/2006			6.7		mg/L	Outlier based on TKN sample being higher than adjacent sampling events and SWFWMD data from the same month. Likely lab error. Was not removed from analysis.
TKN	1/30/2008		4.7			mg/L	Outlier based on adjacent sampling events and SWFWMD data from the same month. Likely lab error. Was not removed from analysis.
TN	1/30/2008		4.8			mg/L	TKN was an outlier based on adjacent sampling events and SWFWMD data from the same month. Likely lab error. Was not removed from analysis.

K.5 Erroneous and Outlier Data Removed from Analysis

The data listed in the table below was identified in Decision Memo #1 as erroneous or outlier data that should be removed from all graphs and analysis.

Parameter	Date	HCSW-1	HCSW-2	HCSW-3	HCSW-4	Units	Explanation
pH	1/23/2007	8.8	8	8.5	8.9	SU	Compared HCSW-1 and HCSW-4 to SWFWMD measurements for January and February 2007; not an actual exceedance but equipment malfunction. All measurements were elevated. Removed from analysis.
	1/4/2011	4.8					When compared measurement to SWFWMD collected that month and to previous months was found to be much lower than other values; not exceedance but equipment malfunction. Removed from analysis.
Ammonia	7/31/2008	0.24	0.41	0.32	0.31	mg/L	Elevated concentrations are either due to laboratory method change or a seasonal fluctuation in the nitrogen cycle. Removed from analysis
	8/3/2010	0.06	0.1	0.07	0.05		Lab analyzing the data was getting back results that were ten-times higher than other labs. Split sampling conducted in October 2011, verified that it was lab error. All results during time period of higher results (August 2010 to July 2011) removed from analysis.
	9/8/2010	0.1	0.12	0.16	0.12		
	10/6/2010	0.01	0.24	0.01	0.2		
	11/3/2010	0.01	0.01	0.05	0.01		
	12/7/2010	0.08	0.11	0.1	0.1		
	1/4/2011	0.03	0.08	0.14	0.08		
	2/3/2011	0.18	0.13	0.16	0.2		
	3/2/2011	0.11	0.13	0.2	0.15		
	4/5/2011	0.13	0.13	0.13	0.17		
	5/3/2011	0.12	0.22	0.31	0.19		
	6/8/2011				0.27		
	7/5/2011	0.02	0.02	0.1	0.02		
Nitrate-Nitrite	6/20/2007			9.5		mg/L	Order of magnitude higher than adjacent sampling events and SWFWMD data from the same month. Likely lab error. Removed from data analysis as an outlier.
TN	6/20/2007			9.7		mg/L	Elevated measurements most likely due to lab analyst or instrument error in the nitrate-nitrite result. The total nitrogen levels recorded are not corroborated by measurements taken before or after the exceedance. Removed from data analysis as an outlier.

Parameter	Date	HCSW-1	HCSW-2	HCSW-3	HCSW-4	Units	Explanation
Fluoride	7/27/2006	2.6				mg/L	Value did not agree with the field duplicate and was an order of magnitude higher than previous values. It also occurred during the MDL elevated period. Removed from analysis.
	5/25/2006		0.5				All values between May 2006 and Feb 2008 are suspect because the MDL was raised above the previously measured maximum; the lab diluted all samples subject to the EPA 300.0 method because the chloride and sulfate concentrations during the drought period were very high. During this period, all fluoride measurements with a U code are removed from the analysis, and all those with I codes (almost all of the non-U samples) should be considered estimates only.
	6/29/2006		0.5				
	7/27/2006		0.5				
	8/21/2006		0.5	0.5	0.5		
	9/27/2006		0.5	0.5	0.5		
	10/19/2006	1	0.5	1	1		
	11/9/2006	1	0.5	2.5	2.5		
	12/13/2006	0.5	0.5	1	2.5		
	1/23/2007	1	1	2	2.5		
	2/14/2007	1	0.5	2.5	2.5		
	3/14/2007	1	1	2.5	5		
	4/25/2007	1	0.5	0.5	1		
	5/16/2007		0.5	1	0.5		
	6/20/2007		0.5	2.5	1		
	7/18/2007		0.5	1	1		
	8/27/2007		0.5	0.5	0.5		
	9/26/2007		0.5	0.5	0.5		
	11/29/2007		0.26				
	12/17/2007		0.25				
	1/30/2008		0.25				
	2/26/2008		0.25				
Total Radium	7/27/2004	4.76	5.12	4.16	3.26	pCi/L	Blank sample results had high values (2.52 pCi/L) for Radium 228. The high blank measurement makes all other Radium 228 values suspect and most likely high by the same amount found in the blank. Removed from analysis.

About Cardno

Cardno is an ASX-200 professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage, and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

Cardno Zero Harm

At Cardno, our primary concern is to develop and maintain safe and healthy conditions for anyone involved at our project worksites. We require full compliance with our Health and Safety Policy Manual and established work procedures and expect the same protocol from our subcontractors. We are committed to achieving our Zero Harm goal by continually improving our safety systems, education, and vigilance at the workplace and in the field. Safety is a Cardno core value and through strong leadership and active employee participation, we seek to implement and reinforce these leading actions on every job, every day.

www.cardno.com