Horse Creek Stewardship Program
2008 Annual Report

FINAL

SEPTEMBER 2010

PREPARED BY

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INTRODUCTION

This is the sixth annual report summarizing the status of the Horse Creek Stewardship Program (HCSP). After a series of legal challenges to the required permits, the Mosaic Company (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 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 sixth of a series of Annual Reports, presents the results of the first six years of monitoring, including historical data from the last decade. Approximately 12,000 acres of land in the Upper Horse Creek Basin had been mined at the time the HCSP was initiated; about 10,000 acres are located upstream of all HCSP monitoring stations on land controlled by Mosaic, with the remaining mined area on other parties' lands lying upstream of all but the northernmost monitoring location. From 2003 to 2008, a total of 1,893 acres of land located upstream of the northernmost Horse Creek monitoring location was mined by Mosaic.

RECENT MINING AND RECLAMATION

A total of 135.12 acres was mined in the Horse Creek Basin at the Mosaic Fort Green Mine in 2008. Some additional phosphate mining may or may not have been conducted by other companies in the Horse Creek drainage basin in 2008, but Mosaic is not aware of the extent or timing of that mining. In 2008, Mosaic planted a total of 162.10 acres, while 291.21 acres were tailed or graded in the Horse 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. Rainfall data were collected daily from one SWFWMD gauging station and three Mosaic rain gauges located in the Horse Creek Basin. Water quality data were collected during monthly sampling events, continuously from one Horse Creek location, and during biological sampling events. Biological (fish and benthic macroinvertebrates) sampling events were generally conducted three times each year.

WATER QUANTITY

For 2008, temporal patterns of average daily stream flow and stage were similar across all stations, with the majority of high flows and stages occurring during the rainy season (June through October). Certain periods in the dry season (May, October - December) were extremely dry, resulting in periods of little to no flow. Therefore, Mosaic's NPDES-permitted discharges upstream of HCSW-1 only discharged for four months of the year. Rainfall and discharge in 2008 were above levels recorded in 2006 and 2007, but were below levels during earlier years of the HCSP (2003-2005) and the long-term average (Durbin and Raymond 2006). Three consecutive years of below average rainfall and streamflow in Horse Creek have likely had some effect on the water quality and biological communities of the stream.

WATER QUALITY

Water quality parameters in 2008 were always within the desirable range relative to trigger levels and water quality standards at the station closest to mining (HCSW-1, Table 17). All stations in Horse Creek were affected by the low rainfall and streamflow of 2006 to 2008. Algal blooms in warm months when streamflow was low contributed to trigger level exceedances of chlorophyll a, fatty acids, total nitrogen, total ammonia and dissolved oxygen. Dissolved ions (calcium, sulfate, TDS, iron, and fluoride) exceeded the trigger levels during the dry season when rainfall and streamflow were very low, and groundwater baseflow and agricultural irrigation were a high percentage of the total flow.

There was no evidence of temporal trends that could be attributed to anything other than general wet season/dry season fluctuations or longer-term climatic oscillations (Figure 75). Alkalinity and specific conductance show a significant increasing trend at HCSW-1, but these potential trends are heavily influenced by the abnormally low rainfall and streamflow of 2006 - 2008. Orthophosphate shows a significant increasing trend and dissolved oxygen a decreasing trend at HCSW-4. These trends may have been influenced by the last two dry years, and it is also likely that cumulative impacts of agricultural landuse may also be contributing to changes in water quality at this downstream station.

Significant differences between stations were evident for several parameters. Overall, HCSW-2 was the most dissimilar from the other three stations, especially in pH, dissolved oxygen, and some dissolved ions. Some nutrients (nitrate + nitrite and orthophosphate) and dissolved ions (specific conductivity, calcium, sulfate) had higher concentrations downstream in Horse Creek, probably because of increased groundwater seepage and agricultural runoff in the lower Horse Creek basin.

In general, pH, dissolved oxygen, and most dissolved ions are higher when the overall quantity of water in the Horse Creek system is low. Conversely, turbidity, color, iron, and some nutrients are high when the water quantity is also high. Total radium was correlated with increased NPDES discharge but not streamflow or rainfall. When water quantity in Horse Creek is low, the stream may be 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, an increased amount of sediment and organic debris is washed into the stream, leading to increases in turbidity, color, iron, and nitrogen.

BENTHIC MACROINVERTEBRATES

Benthic invertebrate habitat scores were "Optimal" to "Sub-optimal" and SCI scores were "Healthy" or "Impaired" at all stations in 2008; these scores are typical of southwestern Florida streams, including those used to develop the Habitat Assessment and SCI indices. Species diversity in Horse Creek exhibits both seasonal and year-to-year variation. When considered over time from 2003 to 2008, the SCI scores were variable over time at each station, but showed no monotonic trend. SCI scores and invertebrate diversity were significantly lower overall at HCSW-2.

FISH

Forty-one species of fish have been collected from 2003 to 2008. For 2008 sampling, the effects of Hurricane Charley are no longer affecting fish abundance and diversity at downstream stations. Before Hurricane Charley, species richness and diversity were lowest at HCSW-1 and highest at HCSW-4. In 2008, fish diversity was highest at HCSW-4 and HCSW-1 and lowest at HCSW-2, which suffered from extremely low flows. Fish communities were similar for all years when stations were combined and for all stations when years were combined.

CONCLUSIONS

Although this report covers only the sixth year of an ongoing monitoring program, some general conclusions can be drawn. Expected relationships between rainfall, runoff and stream flow were observed in the 2003 to 2008 water quantity data. Program trigger levels were exceeded for several parameters in 2008 and four parameters had significant trends from 2003 to 2008, but the exceedances and trends were related to the low rainfall and streamflow for 2006 to 2008 or the influence of surrounding land use. There is no evidence of mining impacts on water quality. The benthic macroinvertebrate and fish communities found in Horse Creek in 2003 to 2008 were typical of those found in a Southwest Florida stream; no impacts from mining were apparent, and effects from the 2004 hurricanes are no longer evident.

RECOMMENDATIONS

There are no current report recommendations at this time.

SECTION 1

Introduction

As a result of proposed mining operations by The Mosaic Company (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 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 Mosaic's activities, if any are found. The program is limited to the investigation of the potential impact of Mosaic mining activities on 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 exceedence 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 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

Sampling of fish, benthic macroinvertebrates and field water quality parameters (temperature, dissolved oxygen, conductivity, turbidity and pH) three times annually at 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 mined, about 10,000 acres of which lie upstream of all HCSP monitoring stations on land controlled by Mosaic, with the remaining mined area on other parties' lands lying upstream of all but the northernmost monitoring location. In 2008, 135.12 acres were mined in the Horse Creek Basin upstream of the northernmost monitoring location (Figure 1). 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 - April, July - September and October - 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 sixth of a series of Annual Reports, presents the results of monitoring conducted in 2008. Additional sources of data for the last decade have also been included to provide a short historical perspective. A separate report contains a review and summary of all available historical water quality and biological information for Horse Creek (Durbin and Raymond 2006).

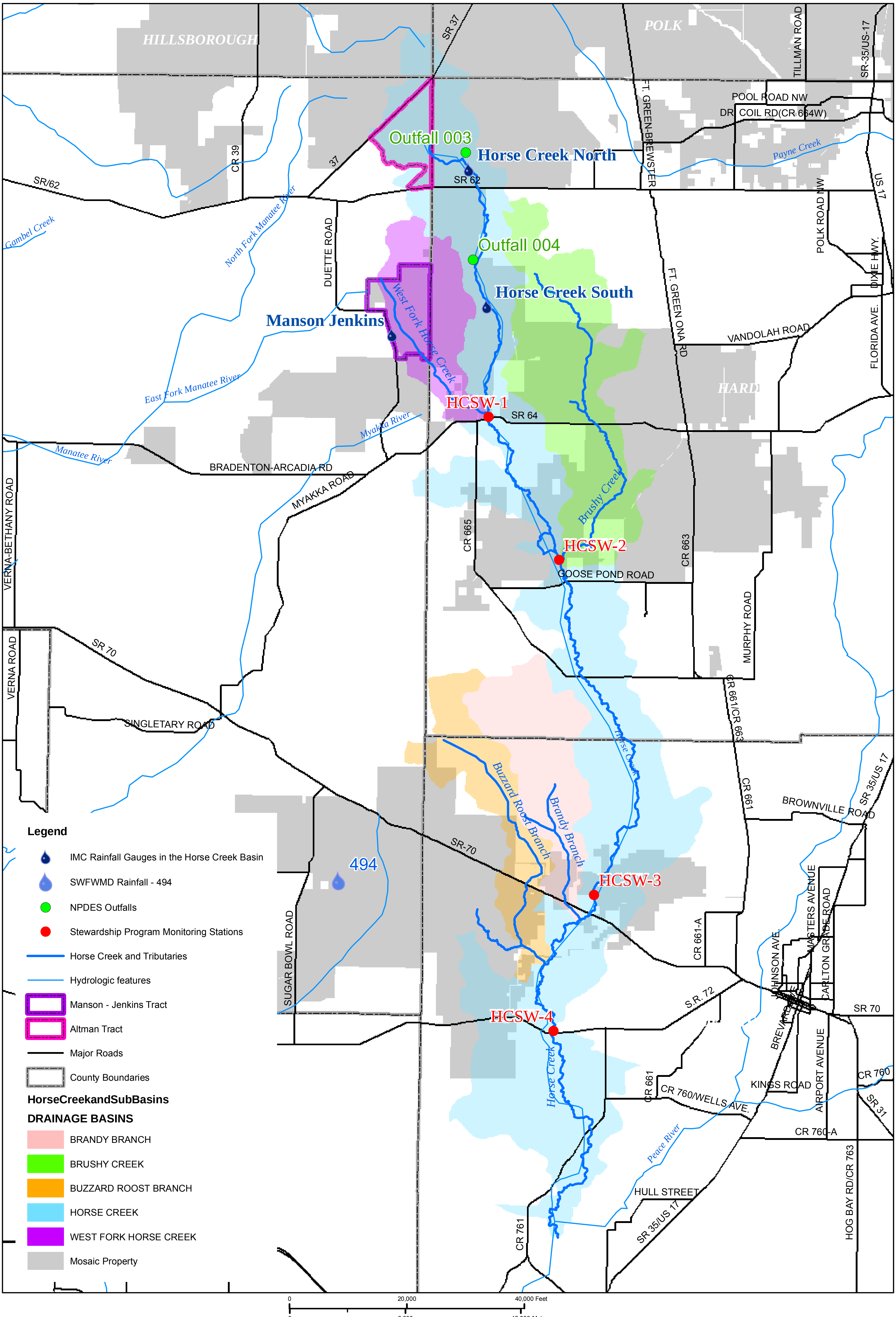

Figure 1. Overview of drainage basins, HCSP sampling locations, and Mosaic property in the Horse Creek Basin.

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SECTION 2

Description of 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 and 2). 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 - 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 72 º F. Summer temperatures average 80 ºF, and winter temperatures average 60 º F (Hammett, 1990). The average daily temperatures in Hardee County, in the northern Horse Creek Basin, range from is 52 º F to 91 º F (Robbins et al. 1984). The average daily temperatures in DeSoto County, in the southern Horse Creek Basin, range from 49 º F to 92 º F. 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 52 inches, with more than half of that falling during localized thundershowers in the wet season (June - September) (Hammett, 1990). Rain during fall, winter, and spring is usually the result of large, broad frontal systems instead of local storms (Hammett, 1990). November is typically the driest month of the year, averaging 1.77 inches over the historic period from 1915 to 2004. The months of April and May are also characteristically dry, averaging 2.56 and 3.95 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 month of the year is typically June, averaging 8.27 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. Mining is the primary land use above State Road 64, but the percentage of land devoted to mining decreases rapidly downstream. Agricultural land use, on the other hand, more than doubles in acreage from above County Road 663 (HCSW-2) to above SR 72 (HCSW-4). Rangeland covers a greater percentage of land in the northern part of the basin than in the southern portion. Upland forest and wetland area increase substantially from above SR 64 (HCSW-1) to above CR 663 (HCSW-2), but the percent forest and wetland cover remains relatively constant between CR 663 and further downstream (Durbin and Raymond 2006).

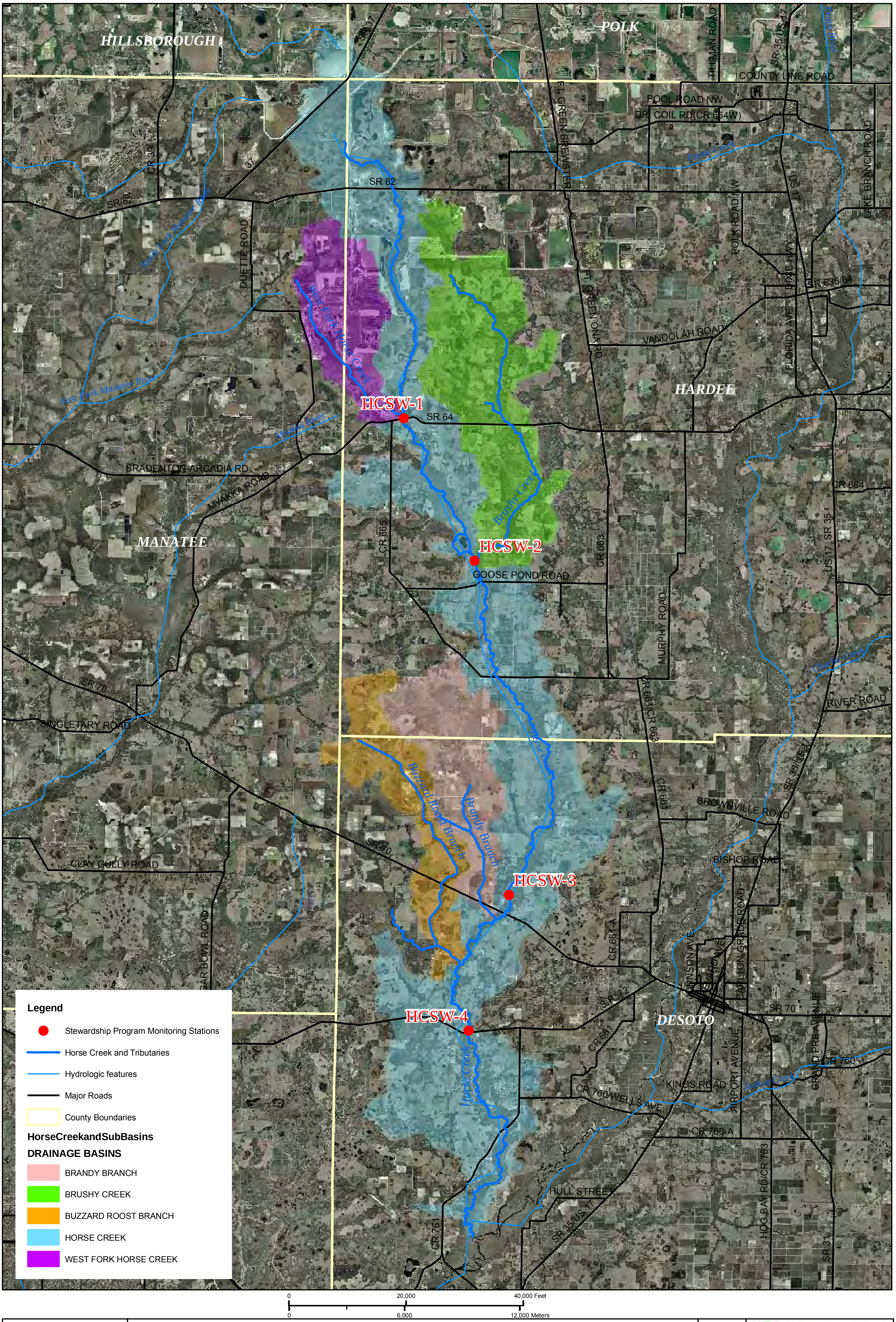

Figure 2. Aerial photograph of the Horse Creek Basin and HCSP sampling locations

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SECTION 3

Summary of Mining and Reclamation Activities

3.1 MINING

A total of 135.12 acres were mined in the Horse Creek Basin at the Mosaic Fort Green Mine in 2008 (Figure 3). There have been, and will be in the future, mining activities in the Horse Creek Basin outside of those performed by Mosaic. Some additional phosphate mining may or may not have been conducted by other companies in the Horse Creek drainage basin, but Mosaic is not aware of the extent or timing of that mining. 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).

There are three clay settling areas in the Horse Creek Basin at the Fort Green Mine. 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 ft. NGVD, and a final pool elevation of 146 ft. NGVD. The effective area of the dam is approximately 933 acres. 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, using the 003 outfall, through spillways located in the return water ditch near the southwest corner of FGH-3. Clays are introduced into the settling area approximately midway on the east wall.

The FGH-4 clay settling area is located predominantly in Section 31, T33S, R23E. Construction of the clay settling area 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 ft. NGVD, and a final pool elevation of 159.0 ft. NGVD. The effective area of the dam 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. Decant spillways located in the south return water ditch also have the capability of discharging water to the 004 outfall. 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.

Both the FGH-3 and FGH-4 settling areas have real-time monitoring of the pond level, which is relayed to the PRMRWSA. Any sudden drop in pond level elevations, suggesting a substantial release of wastewater from the settling areas, would be detected promptly, allowing for an expedited response to the situation. The third settling area, FM-1 was constructed in 2006-2007 and is located predominately in Section 1, T34S, R22E. The settling area was designed by Ardaman and Associates with a crest elevation of 164 NGVD and a final pool elevation of 159 NGVD. The effective area of the dam is approximately 350 acres. Two decant spillways, both located on the west wall of the dam, are designed to return water to a marina 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 004 outfall; thus discharges from the clay settling area can be routed to either the Myakka or Horse Creek basins.

3.2 RECLAMATION

Reclamation of lands that have been mined is an ongoing process at Mosaic's Fort Green Mine including lands in the Horse Creek Basin. The reclamation process consists of backfilling of 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. Planting of both upland and wetland communities is done with appropriate species. Reclaimed areas are monitored and supplemental plantings are done as necessary until the revegetation of the land is successful. In 2008, there was a total of 162.10 acres planted in the Horse Creek Basin (83.6 of those acres were in the West Fork Horse Creek Basin and 78.5 acres were in the Horse Creek Basin). Some additional upland planting of longleaf and slash pines in HC9 along with wetland planting in HC11occurred in February 2008. Tailing/grading activities also occurred in the Horse Creek Basin, mainly in the latter part of the year, totaling 291.21 acres.

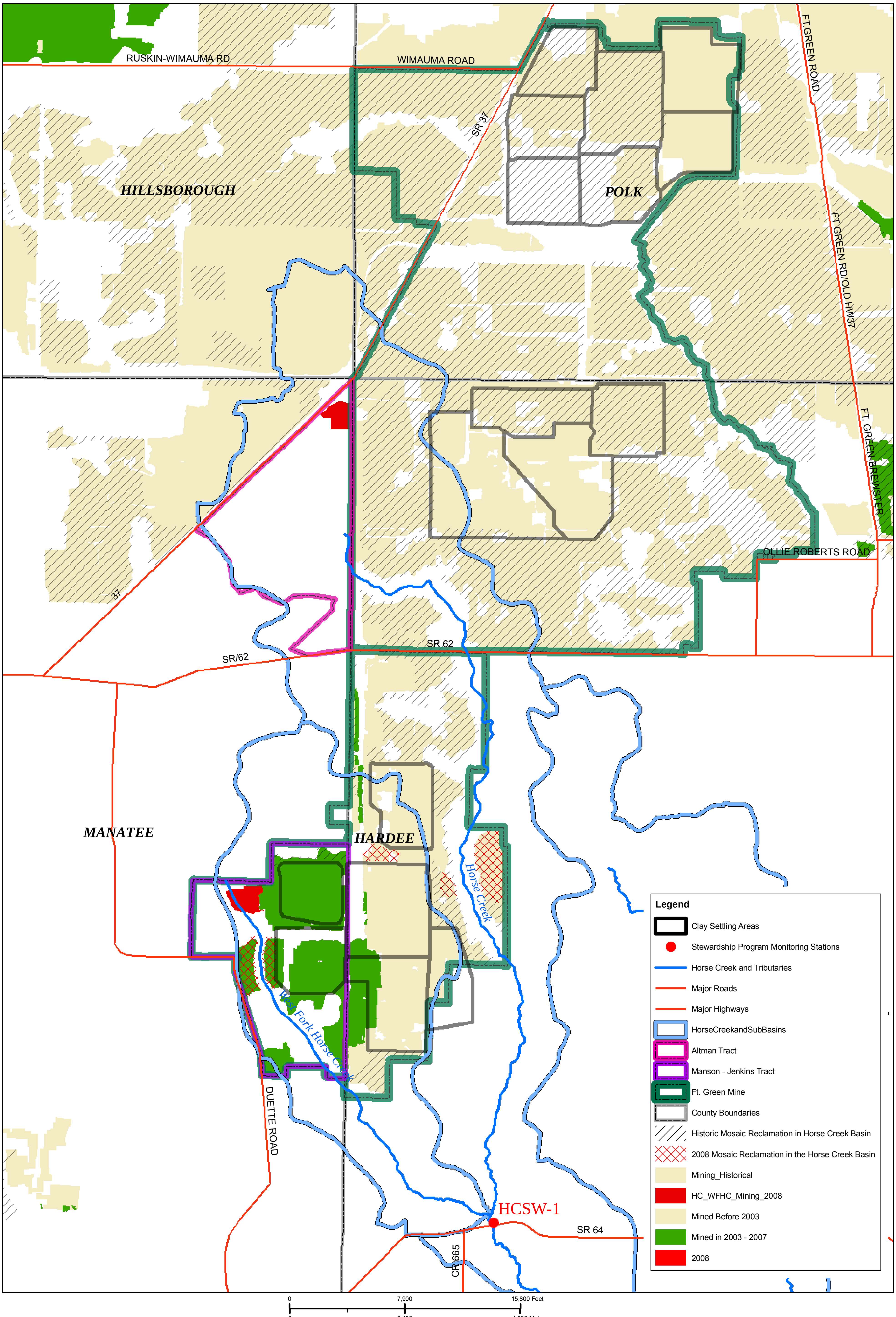

Figure 3. Mining and reclamation areas in the Horse Creek Basin

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SECTION 4

Methods

4.1 STATION LOCATIONS AND SAMPLING SCHEDULE

Four Horse Creek locations are monitored for physical, chemical, and biological parameters (Figure 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
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 has been conducted monthly beginning in April 2003, while biological sampling events have been conducted an average of three times per year (Table 1).

Table 1 2008 Schedule of Water Quality and Biological Sampling Events of the HCSP

Date	Water Quality Sampling Events	Biology Sampling Events
30 January 2008	X	
26 February 2008	X	
27 March 2008	X	
23 April 2008	X	
24 April 2008		X
29 May 2008	X (HCSW-1 was dry)	
26 June 2008	X	
31 July 2008	X	
26 August 2008	X	
12 September 2008		X
30 September 2008	X	
16 October 2008	X	
19 November 2008		X
29 November 2008	X	
4 December 2008	X	

4.2 WATER QUANTITY

Provisional 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 stream cross sections were surveyed by Mosaic at HCSW-2 and HCSW-3; stage data were obtained at those stations during monthly water quality sampling. Discharge data were obtained for Mosaic's National Pollutant Discharge Elimination System (NPDES)-permitted discharges into Horse Creek (Outfalls 003 and 004) for 2003 - 2008 (Figure 1). Daily rainfall data were obtained from the USGS from SWFWMD's Horse Creek IMC gauge 494 and from Mosaic's rain gauges in the Horse Creek Basin (Figure 1). The general relationship between rainfall and streamflow was graphically evaluated. All rainfall gauges are located in the upper portion of the Horse Creek basin, 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 was 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 allow for the detection of instantaneous conditions or general water quality changes not observed during the collection of monthly grab samples. Low flow conditions resulted in no continuous data for the late dry season of 2008.

Water quality samples were obtained monthly, when flow was present, by Mosaic at each of the four monitoring stations beginning in April 2003. The four locations were sampled the same day, working from upstream to downstream. 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, 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 2). All calibration activities were documented and records checked for completeness and accuracy. Field measurements by ENTRIX in association with the three biological sampling events employed an YSI 6920 multiparameter data sonde with the same measuring methods and acceptance limits listed in Table 2. ENTRIX also employed a Hach 2100P unit for turbidity measurement.

Table 2 HCSP Water Quality Sampling Field Methods and Acceptance Limits Associated with Monthly Sampling by Mosaic Staff.

Analyte	Meter Used	Method	Minimum Detection Limit	Acceptance Limit
pH	Hach Sension 2	150.1	1 su	+/- 0.2 standards units of the calibration standard
Temperature	Hach Sension 2	170.1		1 degree Centigrade
Specific Conductivity	Hach CO150	120.1	10 uS/cm	+/- 5% of the calibration standard
Dissolved Oxygen	YS1 Model 52	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 and their pH levels checked. Hydrochloric acid was added in the field to unpreserved samples for petroleum range organics analysis. 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 3. Table 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 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 Council (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). In addition, results were compared with applicable Florida surface water quality standards (which in many cases are the same as the trigger values).

Table 3. Parameters Analyzed and Laboratory Methods for HCSP 2003 - 2008 Monthly Water Quality Samples.

Parameter	Method	Hold Time	Preservation	Minimum Detection Limit	Container
Color	110.2	48 hours	Unpreserved	5 PCU	Clear HDPE bottle
Total Kjeldahl Nitrogen	351.2	28 days	Sulfuric Acid, pH < 2	0.05 mg/l	Clear HDPE bottle
Nitrate-Nitrite Nitrogen	353.2	28 days	Sulfuric Acid, pH < 2	0.004 mg/l	Clear HDPE bottle
Total Ammonia Nitrogen	350.1	28 days	Sulfuric Acid, pH < 2	0.005 mg/l	Clear HDPE bottle
Orthophosphate	365.1	48 hours	Unpreserved	0.002 mg/l	Clear HDPE bottle
Chlorophyll *a*	SM 10200H	48 hours	Unpreserved	0.25 mg/l	Opaque plastic
Specific Conductivity	120.1	28 days	Unpreserved	10 µS/cm	Clear HDPE bottle
Total Alkalinity	310.1	14 days	Unpreserved	0.594 mg/l CaCO3	Clear HDPE bottle
Dissolved Calcium*	200.7	28 days	Unpreserved	0.03 mg/l	Clear HDPE bottle
Dissolved Iron*	200.7	28 days	Unpreserved	0.029 mg/l	Clear HDPE bottle
Chloride	300.0	28 days	Unpreserved	0.353 mg/l	Clear HDPE bottle
Fluoride	300.0	28 days	Unpreserved	0.03 mg/l	Clear HDPE bottle
Total Radium (Radium 226+228)	903.0	6 months	Nitric Acid, pH < 2	1 pCi/l	Clear HDPE bottle
Sulfate	300.0	28 days	Unpreserved	0.339 mg/l	Clear HDPE bottle
Total Dissolved Solids	160.1	7 days	Unpreserved	7.26 mg/l	Clear HDPE bottle
Petroleum Range Organics	FL-PRO	7 days	Hydrochloric Acid, pH < 2	0.029 mg/l	Amber Glass Bottle
Fatty Amido-amines	8270	7 days	Unpreserved	0.2 mg/l	Amber Glass Bottle
Total Fatty Acids	8270C	7 days	Unpreserved	0.5 mg/l	Amber Glass Bottle

- All water samples were preserved at 4C while awaiting analysis.
- Orthophosphate samples were 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.
- 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 PRMRWMA, 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.
- MDLs changed for total Kjeldahl nitrogen, nitrate-nitrite, total ammonia nitrogen, orthophosphate, chlorophyll a, total alkalinity, dissolved calcium, dissolved iron, chloride, fluoride, sulfate, TDS, and FL-PRO in July 2008 (changed for color in March 2006). This was in conjunction with the switch to Benchmark labs for water quality analysis.

Table 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	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, Incl.Oleic, Linoleic, and Linolenic Acid	EPA/600/4-91/002	mg/l	Monthly[5]	>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[5]	>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: Macroinvertebrates	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) 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 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.

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

4.4 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate sampling was conducted at each of the four sampling stations on 24 April 2008, 12 September 2008, and 19 November 2008. At each station, a Stream Habitat Assessment (DEP-SOP-001/01 FT 3100) was performed, and a Physical/Chemical Characterization Field Sheet (DEP Form FD 9000-6) 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 according to the Stream Condition Index (SCI) protocol developed by the DEP (DEP-SOP-002/01 LT 7200) 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-m segment of stream. Utilizing this methodology, 20 0.5-m D-frame dip net sweeps are performed within a 100-m 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 5). The general interpretation for SCI score ranges are provided in Table 6. The calculation methodology for the SCI was revised by DEP in June 2004, and this report uses the new methodology. This change requires 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, 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.

Table 5. Equations for Calculating SCI Metrics for Peninsular Florida (Range from Zero to Ten).

SCI Metric	Peninsula Score (*)
Total Taxa	10(X-16)/25
Ephemeropteran Taxa	10X/5
Trichopteran Taxa	10X/7
Percent Collector-Filterer Taxa	10(X-1)/39
Long-lived Taxa	10X/4
Clinger Taxa	10X/8
Percent Dominant Taxa	10-(10[(X-10)/44])
Percent Tanytarsini	10[1n(X+1)/3/3]
Sensitive Taxa	10X/9
Percent Very Tolerant Taxa	10-(10[1n(X+1)/4.1])

* 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.

Fortunately, the revisions to the SCI protocol 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 previous years' 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). Table 5 provides the new list of metrics used in calculating SCI scores, while the parameter table from the HCSP methodology document (copied as Table 4 above) includes the metrics used in the original SCI protocol. Table 6 gives the ecological interpretation of SCI scores as given by the FDEP.

The Shannon-Wiener Diversity Index was calculated using Ecological Methodology Software, Version 6.1 (www.exetersoftware.com). In the future, when more than a few years of data will be available, the focus of the analyses will be to screen for statistically significant declining trends with respect to presence, abundance, and distribution of native species, as well as SCI values.

Table 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)	71-100	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)	35-70	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 concurrently with the benthic macroinvertebrate sampling at each station on 24 April 2008, 12 September 2008, and 19 November 2008. Fish were collected with a 4-foot x 8-foot seine (3 mm mesh size) and by electrofishing with a Smith-Root, Inc. backpack unit (Model 15-B Electrofisher). Electrofishing was timed (typically 4 to 6 minutes), and the number of seine hauls (typically 3 or 4) 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 8 to 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 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. The focus of these analyses will be to screen for statistically significant declining trends with respect to presence, abundance, and distribution of fish in future annual reports, when more than a few years of data are available.

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 (see explanation below).

The sampling segment at HCSW-1 is a deeply incised, narrow valley with very steep banks of rock-like outcroppings (Figure 4). 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). 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). 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). 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

Beyond the immediate response of the stream to the 2004 hurricanes, the overall morphometry of Horse Creek continued to undergo noticeable changes through 2008. Between the April 2005 and November 2008 biological sampling events, a number of changes were evident.

At HCSW-1, the channel configuration in the sampling area is essentially fixed by the deeply incised, rock-like banks. (However, where at least portions of the streambed were clean, rock-like material during prior sampling events, the September 2005 biological event found the bottom covered by at least several inches of sand throughout the sampling area.) Sand and silt deposition continued into 2008, leaving the majority of the benthic habitat smothered. This led to less suitable substrate available for invertebrate colonization (Figures 5-7).

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. Smothering continued into 2007, lowering substrate availability and water velocity (Figures 5-7). Horse Creek at this station became choked with water hyacinth during the beginning of the 2008, limiting flow. High summer rains washed most of the plant material away, and then at the end of the year, the remaining plant material and previously inundated bank vegetation was decomposing in the stream. Under low flow conditions, it is likely that the accrued sand would prevent water from traveling from Horse Creek Prairie through the biological sampling area to the monthly water quality sampling station at Goose Pond Road. If that is the case, water at the Goose Pond Road station may be entirely a result of flow from Brushy Creek, a tributary of Horse Creek that lies parallel to Horse Creek at the biology sampling area, but joins it before the Goose Pond Road station.

At HCSW-3, shoreline changes were apparent, with significant erosion in some places and deposition in others. Some spots that had been steep shorelines were much more gradual, and vice-versa. The canopy of the floodplain forest continues to recover through 2007 (Figures 5-7). Sand and silt smothering worsened at this station through November 2007, and water hyacinth also moved in, blocking some areas of the channel completely and reducing the water velocity. Water hyacinth cover increased in early 2008, before it washed away during summer high flow rates, and then was found decomposing on the banks after water levels dropped once again in November 2008.

At HCSW-4, the stream channel is steep-sided and generally deeper throughout the sampling area, which continues to complicate sampling efforts. Much of the channel bed at mid-stream has a substantial layer of soft sand which has obviously been recently deposited, and which continues to move slowly downstream. Where a USGS staff gauge reading of 5.0 feet indicated favorable biological sampling conditions prior to Hurricane Charley, the stage should be at least one foot lower now to provide the same degree of access (particularly for fish sampling); due to the deeper channel created by Hurricane Charley. In 2008, water hyacinth, not previously recorded at this station, was present along with other vegetation growing along the banks. More bank erosion was noted in 2008, with high water levels and flow rates flooding the banks and washing away some of the water hyacinth later in the year.

Even though the last few years had less rainfall than previous years, sand smothering was still a noticeable problem. During times of high stream flow, summer months, sand was rapidly moved downstream and deposited on the outer banks of curves in the stream. Sand deposition can still occur during dry periods, and may actually appear worse due to uneven deposition connected with rapid increases and decreases in streamflow.

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. Panoramic Photographs of the HCSP Sampling Locations, Photos taken on 25 April 2003.

Figure 5. Photographs of HCSP Sampling Locations on 24 April 2008.

Figure 6. Photographs of HCSP Sampling Locations on 12 September 2008.

Figure 7. Photographs of HCSP Sampling Locations on 19 November 2008.

S E C T I O N 5

Results and Discussion

Below we present a summary of water quantity and quality data collected as part of the HCSP in 2008. In addition, results of the 2008 benthic macroinvertebrate and fish sampling are presented.

5.1 WATER QUANTITY

5.1.1 Rainfall

Continuous rainfall data are collected by the SWFWMD at HCSW-3 (SWFWMD Station 494). (Previous HCSP Annual reports used the USGS gauge at HCSW-1, which has been discontinued.) Figure 8 includes 2008 total monthly rainfall data from SWFWMD gauge 494, as well as data from the three Mosaic rain gauges located in the Horse Creek watershed (see Figure 1 for locations). Total and median monthly rainfall in 2008 was slightly different at each station, but the heaviest rainfall was observed during June to August 2008 at all four locations (Figure 8). Overall rainfall for 2008 was less than that for 2003 – 2005, but greater than totals observed in 2006 and 2007 (Table 7, Figure 9) and below the historic range (52 in) for that station (Durbin and Raymond 2006). When one of rainfall gauges was non-functional, average daily rainfall was calculated from the other functional gauges, and total monthly or annual rainfall was calculated from these adjusted daily averages.

Table 7. Annual Total Rainfall in Inches at Gauges in the Horse Creek Watershed in 2003 to 2008.

Gauge	2003	2004	2005	2006	2007	2008
Horse Creek North	53.40	53.82	54.52*	31.82*	33.90	40.49
Horse Creek South	59.75	60.74	64.53	34.17	31.97	36.80
Manson Jenkins	30.10*	62.15	31.34*	41.26	32.48	37.48
SWFWMD 494	60.10	53.28	69.80	37.75	38.21	53.48
Average of Gauges	53.67	57.39	62.55	37.53	34.14	42.06

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

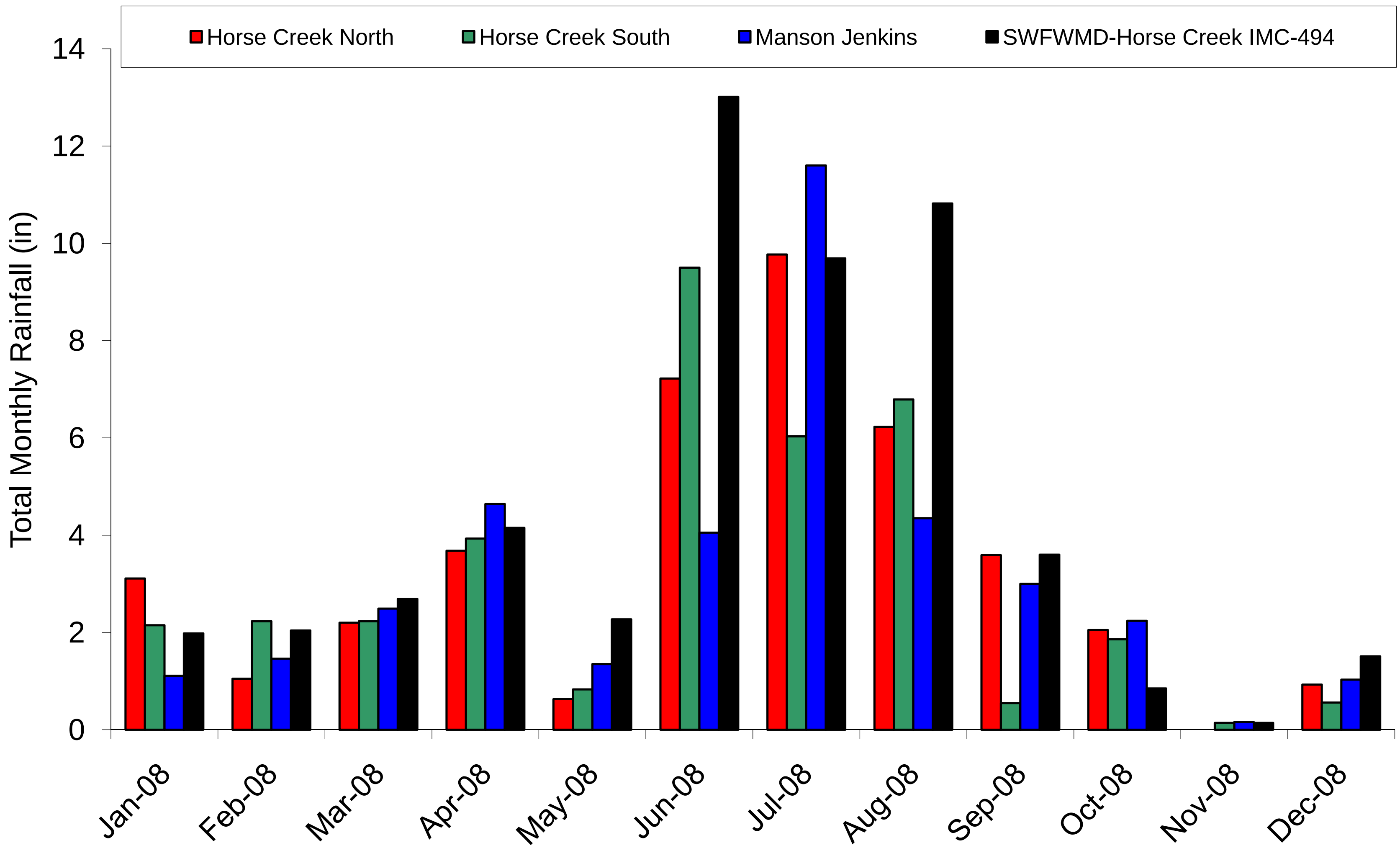

Figure 8. **Total Monthly Rainfall From Gauges in the Horse Creek Watershed in 2008.**

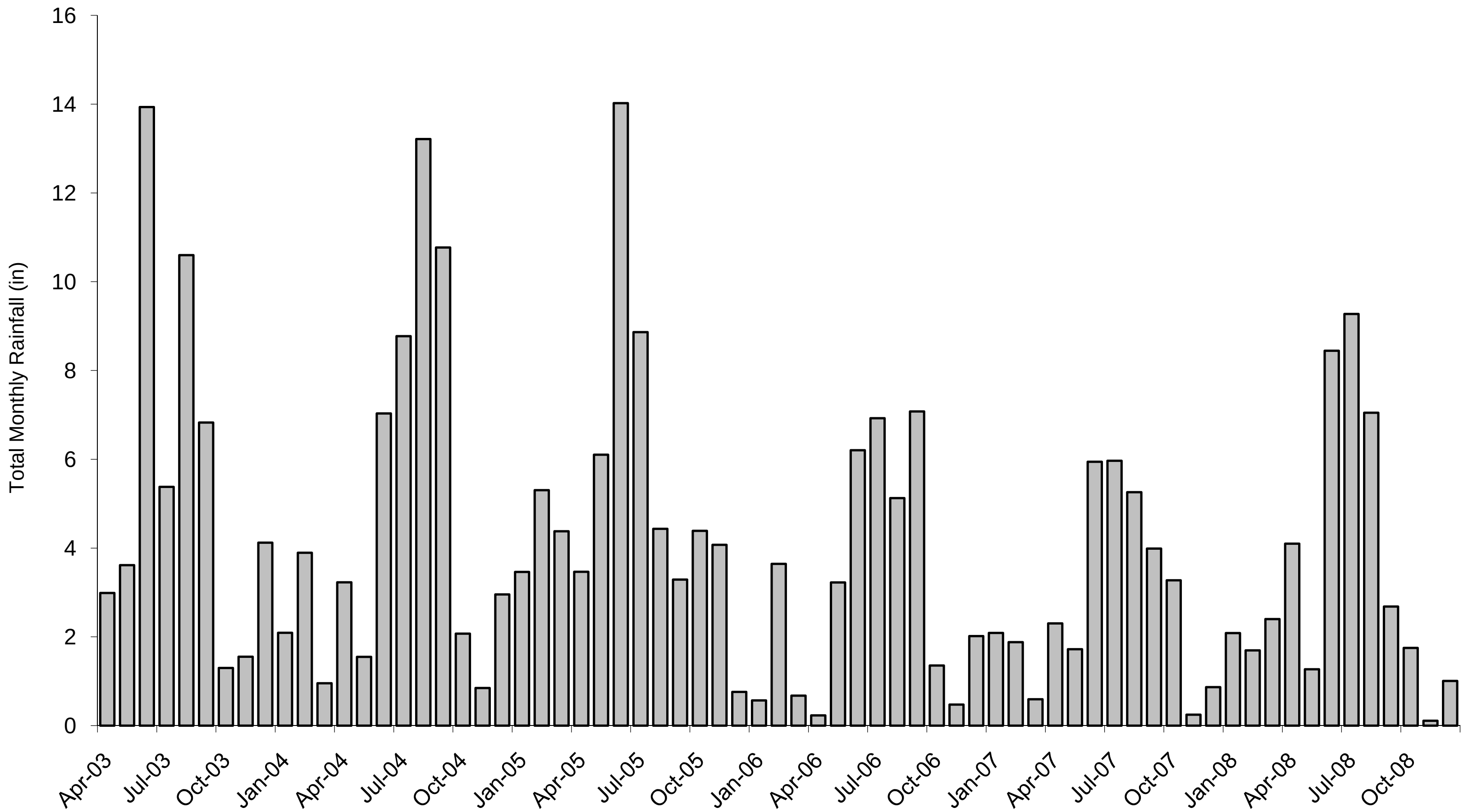

Figure 9. Total Monthly Rainfall From the Average of Four Gauges in the Horse Creek Watershed in 2003 - 2008.

5.1.2 Stream Stage

Figure 10 illustrates the relationship between the 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 and HCSW-4 (after adjustment to NGVD datum). Patterns of daily stage levels were clearly temporally correlated among the four stations (Figure 10). 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 three of the six stations had gauge heights that were 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 8). Such close correspondence is expected for a fairly small watershed in a low gradient setting like peninsular Florida.

Mean daily stage levels in 2008 were very low throughout the year at HCSW-1 and during the dry season at HCSW-4. Stage duration curves for 2008 were developed for HCSW-1 and HCSW-4 (Figure 11) to indicate the percentage of time stream stage was above particular elevations. Stage at HCSW-1 varied only two feet between the curve's P10 (68.5 ft) and P90 (66.5 ft) in 2008, indicating that stream height was relatively constant over time (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 small difference in height between the maximum and the P10 show that 2008 rainfall was not enough to raise the stream significantly at HCSW-1. Stream stage at HCSW-4 is more variable than at HCSW-1 between the P10 (18.3 ft) and P90 (12.6 ft) (about six feet), but it also showed a small rise in stage beyond the P10 level (~3 feet). Stage levels in 2008 were slightly higher than the low levels in 2006 and 2007, but were lower than those recorded in 2003, 2004, and 2005.

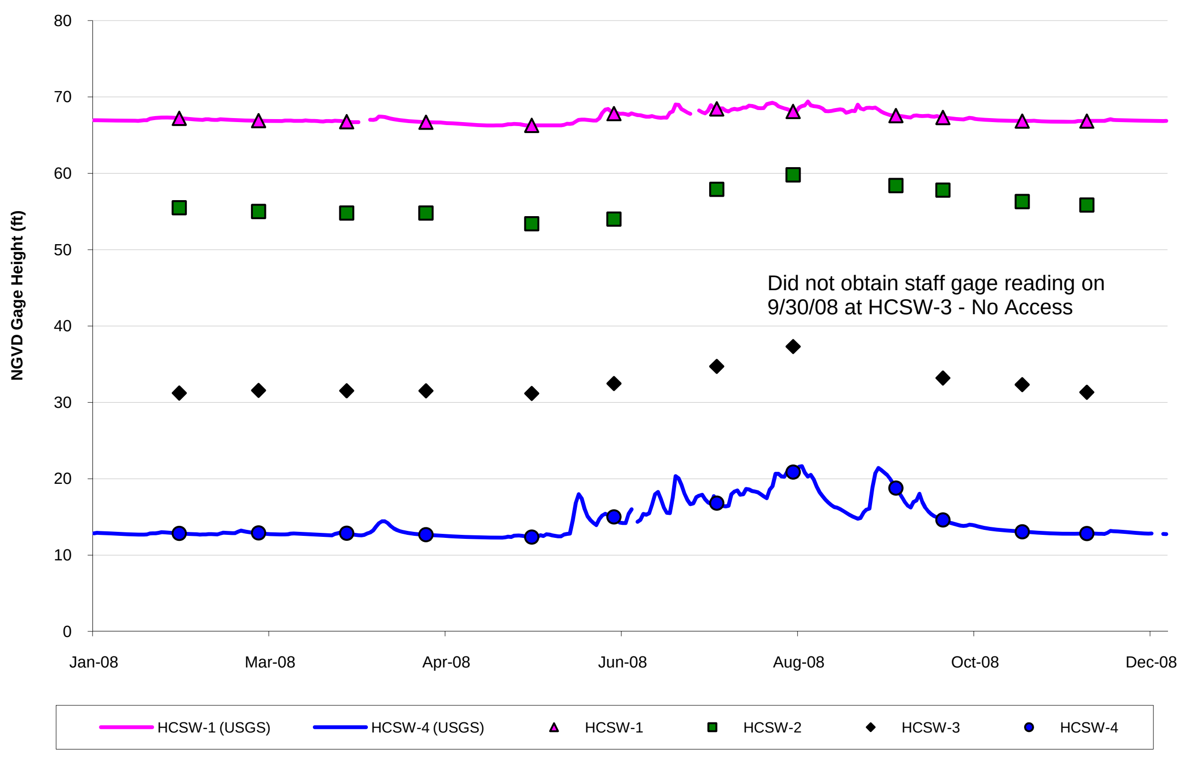

Figure 10. Stream Stage at HCSP Monitoring Stations in 2008. Individual data points are from Mosaic's monthly monitoring; continuous lines are average daily stage from USGS (Stations 02297155 and 02297310).

Table 8. Coefficients of Rank Correlation (r_s) for Spearman's Rank Correlations of Monthly Gauge Height (NGVD) for 2003-2008 ($p < 0.0001$).

	HCSW-1 (USGS)	HCSW-4 (USGS)	HCSW-1 (Mosaic)	HCSW-2 (Mosaic)	HCSW-3 (Mosaic)	HCSW-4 (Mosaic)
HCSW-1 (USGS)		0.90	0.99	0.70	0.82	0.89
HCSW-4 (USGS)			0.89	0.84	0.94	0.99
HCSW-1 (Mosaic)				0.69	0.80	0.88
HCSW-2 (Mosaic)					0.88	0.83
HCSW-3 (Mosaic)						0.93
HCSW-4 (Mosaic)						

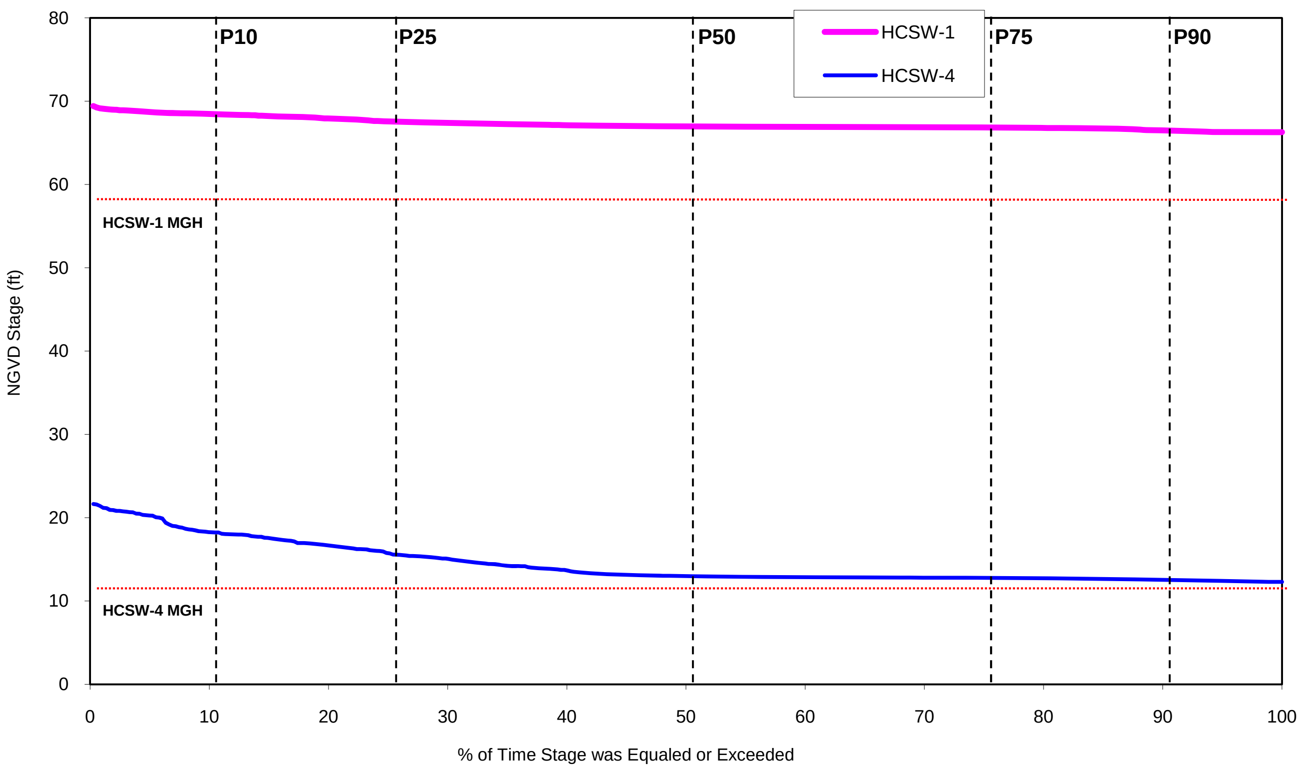

Figure 11. Stage Duration Curves for HCSW-1 and HCSW-4 in 2008, showing percent of year water levels were at or above a given stage. Typical reference points of 10% (P10), 25% (P25), 50% (P50), 75% (P75), and 90% (P90) are indicated on the graph, as well as the minimum gauge heights of HCSW-4 (10.96 ft, NGVD) and HCSW-1 (58.12 ft NGVD). (Figure uses provisional data from USGS website, USGS Stations 02297155 and 02297310).

5.1.3 Discharge

The average daily stream flow for 2008, obtained from the USGS continuous recorder data for HCSW-1 and HCSW-4, is presented in Figure 12 and Table 9. The seasonal pattern of streamflow seen in 2008 is similar to historical monthly patterns (Durbin and Raymond 2006), with the highest flows occurring during the wet-season months of June through October. Average daily stream flows exhibited a similar pattern at both HCSW-1 and HCSW-4 (Figure 12); stream discharge, however, was much higher at HCSW-4 than at HCSW-1 as a logical consequence of HCSW-4's lower position in the basin. Average daily streamflow was significantly less in 2006 –

2008 than it was in 2003 – 2005 at HCSW-1 (One-way ANOVA $F = 13.10$, $p < 0.0001$, Duncan's post hoc test). At HCSW-4, streamflow in 2008 was also significantly less than 2003 – 2005 and similar to 2006 and 2007 (One-way ANOVA $F = 11.98$, $p < 0.0001$, Duncan's post hoc test). The 10th and Median percentile of discharge at HCSW-1 and HCSW-4 in 2008 was similar to historic averages (Table 9), but the 90th percentile streamflow was below average historic flow.

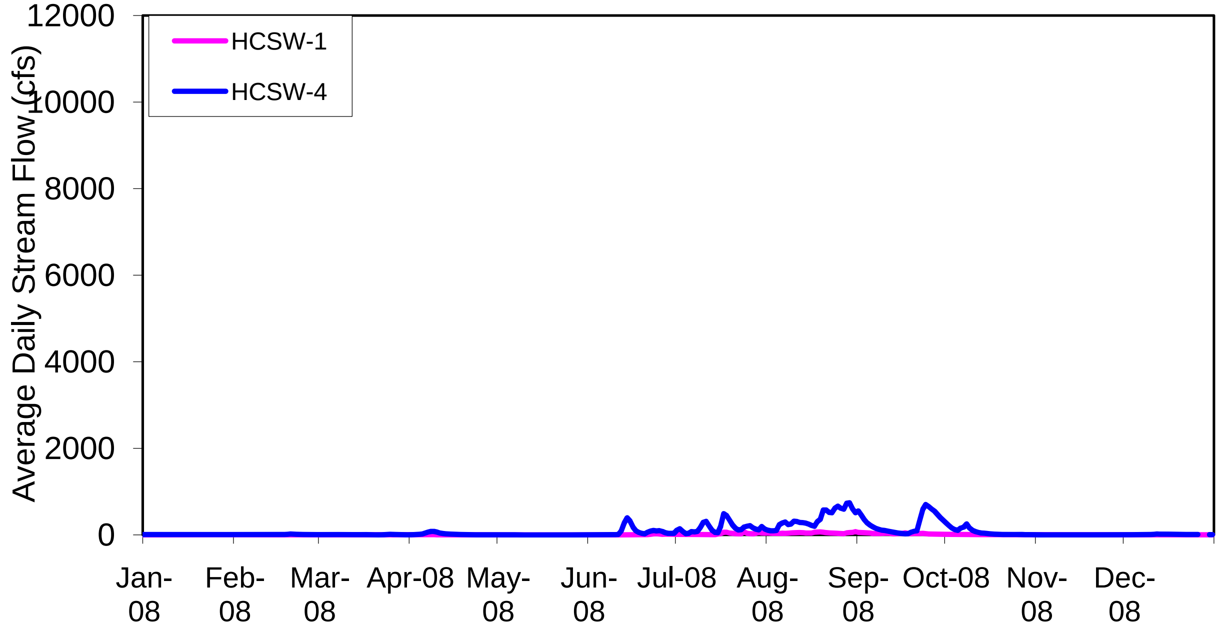

Figure 12. Average Daily Stream Flow for HCSW-1 and HCSW-4 in 2008 (Figure uses provisional data from USGS website).

Table 9. Median, 10th Percentile, and 90th Percentile Stream Discharge at HCSW-1 and HCSW-4 in 2003-2008, Based upon Provisional Data from USGS Website.

Station	Year	10th	Median	90th
HCSW-1	2003	2 cfs	20 cfs	127 cfs
	2004	< 1 cfs	7 cfs	166 cfs
	2005	6 cfs	21 cfs	134 cfs
	2006	< 1 cfs	5 cfs	29 cfs
	2007	< 1 cfs	3 cfs	8 cfs
	2008	0 cfs	2 cfs	39 cfs
HCSW-4	2003	21 cfs	84 cfs	1222 cfs
	2004	15 cfs	56 cfs	1184 cfs
	2005	36 cfs	145 cfs	653 cfs
	2006	4 cfs	24 cfs	379 cfs
	2007	4 cfs	14 cfs	43 cfs
	2008	2 cfs	13 cfs	285 cfs

5.1.4 Rainfall-Runoff Relationship

Stream discharge at HCSW-1 and the average daily rainfall for 2008 (average of daily rainfall at 494 (SWFWMD gauge) and three Mosaic rain gauges upstream of Highway 64) are compared in Figure 13. 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 494 (SWFWMD gauge) and three Mosaic rain gauges, as well the average total monthly rainfall of the gauges for the years 2003 - 2008. The correlation between stream discharge at HCSW-1 and rainfall was statistically significant for each rainfall gauge (Table 10). 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 (0.45 > r < 0.60). The lag between rainfall and runoff, as well as other antecedent condition factors, are strongly affecting this relationship.

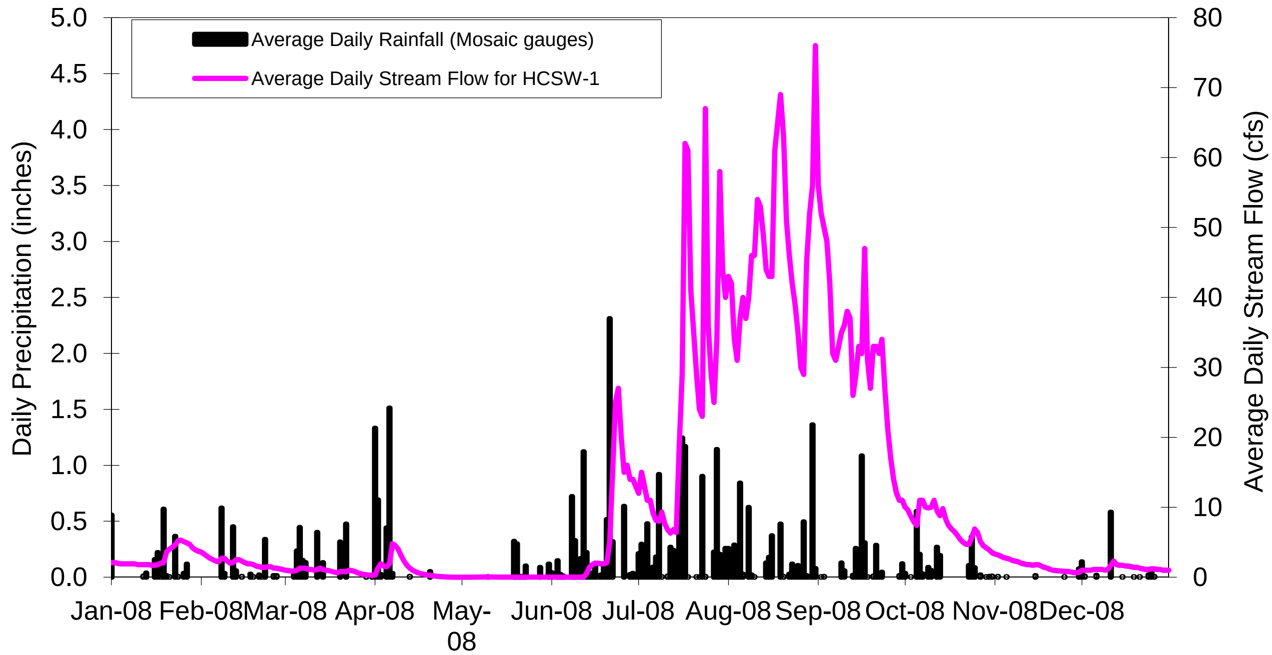

Figure 13. Average Daily Stream Flow at HCSW-1 and Average Daily Rainfall (from 3 Mosaic gauges and 1 SWFWMD gauge) in the Horse Creek Watershed in 2008 (Figure uses provisional data from USGS website).

Table 10. Coefficients of Rank Correlation (r_s) for Spearman's Rank Correlations of HCSW-1 Monthly Average Stream Discharge and Total Monthly Rainfall at SWFWMD Gauge and Three Mosaic Gauges in 2003 - 2008.

Rainfall Gauge	r_s (with HCSW-1 Streamflow)	p value	N (Sample Size)
Horse Creek North	0.55	<0.001	63
Horse Creek South	0.57	<0.001	69
Manson Jenkins	0.45	<0.001	65
494 (SWFWMD)	0.50	<0.001	69
Average Rainfall	0.60	<0.001	69

In an attempt to make stream discharge and rainfall more comparable, HCSW-1 discharge was converted from cubic feet per second (cfs) to equivalent inches of runoff for the 42-square mile area of the watershed lying upstream of the gauging station (USGS website). Figure 14 illustrates the relationship between cumulative daily discharge at HGSW-1 and rainfall from the average of all gauges in the Horse Creek Basin upstream of Highway 64 (3 gauges). In 2006 - 2008, all relatively dry years, cumulative rainfall and discharge were much lower than in 2003 to 2005.

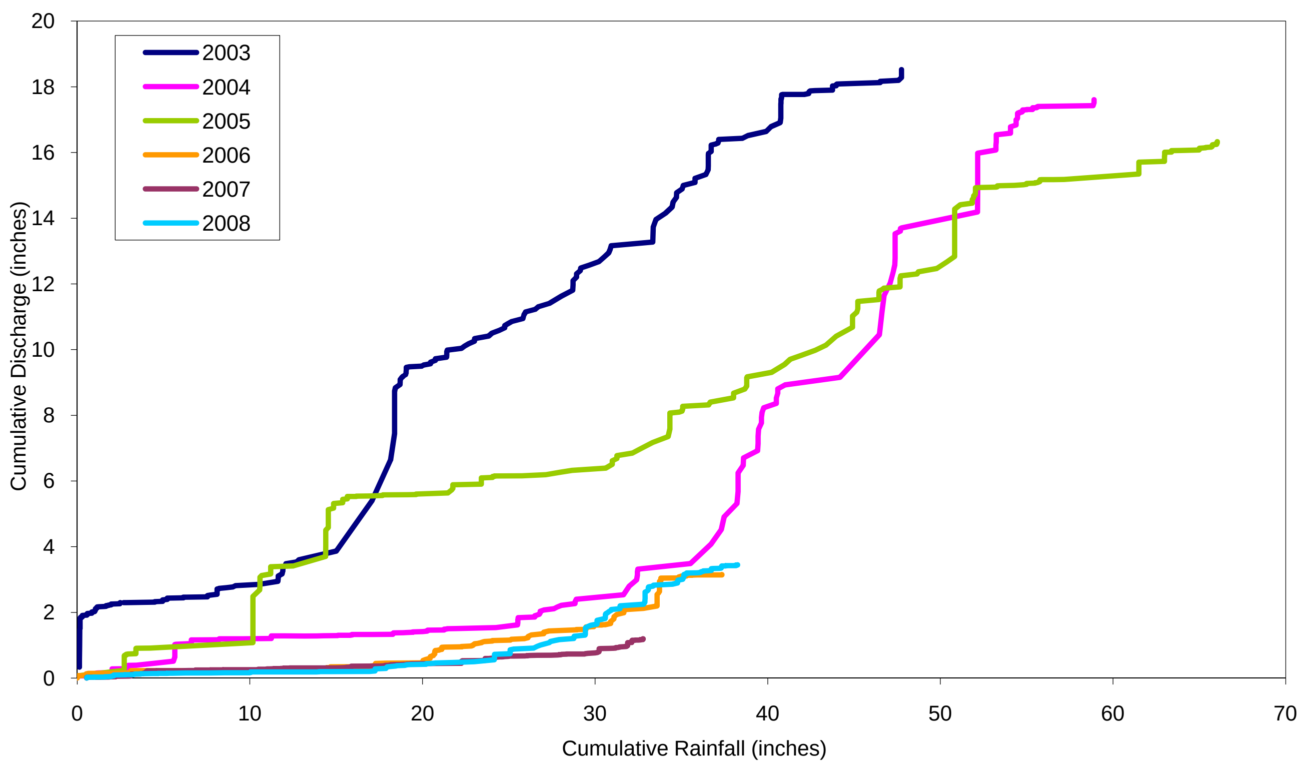

Figure 14. Double Mass Curve of Cumulative Daily Runoff and Rainfall (3 Mosaic gauges) in the Horse Creek Watershed in 2003 - 2008 (Figure uses provisional data from USGS website).

5.1.5 NPDES Discharges

Industrial wastewater is discharged to Horse Creek through two outfalls located at the Fort Green Mine (Outfalls 003 and 004 on NPDES Permits FL0027600, see Figure 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 2008 (Figure 15). The Horse Creek outfalls, however, are not the only discharge points of the mine, so this data represents only a portion of the mine’s rainfall-discharge relationship (Table 11). The Horse Creek portion of the Fort Green Mine is not a distinct entity on the ground; the mine property is continuous and covers portions of several basins. Mosaic has no other discharges to Horse Creek, 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 2008 daily discharge of two Mosaic NPDES outfalls (Outfalls 003 and 004) located upstream of HCSW-1 was plotted against the 2008 daily flow for HCSW-1 (Figure 16). In 2008, there the Ft. Green NPDES outfalls discharged during portions of four months into Horse Creek. Comparing HCSW-1 stream discharge and NPDES discharge in 2003 - 2008 using a Spearman’s rank correlation procedure (Zar 1999) indicates they covary strongly ($r_s = 0.62$, $p < 0.05$). Thus, an increase in one parameter will correspond to an increase in the other, but this does not suggest a causal relationship between NPDES and stream discharge. Just as stream discharge at HCSW-1 was correlated with rainfall (Table 10), so too is NPDES discharge (Table 12, Figure 15), with lagtimes and antecedent conditions affecting this relationship.

Discharge volume at Mosaic’s NPDES outfalls is manually checked for accuracy every week and represents a constant cross-section flowing over a smooth surface. The USGS discharge gauge at HCSW-1 is not checked manually and represents open channel flow, which is much harder to accurately measure. Data from the USGS data recorder at HCSW-1 may be unreliable during some periods; the sensor has been observed to be well above the water line during the dry season, and packed with sand during the wet season.

Table 11. 2008 Total monthly Mosaic Industrial Wastewater Discharge (NPDES) to Horse Creek (Outfalls 003 and 004) and Payne Creek (Outfall 001, 002, 005, 006) from the Fort Green Mine.

Month	Discharge to Payne Creek (MG)	Discharge to Horse Creek (MG)
January	4.90	0.0
February	9.07	0.0
March	11.76	0.0
April	65.82	0.0
May	35.79	0.0
June	26.26	0.0
July	862.71	403.18
August	2,506.03	2,292.69
September	423.47	1,664.67
October	23.96	252.83
November	5.32	0.0
December	0.16	0.0
Annual Total	3,975.24	4,613.37

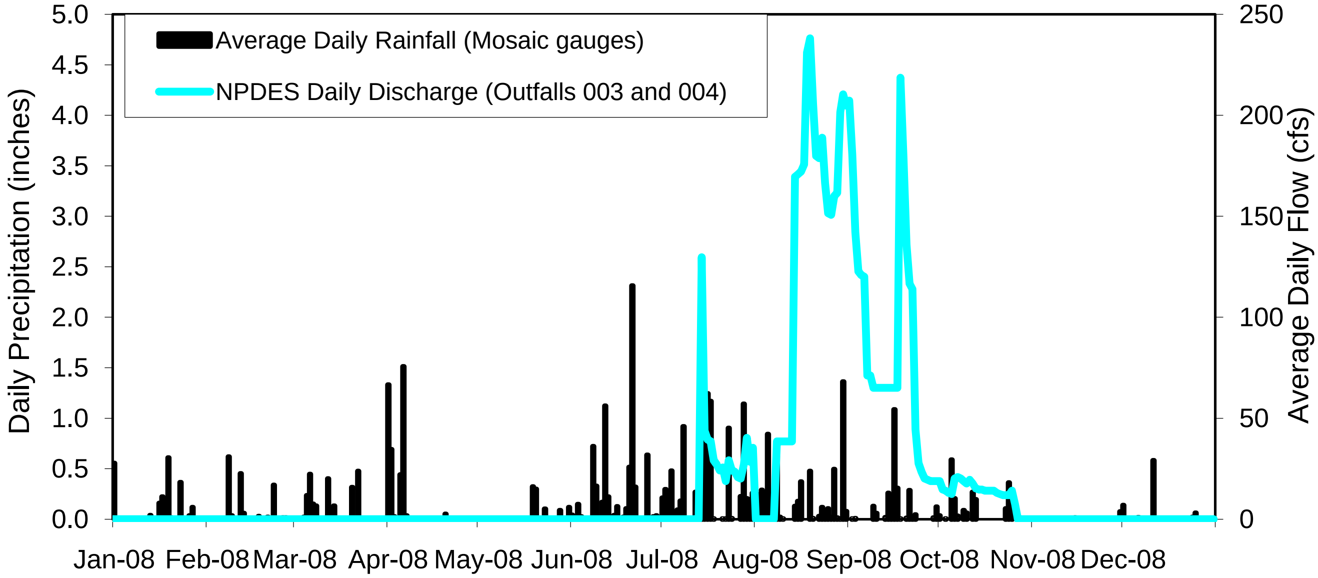

Figure 15. Combined Mosaic NPDES Discharge and Average Daily Rainfall in the Horse Creek Watershed in 2008.

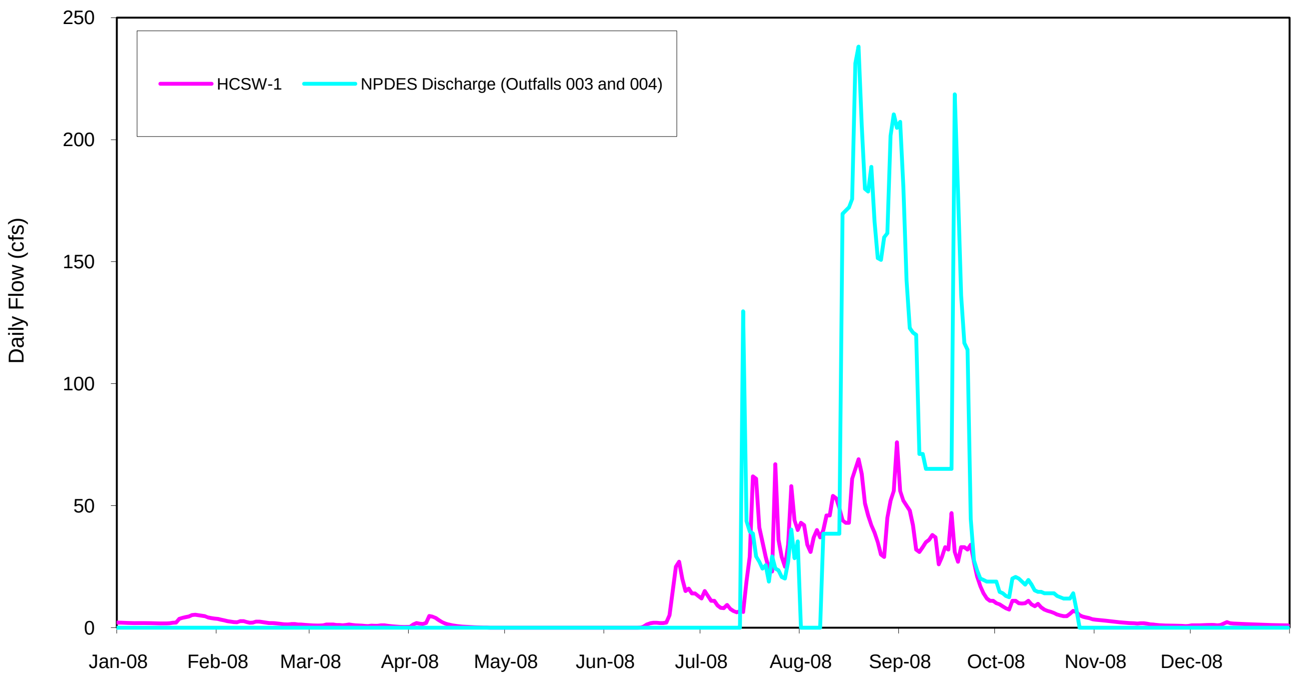

Figure 16. Daily Flow at HCSW-1 and Combined Mosaic NPDES Discharge for 2008 (Figure uses provisional data from USGS website).

Table 12. Coefficients of Rank Correlation (r_s) for Spearman's Rank Correlations of NPDES Monthly Average Discharge and USGS Daily Discharge, Gage Height, and Monthly Total Rainfall at SWFWMD Gauge and Three Mosaic Gauges in 2003 – 2008.

Gauge	r_s (with NPDES Outfall)	p value	N (Sample Size)
HCSW-1 (USGS Discharge)	0.62	< 0.001	69
HCSW-1 (USGS Gauge Ht)	0.66	< 0.001	68
Horse Creek North (Rain)	0.44	< 0.01	63
Horse Creek South (Rain)	0.36	< 0.01	69
Manson Jenkins (Rain)	0.12	0.33	65
494 (SWFWMD Rain)	0.34	< 0.01	69
Average Rainfall	0.38	< 0.01	69

5.1.6 Summary of Water Quantity Results

For 2008, temporal patterns of average daily stream flow and stage were similar across all stations, with the majority of high flows and stages occurring during the rainy season (June through October). The late dry season (April – May) was extremely dry, resulting in periods of little to no flow. Therefore, Mosaic's NPDES-permitted discharges upstream of HCSW-1 only discharged for portions of four months of the year. Rainfall and discharge in 2006, 2007, and 2008 were well below the long-term average (Durbin and Raymond 2006). Three consecutive years of low rainfall and streamflow in Horse Creek have likely had significant impacts on the water quality and biological communities of the stream.

5.2 WATER QUALITY

The results of field measurements and laboratory analyses of water samples obtained monthly from 2008 at each HCSP monitoring station are presented in this section (see Appendix C for water quality figures from 2003 through present). Continuous recorder data for pH, dissolved oxygen, turbidity, and specific conductivity are also presented, along with the field measurements obtained during benthic macroinvertebrate and fish sampling on 24 April, 12 September, and 19 November 2008. Water quality raw data are included in a database on the attached CD-ROM.

Water quality of NPDES discharge is normally obtained periodically when water is discharged from Outfalls 003 and 004. Water was discharged for ninety-nine days in 2008, with multiple water quality samples taken from each outfall. In the NPDES discharge, only chlorophyll *a* was above the HCSW-1 trigger levels (Table 13).

Table 13. Water quality summary of NPDES discharge into Horse Creek during 2008 at Outfalls 003 and 004.

	2008							
	Outfall 003 (August – September)				Outfall 004 (July – October)			
Constituent	Avg	Count	Min	Max	Avg	Count	Min	Max
pH (su)	7.28	6	7.08	7.5	7.19	13	6.61	7.54
Conductivity (umhos/cm)	777	5	695	843	544	13	452	616
Temperature (degrees C)	29.5	5	28	30.7	28.6	13	25.9	31.6
Turbidity (NTU)	5.25	5	3.31	9.59	4.7	13	1.84	10.7
Dissolved Oxygen (mg/L)	6.03	5	5.13	6.72	5.73	13	5.02	8.19
TSS (mg/L)	7.3	6	5.3	9.2	6	14	2.8	10.8
Total Phosphorus (mg/L)	0.66	6	0.14	1.1	0.255	12	0.07	0.93
TKN (mg/L)	1.13	2	0.98	1.27	1.46	4	1.09	1.96
Nitrate-Nitrite (mg/L)	0.135	2	0.04	0.23	0.046	4	0.004	0.07
Total Nitrogen (mg/L)	1.26	2	1.02	1.5	1.51	5	1.13	2.03
Fluoride (mg/L)	1.08	1	1.08	1.08	0.61	2	0.55	0.67
Sulfate (mg/L)	228	1	228	228	138	2	135	141
Chlorophyll *a* (mg/m^3)	**44.6**	1	**44.6**	**44.6**	**21.25**	2	3	**39.5**

5.2.1 Data Analysis

Line graphs are used to display water quality measurements for each parameter during 2008, 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. For continuous recorder data measured at HCSW-1 in 2008, the daily mean of the water quality parameter is plotted with streamflow from the USGS gauge at HCSW-1. Monthly water quality data for 2003–2008 were compared to other data sources (SWFWMD, FDEP, USGS) since 1990 using median box-and-whisker plots[1]. Graphical representations of HCSP data include undetected values, represented by the respective MDLs for each parameter, except for total nitrogen, total radium, FL-PRO, fatty acids, and amines. Because so many of the results for FL-PRO, fatty acids, and amines were undetected, we chose to display only the detected values for clarity. Total nitrogen and total radium are composite parameters

[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).

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 (Appendix D) 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 is 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. 2005). 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. 2005).

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 only five years of data, the power of the test to detect trends of small magnitude will 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. Since HCSW-1 and HCSW-4 were the only stations with regularly recorded flow available (USGS flow data), and the fact that flow data was 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 14. The year was split into three seasons, corresponding to wet/dry periods. Season one encompassed the first part of 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 rainy) and season three represented the second dry season during the calendar year, October through December. Parameters that were significantly correlated with USGS streamflow were corrected for the effect of annual variation in streamflow using a LOWESS smooth (F=0.5) before the Seasonal Kendall Tau was performed. LOWESS (locally weighted scatterplot smoothing) in the seasonal Kendall Tau describes the relationship between the concentrations of a water quality parameter and streamflow using a weighted linear least squares regression. The residuals of the smooth have the effect of streamflow subtracted, and are call 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. The Sen slope estimate for a parameter was only reported if the trend was statistically significant. For those parameters where SWFWMD data was used for trend analysis (fluoride, nitrate+nitrite, ammonia), the magnitude of the slope estimate may not be accurate because some data in 2007 was missing from the SWFWMD dataset.

Table 14. Summary of seasonal Kendall-tau with LOWESS (F=0.5) (unless noted) for HCSW-1 and HCSW-4 from 2003-2008.

Parameter	HCSW-1			HCSW-4		
	tau	p-value	slope	tau	p-value	slope
pH	0.29	0.19	N/A	-0.02	0.91	N/A
Dissolved Oxygen	-0.24	0.28	N/A	-0.56	**0.01**	**-0.40**
Turbidity	0.07	0.83	N/A	0.07	0.83	N/A
Color, total	0.11	0.66	N/A	0.20	0.39	N/A
Nitrogen, total	-0.16	0.52	N/A	-0.02	1.00	N/A
Nitrogen, total kjeldahl	-0.02	1.00	N/A	0.07	0.83	N/A
Nitrogen, ammonia*	-0.07	0.83	N/A	-0.22	1.00	N/A
Nitrogen, nitrate-nitrite*	-0.02	1.00	N/A	0.24	0.28	N/A
Orthophosphate[2]	0.33	0.13	N/A	0.58	**0.01**	**0.02**
Chlorophyll a[1]	0.20	0.36	N/A	0.13	0.57	N/A
Specific Conductance	0.47	**0.03**	**15.31**	0.02	1.00	N/A
Calcium, dissolved	0.38	0.08	N/A	0.24	0.28	N/A
Iron, dissolved	0.11	0.66	N/A	-0.02	1.00	N/A
Alkalinity	0.47	**0.03**	**4.58**	0.29	0.19	N/A
Chloride	0.38	0.08	N/A	0.07	0.83	N/A
Fluoride*[3]	-0.07	0.83	N/A	-0.02	0.39	N/A
Sulfate	0.02	1.00	N/A	-0.11	0.66	N/A
Total Dissolved Solids	0.29	0.19	N/A	0.07	0.83	N/A
Radium, Total	0.42	0.05	N/A	0.02	1.00	N/A

*SWFWMD data was used from April 2003-December 2008 (some parameters missing 2007 data).
[1]Data was not correlated with streamflow for either station; LOWESS was not used.
[2]Data was not correlated with streamflow for HCSW-4; LOWESS was not used.
[3]Data was not correlated with streamflow for HCSW-1; LOWESS was not used.

Differences in water quality between stations from 2003 to 2008 for each water quality parameter were evaluated using ANOVA and Duncan's post hoc test (Table 15). 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 15. Parameters whose MDLs have changed over the course of the program were omitted because of limited comparable data between sampling events and stations (fluoride, nitrate+nitrite, ammonia).

Table 15. Summary of results from ANOVA for differences between stations from 2003-2008.

Parameter	F	p-value
pH	25.05	< 0.001
Dissolved Oxygen	78.24	< 0.001
Turbidity	0.93	0.43
Color, total	3.38	0.019
Total Nitrogen	3.39	0.018
Total Kjeldahl Nitrogen	6.98	< 0.001
Orthophosphate	20.94	< 0.001
Chlorophyll A	10.49	< 0.001
Specific Conductance	24.73	< 0.001
Calcium, dissolved	36.72	< 0.001
Iron, dissolved	1.29	0.28
Alkalinity	34.93	< 0.001
Chloride	11.67	< 0.001
Sulfate	32.33	< 0.001
Total Dissolved Solids	30.23	< 0.001
Radium, Total	2.27	0.08

Water quality parameters were compared with water quantity variables recorded during the same month from 2003 to 2008: 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 12), 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 16. 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 because of limited comparable data between sampling events and stations (fluoride, nitrate+nitrite, ammonia).

Table 16. 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 - 2008.

	HCSW-1			HCSW-4		
	NPDES	Rainfall	Streamflow	NPDES	Rainfall	Streamflow
pH	-0.16	-0.28*	0.45*	-0.38*	-0.38*	-0.60*
Dissolved Oxygen	-0.43*	-0.58*	-0.37*	-0.61*	-0.59*	-0.71*
Turbidity	0.41*	0.36*	0.40*	0.46*	0.40*	0.64*
True Color	0.28*	0.42*	0.35*	0.52*	0.37*	0.67*
Total Nitrogen	0.28*	0.44*	0.33*	0.23	0.20	0.31*
TKN	0.32	0.47	0.36	0.40*	0.37*	0.42*
Orthophosphate	-0.21	-0.15	-0.46*	0.12	0.05	0.04
Chlorophyll a	-0.26	-0.17	-0.18	0.13	0.07	0.11
Specific Conductance	-0.04	-0.22	-0.41*	-0.60*	-0.41*	-0.87*
Calcium	-0.09	-0.31*	-0.50*	-0.65*	-0.44*	-0.88*
Iron	0.47*	0.61*	0.73*	0.59*	0.52*	0.84*
Alkalinity	-0.10	-0.24*	-0.31*	-0.49*	-0.65*	-0.77*
Chloride	-0.49*	-0.46	-0.65*	-0.62*	-0.44*	-0.86*
Sulfate	0.07	-0.11	-0.40*	-0.63*	-0.36*	-0.85*
TDS	0.10	-0.04	-0.32*	-0.48*	-0.28*	-0.79*
Total Radium	-0.31*	0.08	-0.14	-0.27*	0.13	-0.17

* - Statistically significant at $p < 0.05$

5.2.2 Physio-Chemical Parameters

pH

Levels of pH, dissolved oxygen, and turbidity 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 2008 sampling events at all stations (Figure 17). Values obtained during biological sampling events were fairly consistent with pH levels determined during the monthly water quality sampling events (Figure 17). The pH levels at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (FDEP, SWFWMD, USGS) (Figures 18 and 19). Continuous pH data obtained daily at HCSW-1 in 2008 was within a range similar to that obtained during monthly water quality sampling (Figure 20).

HCSW-1 and HCSW-4 exhibited no monotonic trends over the last six years for pH (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 14). Levels of pH were significantly different among stations in 2003 – 2008 (ANOVA $F = 25.05$, $p < 0.0001$, Table 15). Station HCSW-2, which had significantly lower pH than other stations (Duncan's multiple range-test, $p < 0.05$), lies just downstream of a large swamp complex that has the potential to add substantial organic acids from plant decomposition and will tend to decrease the pH (Reid and Wood 1976). Levels of pH were significantly correlated with streamflow ($r_s = 0.45$) and rainfall ($r_s = -0.28$) at HCSW-1 and with streamflow ($r_s = -0.60$), rainfall ($r_s = -0.38$), and NPDES discharge ($r_s = -0.38$) at HCSW-4 (Spearman's rank correlation, $p > 0.05$, Table 16).

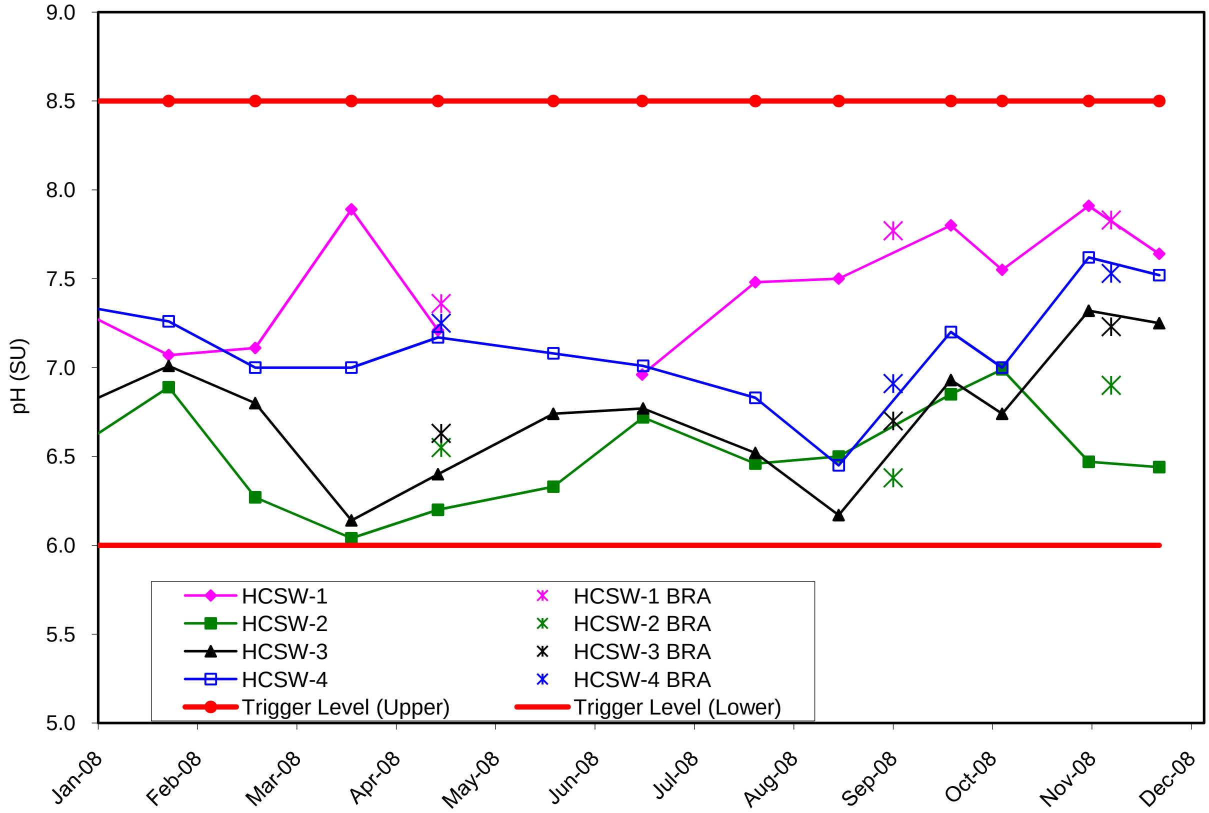

Figure 17. Values of pH Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2008. Minimum Detection Limit = 1 su.

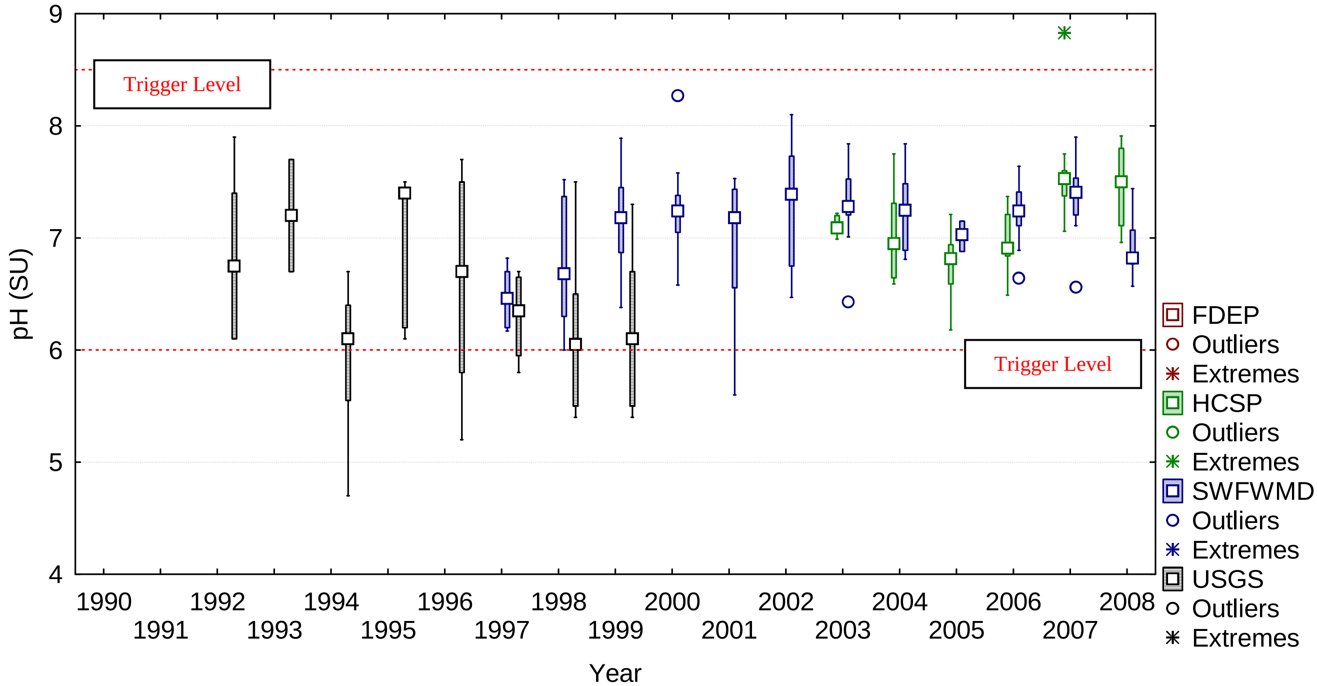

Figure 18. HCSW-1 Values of pH Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

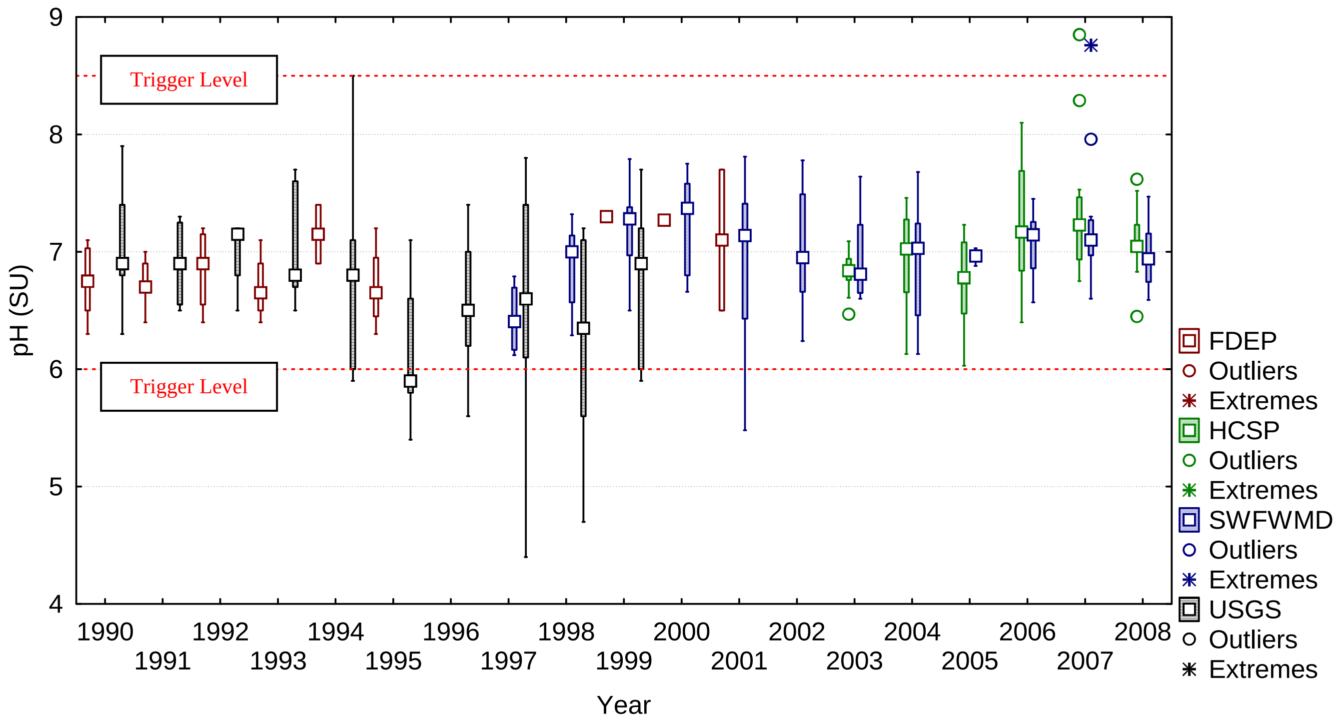

Figure 19. HCSW-4 Values of pH Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

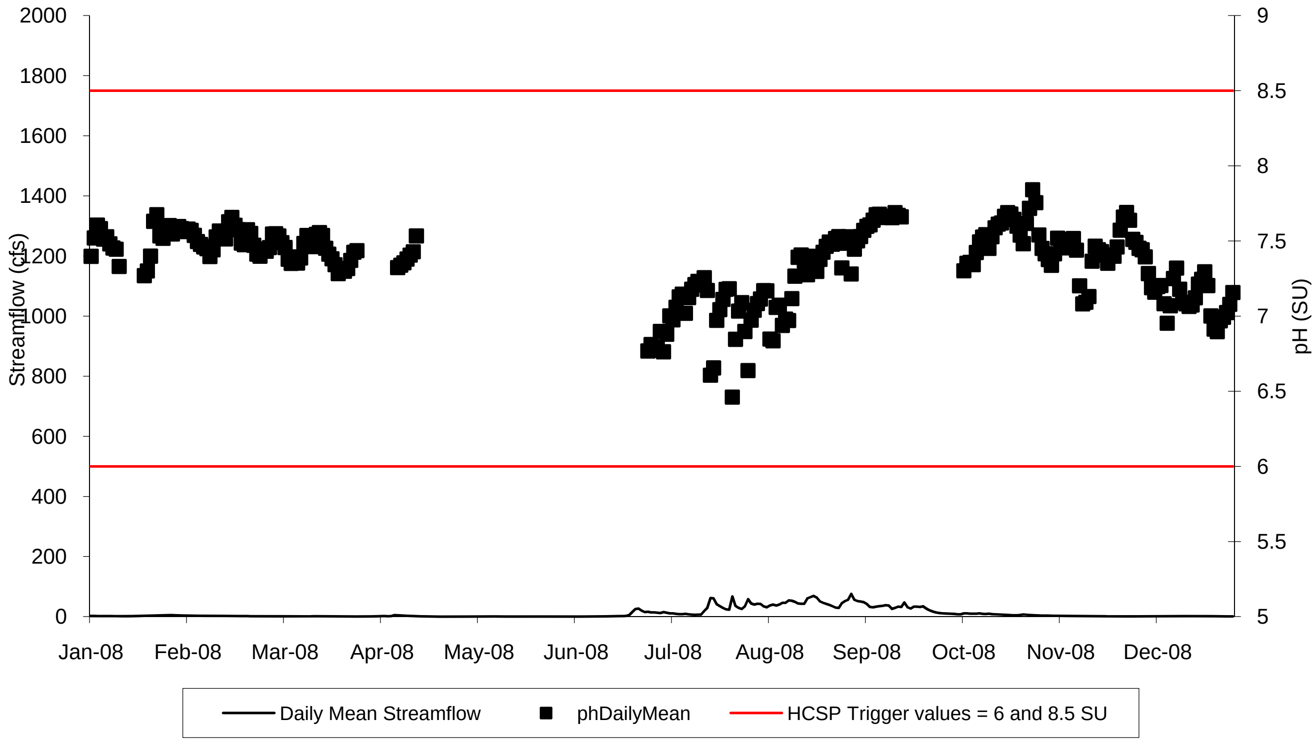

Figure 20. Relationship Between Daily Mean pH (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow (from USGS Provisional Data) for 2008. Minimum pH Detection Limit = 1 SU.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations were above the trigger level and Class III Standard of 5.0 mg/l (indicating desirable conditions) during all sampling events in 2008 at HCSW-1 (Figure 21). However, levels of DO were always below 5.0 mg/l at HCSW-2; this station is just downstream of the Horse Creek Prairie, a blackwater swamp that typically has low DO concentrations. In addition, DO was below the trigger value at HCSW-3 from February through October 2008 and at HCSW-4 from July through September, corresponding to times of either very low streamflow (stagnant conditions) or high temperatures. DO concentrations at HCSW-1, HCSW-2, HCSW-3, and HCSW-4 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 21 and 24).

The DO levels at HCSW-1 measured by the HCSP are consistent with other water quality data sources (Figures 22 and 23) and exhibited no monotonic trend between 2003 and 2008 (Seasonal Kendall Tau = -0.24, $p = 0.28$, Table 14). However, there was a slight decreasing monotonic trend for DO at HCSW-4 (Seasonal Kendall Tau with LOWESS, Tau = -0.56, $p = 0.01$, Sen slope = -0.40 mg/L per year) (Figures 22 and 23). Although the trend analysis at HCSW-4 indicates that dissolved oxygen may be declining by about 0.40 mg/L per year from 2003 to 2008, this decline is likely caused by extreme differences in rainfall between the beginning and end of the sampling period. Given that HCSW-1 does not show a trend, it is unlikely that mining activities are contributing to the dissolved oxygen changes at HCSW-4.

Levels of dissolved oxygen were significantly different among stations in 2003 - 2008 (ANOVA , $F = 78.2$, $p < 0.0001$, Table 15), with HCSW-2 significantly lower than other stations followed by HCSW-3 (Duncan's multiple range test, $p < 0.05$). Dissolved oxygen was negatively correlated with streamflow, rainfall, and NPDES discharge at both HCSW-1 and HCSW-4 (Spearman's rank correlations $-0.37 > r > -0.71$, $p < 0.05$, Table 16). During the wet season, higher temperatures in the stream drive down the oxygen saturation.

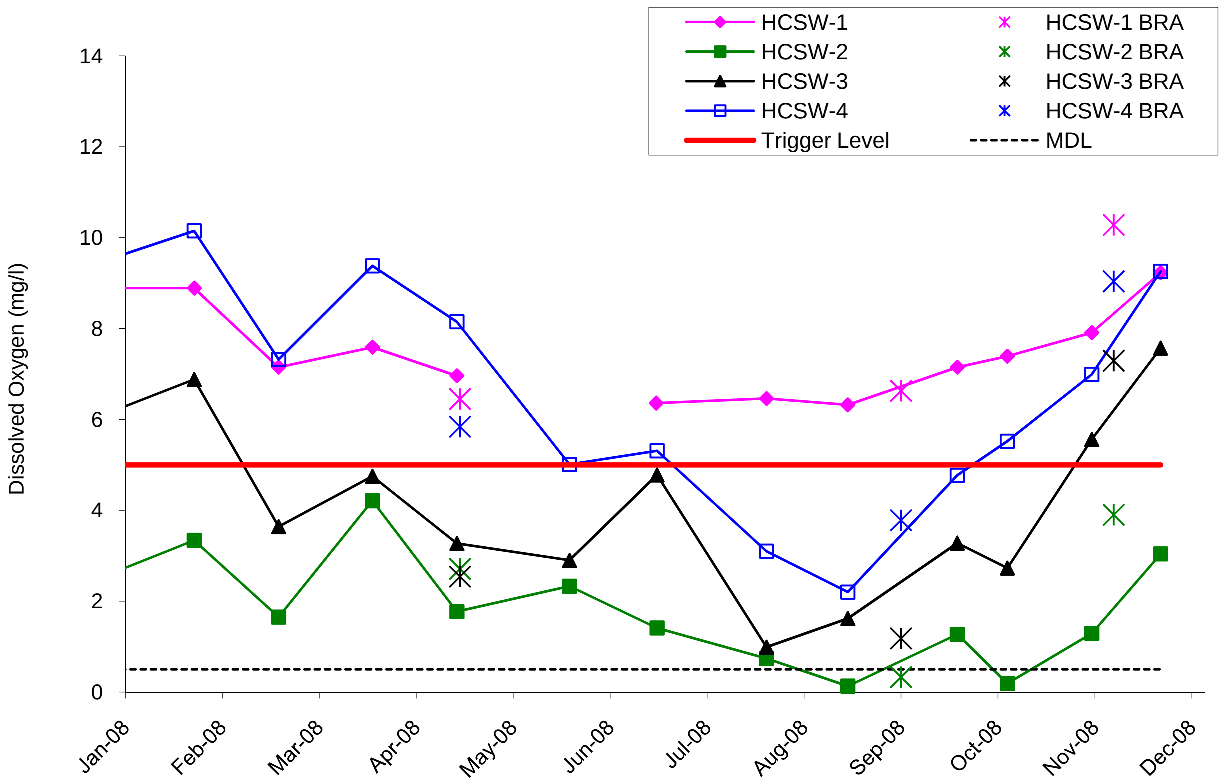

Figure 21. Dissolved Oxygen Levels Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2008.

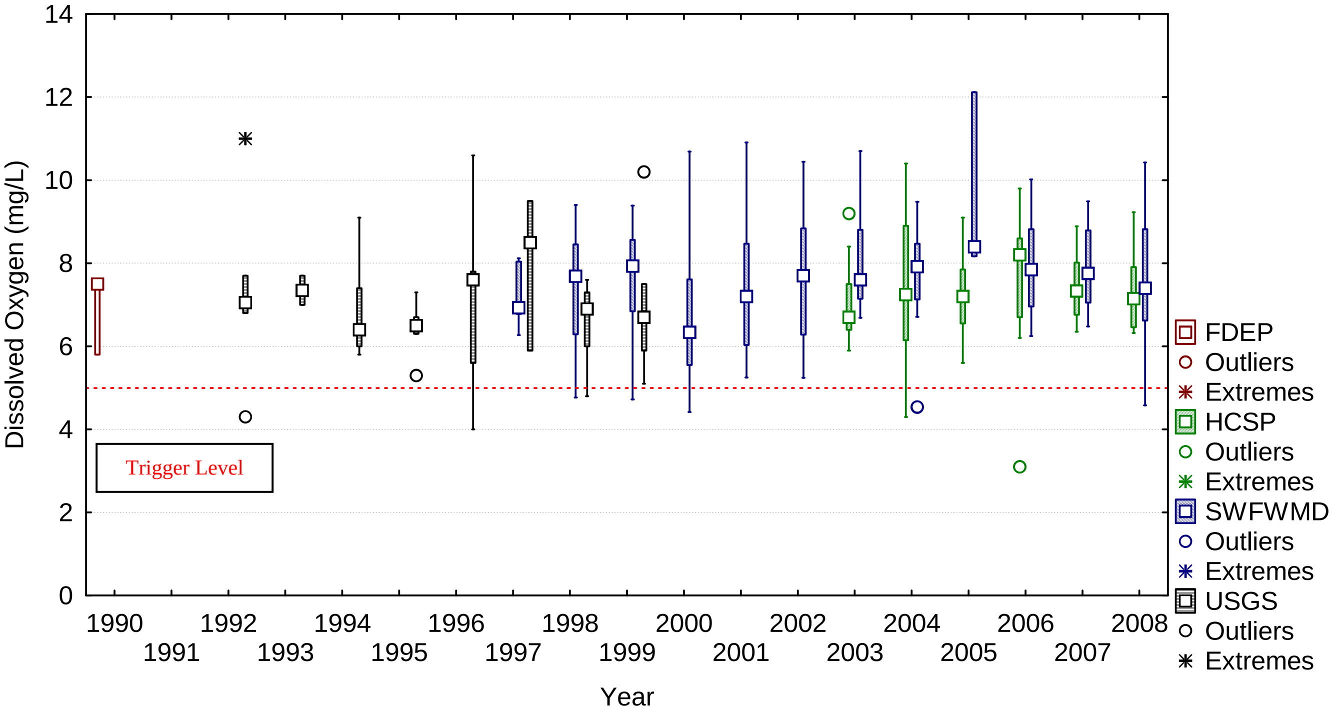

Figure 22. HCSW-1 Values of Dissolved Oxygen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

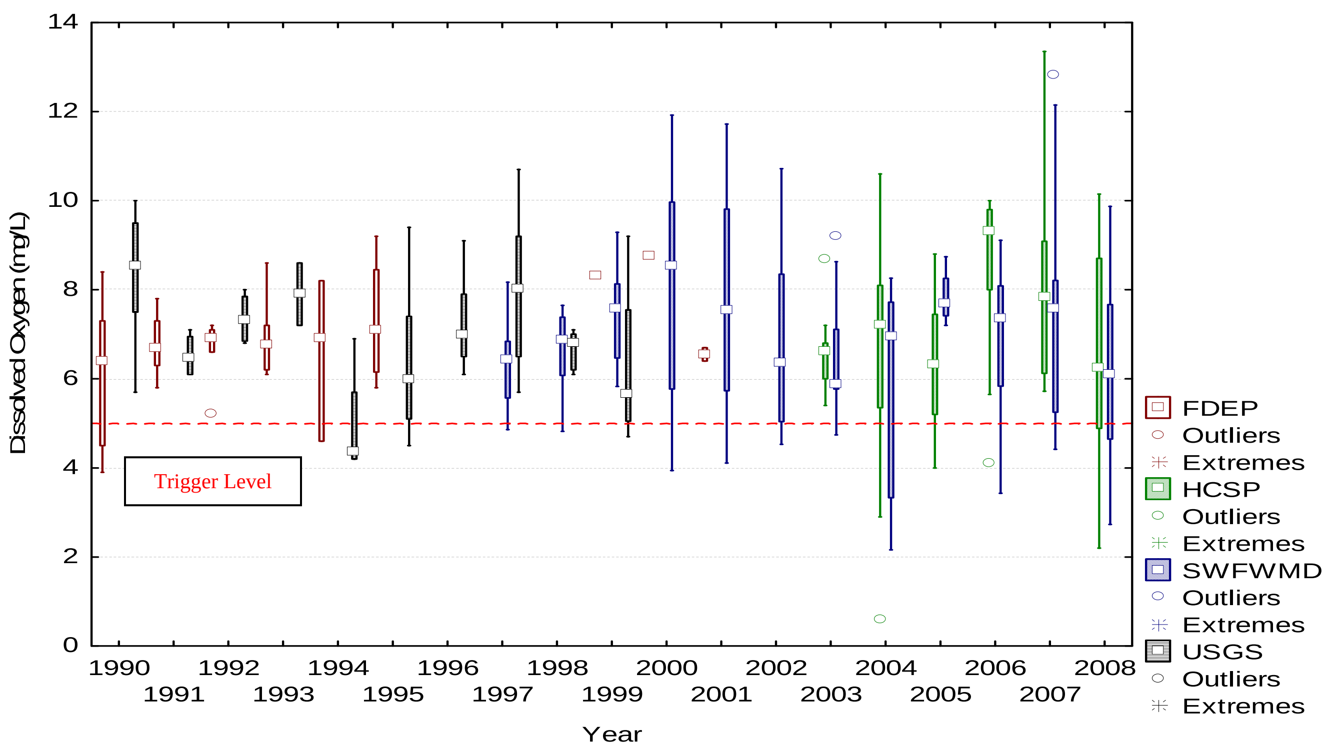

Figure 23. HCSW-4 Values of Dissolved Oxygen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

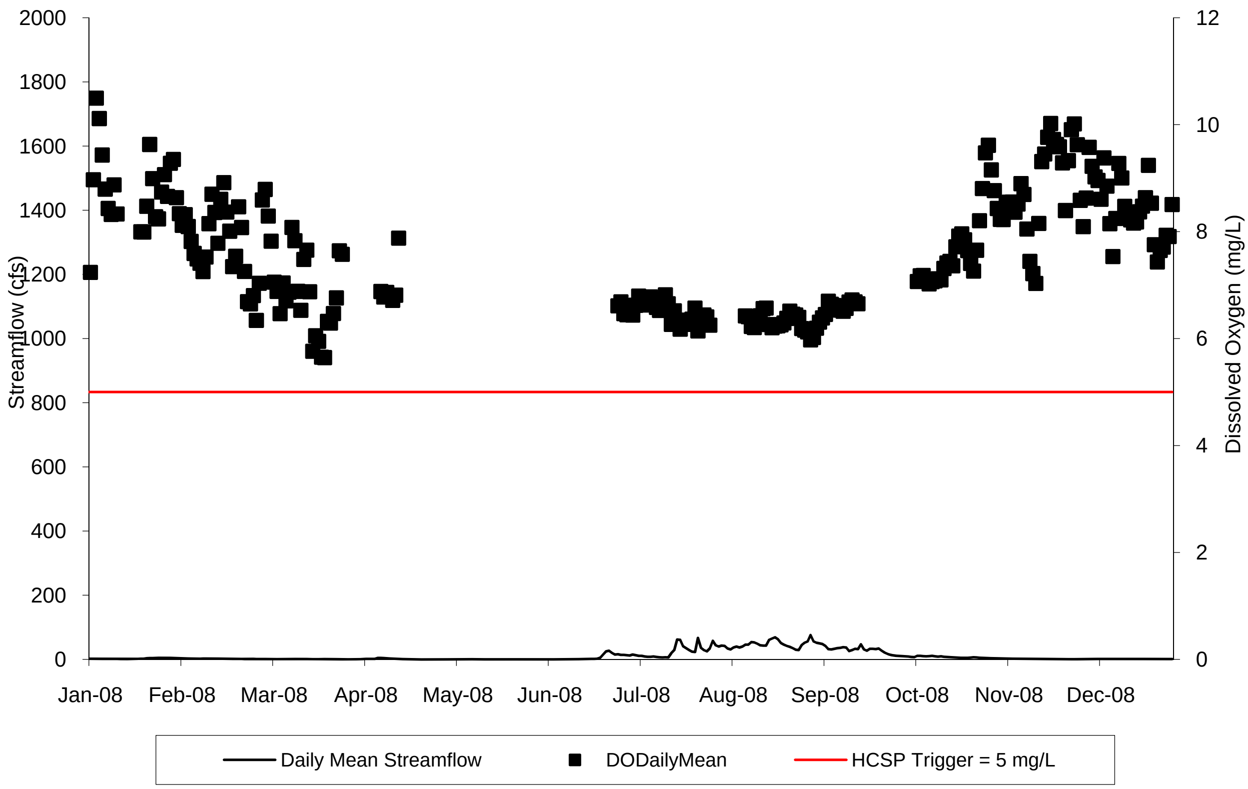

Figure 24. Relationship Between Daily Mean DO (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow (from USGS Provisional Data) for 2008. Minimum DO Detection Limit = 0.50 mg/L.

Turbidity

Turbidity levels obtained during biological sampling events or with the continuous recorder at HCSW-1 were similar to those found during monthly water quality sampling events (Figures 25 and 28). Turbidity levels at all stations in 2008 were below the trigger level and Class III Surface Water Quality Standard of 29 nephelometric turbidity units (NTUs). The turbidity levels at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$) (Figures 26 and 27, Table 14). Turbidity levels as measured monthly were not significantly different among stations in 2003 - 2008 (ANOVA, $F = 0.93$, $p = 0.43$, Table 15). Turbidity was positively correlated with streamflow, rainfall, and NPDES discharge at HCSW-1 and HCSW-4 (Spearman's rank correlations $0.36 < r < 0.64$, Table 16).

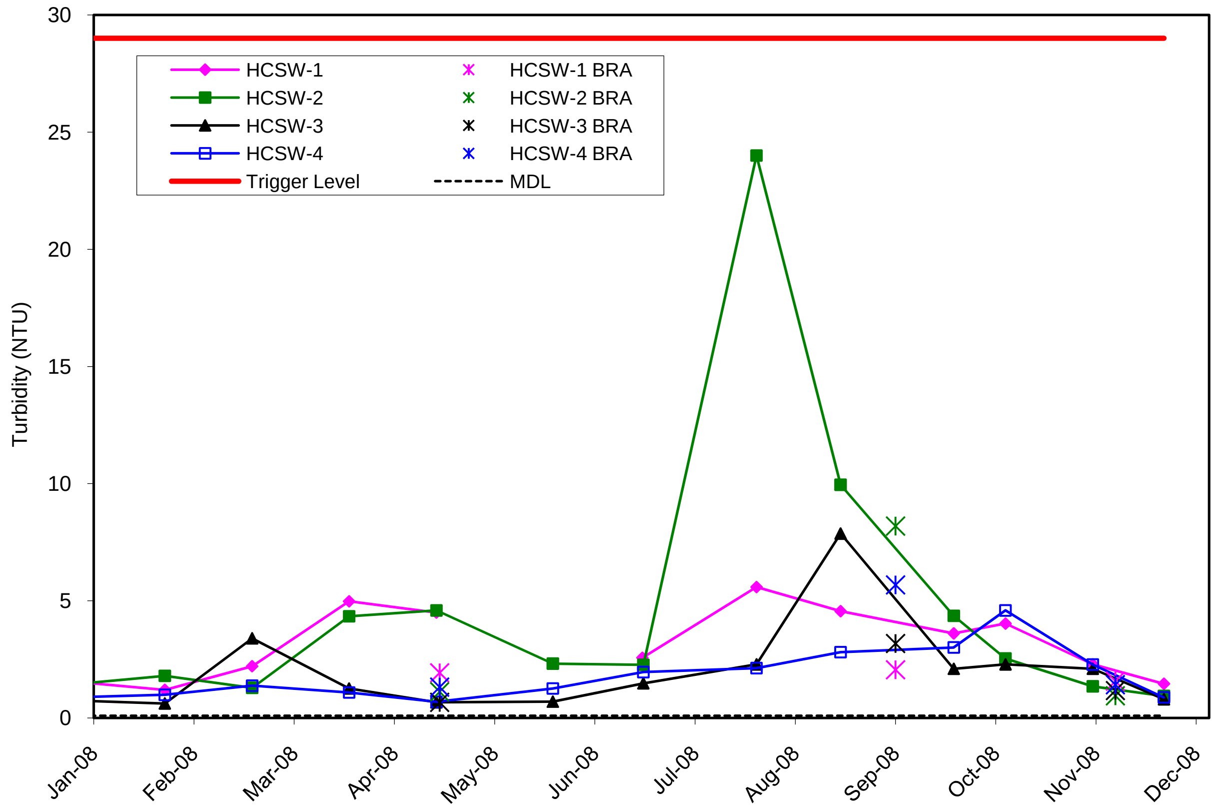

Figure 25. Turbidity Levels Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2008.

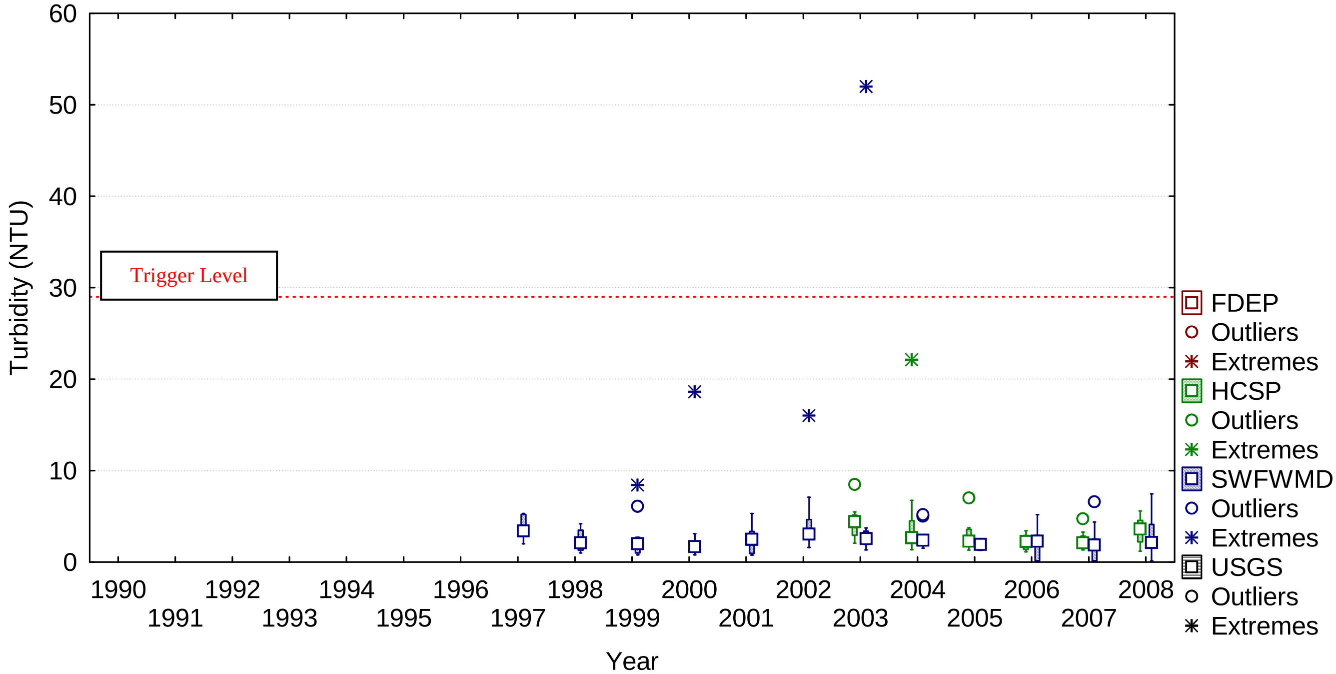

Figure 26. HCSW-1 Values of Turbidity Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

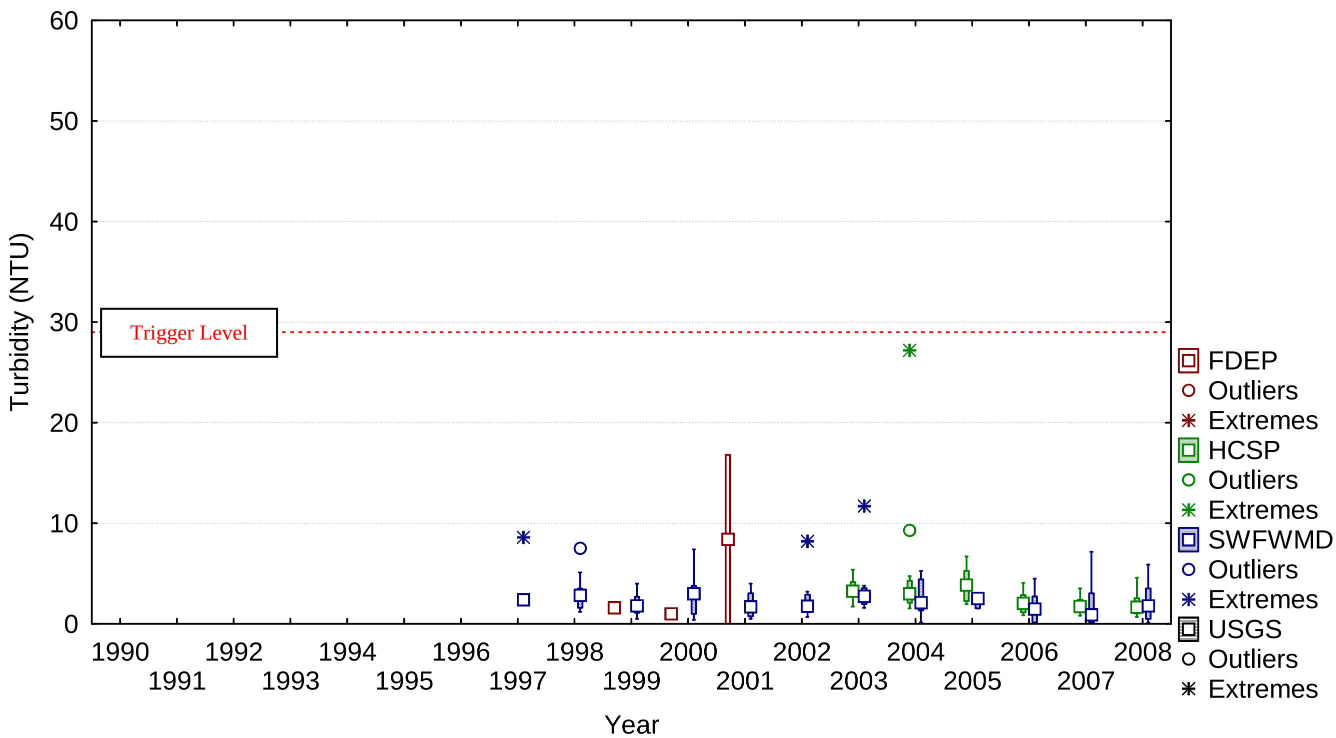

Figure 27. HCSW-4 Values of Turbidity Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

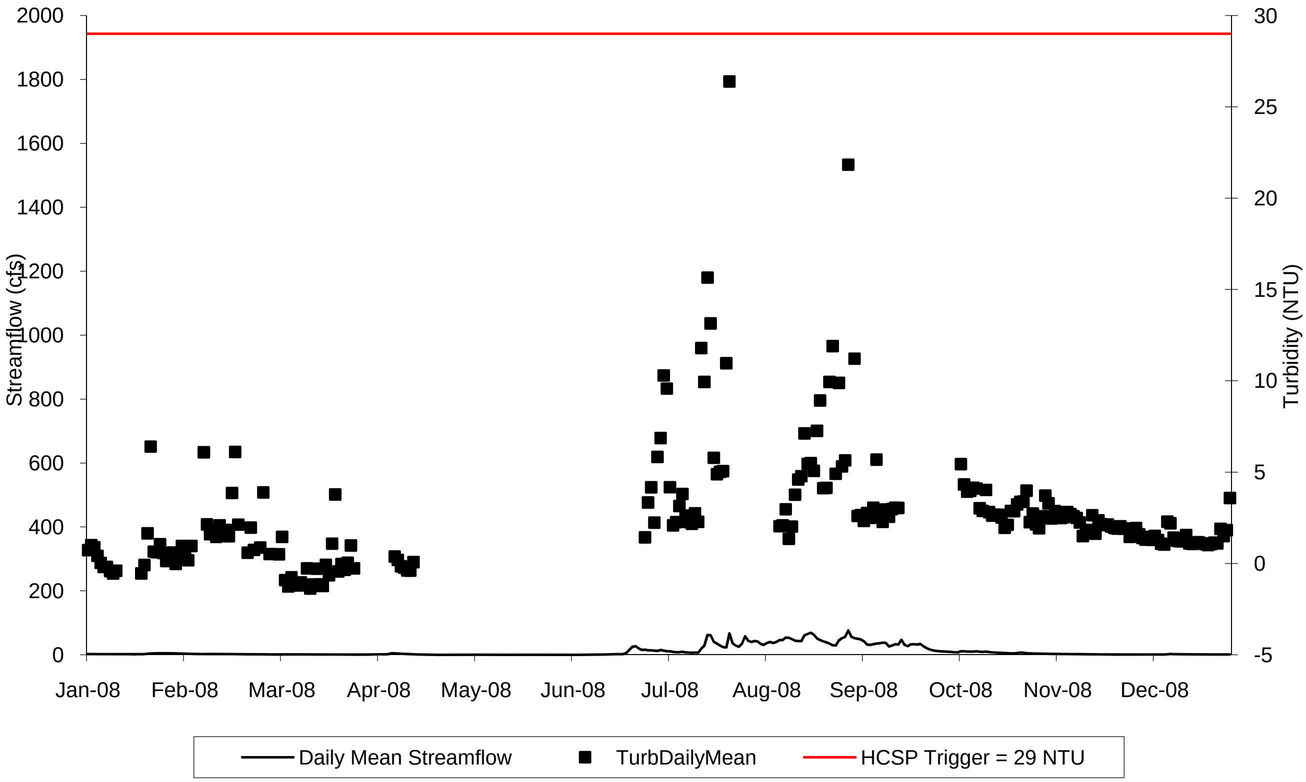

Figure 28. Relationship Between Daily Mean Turbidity (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow (from USGS Provisional Data) for 2008. Minimum pH Detection Limit = 0.1 NTU.

Color

All color values in 2008 were above the trigger level of 25 Platinum-Cobalt units (PCU) (indicating desirable conditions) during all events at all stations (Figure 29). The color levels at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$) (Figures 30 and 31, Table 14). Color levels were significantly different among stations in 2003 - 2008 (ANOVA, $F = 3.38$, $p = 0.02$, Table 15), with HCSW-2 having higher color than other stations (Duncan's multiple range test, $p < 0.05$). Color was positively correlated with streamflow, rainfall, and NPDES discharge at HCSW-1 and HCSW-4 (Spearman's rank correlations $0.28 < r < 0.67$) (Table 16).

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. 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 water during the drier parts of the year or during dry years like 2006 and 2007. This agricultural factor is also noted below with respect to several other parameters.

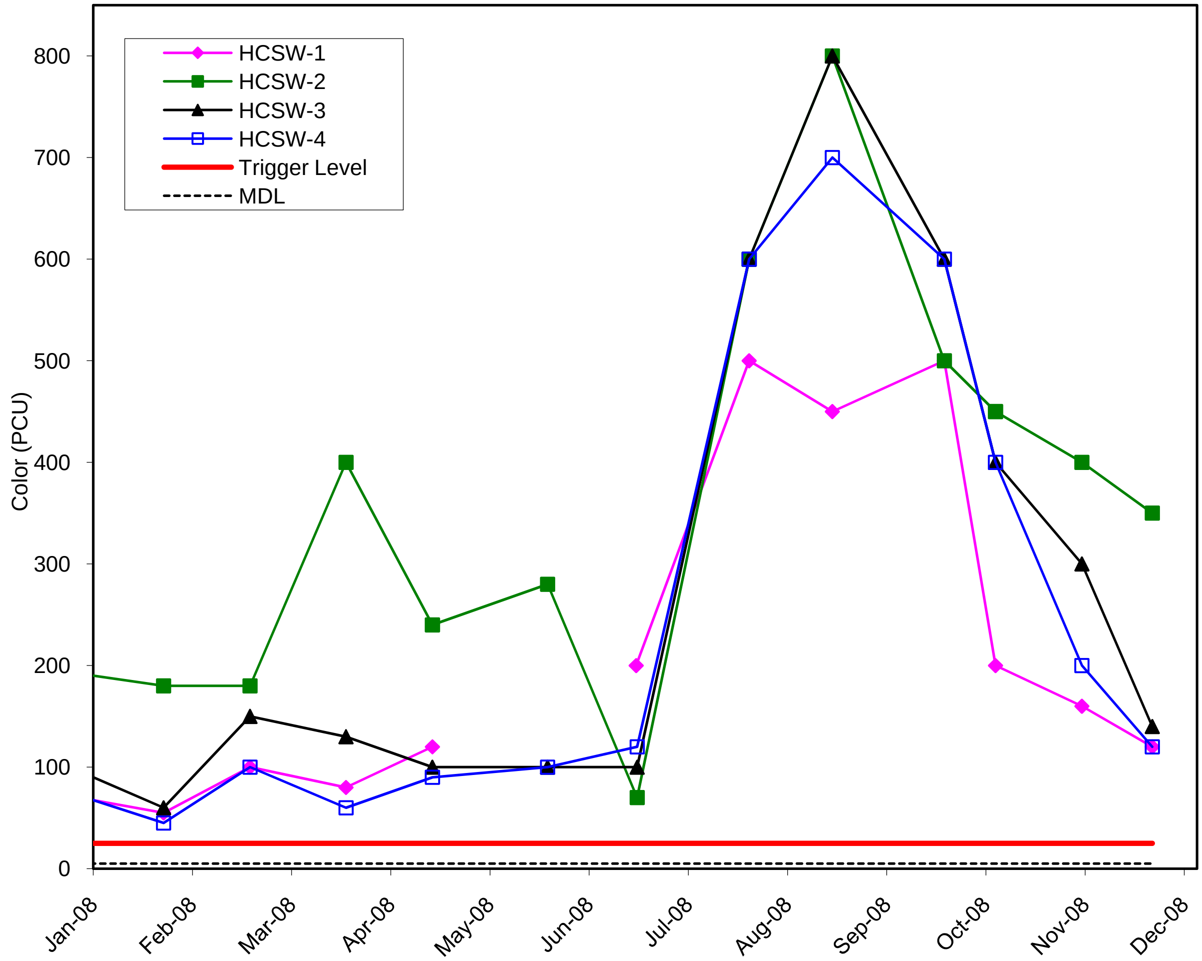

Figure 29. Color Levels Obtained During Monthly HCSP Water Quality Sampling in 2008.

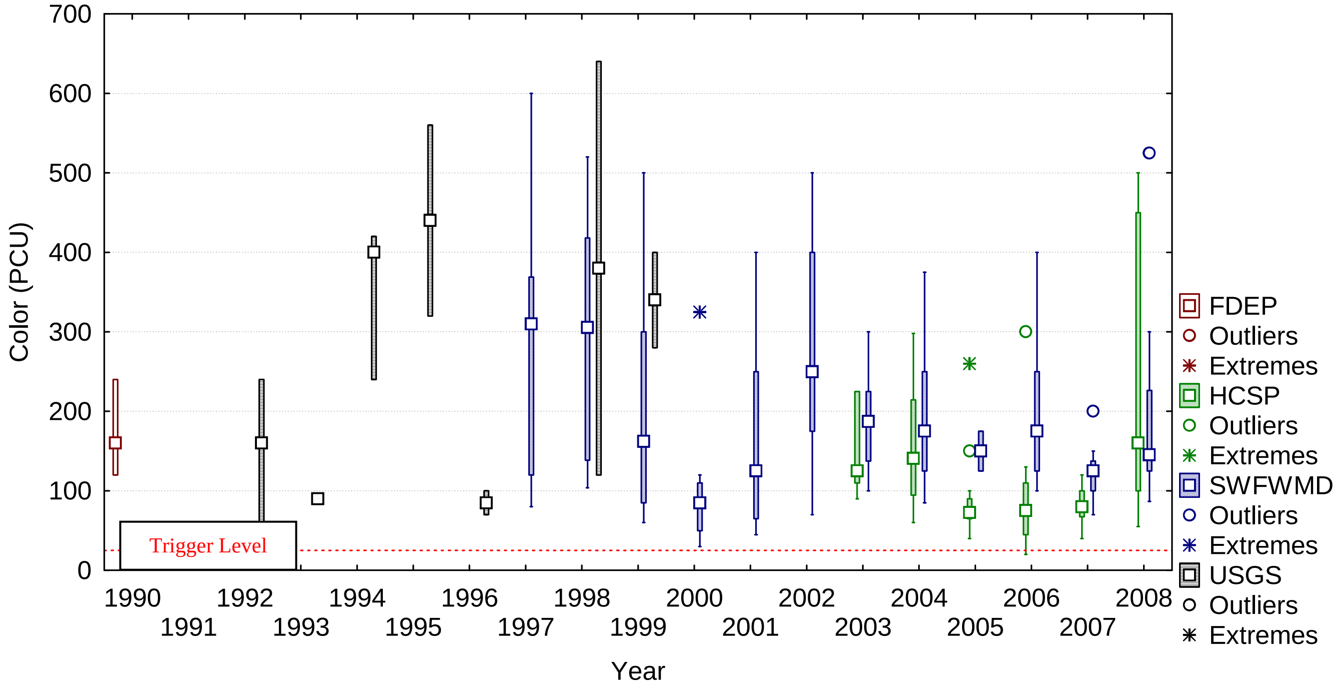

Figure 30. HCSW-1 Values of Color Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

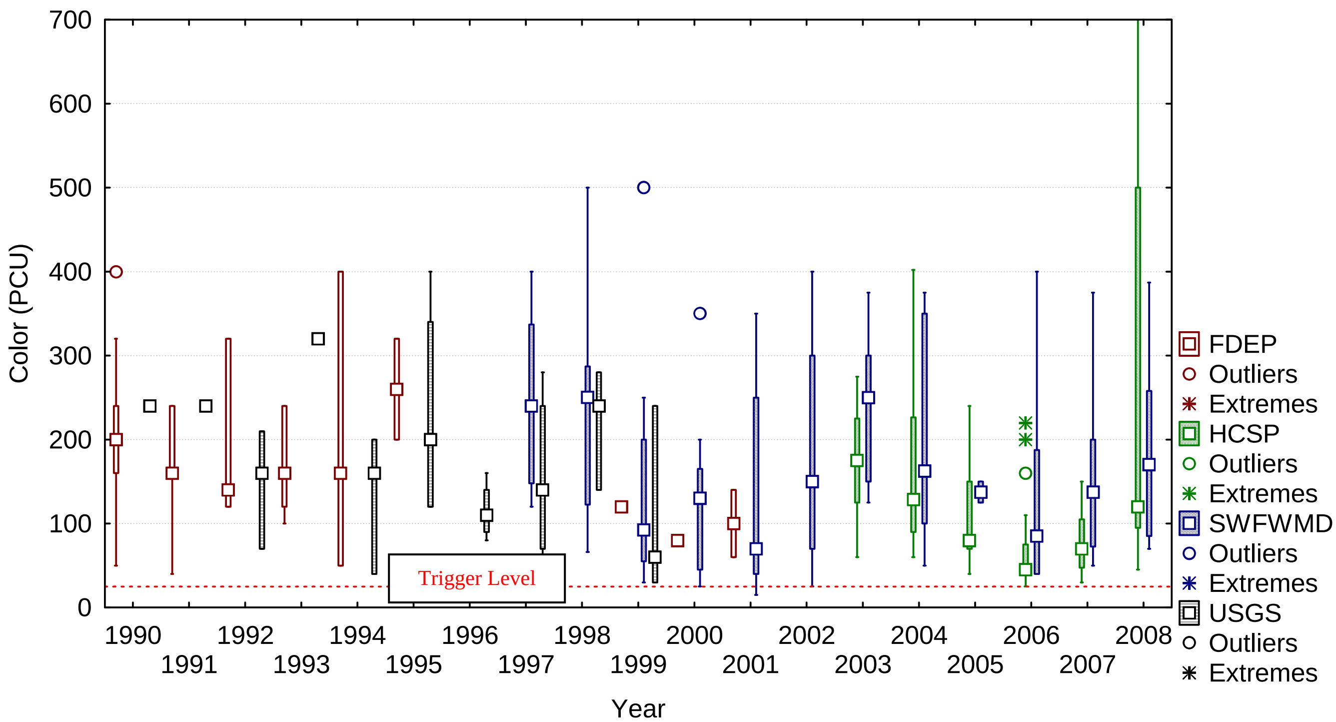

Figure 31. HCSW-4 Values of Color Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

5.2.3 Nutrients

Total Nitrogen

Total nitrogen[2] concentrations were between 0 and 2.0 mg/l during most sampling events at all stations in 2008 (Figure 32). During 2008, total nitrogen was consistently below the trigger value of 3.0 mg/l, except in January 2008 at HCSW-2 (likely lab error). 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 and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$) (Figures 33 and 34, Table 14). Total nitrogen concentrations were significantly different among stations for 2003 – 2008 (ANOVA, $F = 3.4$, $p = 0.02$, Table 15), with lower concentrations at HCSW-1 than other stations (Duncan's multiple range test, $p < 0.05$). Total nitrogen was weakly positively correlated with streamflow, rainfall, and NPDES discharge at HCSW-1(Spearman's rank correlations $0.28 < r < 0.44$, $p < 0.05$) but only streamflow at HCSW-4 (Spearman's rank correlation $r = 0.31$, $p < 0.05$) (Table 16).

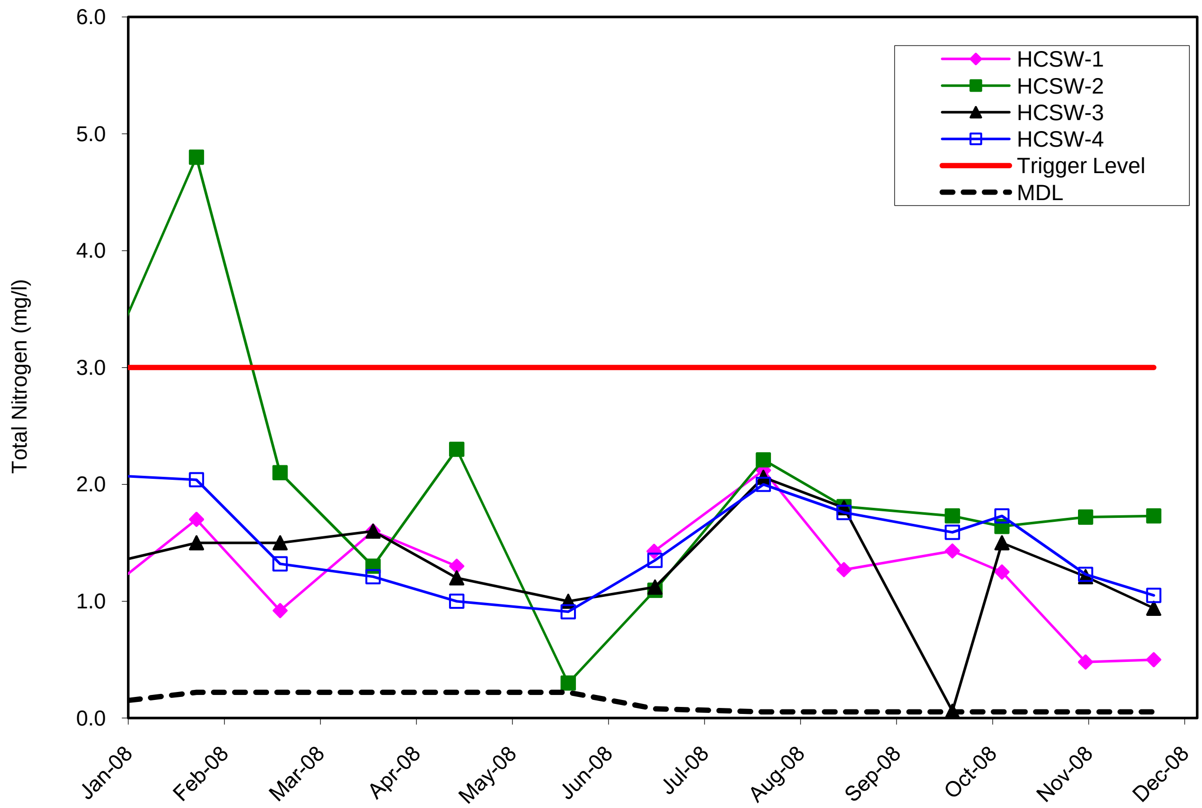

Figure 32. Total Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2008.

2 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.

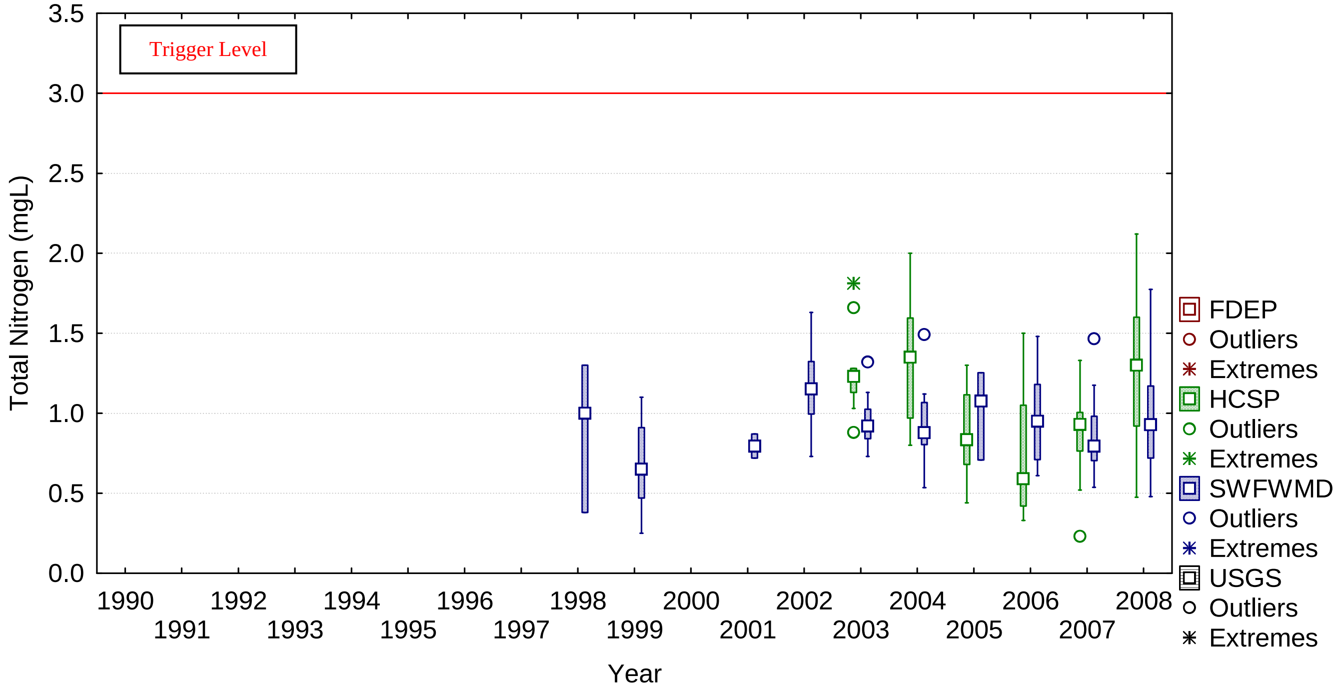

Figure 33. HCSW-1 Values of Total Nitrogen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

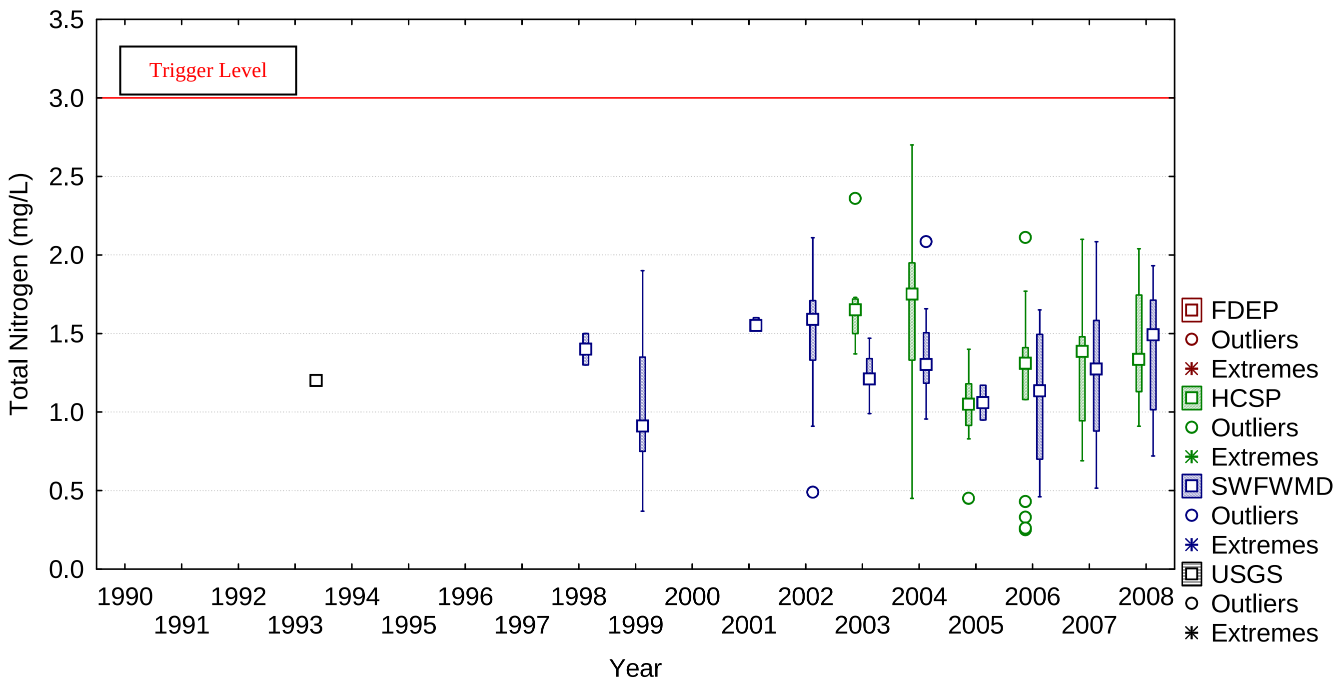

Figure 34. HCSW-4 Values of Total Nitrogen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

Total Kjeldahl Nitrogen

As noted above, total Kjeldahl nitrogen (TKN) comprised the majority of total nitrogen in most samples (Figure 35, compare with Figure 32). The HCSP does not have an independent trigger value for TKN. The total Kjeldahl nitrogen concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$) (Figures 36 and 37, Table 14). Concentrations of TKN were significantly different among stations (ANOVA, $F = 6.98$, $p = 0.0002$, Table 15), with HCSW-2 having a higher concentration than the other three stations (Duncan's multiple range test, $p < 0.05$). Total Kjeldahl nitrogen was positively correlated with streamflow, rainfall, and NPDES discharge at HCSW-4 (Spearman's rank correlations $0.37 < r < 0.42$) but not at HCSW-1 (Table 16).

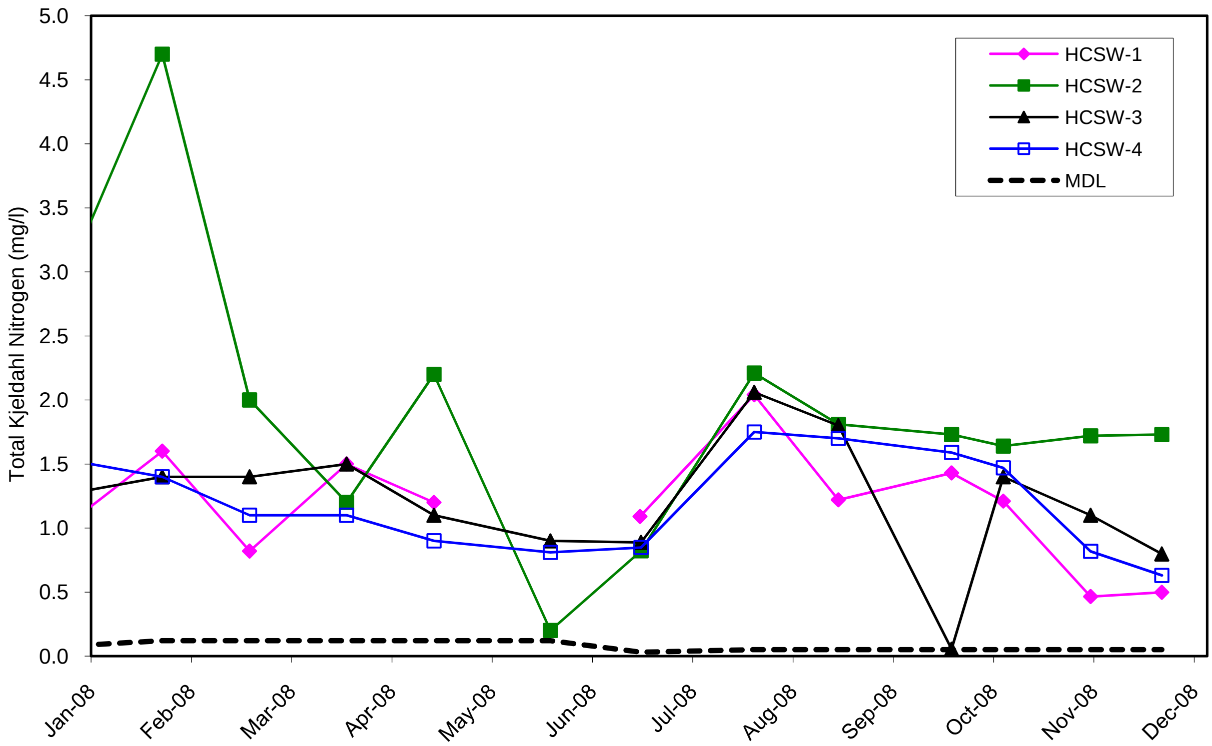

Figure 35. Total Kjeldahl Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2008.

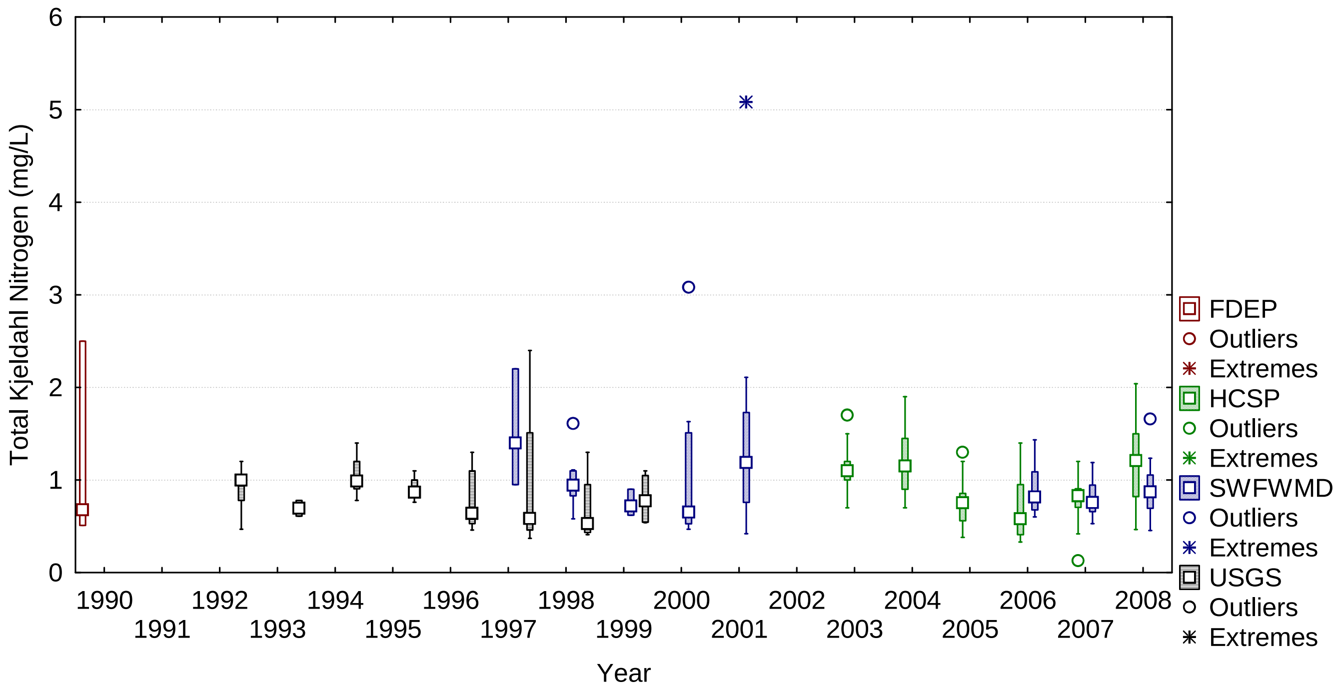

Figure 36. **HCSW-1 Values of Total Kjeldahl Nitrogen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.**

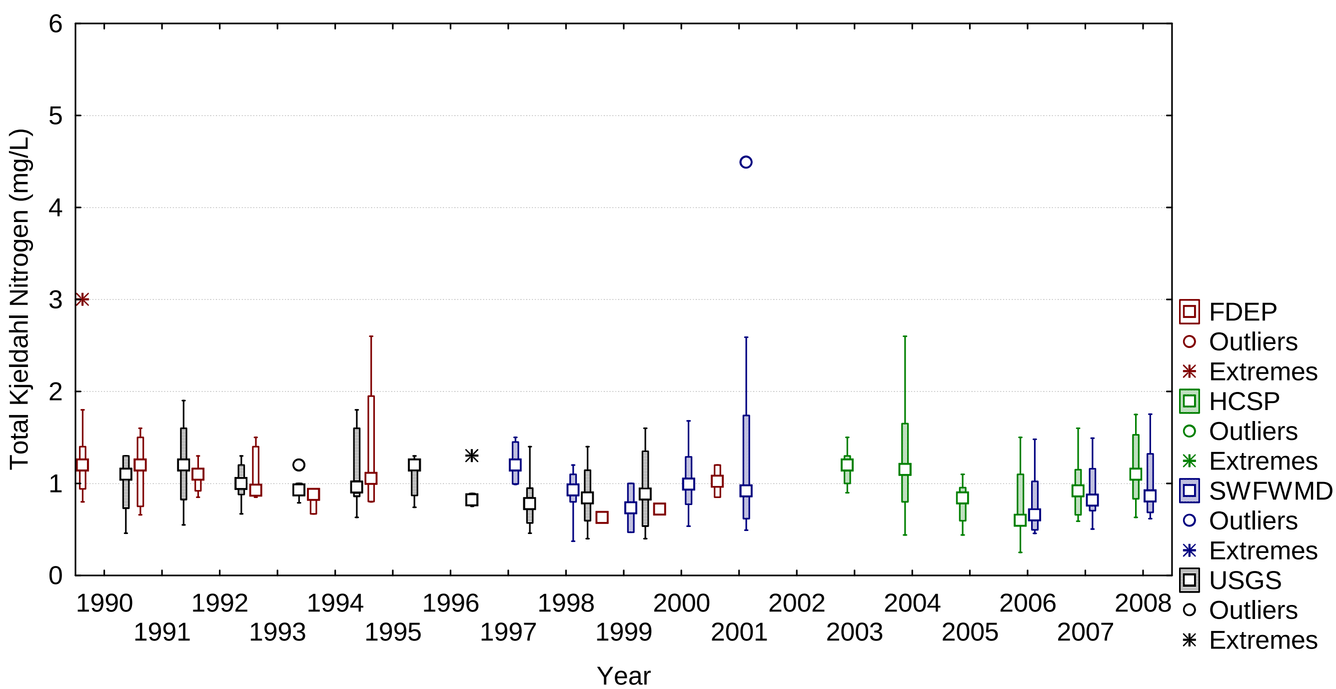

Figure 37. **HCSW-4 Values of Total Kjeldahl Nitrogen Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.**

Nitrate-Nitrite Nitrogen

Nitrate+nitrite concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources, but could not be analyzed for monotonic trends or correlations with water quantity because of changes in MDL's over the course of the HCSP (Figures 39 and 40). Based on an alternate trend analysis performed on data collected by SWFWMD from 2003-2008, there are no monotonic trends in nitrate+nitrite for HCSW-1 or HCSW-4 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 14).

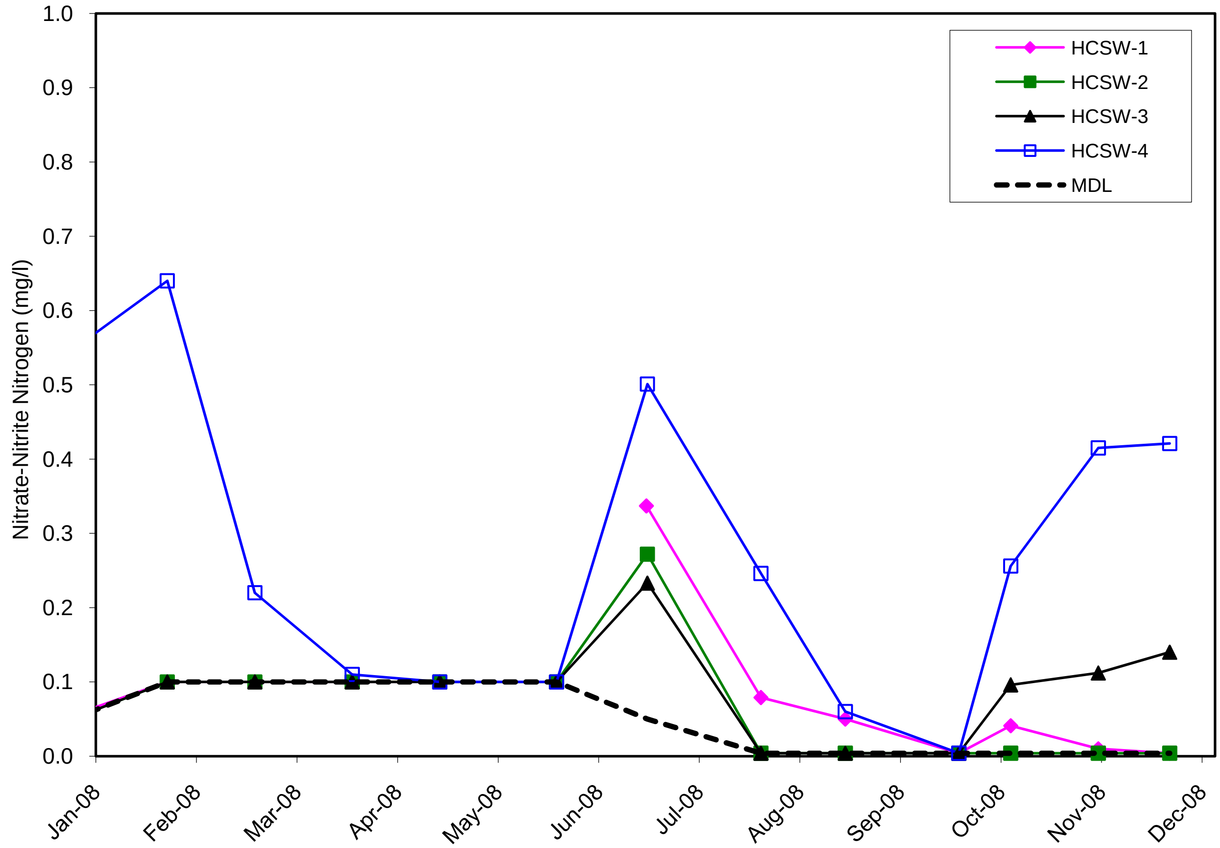

Figure 38. Nitrate-Nitrite Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2008.

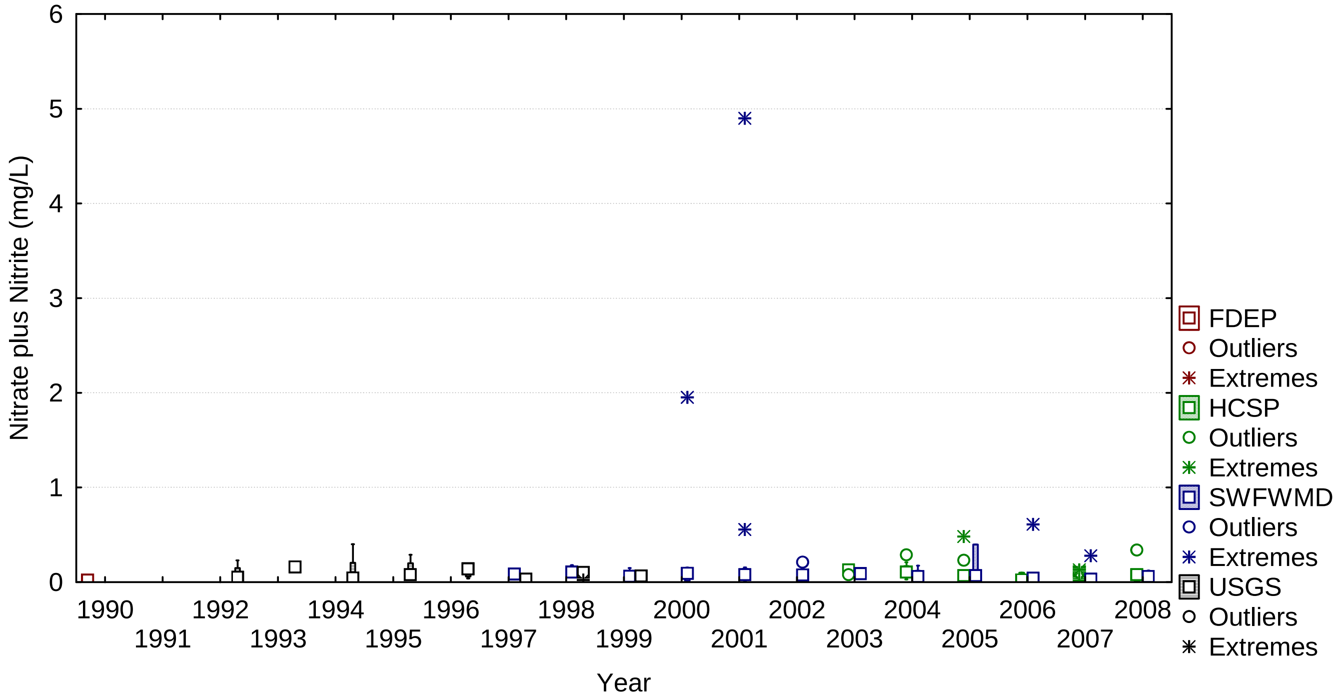

Figure 39. HCSW-1 Values of Nitrate plus Nitrite Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

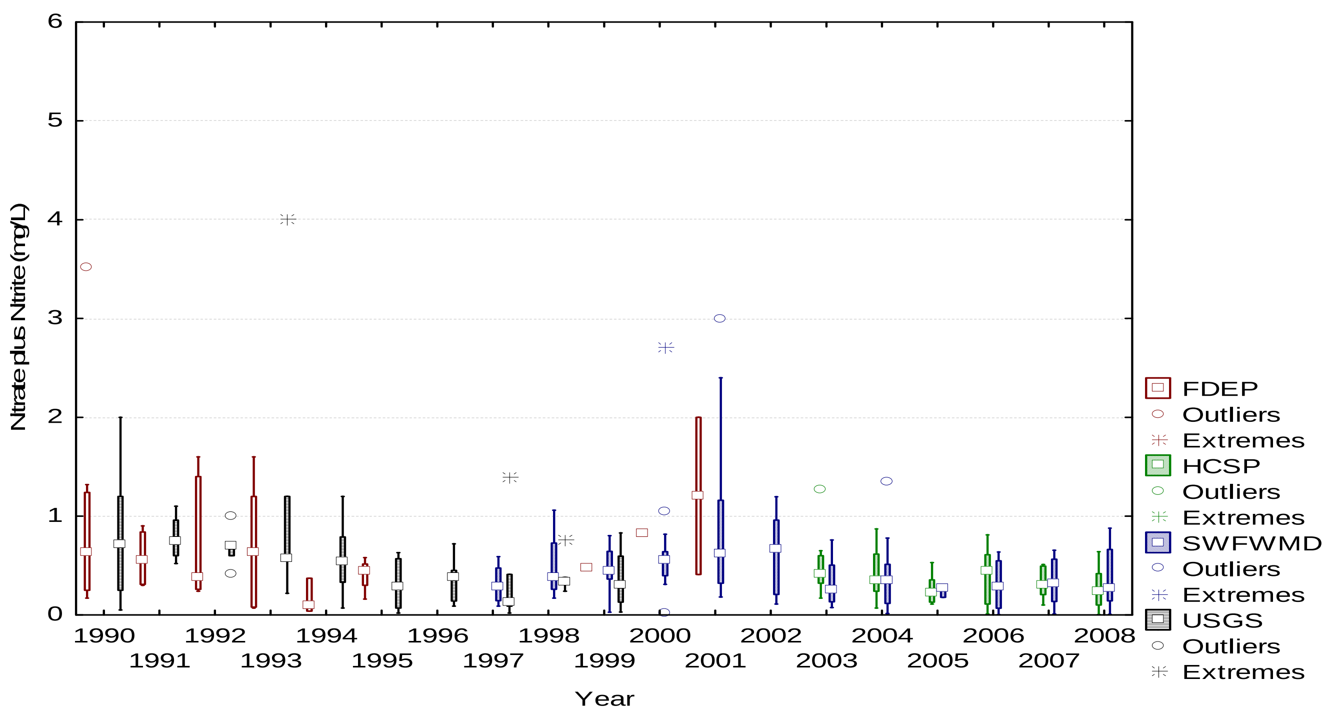

Figure 40. HCSW-4 Values of Nitrate plus Nitrite Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

Total Ammonia Nitrogen

Total ammonia nitrogen levels were within a similar range during all sampling events at all stations (Figure 41). Three stations (HCSW-2, HCSW-3 and HCSW-4) exceeded the HCSP trigger value of 0.3 mg/L during July 2008. It is likely that organic decomposition from stormwater runoff during June to August storm events may have increased the in-stream concentration of organic nitrogen and ammonia, which slightly increased the overall total nitrogen concentration. At the same time, dissolved oxygen at several stations was very low, probably from additional oxygen demand from the large marsh above HCSW-2. Depressed dissolved oxygen resulted in a lower rate of nitrification of ammonia to nitrite and nitrate. The ammonia concentrations at HCSW-1 and HCSW-4 measured by the HCSP are at levels within the range for the last decade of data (Figures 42 and 43), but could not be analyzed for monotonic trends or correlations with water quantity because of changes in MDL's over the course of the HCSP. Based on an alternative trend analysis performed on data collected by SWFWMD from 2003-2008, there are no monotonic trends in total ammonia nitrogen for HCSW-1 or HCSW-4 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 14).

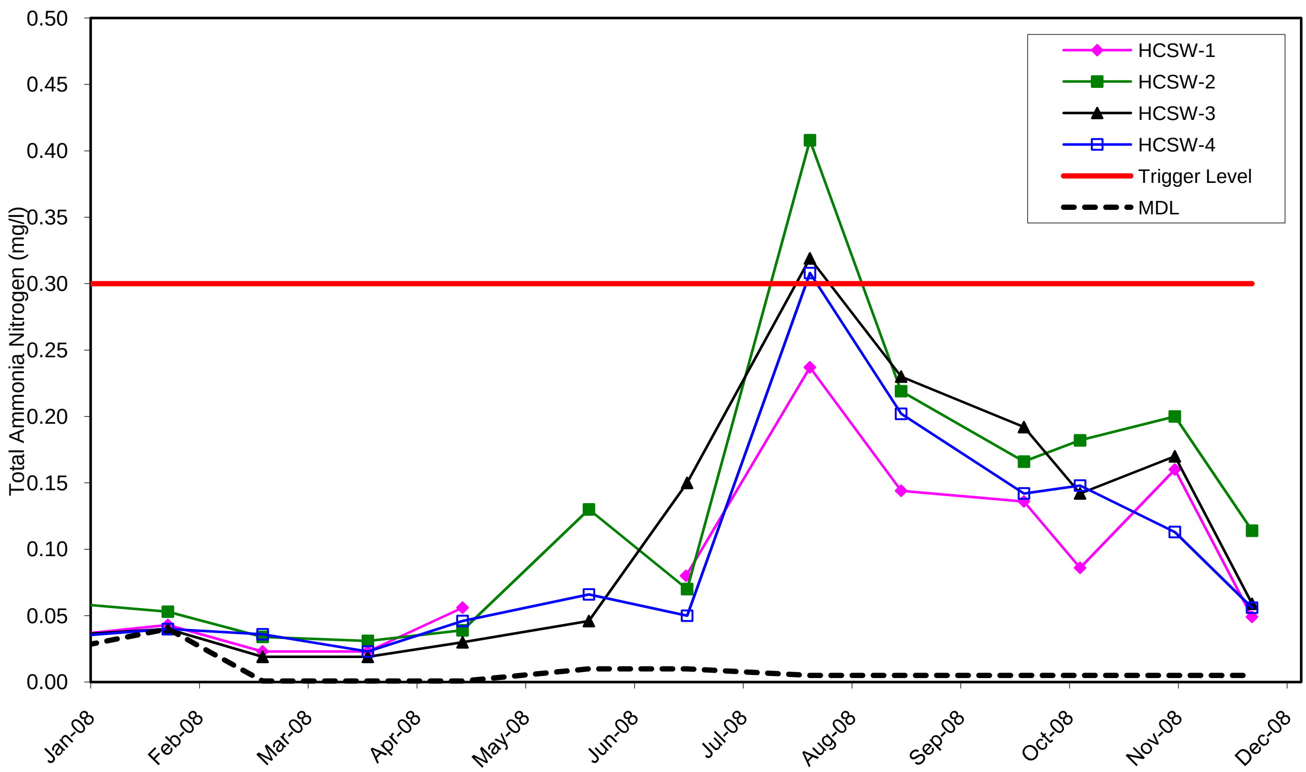

Figure 41. Total Ammonia Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2008.

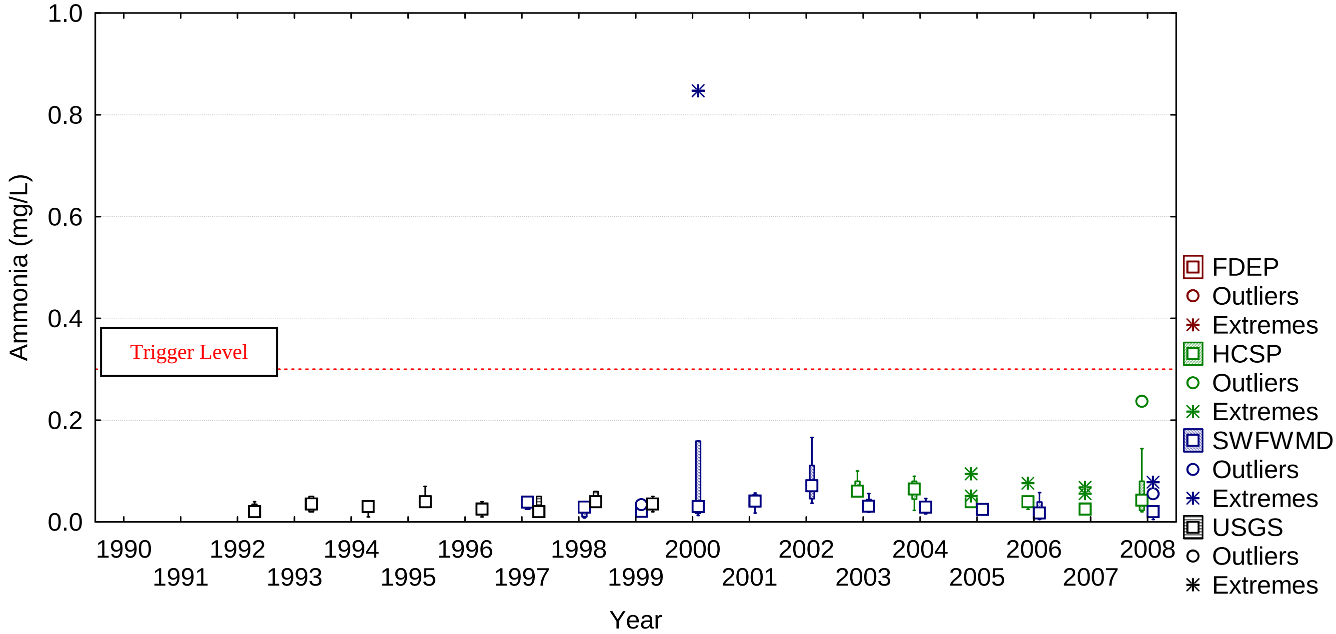

Figure 42. HCSW-1 Values of Ammonia Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

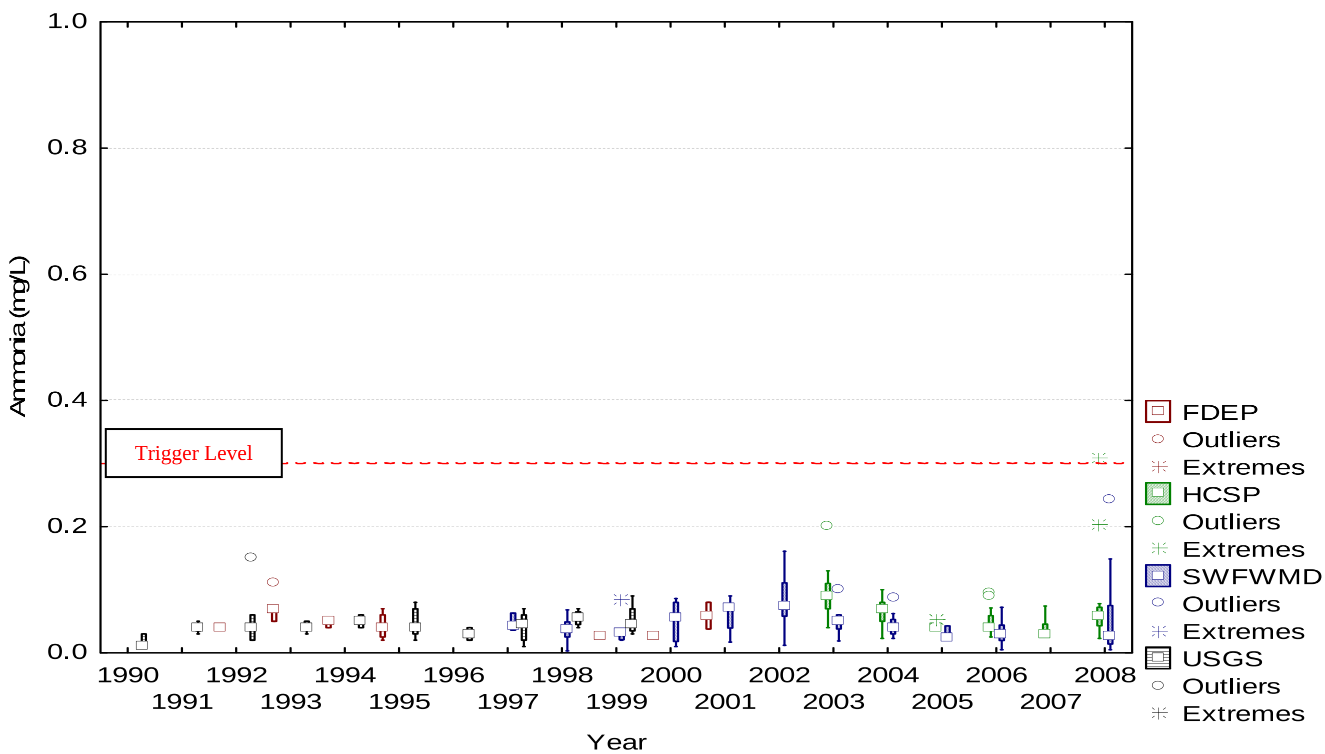

Figure 43. HCSW-4 Values of Ammonia Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

Orthophosphate

Levels of orthophosphate were well below the trigger level of 2.5 mg/l in 2008 (Figure 44). The orthophosphate concentrations at HCSW-1 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$), but there was an increasing monotonic trend at HCSW-4 (Seasonal Kendall Tau = 0.58, $p = 0.01$, Sen slope estimator = 0.02 mg/L per year) (Figures 45 and 46, Table 14). Although the trend analysis at HCSW-4 indicates that orthophosphate may be increasing by about 0.02 mg/L per year from 2003 to 2008, this increase is not ecologically significant (the trend is very small when compared to the overall concentration of orthophosphate in the stream). The trend at HCSW-4 could be related to intensity of fertilizer use in agricultural areas in the downstream basin of Horse Creek or extreme differences in rainfall between the beginning and end of the sampling period. Given that HCSW-1 does not show a trend, it is unlikely that mining activities are contributing to the orthophosphate changes at HCSW-4.

Orthophosphate concentrations were significantly different among stations (ANOVA, $F = 20.9$, $p < 0.0001$, Table 15), with concentrations at HCSW-2 lower and HCSW-4 higher than other stations (Duncan's multiple range test, $p < 0.05$). Orthophosphate was negatively correlated with streamflow at HCSW-1, only (Spearman's rank correlation $r = -0.46$, $p < 0.05$) (Table 16). While the observed phosphorus levels would be considered quite high in some portions of the state, they are well within the expected range for streams in the Bone Valley Phosphate Region.

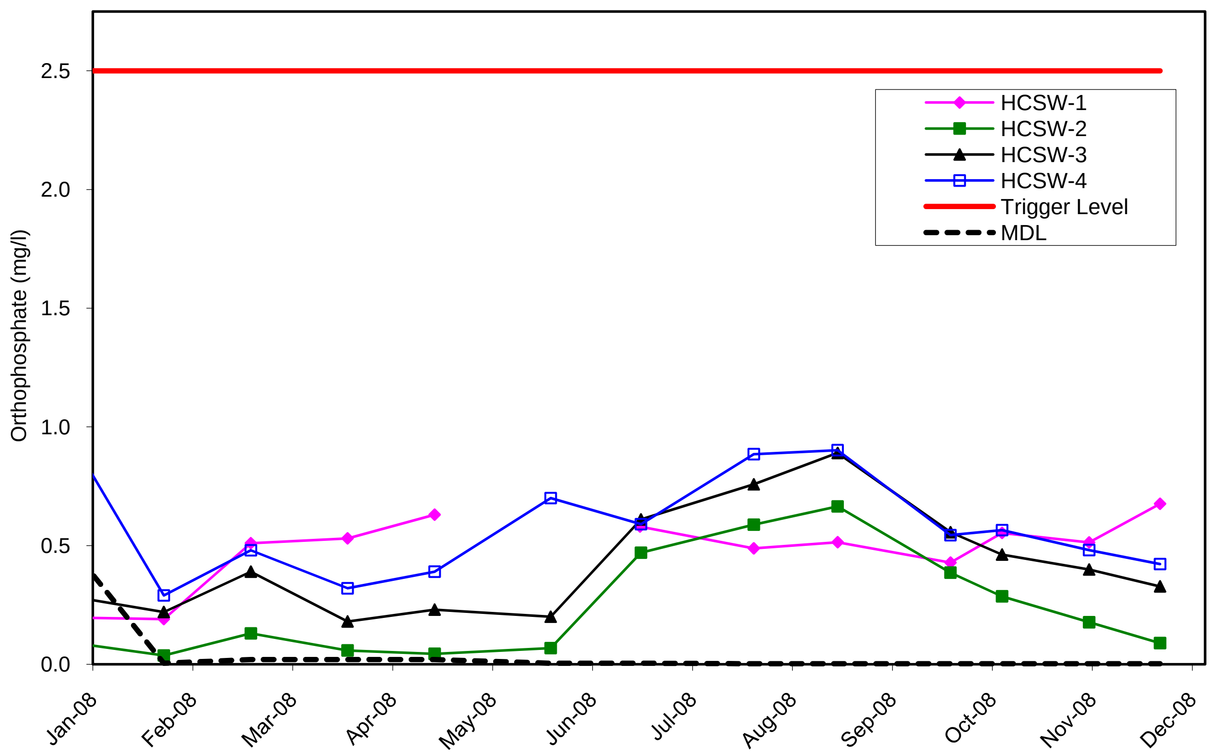

Figure 44. Orthophosphate Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2008.

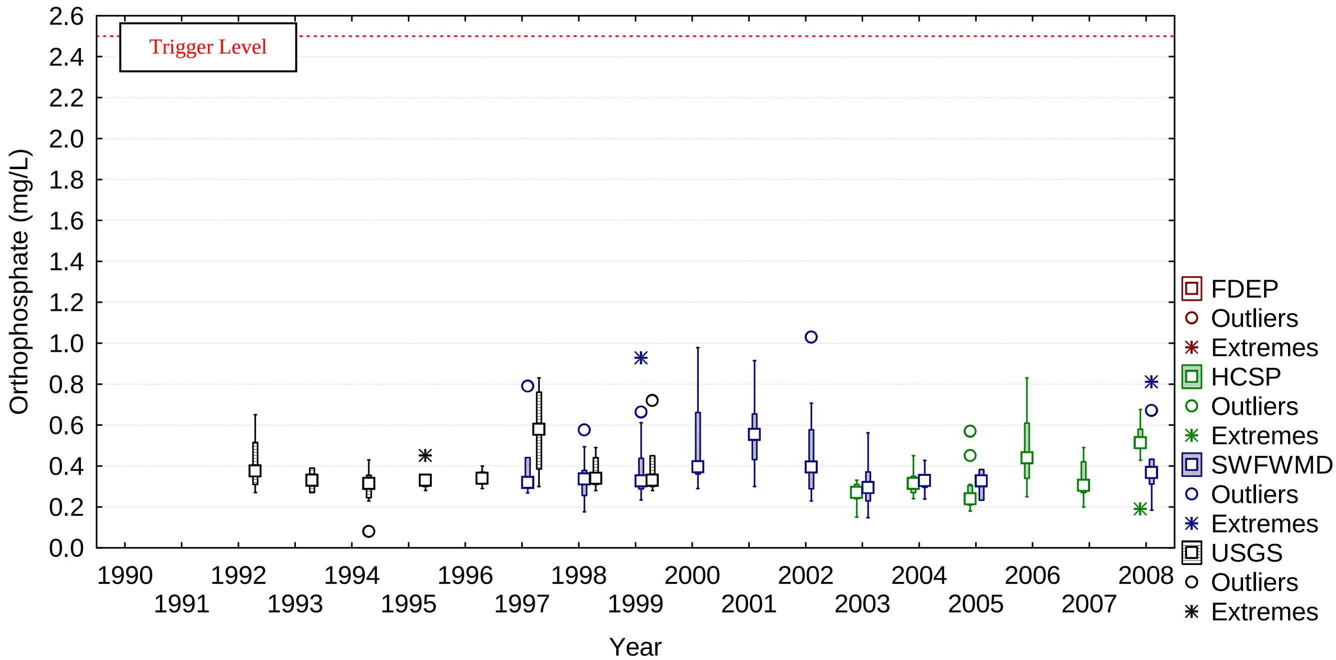

Figure 45. **HCSW-1 Values of Orthophosphate Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.**

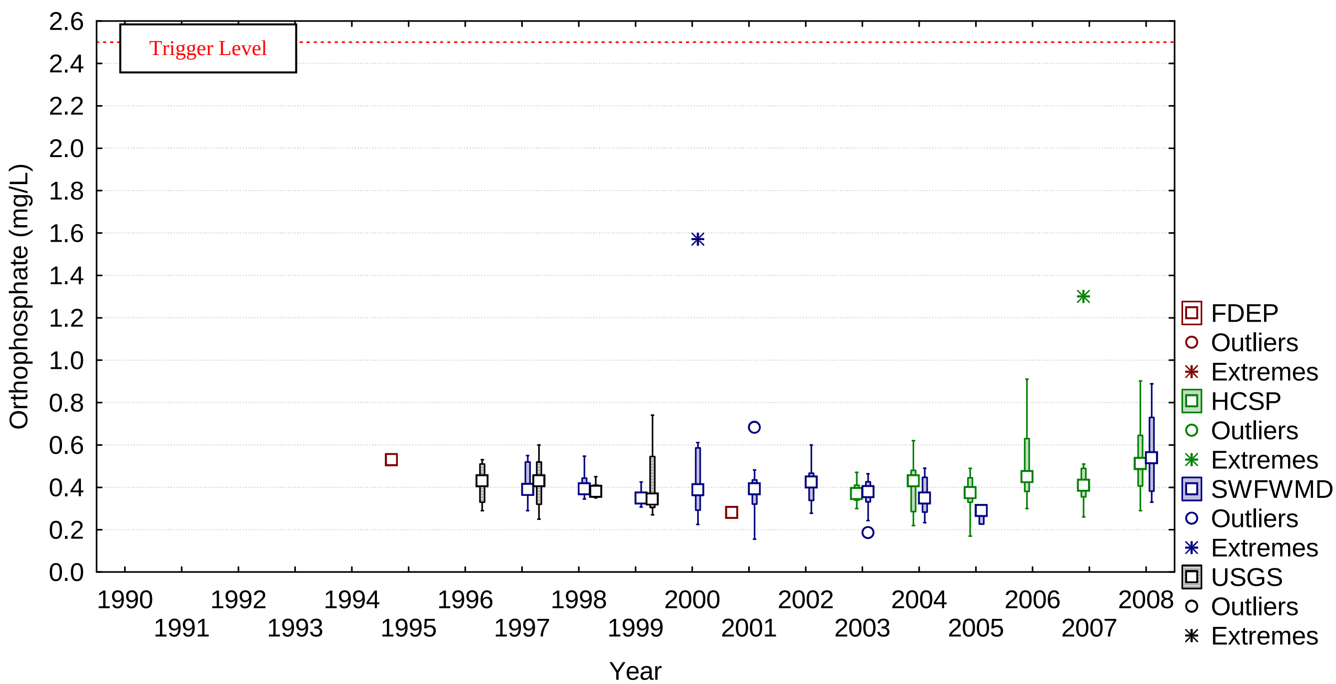

Figure 46. **HCSW-4 Values of Orthophosphate Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.**

Chlorophyll-a

Chlorophyll *a* values were well below the trigger level of 15 mg/m^3 during most sampling events at three stations in 2007, but HCSW-2 exceeded the trigger value for chlorophyll *a* in July of 2008 (Figure 47). The chlorophyll *a* concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau, $p > 0.05$) (Figures 48 and 49, Table 14). Chlorophyll *a* concentrations were significantly different between stations (ANOVA, $F = 10.5$, $p < 0.0001$, Table 15), with HCSW-2 significantly higher than other stations (Duncan's multiple range test, $p < 0.05$).). Chlorophyll *a* was not correlated with streamflow, rainfall, and NPDES discharge at HCSW-1 or HCSW-4 (Spearman's rank correlation, $p > 0.05$) (Table 16).

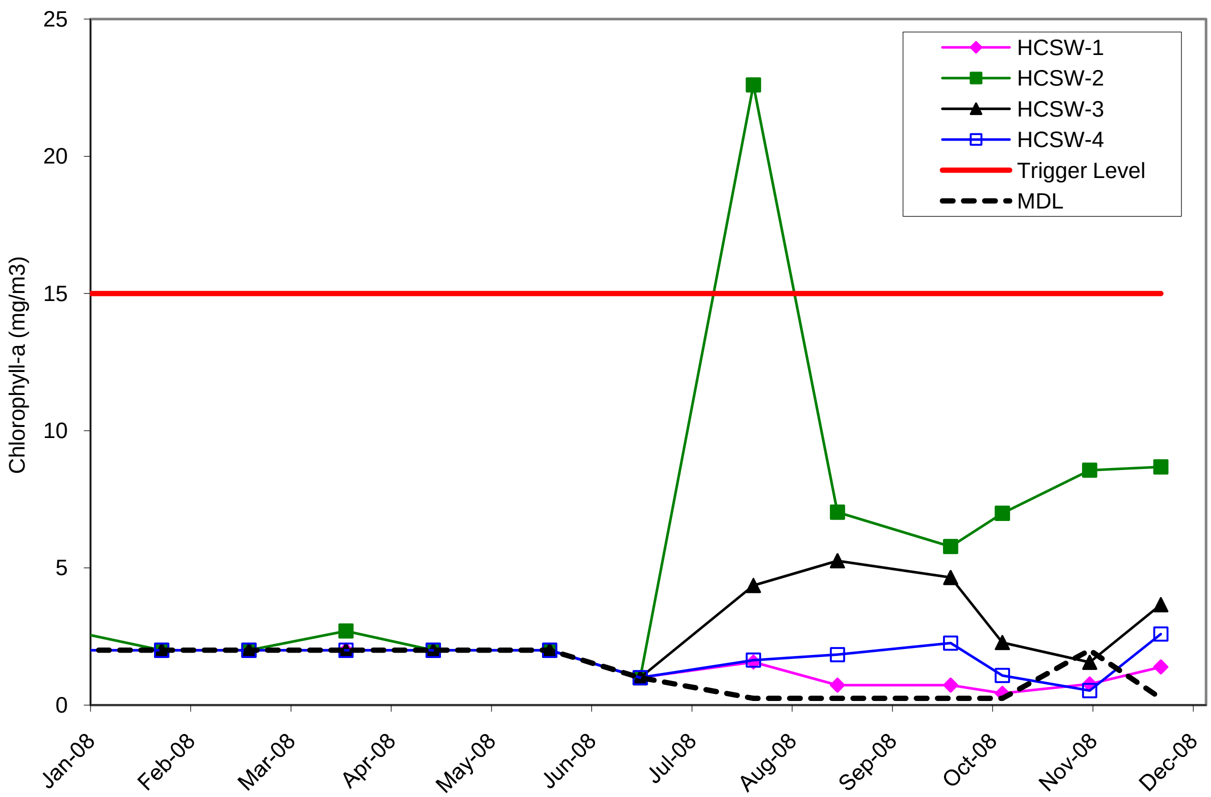

Figure 47. Chlorophyll-a Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2008.

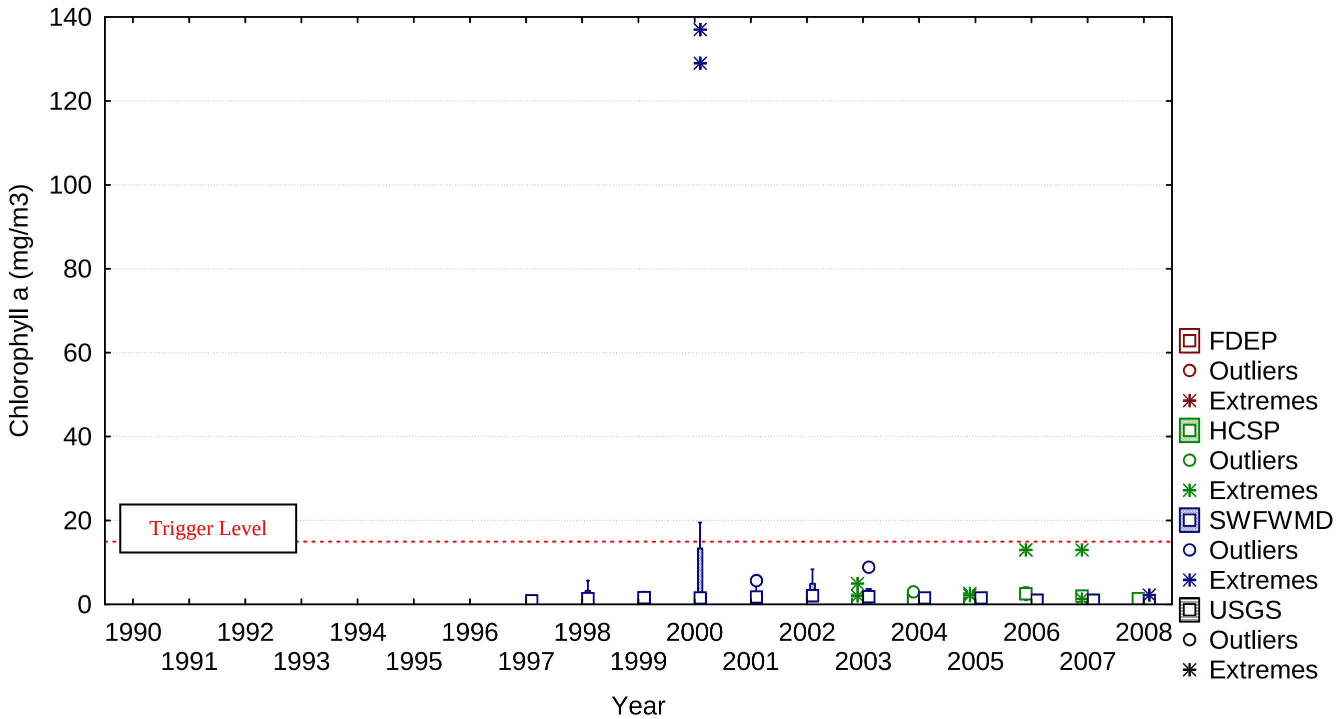

Figure 48. HCSW-1 Values of Chlorophyll a Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

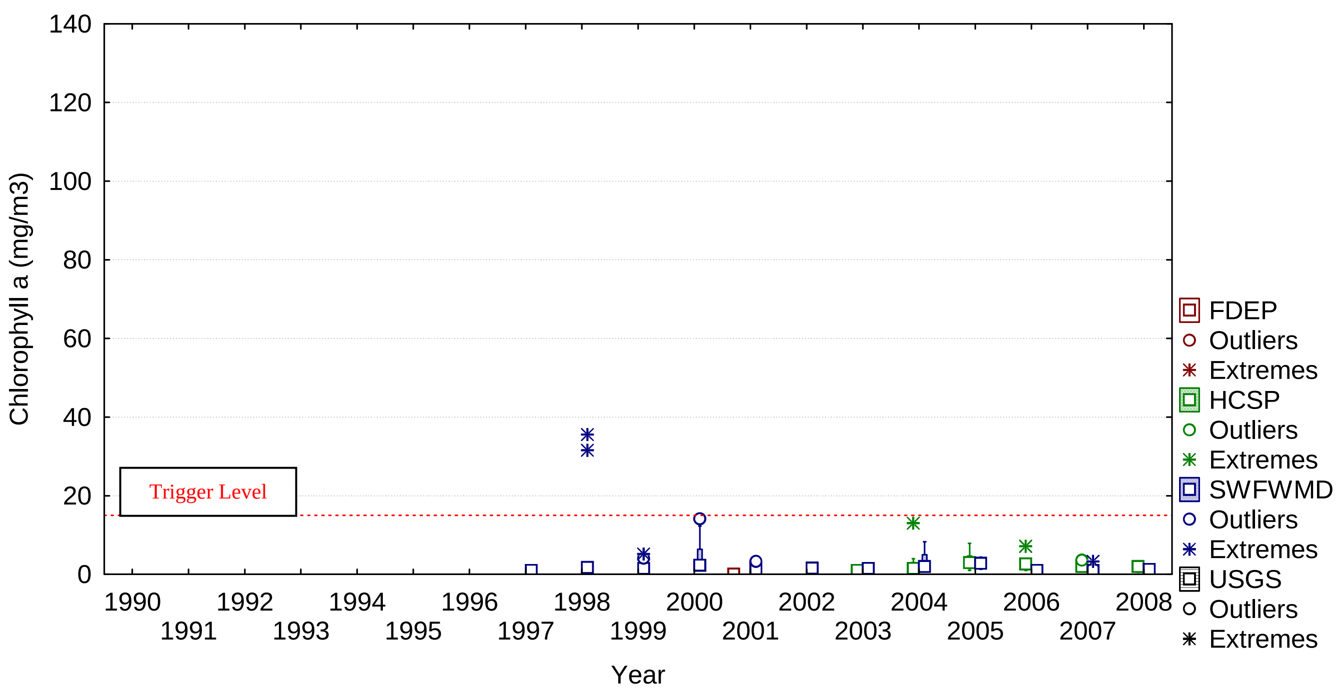

Figure 49. HCSW-4 Values of Chlorophyll a Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

5.2.4 Dissolved Minerals, Mining Reagents and Radionuclides

Specific Conductivity

During all sampling events and stations, specific conductivity levels were well below the trigger level of ≤1275 µmhos/cm[2] (Figure 50). Levels of specific conductivity determined during each biological sampling event were consistent with those obtained during monthly water quality sampling events (Figure 50). Mean daily specific conductivity values obtained from the recorder at HCSW-1 were within the range obtained during the monthly water quality sampling events (Figure 53). The specific conductivity at HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited neither increasing nor decreasing monotonic trends since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 14), but there was an increasing monotonic trend at HCSW-1 (Seasonal Kendall Tau with LOWESS = 0.47, $p = 0.03$, Sen slope = 15.31 umhos/cm per year) (Figures 51 and 52). Given that specific conductivity at HCSW-1 is correlated with streamflow but not NPDES discharge, it is likely that this trend is strongly influenced by the dry conditions and subsequent higher than average conductivity in 2006 to 2008 rather than mining activities.

Specific conductivity was significantly different among stations (ANOVA, $F = 24.7$, $p < 0.0001$, Table 15), with the HCSW-1 and HCSW-2 lower than the other stations (Duncan's multiple range test, $p < 0.05$). Specific conductivity was negatively correlated with streamflow, rainfall, and NPDES discharge at HCSW-4 (Spearman's rank correlations $-0.41 > r > -0.87$, $p < 0.05$), but only streamflow at HCSW-1 (Spearman's rank correlation r = -41, $p < 0.05$) (Table 16).

Higher conductivity at downstream stations was probably the cumulative result of contributions of groundwater that either seeped into Horse Creek directly or ran off of agricultural 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 also 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, which generally contains more concentrated dissolved ions than surface water, is closer to the surface in the lower Horse Creek Basin, making seepage into the stream more likely. Because 2006 to 2008 have been dryer-than-average years, specific conductivity has increased even more at the downstream stations as baseflow contributions and agricultural runoff increase.

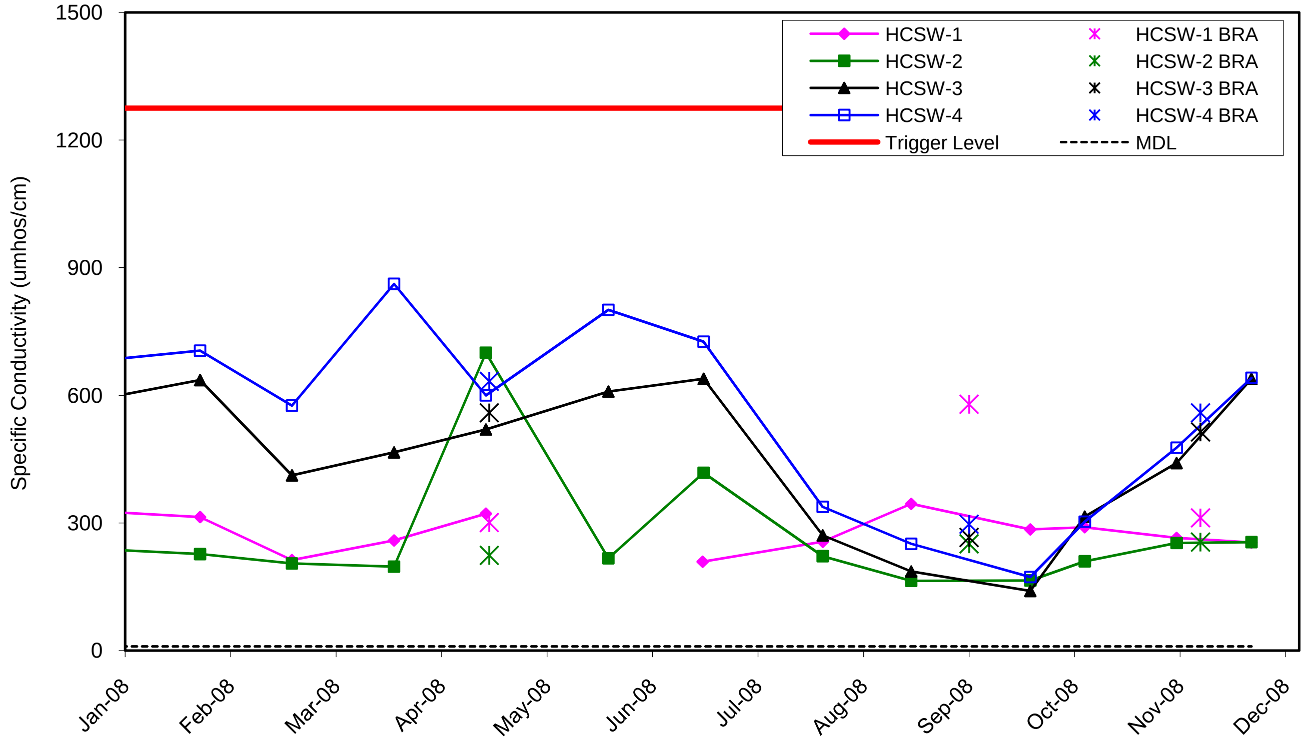

Figure 50. Levels of Specific Conductivity Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2008.

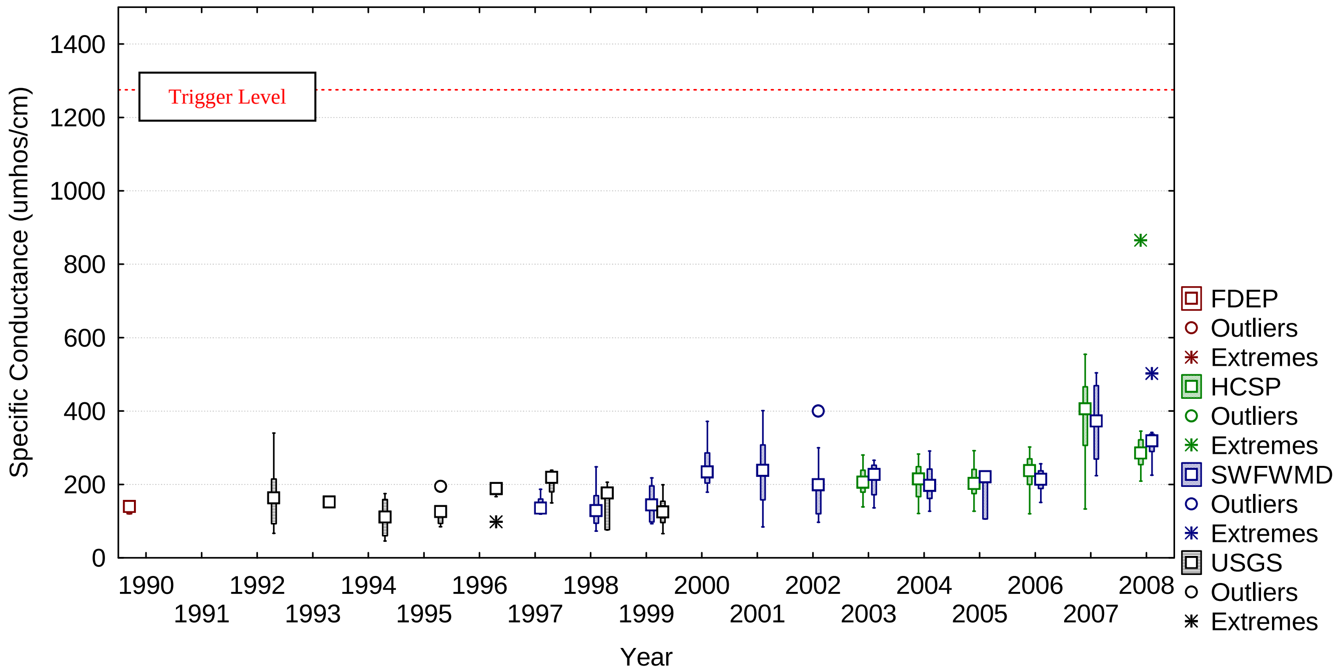

Figure 51. HCSW-1 Values of Specific Conductance Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

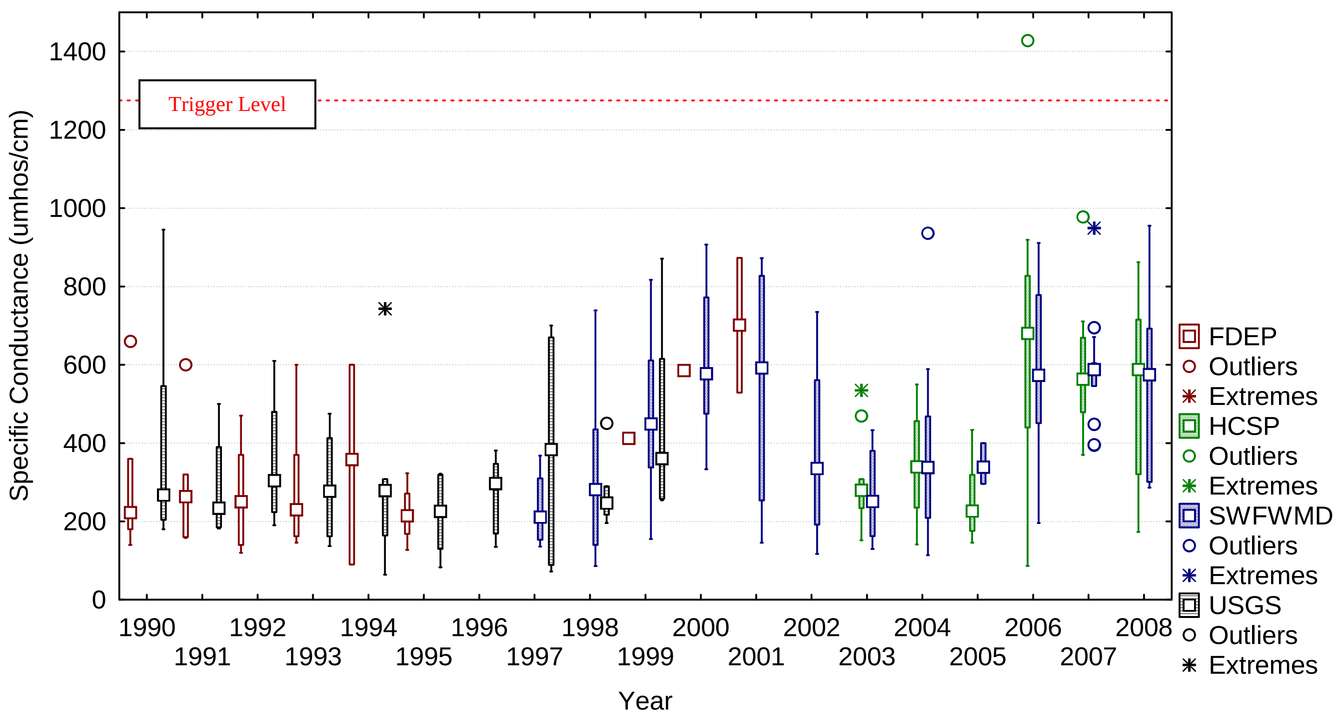

Figure 52. HCSW-4 Values of Specific Conductance Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

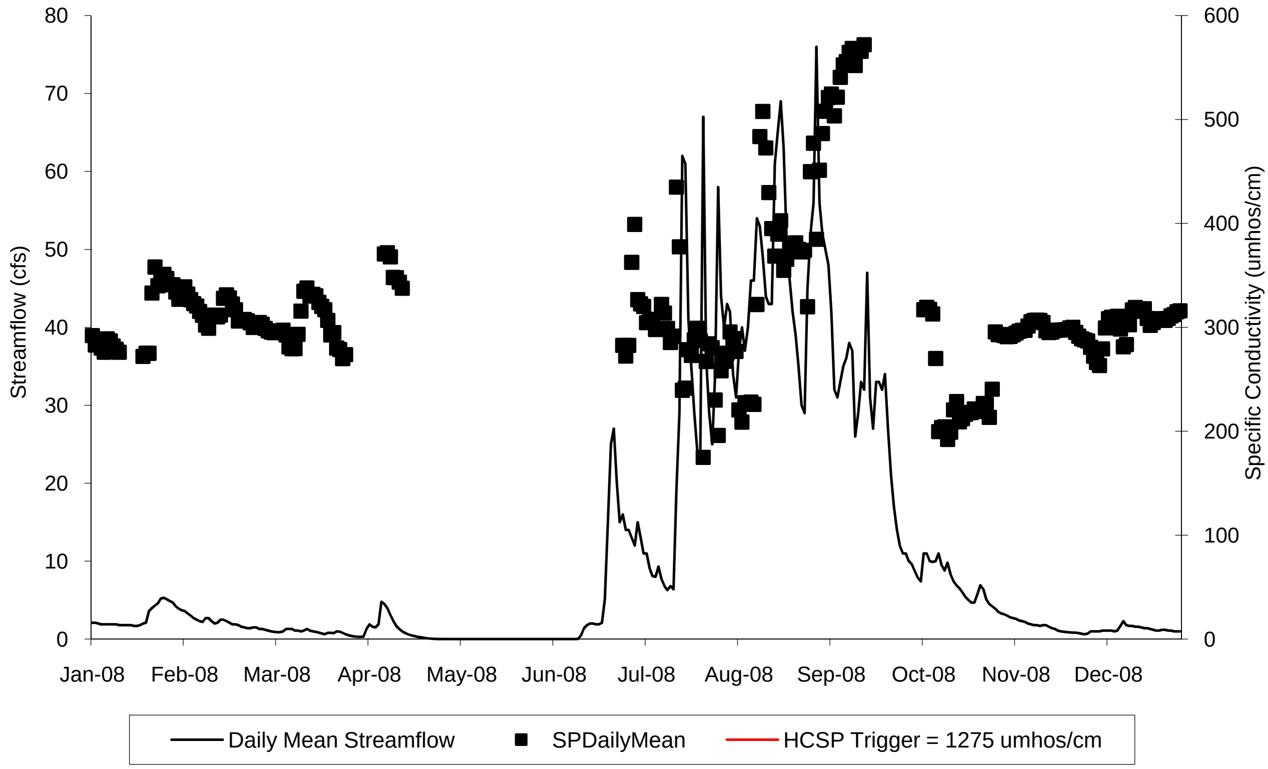

Figure 53. Relationship Between Daily Mean Specific Conductivity (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow (from USGS Provisional Data) for 2008. Min. Detection Limit = 100 umhos/cm.

Dissolved Calcium

Calcium levels were lower than the trigger value of 100 mg/l at all stations during most events, except during March and May 2008 at HCSW-4 when rainfall and streamflow were low. The calcium concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources, and show no monotonic trend from 2003 to 2008 (Seasonal Kendall Tau with LOWESS, $p > 0.05$) (Figures 55 and 56, Table 14).

Concentrations of calcium were significantly different between stations (ANOVA, $F = 36.72$, $p < 0.001$), with significantly higher levels at HCSW-4 than the other stations (Duncan's post hoc test, $p < 0.05$) (Figure 54, Table 15). As with specific conductivity, calcium levels were higher downstream where groundwater contributes more to baseflow. Calcium was negatively correlated with the streamflow, rainfall, and NPDES discharge at HCSW-4 and streamflow and rainfall at HCSW-1 (Spearman's rank correlations $-0.31 < r < -0.88$, $p < 0.05$) (Table 16).

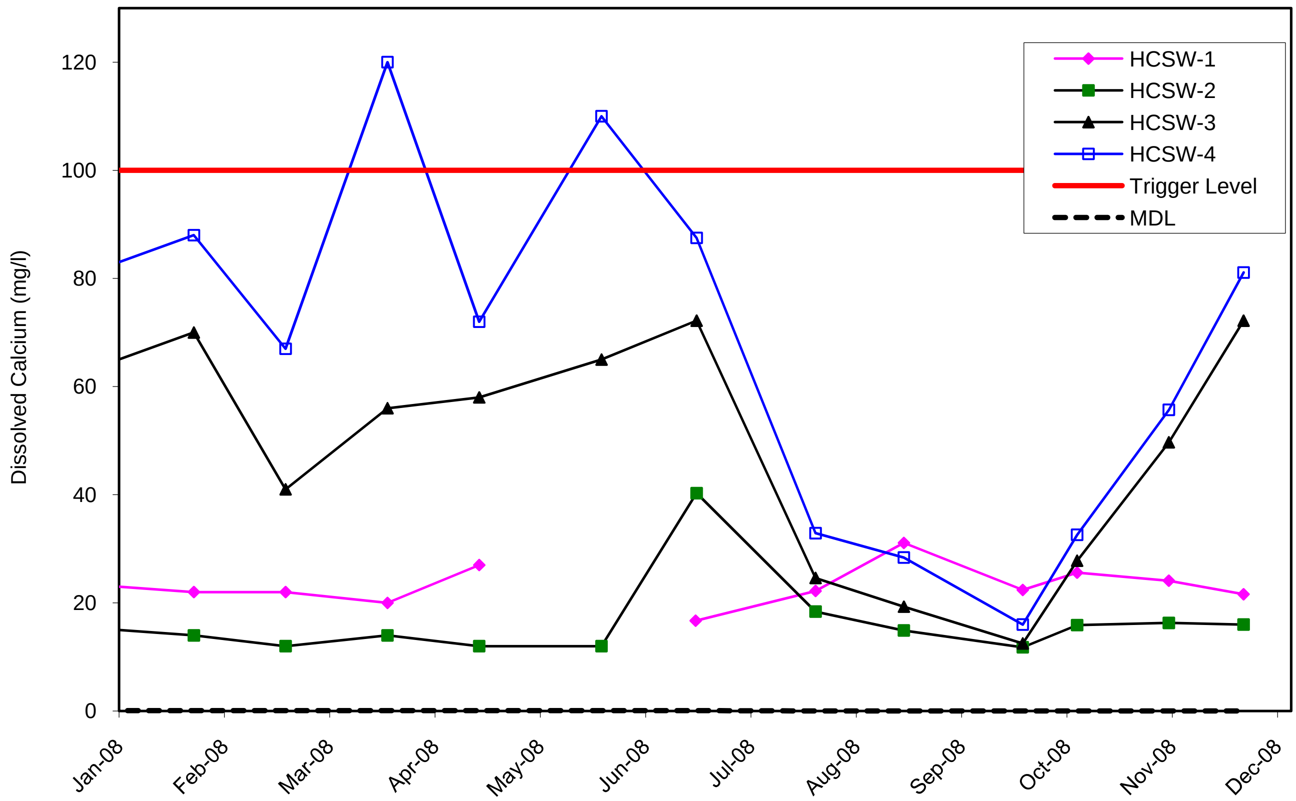

Figure 54. Dissolved Calcium Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2008. Minimum Detection Limit = 0.1 mg/l.

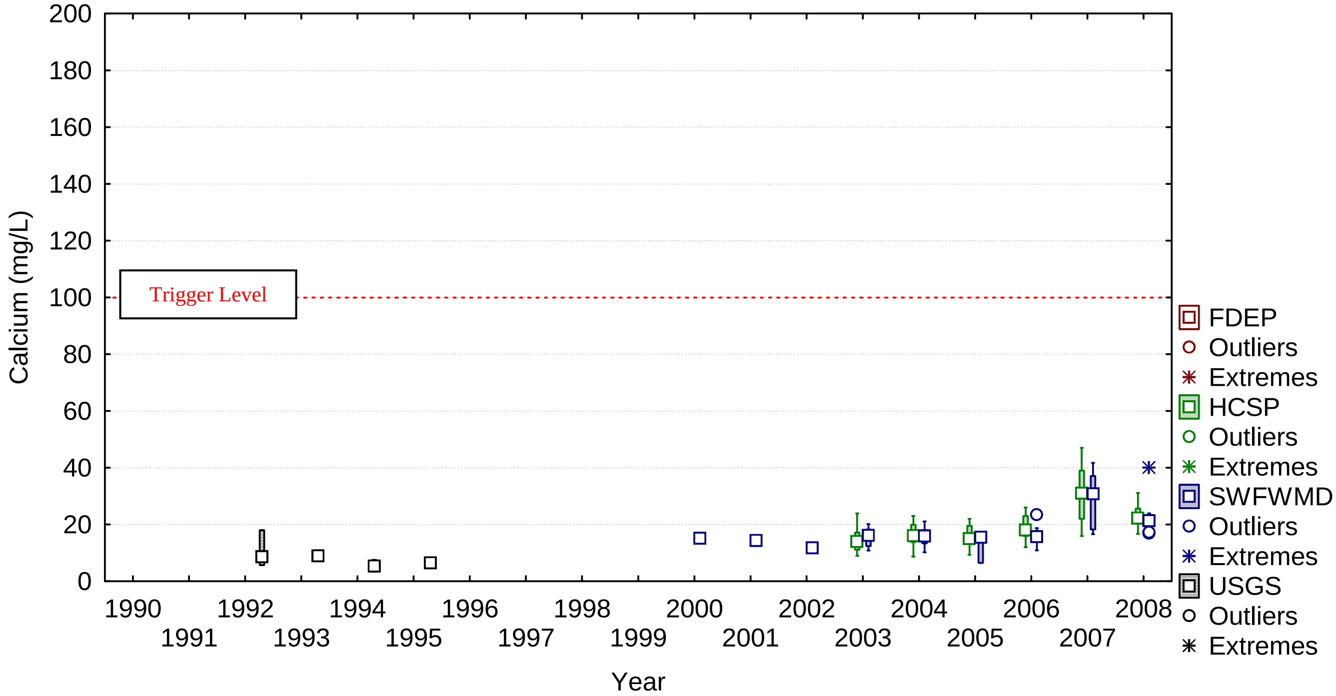

Figure 55. **HCSW-1 Values of Calcium Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.**

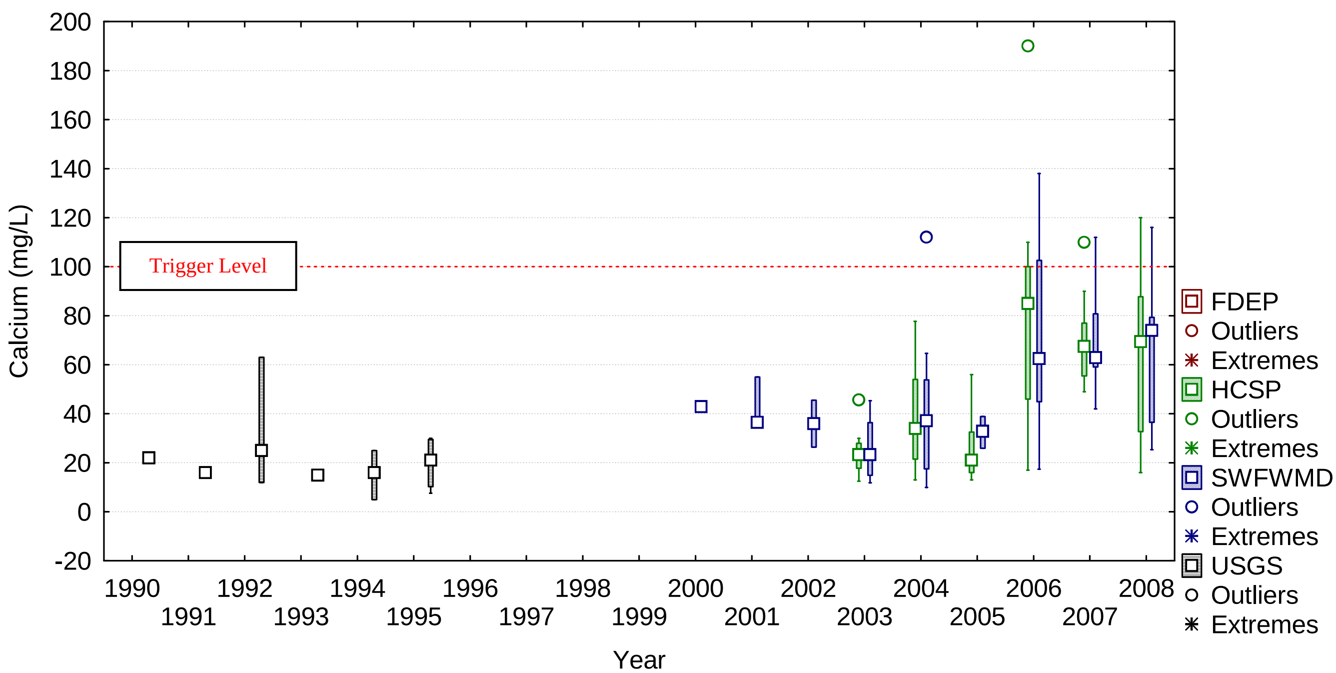

Figure 56. **HCSW-4 Values of Calcium Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.**

Dissolved Iron

Levels of dissolved iron at all stations were below the trigger level of 1 mg/l during all sampling events (Figure 57). Dissolved iron concentrations at HCSW-4 exceeded the trigger value of 0.3 mg/l established for that sampling station from July through October. 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). 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 no observed monotonic trends for dissolved iron since 2003 for HCSW-1 or HCSW-4 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 14). Dissolved iron concentrations were not significantly different among stations (ANOVA, $F = 1.29$, $p = 0.28$, Table 15). Iron was positively correlated with streamflow, rainfall, and NPDES discharge at HCSW-1 and HCSW-4 (Spearman's rank correlations $0.47 > r > 0.84$, $p < 0.05$) (Table 16).

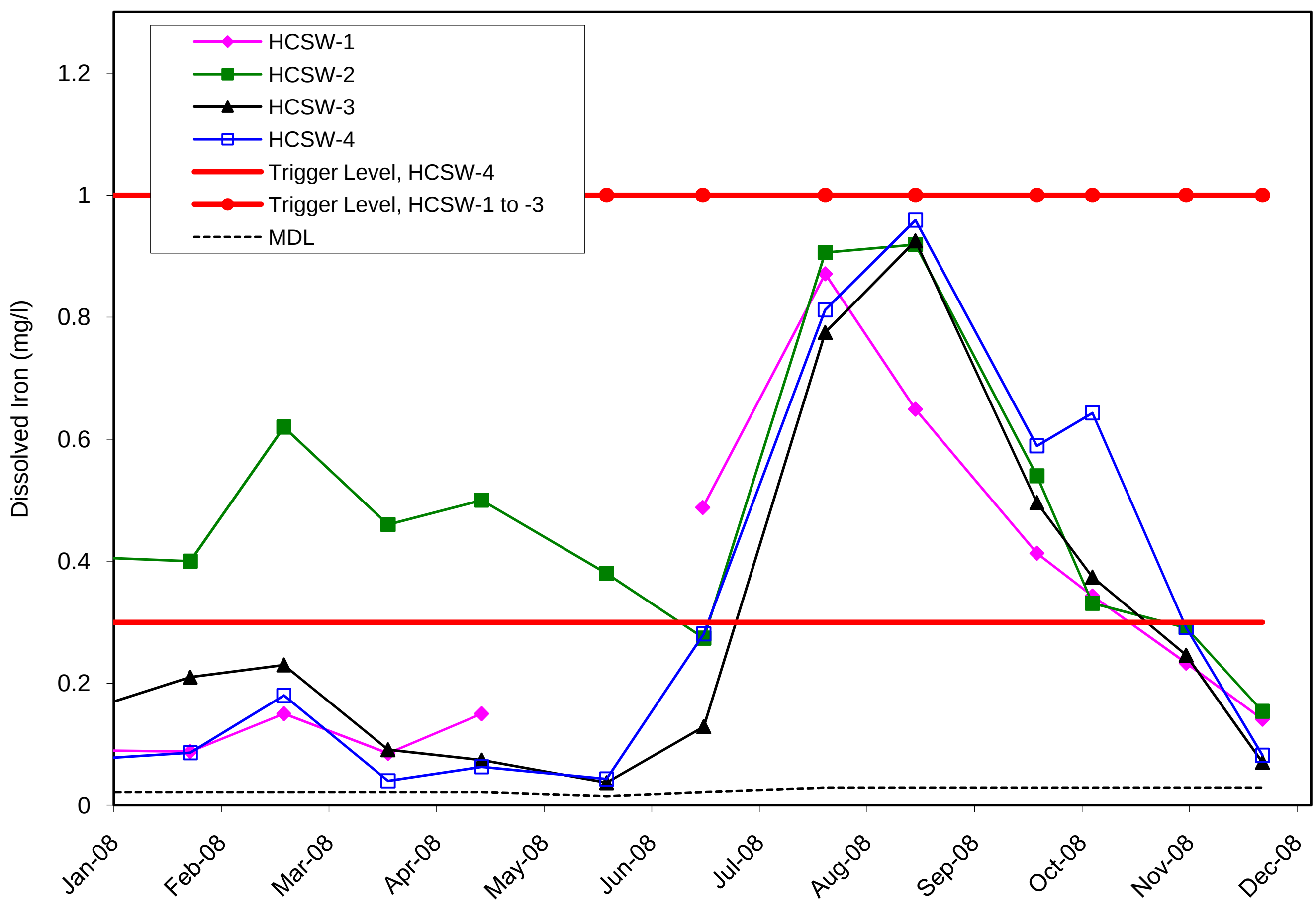

Figure 57. Dissolved Iron Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2008.

Total Alkalinity

Levels of total alkalinity were well below the trigger value of 100 mg/l during 2008. The alkalinity levels at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources. There was no monotonic trend since 2003 at HCSW-4, but an increasing monotonic trend was present at HCSW-1 (Seasonal Kendall Tau with LOWESS = 0.47, p = 0.03, Sen slope = 4.6 mg/L per year) (Table 14, Figures 59 and 60). Given that alkalinity at HCSW-1 is correlated with streamflow and rainfall but not NPDES discharge, it is likely that this trend is strongly influenced by the dry conditions and subsequent higher than average alkalinity in 2006 to 2008 rather than mining activities.

Total alkalinity was significantly different among stations (ANOVA, F = 34.93, $p < 0.001$, Table 15), with highest levels at HCSW-1, then HCSW-4, and finally HCSW-2 and HCSW-3 (Duncan's multiple range test) (Figure 58). Alkalinity was negatively correlated with streamflow, rainfall, and NPDES discharge at HCSW-4 and streamflow and rainfall at HCSW-1 (Spearman's rank correlation $-0.24 > r > -0.77$, $p < 0.05$) (Table 16), 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. High levels of alkalinity at HCSW-1 may be partly attributed to the exposed rock in the stream banks that is unique to that station.

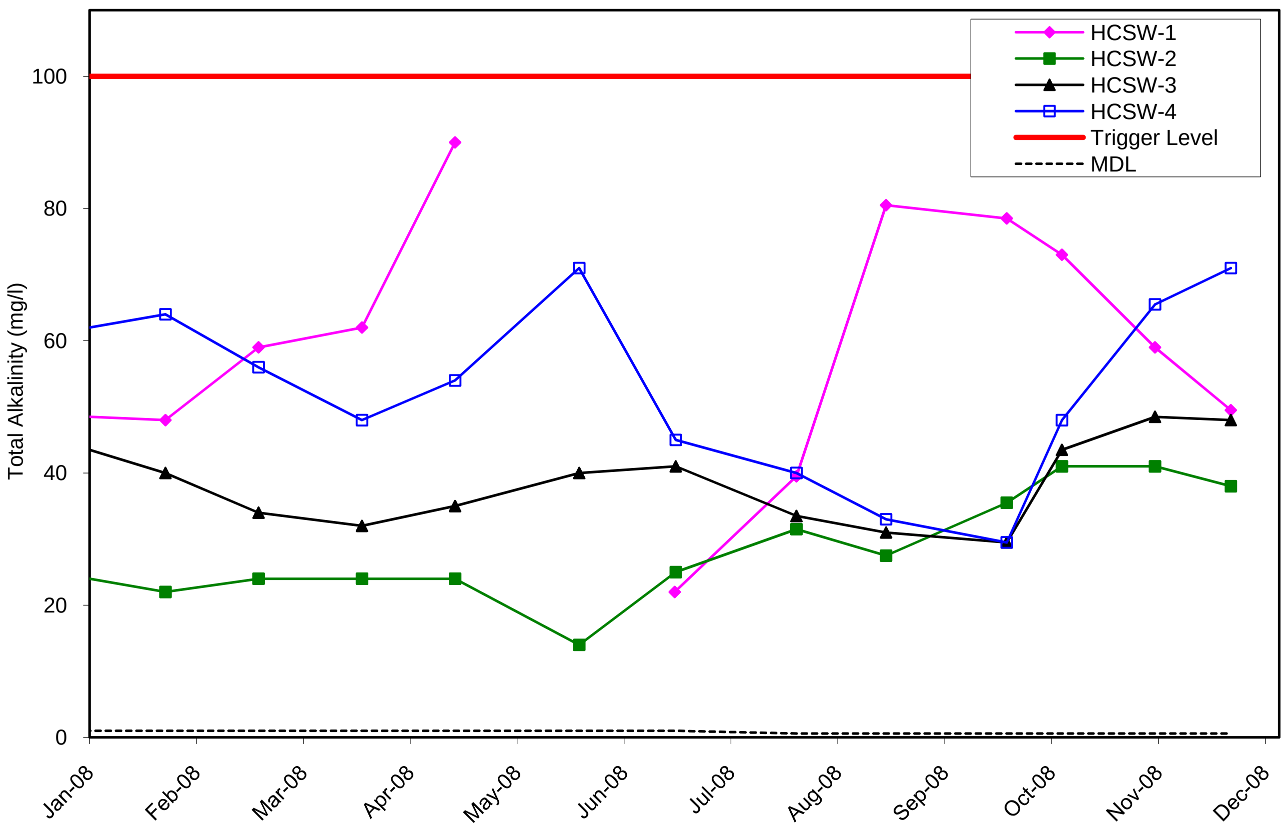

Figure 58. Levels of Total Alkalinity Obtained During Monthly HCSP Water Quality Sampling in 2008.

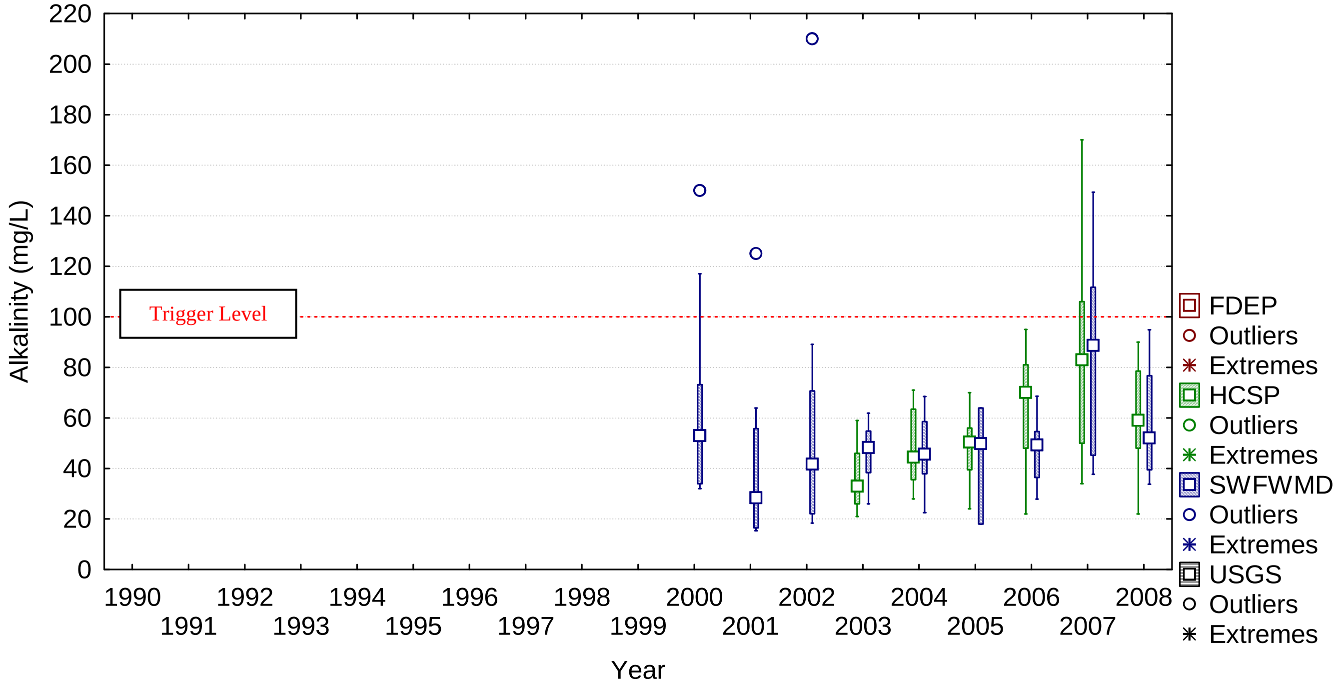

Figure 59. **HCSW-1 Values of Alkalinity Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.**

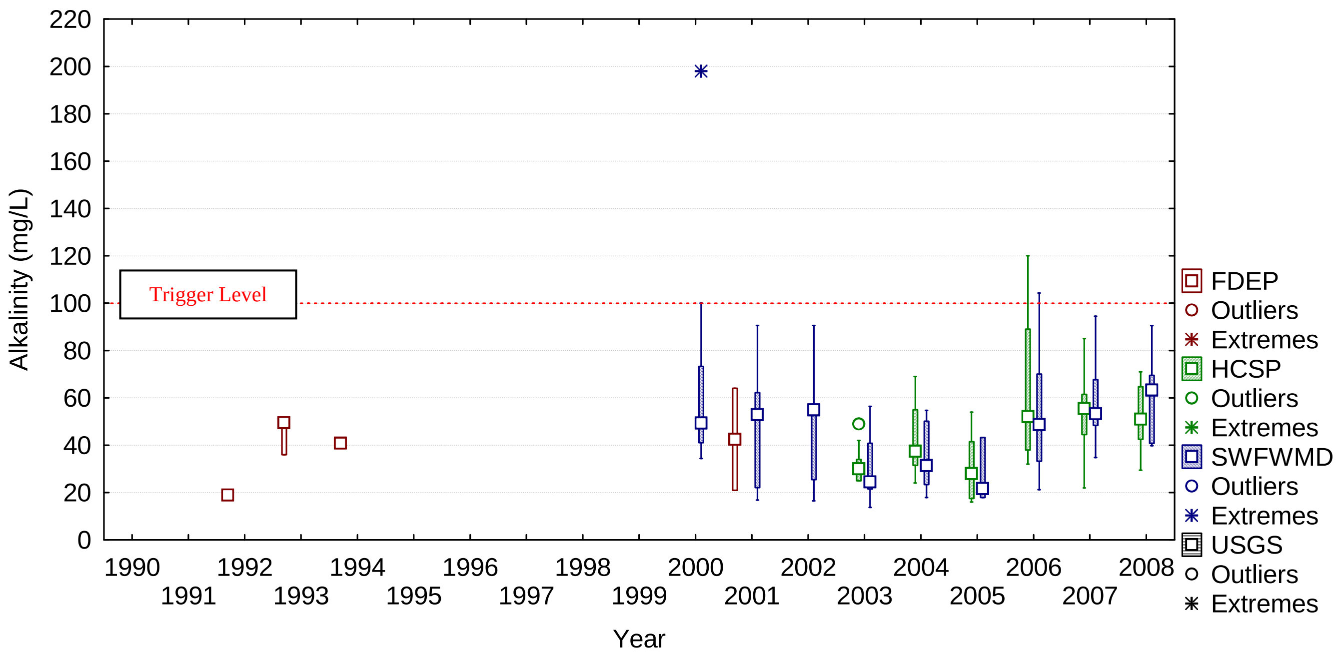

Figure 60. **HCSW-4 Values of Alkalinity Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.**

Chloride

Levels of chloride were below 45 mg/l during 2003 - 2008, considerably lower than the trigger level of 250 mg/l. The chloride concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$) (Figures 62 and 63, Table 14). Chloride concentrations were significantly different among stations during all sampling events (ANOVA, $F = 11.67$, $p < 0.0001$, Table 15), with a pattern of increasing concentration downstream (Figure 61). Chloride was negatively correlated of streamflow, rainfall, and NPDES discharge at HCSW-4 and NPDES discharge and streamflow at HCSW-1 (Spearman's rank correlations $-0.44 > r > -0.86$, $p < 0.05$) (Table 16).

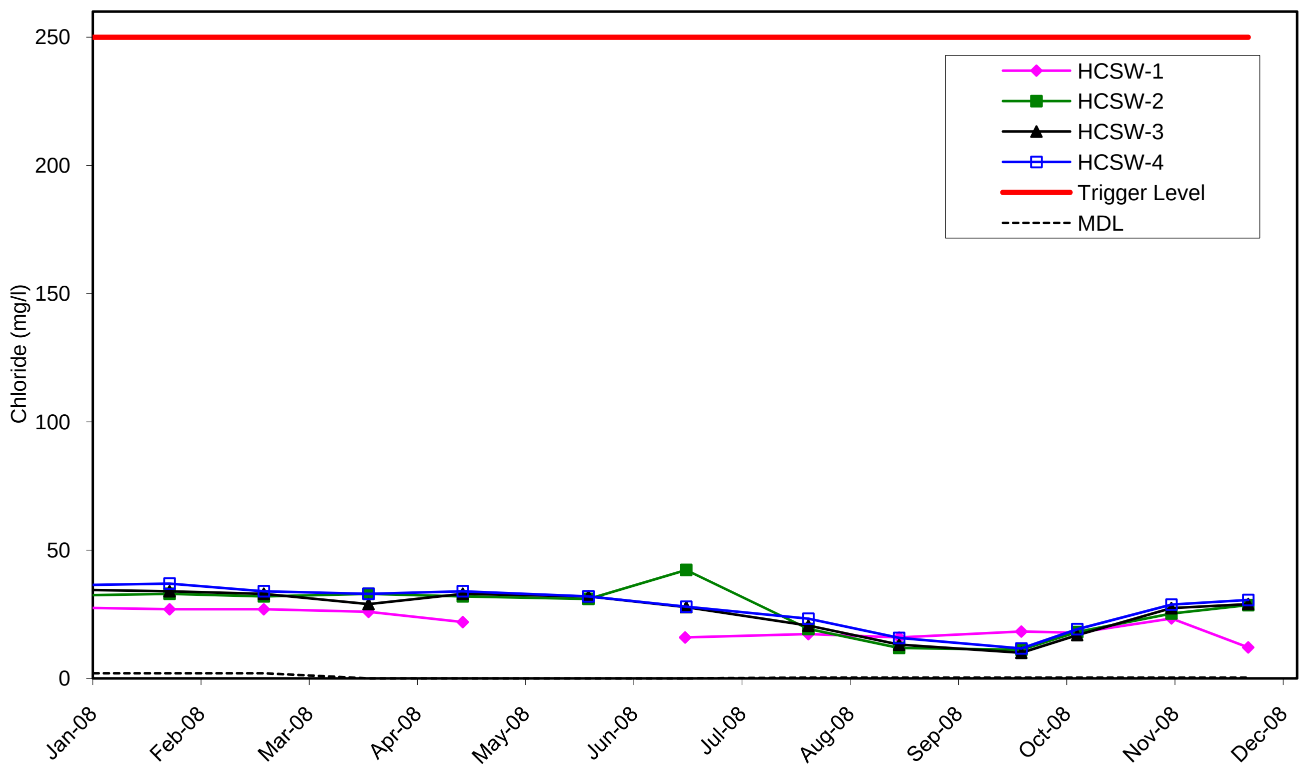

Figure 61. Chloride Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2008. (HCSP trigger value for Chloride is 250 mg/L.)

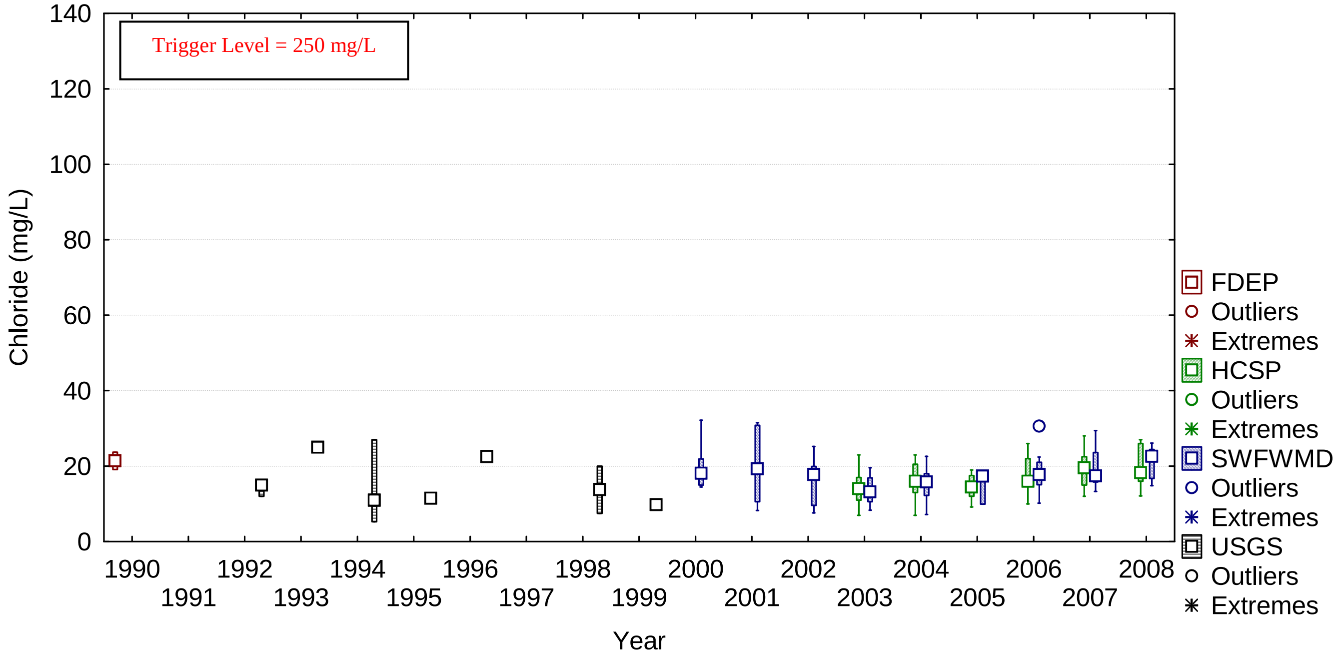

Figure 62. **HCSW-1 Values of Chloride Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.**

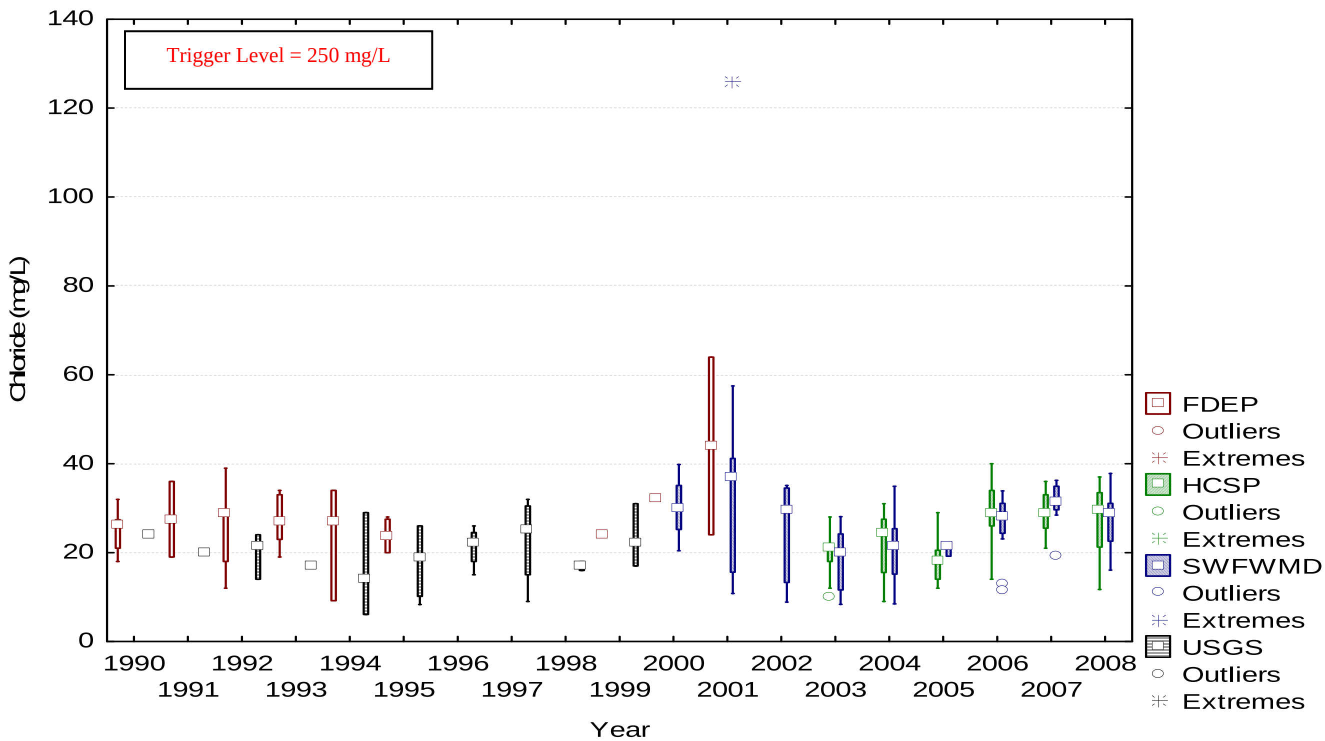

Figure 63. **HCSW-4 Values of Chloride Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.**

Fluoride

Concentrations of fluoride 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. After dramatic changes with the MDL for fluoride in 2007, the MDLs have now been minimized and did not change from April through the remainder of the 2008. The fluoride concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources (Figures 65 and 66). The fluoride concentrations at HCSW-1 and HCSW-4 measured by the HCSP could not be analyzed for monotonic trends or correlations with water quantity because of changes in MDL's over the course of the HCSP. Based on an alternative trend analysis performed on data collected by SWFWMD from 2003-2008, there are no observed monotonic trends at HCSW-1 and HCSW-4 for fluoride (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 14).

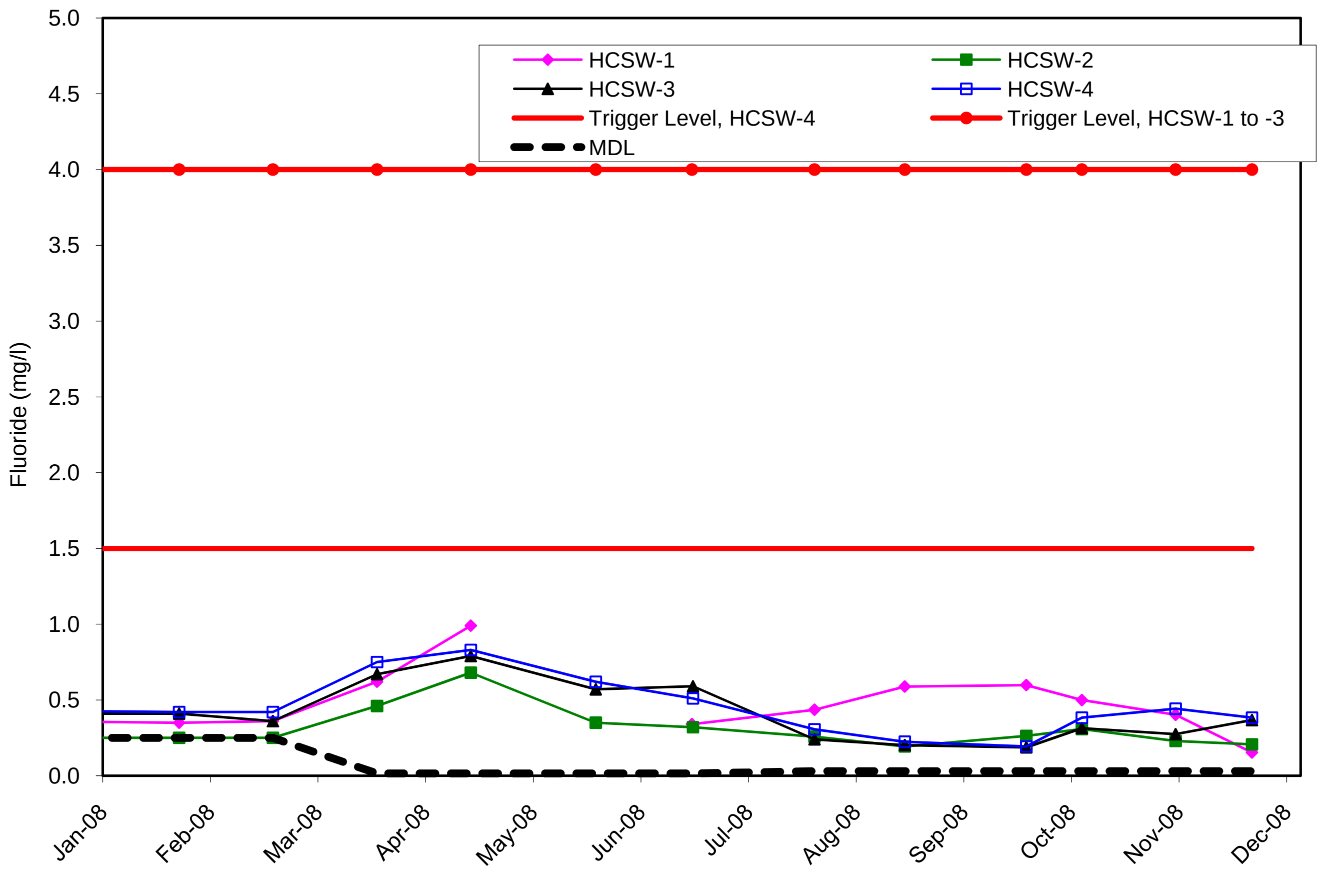

Figure 64. Fluoride Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2008.

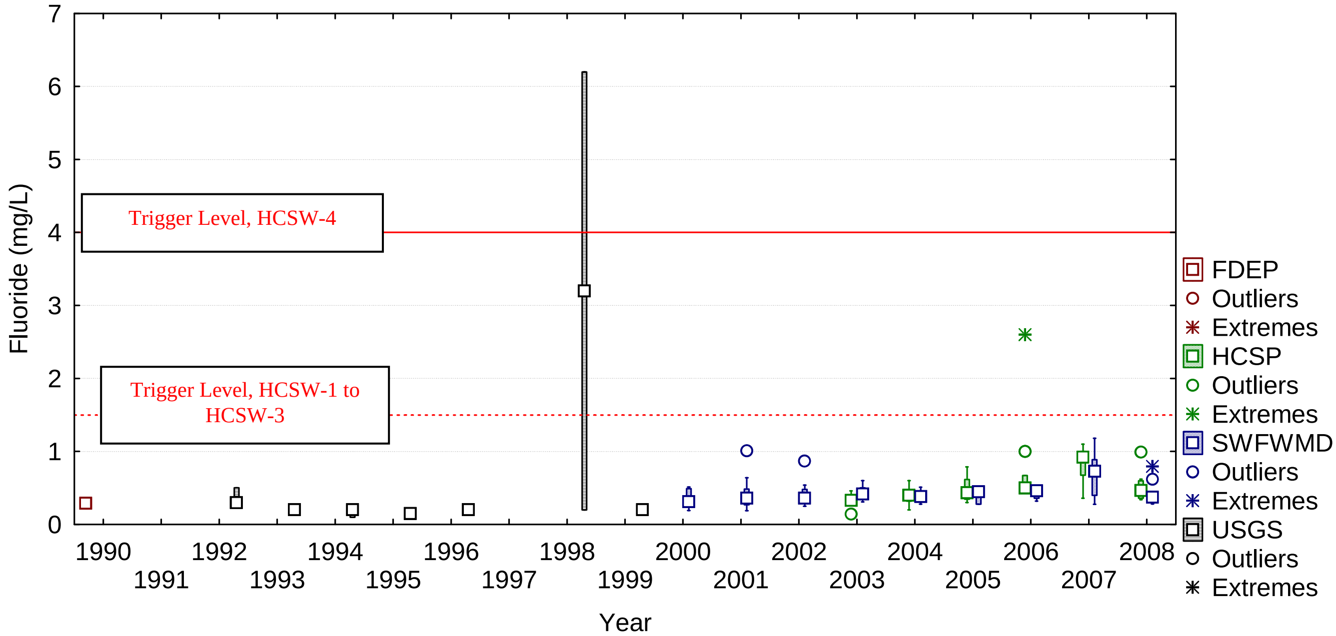

Figure 65. HCSW-1 Values of Fluoride Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

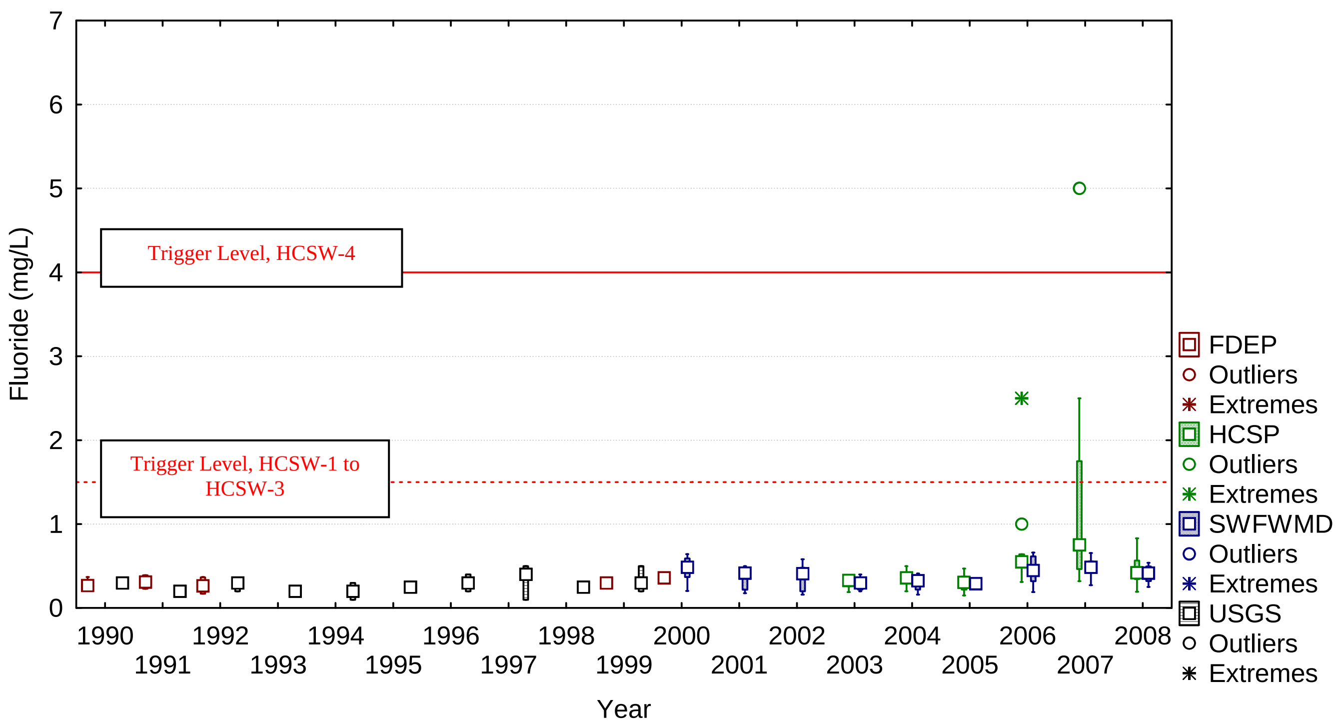

Figure 66. HCSW-4 Values of Fluoride Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

Sulfate

Sulfate concentrations were below the trigger level of 250 mg/l at all sampling stations during most sampling events in 2008, except March, May, and June at HCSW-4 (Figure 67). The sulfate concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trends since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$) (Figures 68 and 69, Table 14). In 2003 - 2008, levels of sulfate were significantly different among stations (ANOVA, $F = 32.33$, $p < 0.001$, Table 15), with lowest levels at HCSW-1 and HCSW-2 and highest at HCSW-3 and HCSW-4 (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 2008. Sulfate was negatively correlated with streamflow, rainfall, and NPDES discharge HCSW-4 and streamflow at HCSW-1 (Spearman's rank correlation $-0.36 > r > -0.85$, $p < 0.05$) (Table 16).

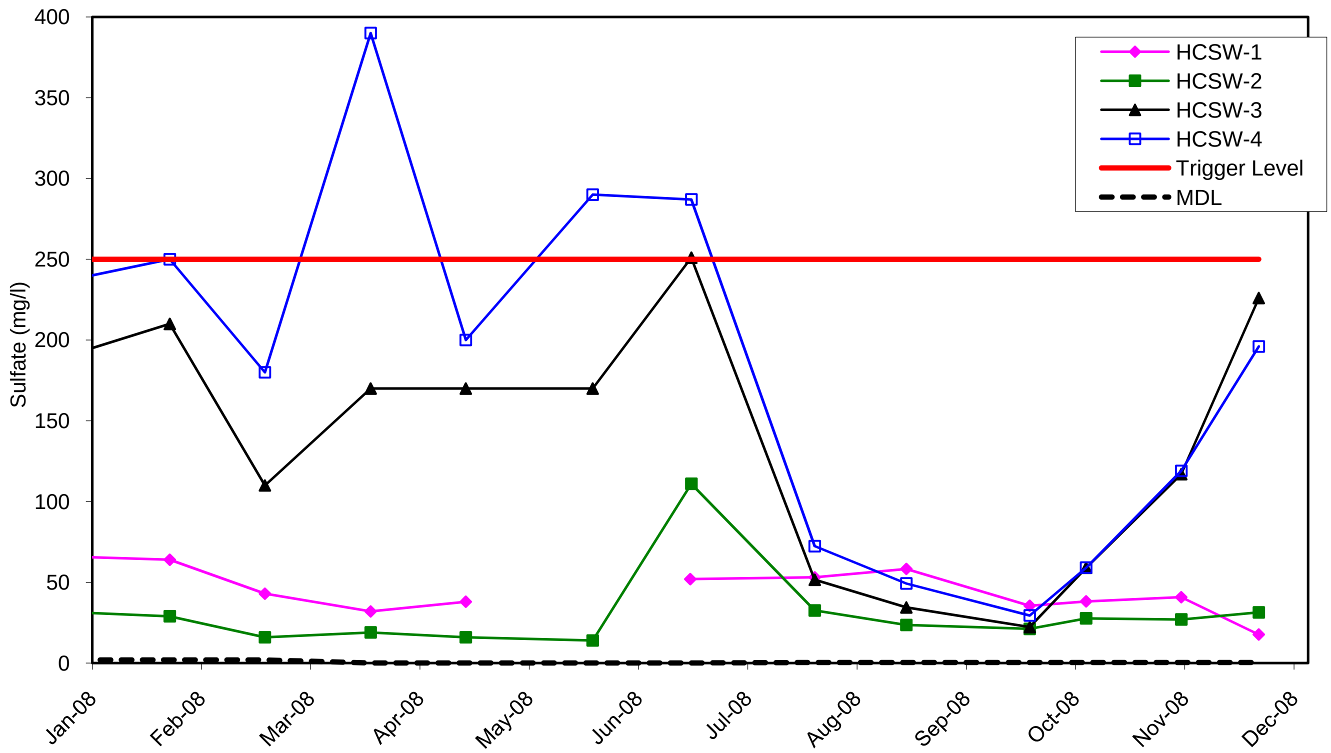

Figure 67. Sulfate Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2008.

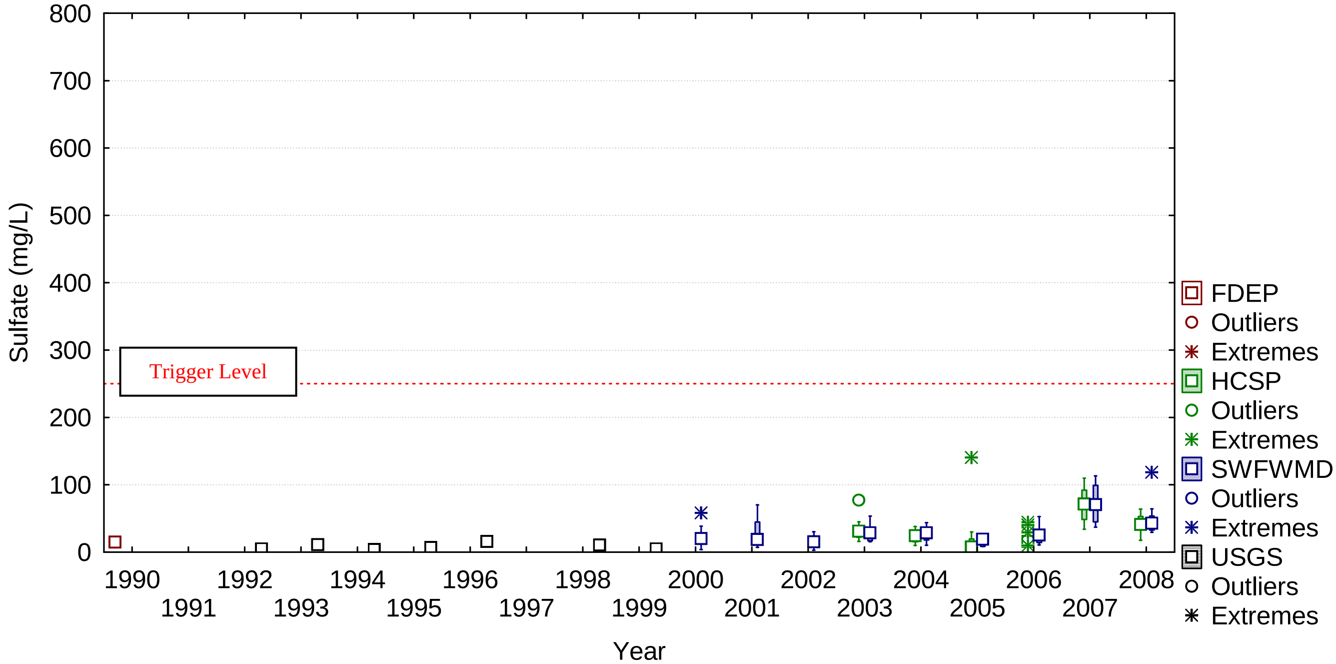

Figure 68. HCSW-1 Values of Sulfate Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

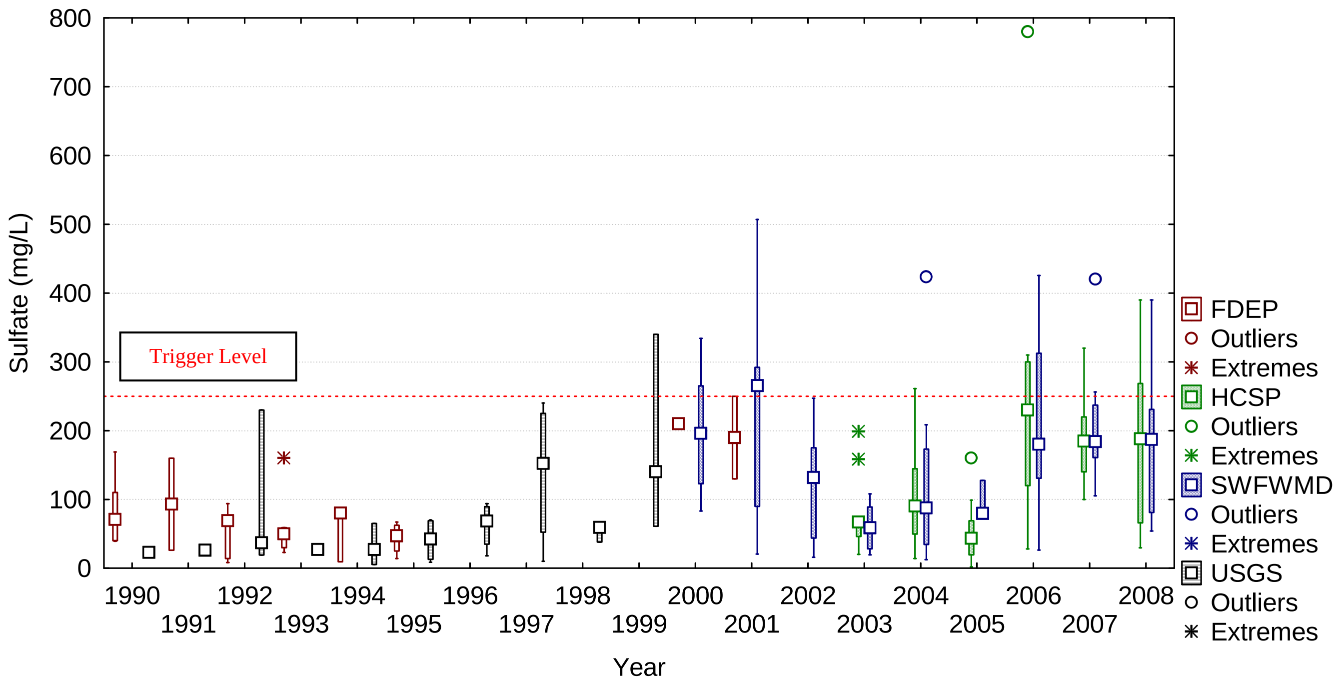

Figure 69. HCSW-4 Values of Sulfate Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

Total Dissolved Solids

Total dissolved solids levels were below the trigger level of 500 mg/l during most sampling events in 2008, except in June at HCSW-3 and January, March, May, and June at HCSW-4. The TDS concentrations at HCSW-1 and HCSW-4 measured by the HCSP are consistent with other water quality data sources and exhibited no monotonic trend since 2003 (Seasonal Kendall Tau with LOWESS, $p > 0.05$) (Figures 71 and 72, Table 14). As with sulfate concentrations, total dissolved solids levels were lowest at HCSW-1 and HCSW-2 and highest at HCSW-4 (ANOVA, $F = 30.23$, $p < 0.0001$, Table 15; Duncan's multiple range test, $p < 0.05$) (Figure 70 Sulfate was negatively correlated with streamflow, rainfall, and NPDES discharge HCSW-4 and streamflow at HCSW-1 (Spearman's rank correlation $-0.28 > r > -0.79$, $p < 0.05$) (Table 16). Both sulfate and total dissolved solids are probably affected by agricultural irrigation return flows and groundwater seepage in the same manner as discussed above for conductivity and calcium.

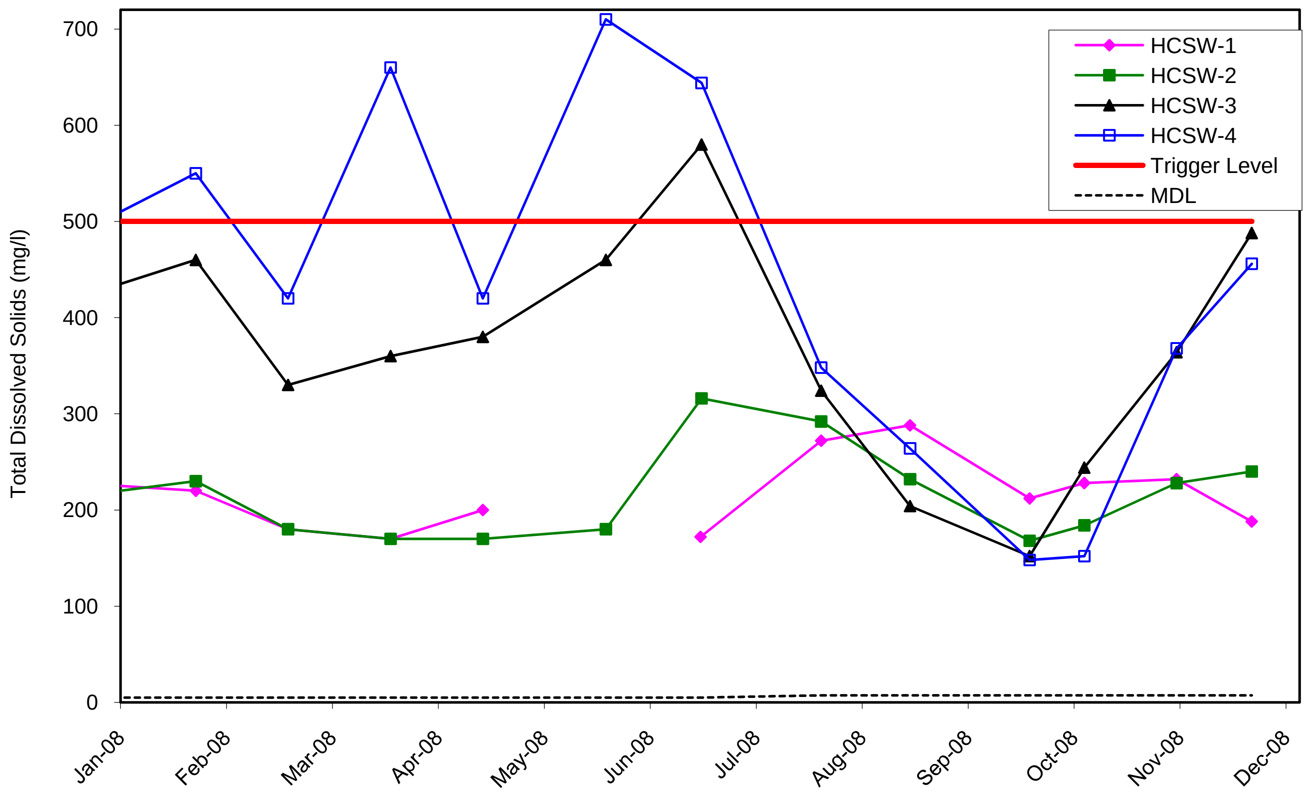

Figure 70. Levels of Total Dissolved Solids Obtained During Monthly HCSP Water Quality Sampling in 2008.

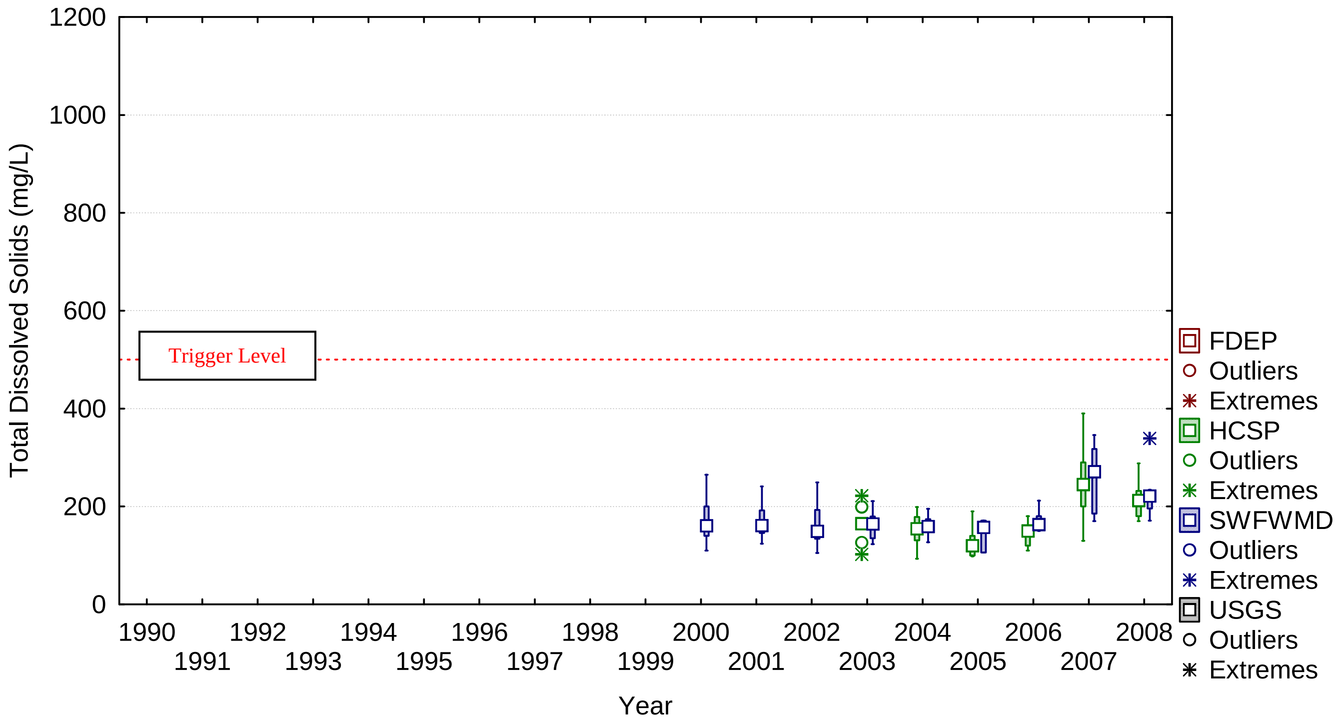

Figure 71. HCSW-1 Values of Total Dissolved Solids Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

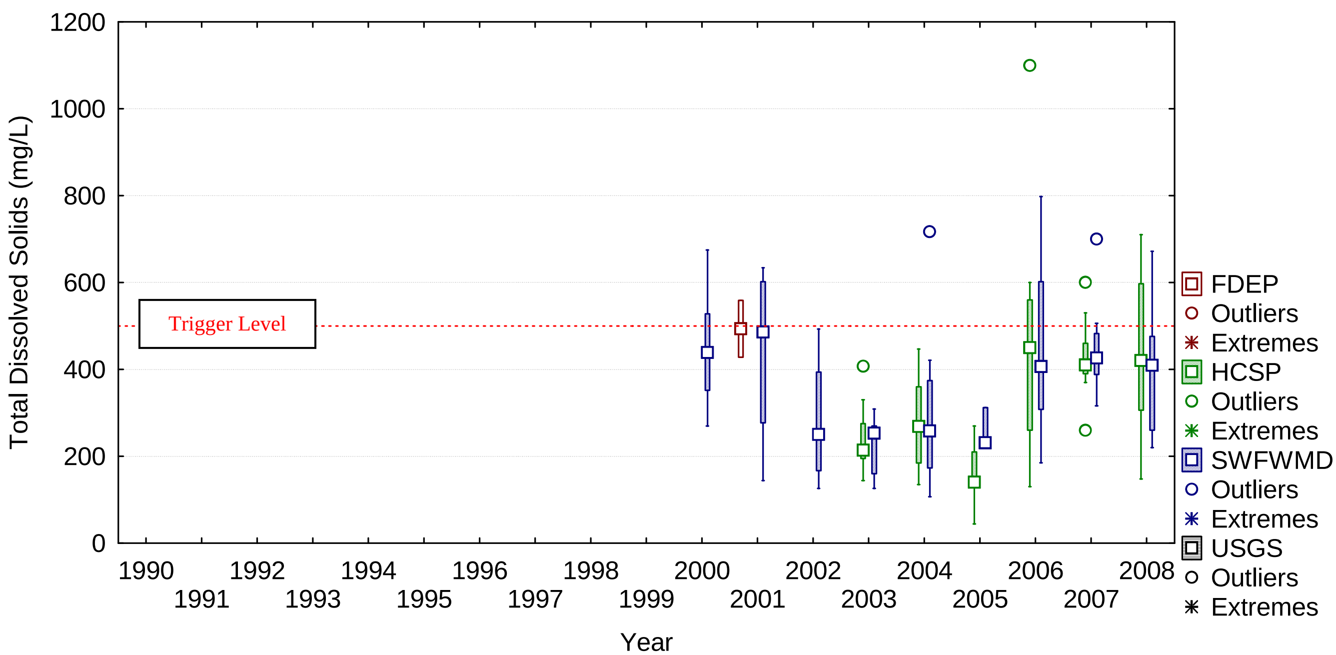

Figure 72. HCSW-4 Values of Total Dissolved Solids Obtained from Various Data Sources (FDEP, SWFWMD, and USGS Data from EPA STORET) for Years 1990 – 2008.

Total Fatty Acids, FL-PRO, and Total Amines

The phosphate beneficiation process that refines the mined phosphate ore uses several chemicals as reagents in the physio-chemical separation process. Three of these chemicals (fuel oil, fatty acids, and fatty amines) were selected for testing in the water-quality sampling program as potential indicator parameters of specific mining wastewater impacts. The FDEP Petroleum Range Organics (FL-PRO) test was selected as a test for fuel oil. Specific test methods were developed for fatty acids (obtained by Mosaic as a by-product of the paper industry and largely composed of oleic and linoleic acids) and fatty amines (fatty acids reacted with ammonia). FL-PRO, fatty acid and amines all degrade biologically and/or photochemically within mine recirculation waters and clay settling areas. These organic parameters were added to the HCSP monitoring list as an extra safeguard, although it was Mosaic's position that they would never be present at detectable limits in any waters discharged from mining areas.

Petroleum range organics were detected five times in 2008, all below the previous MDL of 0.5 mg/L and well below the trigger level of 5.0 mg/L (Figure 73). Total amines and total fatty acids were considered "undetected" at all stations in 2008, although total fatty acids were reported above the trigger level of 0.5 mg/L during December at HCSW-2. Not enough data was available for these three parameters to evaluate differences between stations or relationships with streamflow and rainfall.

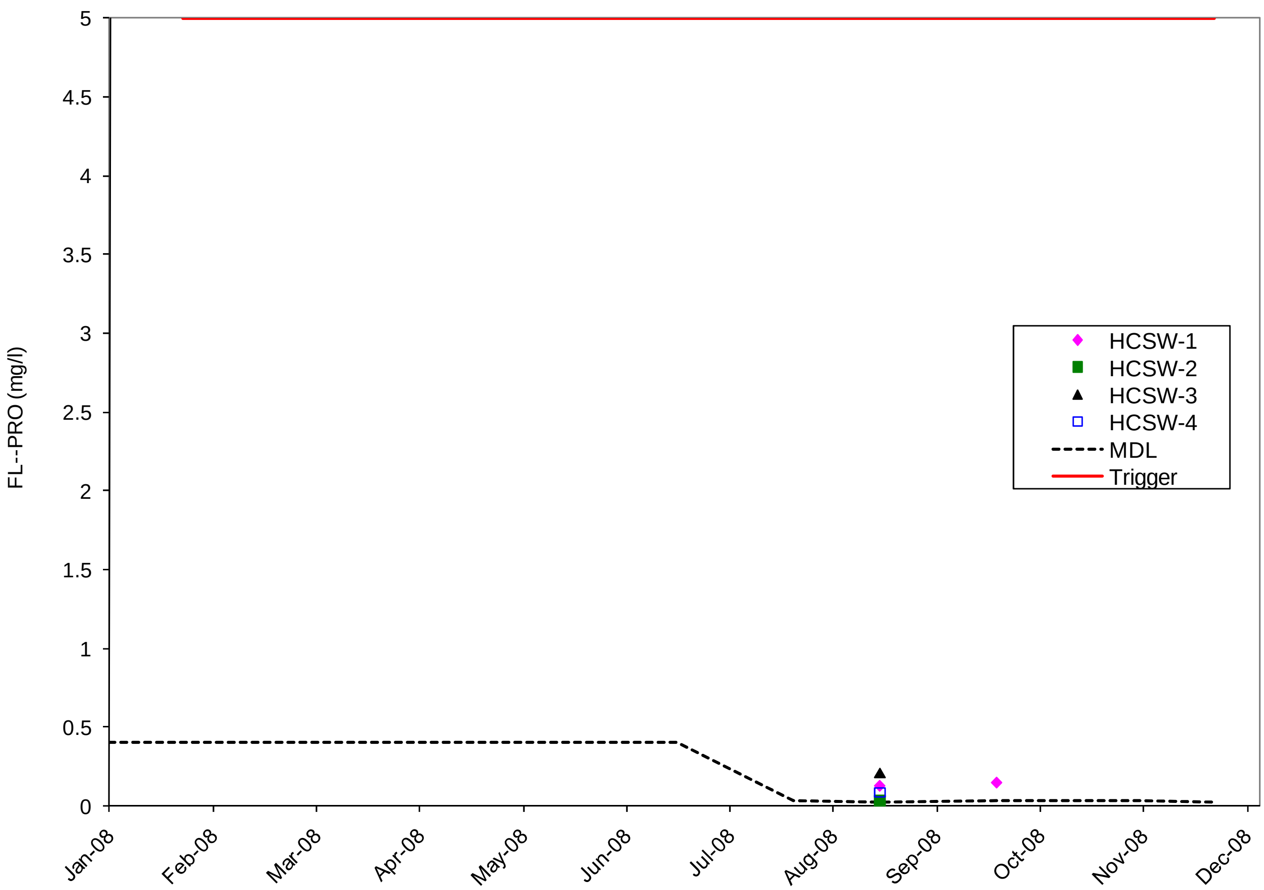

Figure 73. Levels of FL-PRO (Above MDL only) Obtained During Monthly HCSP Water Quality Sampling in 2008.

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). The study also found that general radiochemical concentrations in groundwater from the surficial aquifer were greater below unmined lands than reclaimed lands. 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 2008, total radium[3] levels were below the trigger level of 5 pCi/L (Figure 74). There were no monotonic trends observed since 2003 for total radium at HCSW-1 or HCSW-4 (Seasonal Kendall Tau with LOWESS, $p > 0.05$, Table 14). Total radium levels during 2003-2008 were not significantly different among stations (ANOVA, $F = 2.27$, $p = 0.08$) (Figure 74, Table 15). Total radium was negatively correlated with NPDES discharge at HCSW-1 and HCSW-4 (Spearman's correlations $-0.27 > r > -0.31$, $p < 0.05$, Table 16), indicating that radium was higher when NPDES discharge was low.

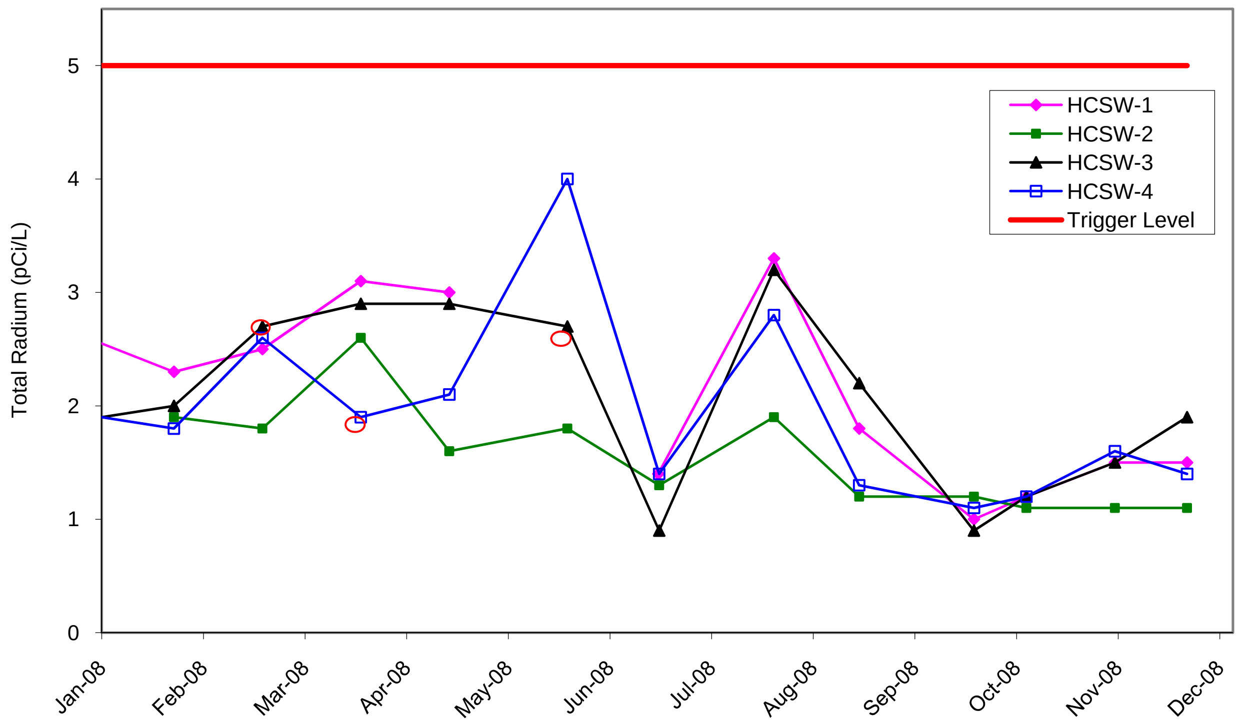

Figure 74. Levels of Total Radium Obtained During Monthly HCSP Water Quality Sampling in 2008. (Data from samples where both Radium 226 and Radium 228 were undetected are circled in red. All but three of the samples were undetected for one of the components.)

3 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. The data in Appendix E reflects these changes. 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.

5.2.5 Summary of Water Quality Results

Water quality parameters in 2008 were always within the desirable range relative to trigger levels and water quality standards at the station closest to mining (HCSW-1, Table 17). All stations in Horse Creek were affected by the low rainfall and streamflow of 2006 to 2008. Algal blooms in warm months when streamflow was low contributed to trigger level exceedances of chlorophyll a, fatty acids, total nitrogen, total ammonia and dissolved oxygen. Dissolved ions (calcium, sulfate, TDS, iron, and fluoride) exceeded the trigger levels during the dry season when rainfall and streamflow were very low, and groundwater baseflow and agricultural irrigation were high.

Trigger levels were not exceeded for any parameters at HCSW-1 in 2008. At HCSW-2, trigger levels were exceeded for dissolved oxygen, total ammonia, chlorophyll *a*, total nitrogen and fatty acids (Table 17). Based upon historical conditions in Horse Creek (Durbin and Raymond 2006), the reported values for dissolved oxygen and pH 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. HCSW-2 is a slow-moving section of Horse Creek located immediately downstream of Horse Creek Prairie, thereby creating conditions that would naturally foster algal growth. The total fatty acid exceedance was probably related to the decomposition of terrestrial vegetation that had grown in the streambed, as the water began to rise at the beginning of the wet season. HCSW-3 exceeded trigger levels for dissolved oxygen, total ammonia, sulfate, and TDS. HCSW-4 exceeded trigger levels for dissolved oxygen, total ammonia, sulfate, TDS, calcium, and iron. Dissolved oxygen triggers were exceeded during summer wet months of 2008, when high temperatures reduce the oxygen carrying capacity of the stream. Sulfate, TDS, iron, and calcium were exceeded in the dry season, when unusually low rainfall and streamflow likely led to increased groundwater inputs from baseflow and agricultural runoff. Other exceedances (high total nitrogen at HCSW-2 and total ammonia at HCSW-2, HCSW-3 and HCSW-4) were isolated. Dissolved iron concentrations consistently exceeded the trigger value set at HCSW-4, 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. None of the observed exceedances can be attributed to mining.

There was no evidence of temporal trends that could be attributed to anything other than general wet season/dry season fluctuations or longer-term climatic oscillations (Figure 75). Alkalinity and specific conductance show a significant increasing trend at HCSW-1, but these potential trends are heavily influenced by the abnormally low rainfall and streamflow of 2006 - 2008. If 2009 has more average rainfall and streamflow, these trends will not be evident. When examined using a two-factor ANOVA testing the relationship between water quality and both season and occurrence of NPDES discharge (Figures 76 and 77), both alkalinity and specific conductance show no relationship with NPDES discharge at HCSW-1 (Two Factor ANOVA, $p > 0.05$). Orthophosphate shows a significant increasing trend and dissolved oxygen a decreasing trend at HCSW-4. These trends may have been influenced by the last two dry years, and it is also likely that cumulative impacts of agricultural landuse may also be contributing to changes in water quality at this downstream station.

Significant differences between stations were evident for several parameters. Overall, HCSW-2 was the most dissimilar from the other three stations, especially in pH, dissolved oxygen, and some dissolved ions. Some nutrients (nitrate + nitrite and orthophosphate) and dissolved ions (specific conductivity, calcium, sulfate) had higher concentrations downstream in Horse Creek, probably because of increased groundwater seepage and agricultural runoff in the lower Horse Creek basin. Differences in topography, geology, and land use that could account for these trends 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. Conversely, turbidity, color, iron, and some nutrients are high when the water quantity is also high. Total radium was correlated with increased NPDES discharge but not streamflow or rainfall. When water quantity in Horse Creek is low, the stream may be 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, an increased amount of sediment and organic debris is washed into the stream, leading to increases in turbidity, color, iron, and nitrogen.

Table 17. Instances of Trigger Level Exceedance Observed in 2008 HCSP Monthly Monitoring.

Sampling Location	Station ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at Goose Pond Road	HCSW-2	01/30/08	Dissolved Oxygen (mg/l)	3.34	5.0
Horse Creek at Goose Pond Road	HCSW-2	02/26/08	Dissolved Oxygen (mg/l)	1.65	5.0
Horse Creek at Goose Pond Road	HCSW-2	03/27/08	Dissolved Oxygen (mg/l)	4.21	5.0
Horse Creek at Goose Pond Road	HCSW-2	04/23/08	Dissolved Oxygen (mg/l)	1.77	5.0
Horse Creek at Goose Pond Road	HCSW-2	05/29/08	Dissolved Oxygen (mg/l)	2.33	5.0
Horse Creek at Goose Pond Road	HCSW-2	06/26/08	Dissolved Oxygen (mg/l)	1.41	5.0
Horse Creek at Goose Pond Road	HCSW-2	07/31/08	Dissolved Oxygen (mg/l)	0.74	5.0
Horse Creek at Goose Pond Road	HCSW-2	08/26/08	Dissolved Oxygen (mg/l)	0.13	5.0
Horse Creek at Goose Pond Road	HCSW-2	09/30/08	Dissolved Oxygen (mg/l)	1.27	5.0
Horse Creek at Goose Pond Road	HCSW-2	10/16/08	Dissolved Oxygen (mg/l)	0.19	5.0
Horse Creek at Goose Pond Road	HCSW-2	11/12/08	Dissolved Oxygen (mg/l)	1.29	5.0
Horse Creek at Goose Pond Road	HCSW-2	12/04/08	Dissolved Oxygen (mg/l)	3.04	5.0
Horse Creek at State Road 70	HCSW-3	02/26/08	Dissolved Oxygen (mg/l)	3.64	5.0
Horse Creek at State Road 70	HCSW-3	03/27/08	Dissolved Oxygen (mg/l)	4.75	5.0
Horse Creek at State Road 70	HCSW-3	04/23/08	Dissolved Oxygen (mg/l)	3.27	5.0
Horse Creek at State Road 70	HCSW-3	05/29/08	Dissolved Oxygen (mg/l)	2.9	5.0
Horse Creek at State Road 70	HCSW-3	06/26/08	Dissolved Oxygen (mg/l)	4.78	5.0
Horse Creek at State Road 70	HCSW-3	07/31/08	Dissolved Oxygen (mg/l)	0.99	5.0
Horse Creek at State Road 70	HCSW-3	08/26/08	Dissolved Oxygen (mg/l)	1.62	5.0
Horse Creek at State Road 70	HCSW-3	09/30/08	Dissolved Oxygen (mg/l)	3.28	5.0
Horse Creek at State Road 70	HCSW-3	10/16/08	Dissolved Oxygen (mg/l)	2.73	5.0
Horse Creek at State Road 72	HCSW-4	07/31/08	Dissolved Oxygen (mg/l)	3.1	5.0
Horse Creek at State Road 72	HCSW-4	08/26/08	Dissolved Oxygen (mg/l)	2.2	5.0
Horse Creek at State Road 72	HCSW-4	09/30/08	Dissolved Oxygen (mg/l)	4.77	5.0
Horse Creek at Goose Pond Road	HCSW-2	01/30/08	Total Nitrogen (mg/L)	4.8	3.0
Horse Creek at Goose Pond Road	HCSW-2	07/31/08	Total Ammonia (mg/L)	0.41	0.3
Horse Creek at State Road 70	HCSW-3	07/31/08	Total Ammonia (mg/L)	0.32	0.3
Horse Creek at State Road 72	HCSW-4	07/31/08	Total Ammonia (mg/L)	0.31	0.3
Horse Creek at Goose Pond Road	HCSW-2	07/31/08	Chlorophyll *a* (mg/m^3)	22.6	15
Horse Creek at Goose Pond Road	HCSW-2	12/04/08	Total Fatty Acids (mg/L)	0.97	0.5
Horse Creek at State Road 70	HCSW-3	06/26/08	Sulfate (mg/L)	251	250
Horse Creek at State Road 72	HCSW-4	03/27/08	Sulfate (mg/L)	390	250
Horse Creek at State Road 72	HCSW-4	05/29/08	Sulfate (mg/L)	290	250
Horse Creek at State Road 72	HCSW-4	06/26/08	Sulfate (mg/L)	287	250
Horse Creek at State Road 70	HCSW-3	06/26/08	TDS (mg/L)	580	500
Horse Creek at State Road 72	HCSW-4	01/30/08	TDS (mg/L)	550	500
Horse Creek at State Road 72	HCSW-4	03/27/08	TDS (mg/L)	660	500
Horse Creek at State Road 72	HCSW-4	05/29/08	TDS (mg/L)	710	500
Horse Creek at State Road 72	HCSW-4	06/26/08	TDS (mg/L)	644	500
Horse Creek at State Road 72	HCSW-4	03/27/08	Dissolved Calcium (mg/L)	120	100
Horse Creek at State Road 72	HCSW-4	05/29/08	Dissolved Calcium (mg/L)	110	100
Horse Creek at State Road 72	HCSW-4	07/31/08	Dissolved Iron (mg/L)	0.81	0.3
Horse Creek at State Road 72	HCSW-4	08/26/08	Dissolved Iron (mg/L)	0.96	0.3
Horse Creek at State Road 72	HCSW-4	09/30/08	Dissolved Iron (mg/L)	0.59	0.3
Horse Creek at State Road 72	HCSW-4	10/16/08	Dissolved Iron (mg/L)	0.64	0.3

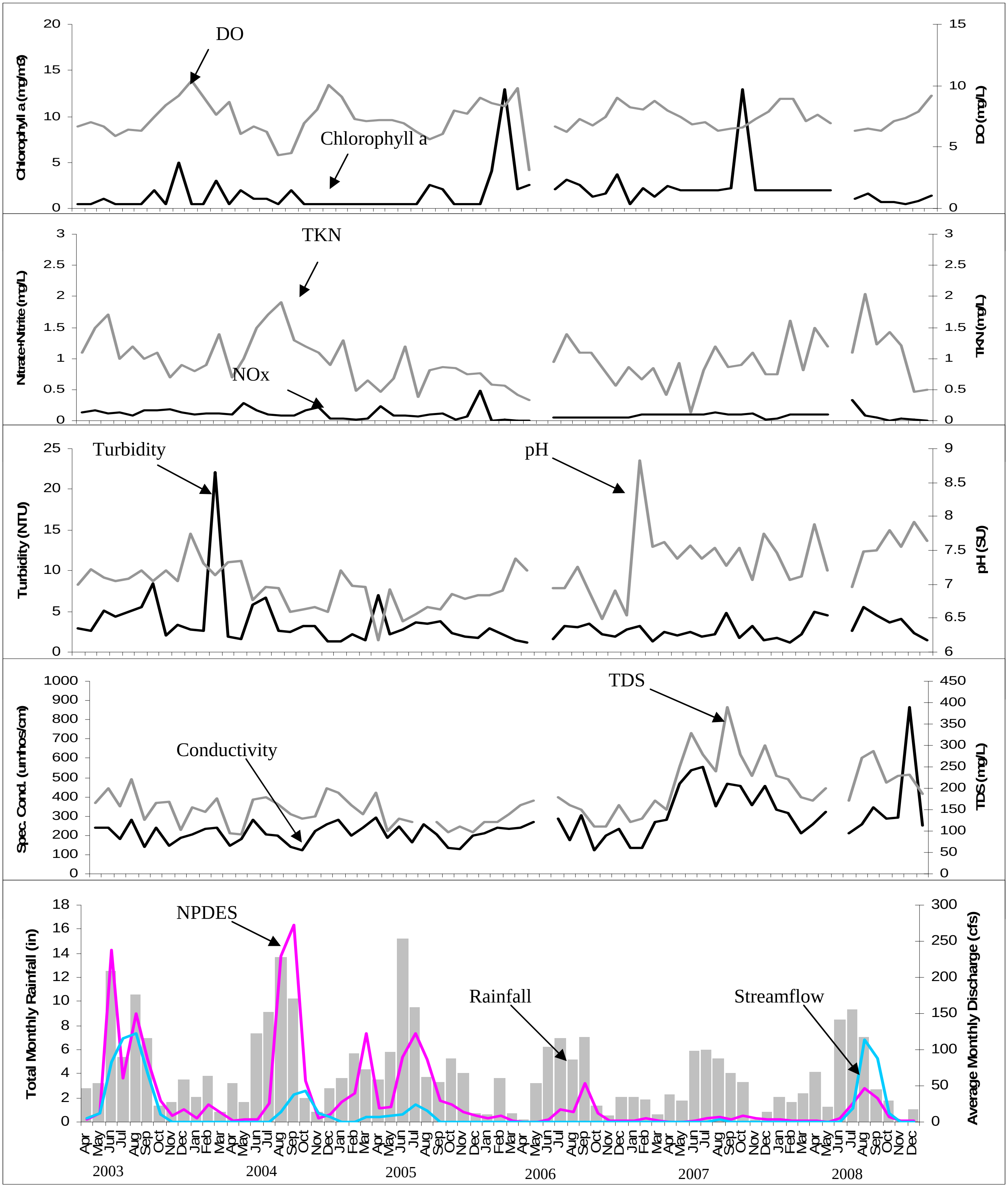

Figure 75. HCSP Water Quality Correlations With Average Monthly NPDES Discharge, Average Monthly Streamflow, and Total Monthly Rainfall at HCSW-1 in 2003 – 2008

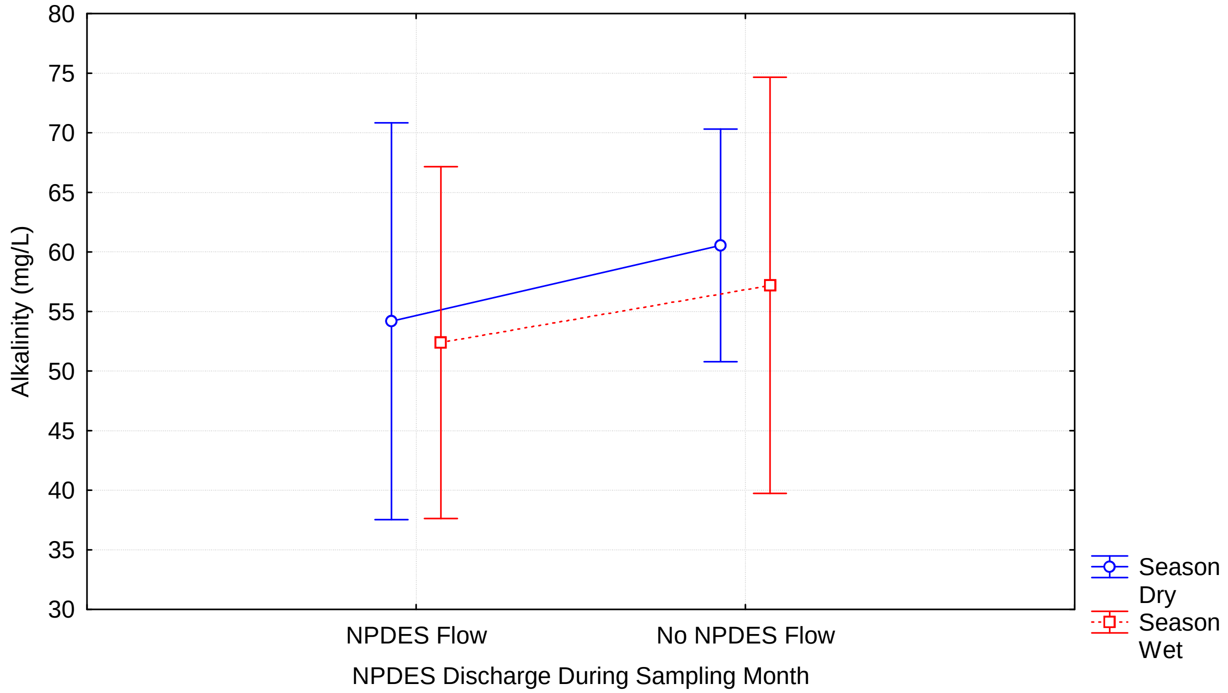

Figure 76. Relationship Between Monthly Alkalinity at HCSW-1 and Two Factors: Season (Wet = June-September) and Occurrence of NPDES Discharge from 2003-2008.

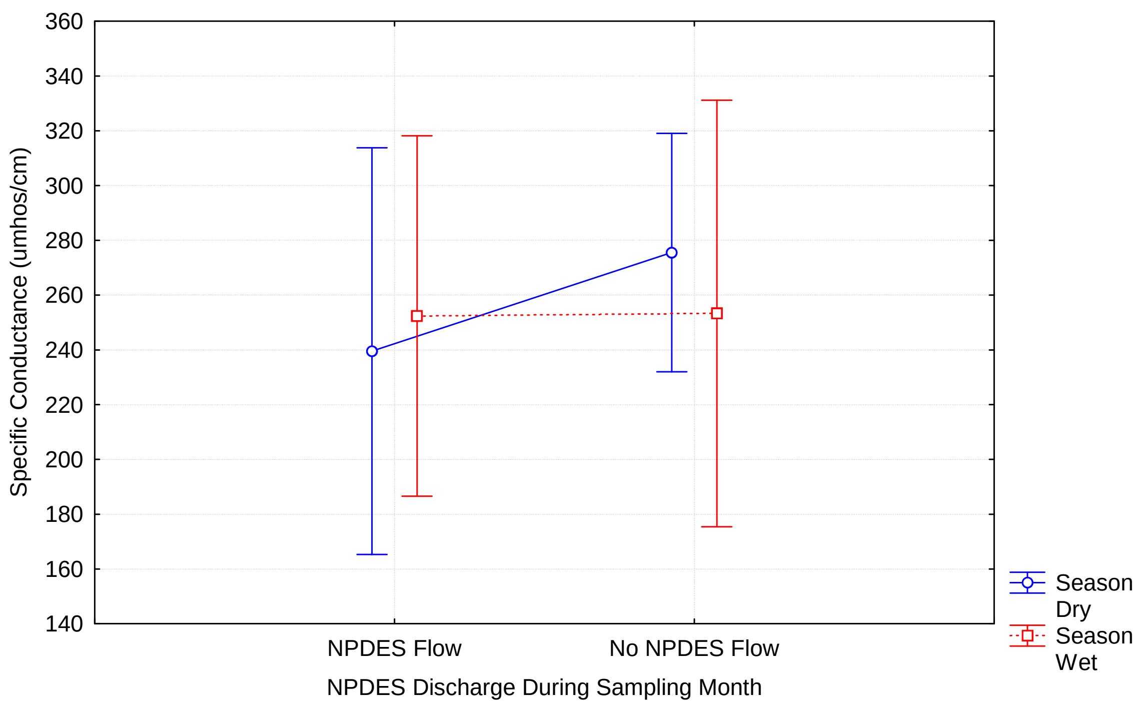

Figure 77. Relationship Between Monthly Specific Conductance at HCSW-1 and Two Factors: Season (Wet = June-September) and Occurrence of NPDES Discharge from 2003-2008.

5.3 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate sampling was conducted at each of the four sampling stations on 24 April 2008, 12 September 2008, and 19 November 2008.

Figure 78. Fish and invertebrate sampling in Horse Creek in 2008.

5.3.1 Stream Habitat Assessment

The majority of the habitat assessment parameters evaluated through the DEP procedure are not directly related to mining, but 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. However, NPDES discharge occurred for portions of four months of the year in 2008 and was unlikely to cause sediment deposition. Habitat smothering in 2008 was fairly high at most stations, because streamflow was very low.

The habitat quality of Horse Creek was within the optimal or sub-optimal range during all sampling events in 2008 (Table 18), as it was for 2003 to 2007 (Figure 79). Prior to Hurricane Charley in 2004, habitat quality at HCSW-1 was not better than at other stations. In 2005, however, HCSW-1 always had optimal habitat quality, while the other three stations, which were more affected by Hurricane Charley, often had sub-optimal habitat quality. In 2006 to 2008, the habitat quality of HCSW-3 and HCSW-4 improved to be near that of HCSW-1. HCSW-2 had low habitat quality in 2006, 2007 and 2008 because of low streamflow through the wet season. The substrate availability score is the percent of available benthic habitat. Due to high flow during the summer, some of the viable substrate could have washed away or become inundated, leading to lower scores. HCSW-2 had a high percent of available habitat in April 2008 due to the abundance of water hyacinth. After high summer rains and streamflow, this aquatic vegetation was swept away, leaving very little substrate to sample, hence the lower score. Some of the minor variation among the sampling events for a given station primarily reflects differences in habitat quality 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.

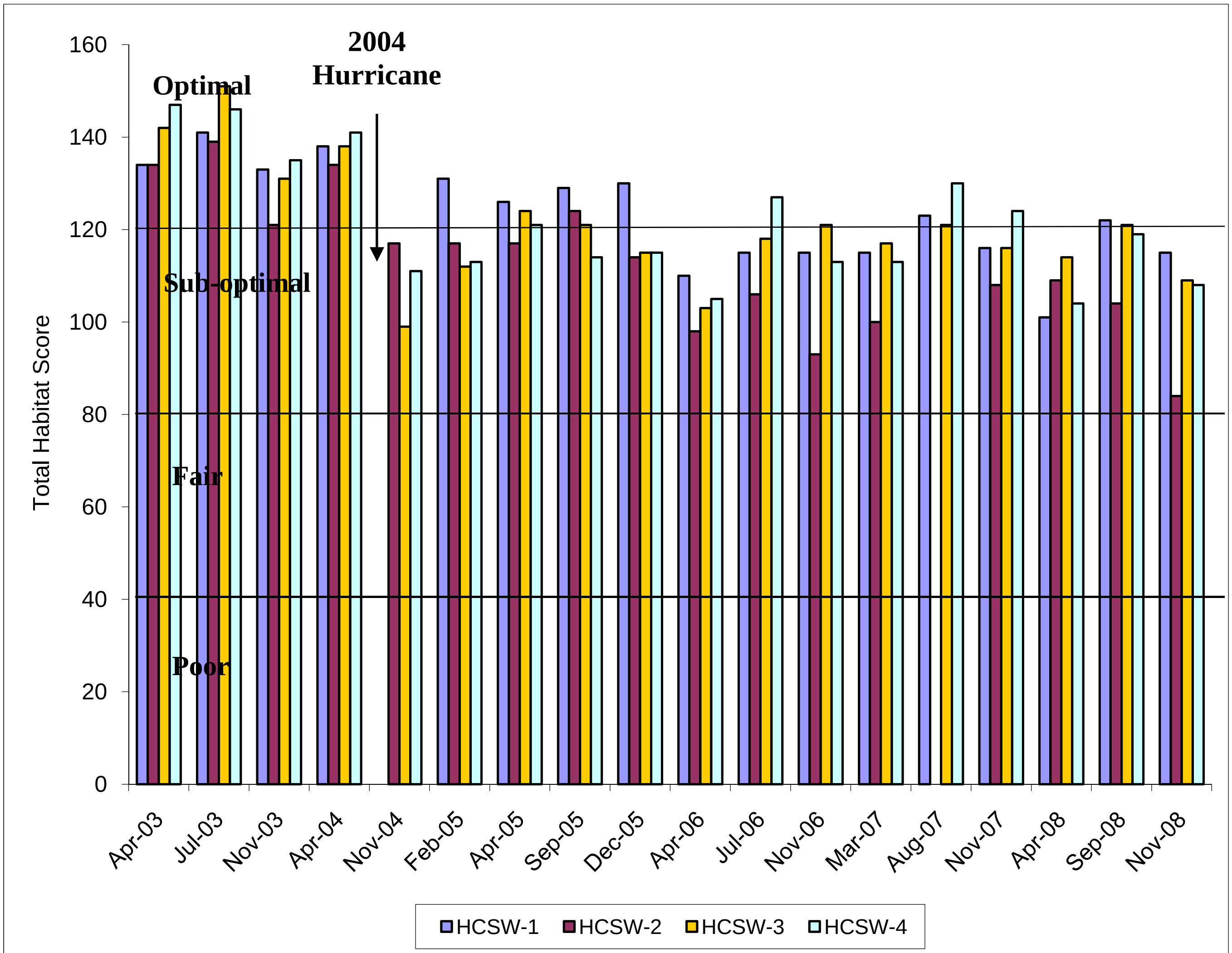

Figure 79. Total Habitat Scores Obtained During HCSP Biological Sampling Events in 2003-2008. (HCSW-1 November 2004 score omitted because of sampler oversight. HCSW-2 August 2007 score omitted due to lack of water.)

5.3.2 Stream Condition Index

A database containing a list of the benthic macroinvertebrate taxa collected during 2003 - 2008 is on the attached CD-ROM. Table 19 provides the SCI metrics, resulting SCI values, and total SCI scores calculated for the benthic macroinvertebrates collected at the four stations during each sampling event in 2008. The numbers of individuals included in Table 19 represent the number extrapolated for the entire sample (i.e., all 20 dipnet sweeps). This estimate is also given in the database, as well as the actual number of individuals in the subsample analyzed by the taxonomist (only a portion of each sample is sorted and processed, per the SOP). The various components of the SCI calculations are briefly described in the subsections below.

Table 18. Habitat Scores Obtained During HCSP Biological Sampling Events in 2008.

	HCSW-1			HCSW-2			HCSW-3			HCSW-4		
	24 April 2008	**12 September 2008**	**19 November 2008**	**24 April 2008**	**12 September 2008**	**19 November 2008**	**24 April 2008**	**12 September 2008**	**19 November 2008**	**24 April 2008**	**12 September 2008**	**19 November 2008**
Substrate Diversity	13	14	18	5	6	6	5	5	8	10	8	6
Substrate Availability	6	9	7	20	6	8	20	20	20	8	4	6
Water Velocity	4	18	11	5	13	2	9	18	11	10	15	13
Habitat Smothering	10	13	11	11	13	8	14	12	10	15	11	10
Artificial Channelization	20	20	20	20	20	20	20	20	20	20	20	20
Bank Stability												
Right Bank	5	5	5	8	8	5	8	8	5	8	6	5
Left Bank	5	5	5	8	8	5	8	8	5	8	6	5
Riparian Buffer Zone Width												
Right Bank	10	10	10	10	10	10	10	10	10	10	10	10
Left Bank	10	10	10	10	10	10	10	10	10	10	10	10
Riparian Zone Vegetation Quality												
Right Bank	9	9	9	5	5	5	5	5	5	10	10	10
Left Bank	9	9	9	5	5	5	5	5	5	10	10	10
Total Score*	**101**	**122**	**115**	**109**	**104**	**84**	**114**	**121**	**109**	**119**	**110**	**104**
Habitat Descriptor	Sub-Optimal	Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal

- * - The maximum possible score under this protocol is 160 (120-160 Optimal, 80-119 Suboptimal, 40-79 Marginal, <40 Poor).

Table 19. SCI Metrics Calculated for Benthic Macroinvertebrates Collected at Four Locations on Horse Creek for the HCSP During 2008.

SCI Metric	HCSW-1						HCSW-2					
	24 April 2008		12 Sept 2008		19 Nov 2008		24 April 2008		12 Sept 2008		19 Nov 2008	
	Raw Score	SCI Value	Raw	SCI Value	Raw	SCI Value	Raw	SCI	Raw	SCI	Raw	SCI Value
Total Taxa	34.5	**7.4**	23.5	**3.0**	27.5	**4.6**	23.5	**3.0**	16.0	**0.6**	21.0	**2.0**
Ephemeropteran Taxa	3.0	**6.0**	3.5	**7.0**	3.5	**7.0**	1.5	**3.0**	0	**0**	0	**0**
Trichopteran Taxa	3.0	**4.3**	1.0	**1.4**	3.5	**5.0**	0.5	**0.7**	0	**0**	0	**0**
Percent Filterer Taxa	7.2	**1.6**	15.2	**3.6**	7.6	**1.7**	3.0	**0.5**	3.3	**0.6**	18.1	**4.4**
Long-lived Taxa	2.0	**5.0**	1.0	**2.5**	3.5	**8.8**	0	**0**	0	**0**	0	**0**
Clinger Taxa	3.0	**3.8**	5.0	**6.3**	5.5	**6.9**	1.5	**1.9**	0.5	**0.6**	0	**0**
Percent Dominant	32.1	**5.0**	37.0	**3.9**	56.0	**0.1**	45.8	**1.9**	51.9	**0.5**	27.3	**6.1**
Percent Tanytarsini	5.8	**5.7**	13.3	**8.0**	4.4	**5.1**	5.7	**5.7**	6.3	**5.4**	26.3	**9.8**
Sensitive Taxa	2.5	**2.8**	1.5	**1.7**	2.5	**2.8**	0	**0**	0	**0**	0	**0**
Percent Very Tolerant	37.5	**1.2**	14.9	**3.3**	3.3	**8.2**	12.1	**3.7**	88.5	**0**	72.3	**0**
Total SCI Score	**47.5**		**45.2**		**55.7**		**22.7***		**8.6**		**24.7**	
Interpretation	**Healthy**		**Healthy**		**Healthy**		**Impaired**		**Impaired**		**Impaired**	
Total Number of	3744		4116		6376		1557		808		3492	
SCI Metric	HCSW-3						HCSW-4					
	24 April 2008		12 Sept 2008		19 Nov 2008		24 April 2008		12 Sept 2008		19 Nov 2008	
	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw	SCI Value
Total Taxa	32.0	**6.4**	10.5	**0**	22.5	**2.6**	35.0	**7.6**	29.0	**5.2**	29.0	**5.2**
Ephemeropteran Taxa	2.5	**5.0**	1.0	**2.0**	1.5	**3.0**	4.0	**8.0**	2.0	**4.0**	3.5	**7.0**
Trichopteran Taxa	4.0	**5.7**	0	**0**	1.5	**2.1**	5.5	**7.1**	2.5	**3.6**	2.5	**3.6**
Percent Filterer Taxa	11.6	**2.7**	0.6	**0**	7.6	**1.7**	8.0	**1.8**	1.8	**0.2**	8.6	**1.9**
Long-lived Taxa	1.5	**3.8**	1.0	**2.5**	1.0	**2.5**	2.0	**5.0**	2.0	**5.0**	2.5	**6.3**
Clinger Taxa	3.5	**4.4**	0	**0**	4.0	**5.0**	4.0	**5.0**	3.0	**3.8**	6.0	**7.5**
Percent Dominant	27.4	**6.0**	60.9	**0**	58.9	**0**	24.3	**6.8**	43.0	**2.5**	11.8	**9.6**
Percent Tanytarsini	10.8	**7.5**	0.6	**0.7**	3.9	**4.8**	3.0	**4.1**	0.7	**1.6**	3.0	**4.1**
Sensitive Taxa	0	**0**	0	**0**	0.5	**0.6**	1.0	**1.1**	1.5	**1.7**	3.0	**3.3**
Percent Very Tolerant	28.9	**1.7**	36.0	**1.2**	10.6	**4.0**	44.3	**0.7**	22.0	**2.4**	28.2	**1.8**
Total SCI Score	**48.0**		**7.1**		**29.3**		**52.5**		**33.1**		**55.8**	
Interpretation	**Healthy**		**Impaired**		**Impaired**		**Healthy**		**Impaired**		**Healthy**	
Total Number of	2493		2421		9405		8378		5400		5868	

* < recommended 150 individuals

5.3.2.1 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 80 illustrates the number of taxa collected at each of the HCSP stations during the quarterly events. In 2008, the highest number of benthic macroinvertebrates species was collected in April. The fewest number of species in 2008 were collected in September at all stations. 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 2003 to 2008, Total Taxa were variable over time at each station, but their scores did not increase or decrease over time (Kendall Tau, p > 0.05) and were not significantly different between stations (ANOVA: F = 0.14, p = 0.98).

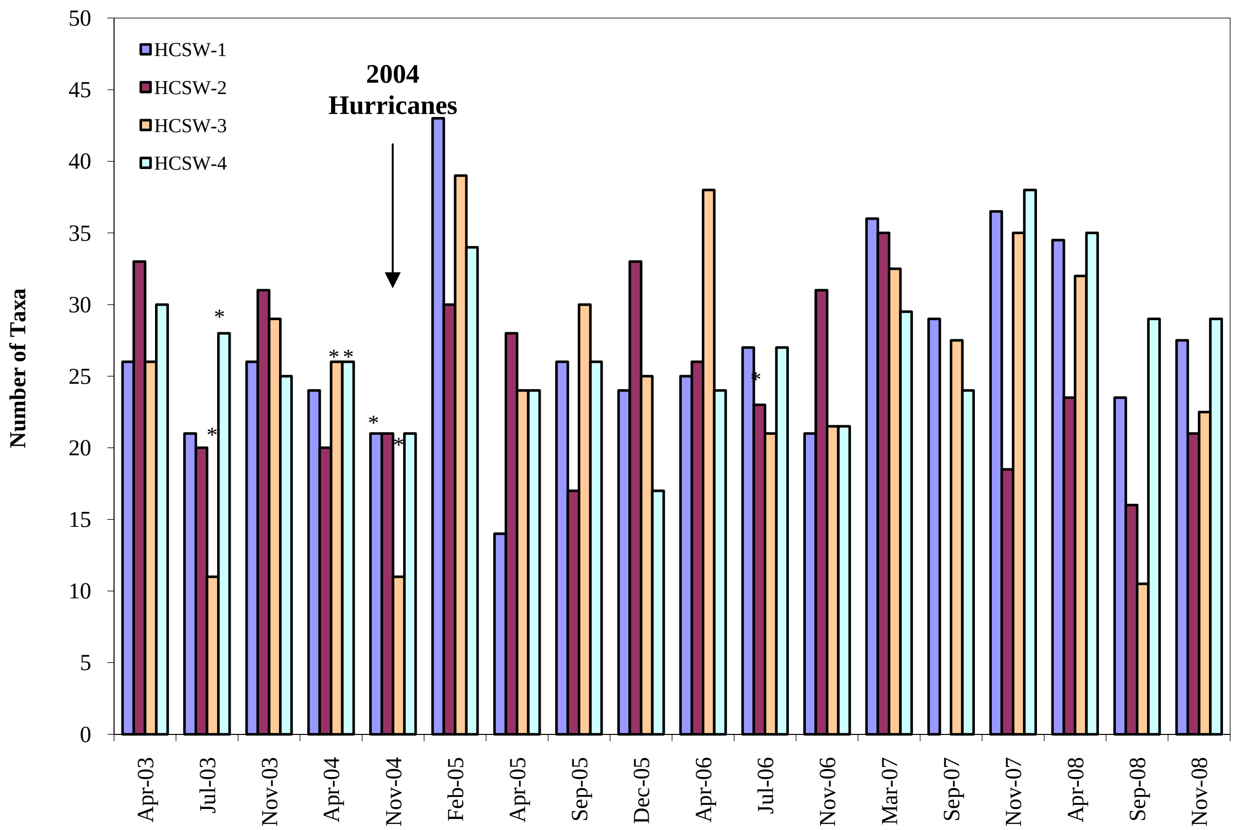

Figure 80. Number of Invertebrate Taxa Collected from the Horse Creek Stewardship Project in 2003 - 2008. (* represent samples with less than the recommended individuals in the sorted portion; the SCI score for these samples is suspect.)

5.3.2.2 Ephemeroptera Taxa

Ephemeropterans (mayflies) are typically associated with more pristine waters and better habitat conditions. A higher taxa count for this group is associated with better habitat value. At least one mayfly taxon must be present to score a SCI metric above zero. This metric was zero twice in 2008, at HCSW-2 in September and November. The greatest number of mayfly taxa collected at any station during any event in 2008 was four (in April at HCSW-4). Although the number of Ephemeroptera taxa was as high as six at some sites used in developing the SCI calculation protocols, typical samples produce only 0-2 taxa (Fore 2004). This is consistent with the findings from the Horse Creek stations (Table 19). When considered over time from 2003 to 2008, Ephemeroptera taxa were variable over time at each station, but their scores did not increase or decrease over time (Kendall Tau, $p > 0.05$); scores were significantly lower at HCSW-2 than other stations (ANOVA: $F = 6.23$, $p = 0.001$, Duncan's multiple range test: $p < 0.05$). Examples of common mayfly species collected in 2008 were *Caenis diminuta* and *Tricorythodes albilineatus.*

5.3.2.3 Trichoptera Taxa

Trichopterans (caddisflies) are also associated with more pristine waters and better habitats, so higher counts of caddisflies are associated with better ecological conditions. At least one taxon must be collected in order for the SCI metric to be above zero. This metric was zero three times in 2008, at HCSW-2 in September and November and at HCSW-3 in September. The greatest number of caddisfly taxa in any sample in 2008 was 5.5 (in HCSW-4 in April). According to Fore (2004), caddisfly taxa ranged from zero to eight in samples used for calibrating the SCI protocol, with most samples having four or fewer taxa. This is quite comparable to the observed pattern from Horse Creek in 2008 (Table 19). When considered over time from 2003 to 2008, Trichoptera taxa were variable over time at each station, but their scores did not increase or decrease over time (Kendall Tau, $p > 0.05$); scores were significantly lower at HCSW-2 than other stations (ANOVA: $F = 6.48$, $p = 0.001$, Duncan's multiple range test: $p < 0.05$). Examples of common caddisfly species found in Horse Creek in 2008 were *Neotrichia sp*., *Oxyethira sp*., and *Cheumatopsyche sp*.

5.3.2.4 Percent Collector-Filterer Taxa

Taxa whose functional feeding group is "collector-filterer" are often more prolific in pristine natural waters. A reduction in the collector-filterer community can indicate a water quality problem. The SCI metric increases as the percentage of a sample comprised by these taxa increases. To score above zero for this metric, more than one percent of the sample must be composed of collector-filterers. Samples at each station during each 2008 event were composed of less than one to eighteen percent collector-filterers (Table 19). This is within the range reported by Fore (2004) in developing the SCI calculation protocol. When considered over time from 2003 to 2008, collector-filterers taxa were variable over time at each station, and their scores had a slight decrease over time (Kendall Tau = -0.56, $p < 0.01$), more specifically, there was a decreasing trend noted at HCSW-4 (Kendall Tau = -0.73, $p = 0.038$); scores were not significantly different among stations (ANOVA: $F = 0.11$, $p = 0.96$). Examples of filter feeder species collected in 2008 were *Tanytarsus sp*. *F*, *Rheotanytarsus exiguous group*, and *Cheumatopsyche sp*.

5.3.2.5 Long-lived Taxa

Long-lived taxa are those that require more than one year to complete their life cycles (Fore, 2004), so they would not be expected in great numbers in intermittent streams or tributaries that go dry before their life cycle can be completed. Some long-lived taxa might also be less frequently encountered in less pristine waters, where these taxa could be exposed to potential contaminants for longer than their short-lived counterparts. To score above zero for this SCI metric, at least one long-lived taxon must be present in a sample. In 2008, the number of long-lived taxa ranged from zero to 3.5. The observed range of long-lived taxa (0 - 5 taxa) in samples collected from Horse Creek in 2003-2008 (Table 19) corresponds with the range used to develop the SCI methodology (Fore 2004). When considered over time from 2003 to 2008, long-lived taxa were variable over time at each station, and their scores had a slight decrease over time (Kendall Tau = -0.41, $p = 0.005$), more specifically, there was a decreasing trend noted at HCSW-2

(Kendall Tau = -0.75, p = 0.036); scores were not significantly different among stations (ANOVA: F = 2.08, p = 0.11). Examples of long-lived species collected in 2008 were *Palaemonetes paludosus* and *Corbicula fluminea*.

5.3.2.6 Clinger Taxa

Taxa whose mode of existence is identified as clinging by Merritt and Cummins (1996) are defined as "having behavioral (e.g., fixed retreat construction) and morphological adaptations for attachment to surfaces in stream riffles." The SCI metric increases as the number of clinger taxa increases within a sample. To score above zero for this SCI metric, at least one clinger taxon must be present in a sample. No clinger taxa were found at HCSW-2 during November of 2008 (Table 19), similar to previous years where clinger taxa were not observed at all. This is presumed to be the result of more sluggish flow at that station, which yields conditions not generally suited for clingers that prefer riffles. Clinger taxa were found at the other three stations at most sampling events in 2008 (no clinger taxa were observed at HCSW-3 in September), with the most in any sample being six (Table 19). While Fore (2004) reported more than ten clinger taxa in some cases, most samples used to develop the SCI protocol had less than five taxa. When considered over time from 2003 to 2008, clinger taxa were variable over time at each station, but their scores did not increase or decrease over time (Kendall Tau, p > 0.05); scores were significantly lower at HCSW-2 than other stations (ANOVA: F = 16.9, p < 0.0001, Duncan's multiple range test: p < 0.05). Common clinger species found in Horse Creek in 2008 were *Neotrichia sp*., *Stenelmis sp.*, and *Rheotanytarsus exiguous group*.

5.3.2.7 Percent Dominant Taxon

As the contribution of the dominant taxon increases, the diversity of taxa within a system generally decreases. Therefore, higher percent contribution by one taxon is interpreted as less ecologically desirable, and lowers the numerical value associated with this metric. The SCI score is zero if the percentage contribution of the dominant taxon is at or above 54 percent, which was the case at HCSW-3 in September and November of 2008. Overall, 10 of the 12 samples in 2008 had a single taxon representing more than one fourth of the invertebrate community (Table 19). For 5 of the 12 samples in 2008, an amphipoda, *Hyalella azteca* complex dominated. The coleopterans (beetle) dominated two samples, with *Microcylloepus pusillus*. Three samples were dominated by gastropods (one location with a tie for dominant gastropod species); three sample were dominated by *Melanoides tuberculata*, an invasive, exotic snail. Dipterans (fly), *Tanytarsus* sp. F and *Chironomus* sp., each dominated a sample. The dominant taxa vary from year to year, with the 2003 samples dominated by molluscs, 2004 and 2006 samples dominated by amphipodans, coleopterans, and dipterans, 2005 samples dominated by ephemeropterans, coleopterans, and dipterans, 2007 samples dominated by gastropods, amphipodans, coleopterans, and dipterans, and 2008 samples were dominated by coleopterans, amphipodans, dipterans, and gastropods. (Need 2008 dominance.) When considered over time from 2003 to 2008, percent dominant taxa were variable over time at each station, but their scores did not increase or decrease over time (Kendall Tau, p > 0.05); scores were not significantly different among stations (ANOVA: F = 2.41, p = 0.07), but scores were higher at HCSW-4.

5.3.2.8 Percent Tanytarsini

Species in the chironomid tribe Tanytarsini (comprising several genera found in Florida) are commonly associated with less disturbed sites. Therefore, as the percentage of Tanytarsini increases for a sampling site, the SCI metric score also increases. If no Tanytarsini individuals are collected in a sample, this SCI metric score is zero; the percent Tanytarsini ranged from 0.6 % to 26 % in 2008. When considered over time from 2003 to 2008, Tanytarsini taxa are increasing over time (Kendall Tau, p < 0.05). Tanytarsini taxa were not significantly different between stations (ANOVA: F = 0.18, p = 0.91). Common chironomids found in 2008 were *Tanytarsus sp. F*, and *Rheotanytarsus exiguous group*.

5.3.2.9 Sensitive Taxa

Sensitive taxa are those that have been identified as sensitive to human disturbance (Fore, 2004). Using this definition, one would expect to find more sensitive taxa in undeveloped "natural" areas as opposed to developed watersheds. At least one sensitive taxon must be collected to raise this SCI metric score above zero. The number of sensitive taxa collected at Horse Creek stations in 2008 ranged from zero to three (Table 19). No sensitive taxa were collected from HCSW-2 in 2008, which corroborates well with the lower dissolved oxygen regime at that station and the sluggish nature of the stream segment there, as caused by its proximity to the Horse Creek Prairie. Also, no sensitive taxa were collected at HCSW-3 during April and September of 2008. When considered over time from 2003 to 2008, sensitive taxa were decreasing over time at HCSW-3 (Kendall Tau, $p < 0.05$), but did not show trends at any other station (Kendall Tau, $p > 0.05$); scores were significantly lower at HCSW-2 and HCSW-3 than other stations (ANOVA: $F = 13.4$, $p = 0.0001$, Duncan's multiple range test: $p < 0.05$). An example of a common sensitive species found in 2008 was *Tricorythodes albilineatus*.

5.3.2.10 Percent Very Tolerant Taxa

Fore (2004), classified a number of taxa as "very tolerant", meaning they are commonly present in areas with marked human disturbance (although they may also be found in undisturbed sites). More disturbed and/or developed areas, therefore, would be expected to have a higher percentage of tolerant taxa in comparison to areas that have not experienced human disturbance. This SCI metric is similar to the percent contribution of dominant taxa in that, as the fraction of a sample comprised by tolerant taxa increases, the calculated metric decreases. If the percentage of very tolerant taxa reaches or surpasses fifty-nine percent, the SCI metric is zero. This occurred twice during the 2008 sampling period at HCSW-2 during September and November (Table 19). When considered over time from 2003 to 2008, percent very tolerant taxa decreased at HCSW-3 (Kendall Tau, $p < 0.05$), but were variable over time at the other stations where scores did not increase or decrease over time (Kendall Tau, $p > 0.05$); scores were significantly lower at HCSW-2 and higher at HCSW-1 than other stations (ANOVA: $F = 8.17$, $p = 0.0001$, Duncan's multiple range test: $p < 0.05$). Common very tolerant taxa found in Horse Creek in 2008 included *Melanoides tuberculata*, *Pyrgophorus platyrachis*, and *Chronomus sp*.

5.3.2.11 SCI Overall Score

Final SCI scores for the samples (with the recommended range of 140-160 individuals in the sorted portion) ranged from 7 to 55 in 2008, similar to other years (Table 19 and Figure 81). When considered over time from 2003 to 2008, the overall SCI scores were variable over time at each station but did not increase or decrease over time (Kendall Tau, $p > 0.05$); scores were significantly lower at HCSW-2 than other stations (ANOVA: $F = 9.08$, $p < 0.0001$, Duncan's multiple range test: $p < 0.05$). SCI scores in 2008 were noticeably lower during the September 2008 event at all stations except HCSW-1. In September 2008, there was higher than average water levels and flow prior to the sampling event. Habitats may not have been accessible to sample because of high water levels, and the greater flow of the stream would have made it more difficult for certain species to remain attached to their preferred habitats. During the September sampling event dissolved oxygen was low and sediment odors indicated anaerobic respiration was occurring, making conditions unsuitable for sensitive benthic invertebrates, and therefore lowering the overall score. Extremely dry conditions through May and June 2008 allowed terrestrial plant species to colonize the stream floor; when the wet season began, this material, along with other organic matter brought in by runoff, began to decompose, causing increased oxygen demand in the stream.

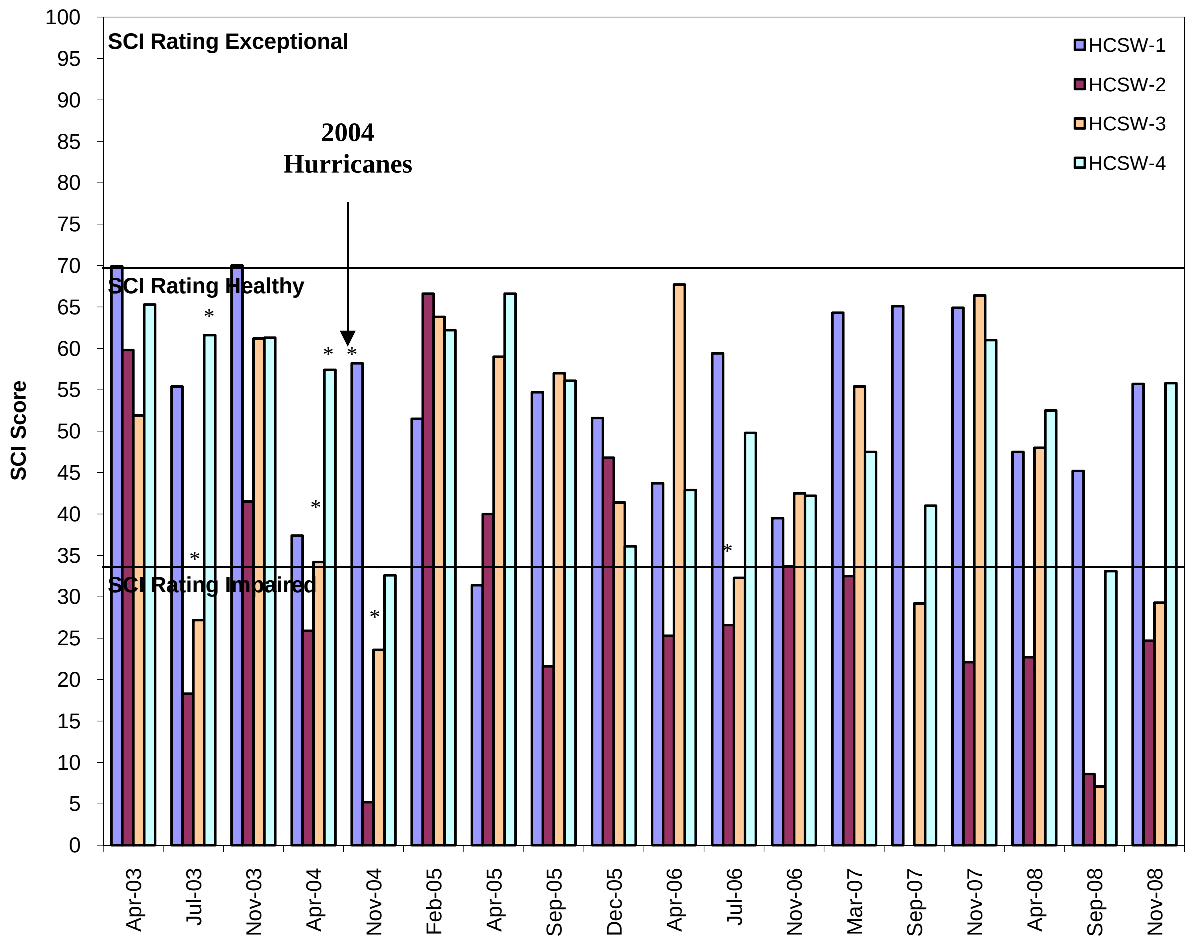

Figure 81. SCI Scores for Samples Collected from Horse Creek, 2003 - 2008. (* represent samples with less than the recommended individuals in the sorted portion; the SCI score for these samples is suspect.)

5.3.3 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, rather than species diversity, was used to account for the high variability of species present from year to year. In Horse Creek in 2008, the Shannon-Wiener Diversity Index ranged from 1.6 to 4.1 (Figure 82). The range of diversity values were similar among all years (2003 -2008), ranging from 1.4 to 4.1 (Figure 83). When stations and dates within years were combined, diversity was not statistically different among years (ANOVA: F = 0.14, p = 0.98) (Figure 84). When stations were combined, diversity was not significantly different among dates (ANOVA: F = 1.57, p = 0.1) (Figure 85). When results from all events in 2003 - 2008 were combined by station (Figure 86), there was a significant difference between stations (ANOVA: F = 3.41, p = 0.02).

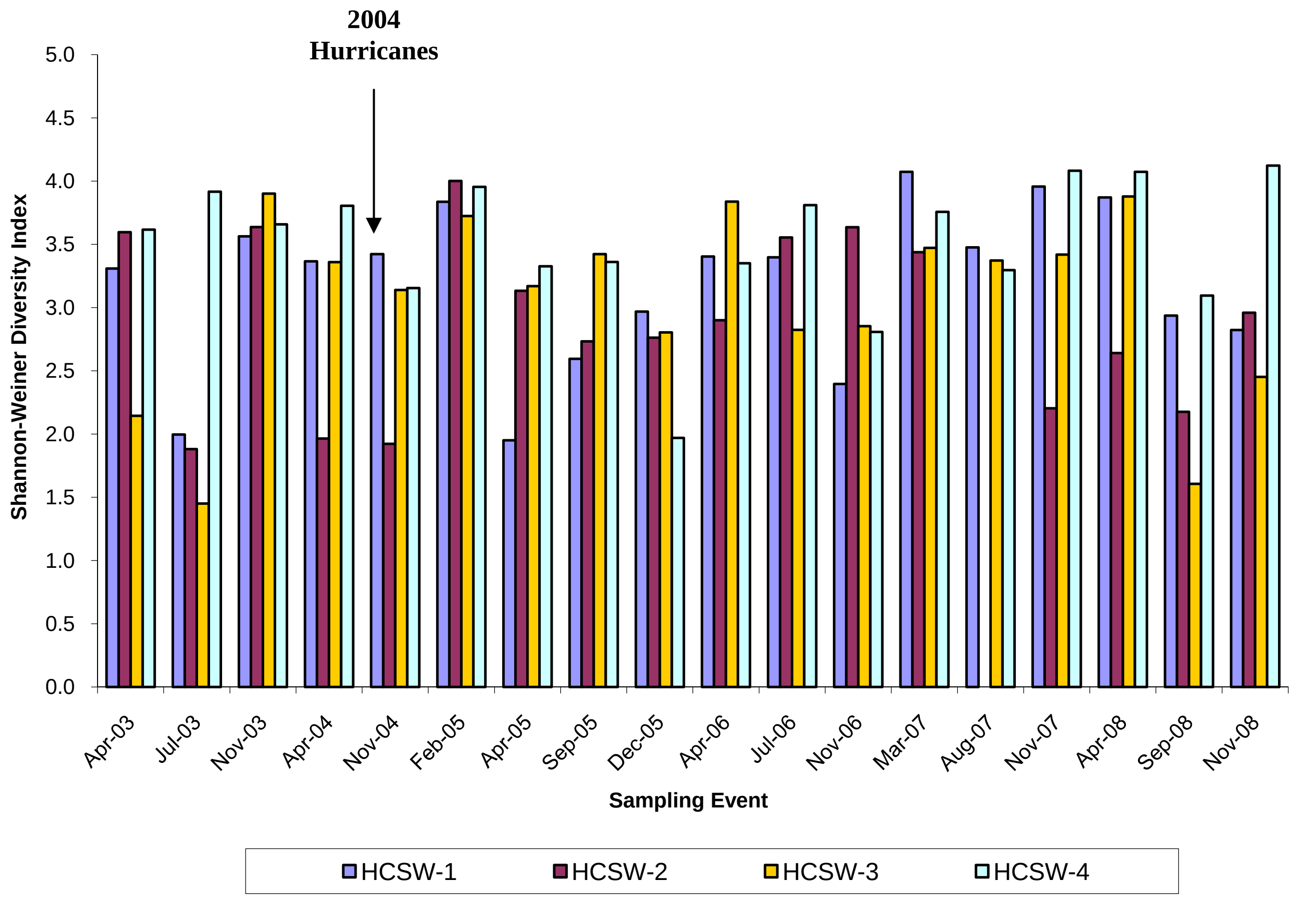

Figure 82. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrate Genera from Four Stations on Horse Creek from 2003 - 2008.

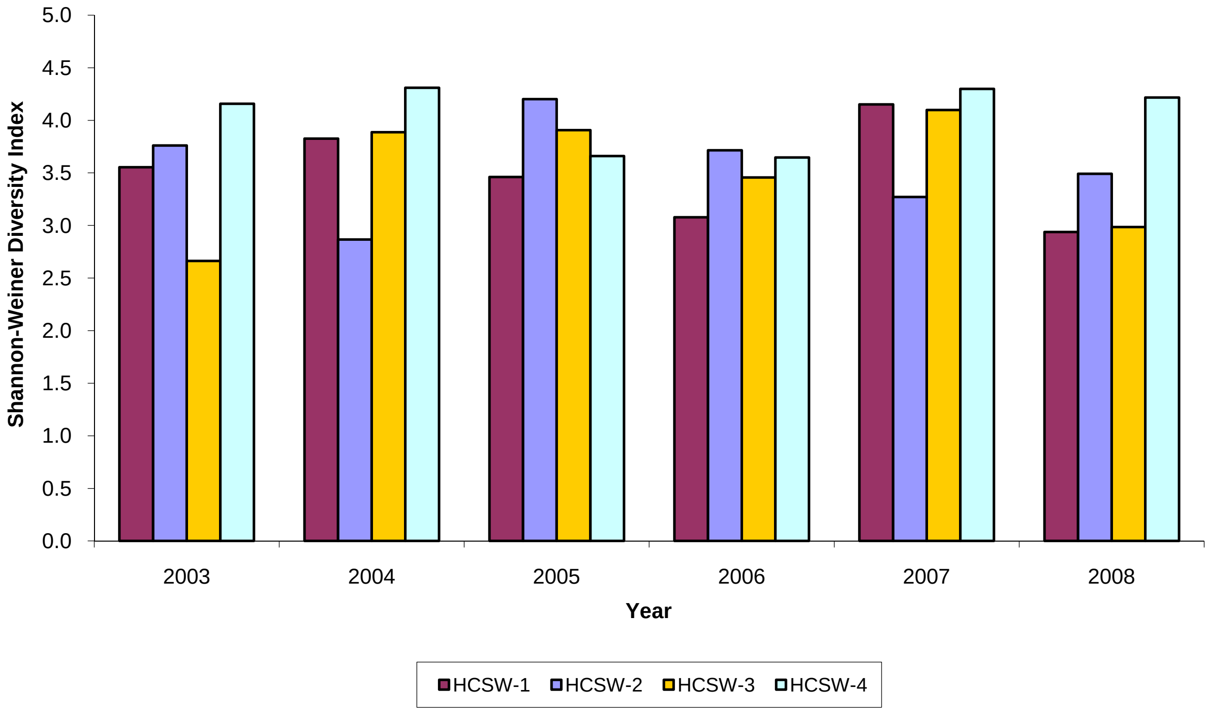

Figure 83. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrates Genera per year from Four Stations on Horse Creek for combined sample dates.

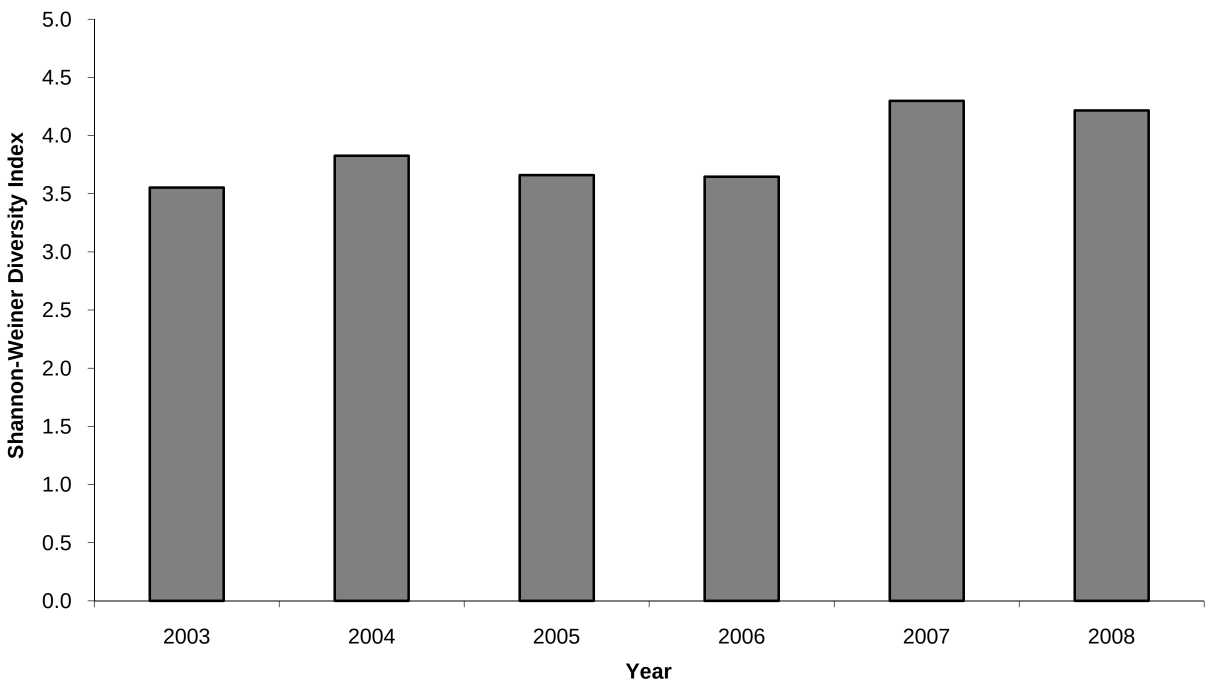

Figure 84. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrates Genera per year from Horse Creek for combined sample dates and stations.

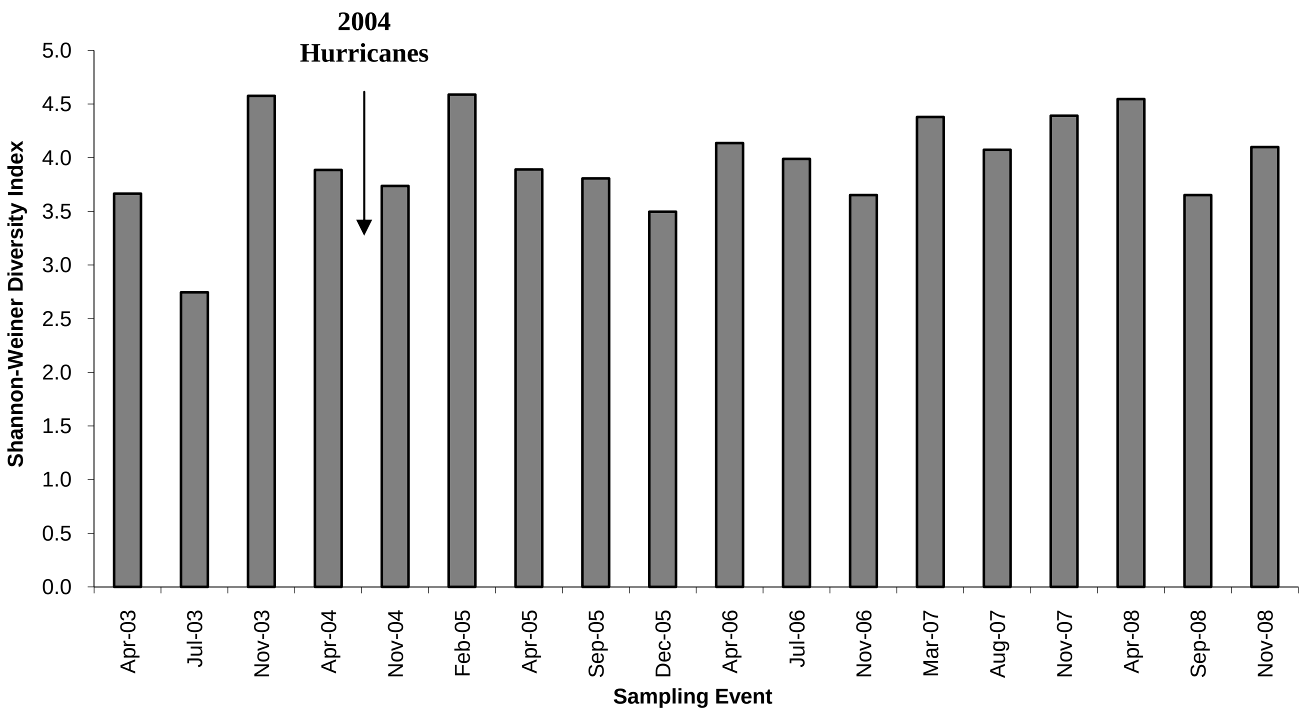

Figure 85. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrates Genera per sample date from Horse Creek for combined stations.

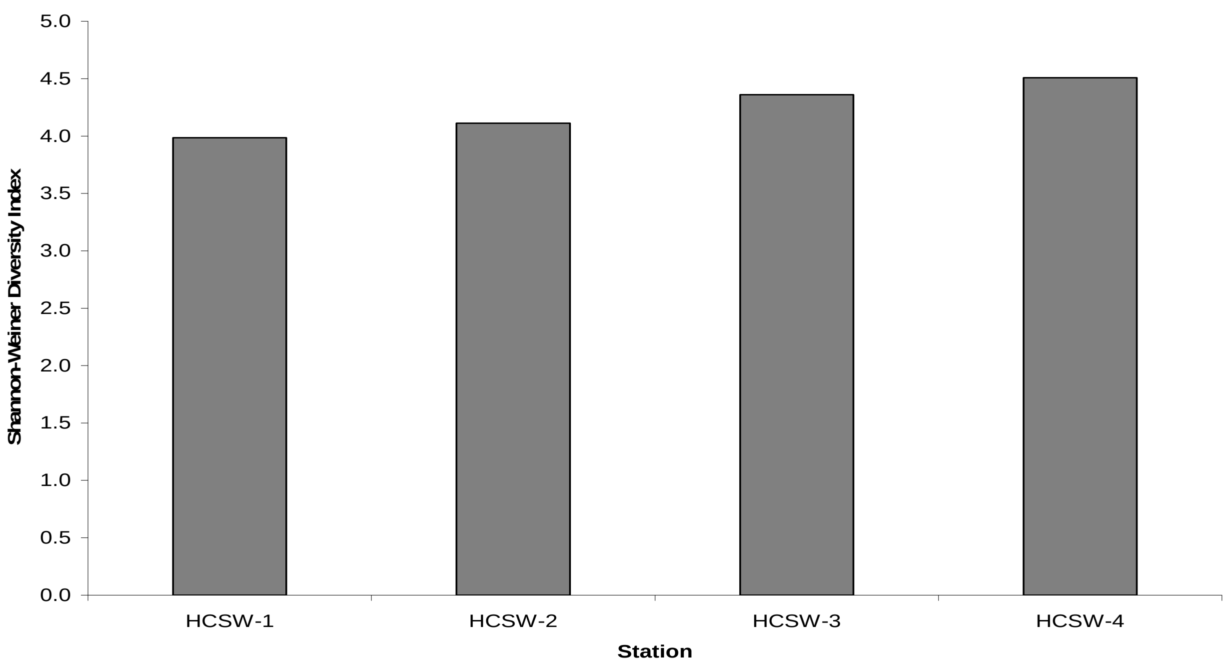

Figure 86. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrates Genera per Station on Horse Creek for combined sample dates.

5.3.4 Summary of Benthic Macroinvertebrate Results

The brief discussion of each of the SCI parameters above conveys two important aspects of this particular ecological metric. First, there can be a large degree of variability among stations and among samples from the same station for a given calculated metric. Second, the actual range over which many of the measured parameters fluctuates can be very small, particularly for the parameters relying on integer counts of taxa (e.g., Ephemeroptera taxa generally range between 0 and about 4 across the various stream types evaluated in developing the SCI). These considerations suggest that care should be exercised in using any individual metric of the SCI as a separate indicator of stream habitat quality. This is the justification for combining all the parameters into a composite index that presumably has a stronger correlation to stream conditions than the separate metrics themselves.

The general quality of the macroinvertebrate community at the Horse Creek stations was within the range commonly observed by ENTRIX in similarly-sized natural streams in this region of Florida. It may appear inconsistent that when the Habitat Assessment scores indicated optimal or sub-optimal conditions, the total SCI scores indicated that the benthic communities were Impaired. However, this is essentially a matter of semantics resulting from the assignment of qualitative categories under the two different assessment protocols (which were developed independently and not necessarily designed to provide matching qualitative assignments for a given location). Following the adoption of the revised SCI calculation procedure, DEP found that the majority of the reference/background stations it had sampled fell into the Healthy category when calculated under the new SCI (R. Frydenbourg, pers. comm.). This indicates that the sampled segments of Horse Creek are comparable in quality (as determined via the SCI) to other reference streams in Florida.

Benthic invertebrate taxa diversity and SCI metrics in Horse Creek exhibit both seasonal and year-to-year variation. Overall, taxa diversity indices and SCI metrics show no monotonic trend over time and are very similar between sampling events and stations. However, HCSW-2 has slightly lower diversity and significantly lower SCI metrics than other stations. Habitat conditions at HCSW-2 are consistently poor, with lower streamflow, dissolved oxygen, and pH than other Horse Creek stations. The source of the poor 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.

5.4 FISH

During 2008, 27 species of fish were collected from the four Horse Creek sampling stations; they are listed in Table 20 (the attached CD-ROM provides all data). In 2008, no new fish species were collected. However, fourteen species of fish that had been collected in 2003-2007 were not collected in 2008.

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. Seven of the 41 species collected from 2003 to 2008 are not native to Florida: the walking catfish (*Clarias batrachus*), African jewelfish (*Hemichromis letourneuxi*), brown hoplo (*Hoplosternum littorale*), vermiculated sailfin catfish[4] (*Pterygoplichthys disjunctivus*), oriental weatherfish (*Misgurnus anguillicaudatus*), sailfin catfish[6] (*Pterygoplichthys pardalis*), and blue tilapia (*Oreochromis aureus*).

5.4.1 Taxa Richness and Abundance

The greatest numbers of individual fish were collected in November 2004 – April 2005 (Figure 88). More species of fish were collected prior to November 2004 than during sampling events in 2005 and 2006, but species richness in 2007 and 2008 is increasing to pre-Hurricane Charley levels (Figure 87). A decrease in species richness at HCSW-2, HCSW-3, and HCSW-4 was clearly evident after the hurricanes of 2004, strongly suggesting that the fish communities of these stations were affected by the hurricanes, but those stations are now slowly recovering. HCSW-1, which was not as strongly affected by the hurricanes, shows similar species richness before and after summer 2004.

Most of the individuals collected at a sampling station consisted of eastern mosquitofish, sailfin molly, or least killifish. 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 2008 sampling events. Spotted sunfish (*Lepomis punctatus*), bluefin killifish (*Lucania* goodei), and sailfin mollies (*Poecilia latipinna*) were collected at all four sampling stations the majority of the time in 2008. Small numbers (as few as one) of individual fish were collected for most of the species found in 2008 (Table 18). Fewer fish species were collected at HCSW-2 in 2008 than the other three stations (Table 18, Figure 88), which may indicate that the pattern of fish species richness is returning to pre-hurricane relationships. In addition, streamflow was very low during biological sampling at HCSW-1 and HCSW-2 in 2008. As with the macroinvertebrate sampling, the number and richness of fish collected in September 2008 were lower at HCSW-2, HCSW-3, and HCSW-4 than during other events in 2008, probably because of low dissolved oxygen concentrations. During the September sampling event dissolved oxygen was low and sediment odors indicated anaerobic respiration was occurring, making conditions unsuitable for many fish species. Extremely dry conditions through May and June 2008 allowed terrestrial plant species to colonize the stream floor; when the wet season began, this material, along with other organic matter brought in by runoff, began to decompose, causing increased oxygen demand in the stream. Besides the low dissolved oxygen conditions, high water levels and flow during sampling were not ideal because some habitats could not be reached by our sampling equipment.

[4] Previously identified in 2004 Annual Report as *Hypostomus plecostomus* (suckermouth catfish). Confirmation identification as *P. disjunctivus* by Florida Museum of Natural History (FLMNH).

Table 20. Fish Collected from Horse Creek during HCSP Sampling in 2008.

		HCSW-1			HCSW-2			HCSW-3			HCSW-4		
	Common Name	24 April 2008	12 Sept 2008	19 Nov 2008	24 April 2008	12 Sept 2008	19 Nov 2008	24 April 2008	12 Sept 2008	19 Nov 2008	24 April 2008	12 Sept 2008	19 Nov 2008
Hemichromis letourneuxi	African jewelfish *						4	4	2	12		3	3
Oreochromis aureus	Blue tilapia*								1		1		
Lucania goodei	Bluefin killifish		1				2	40	3	15	25	46	4
Lepomis macrochirus	Bluegill		2	3									
Enneacanthus gloriosus	Bluespotted sunfish		2										
Labidesthes sicculus	Brook silverside	12	11	11							22		1
Ameiurus nebulosus	Brown bullhead	1						1					1
Hoplosternum littorale	Brown hoplo*								4				
Notropis petersoni	Coastal shiner	45	100	80				31			29	1	31
Gambusia holbrooki	Eastern mosquitofish	90	100	84	460	79	770	296	1576	705	21	474	236
Elassoma evergladei	Everglades pygmy		1										
Jordanella floridae	Flagfish												1
Lepisosteus platyrhincus	Florida gar	3						1					
Fundulus chrysotus	Golden topminnow									12			
Trinectes maculatus	Hogchoker							3			3		
Micropterus salmoides	Largemouth bass							1			16	1	
Heterandria formosa	Least killifish				13		11	61	296	4	6	24	5
Misgurnus anguilllicaudatus	Oriental weatherfish *						1						
Lepomis microlophus	Redear sunfish		1										
Pterygoplichthys pardalis	Sailfin catfish *					33	2						
Poecilia latipinna	Sailfin molly	1					2	37	92	55	1	15	12
Fundulus seminolis	Seminole killifish							1			3		4
Lepomis punctatus	Spotted sunfish	13	1	1			1	14		3	13	9	22
Etheostoma fusiforme	Swamp darter		2	2	10						3		
Clarias batrachus	Walking catfish *			1							1		5
Lepomis gulosus	Warmouth			1						1			
Ameiurus natalis	Yellow bullhead		1										
	Total Taxa	**7**	**11**	**8**	**3**	**2**	**8**	**12**	**7**	**8**	**13**	**8**	**12**
	Total Individuals	**165**	**222**	**183**	**483**	**112**	**793**	**490**	**1974**	**807**	**144**	**573**	**325**

* - Non-native species

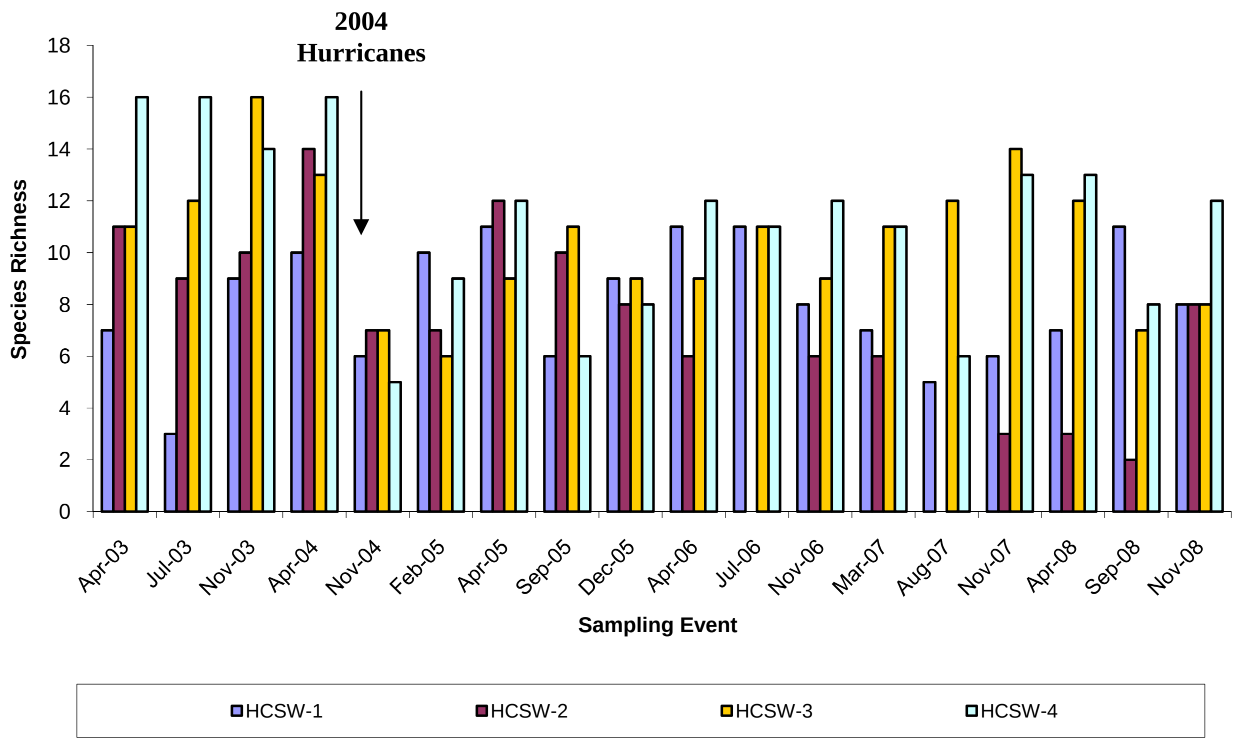

Figure 87. Species Richness for Fish from Four Stations on Horse Creek from 2003 - 2008.

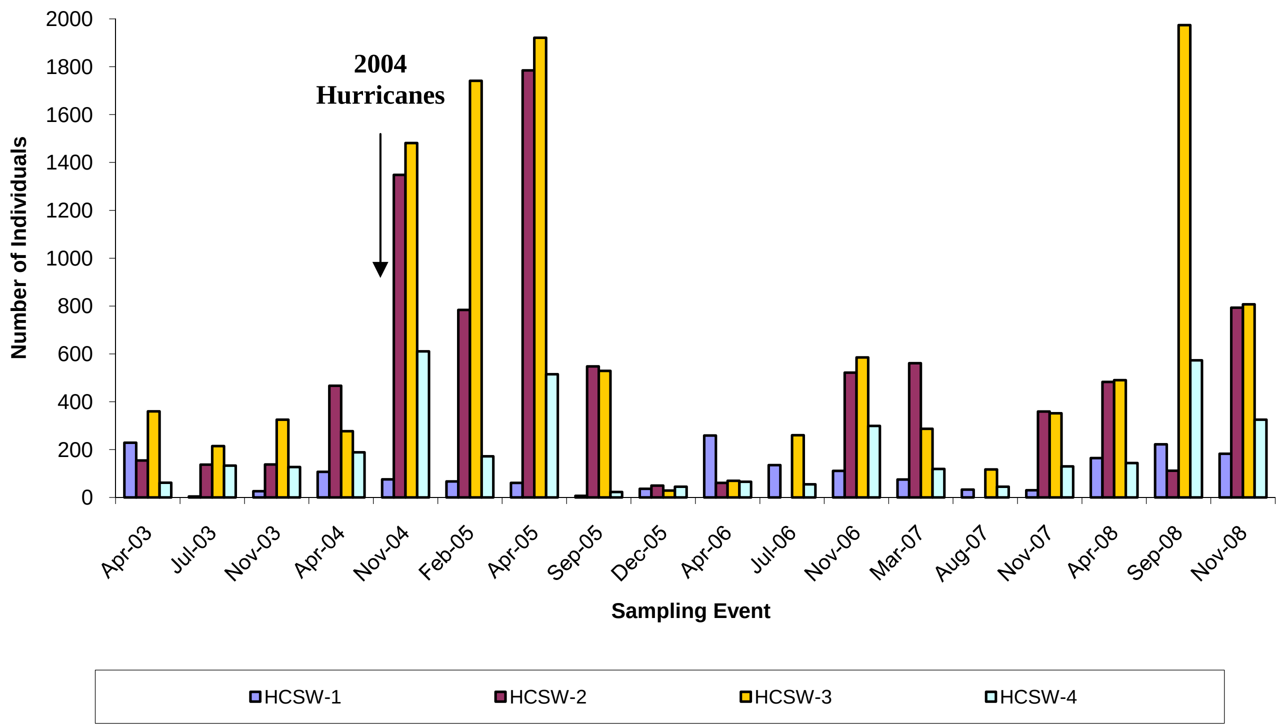

Figure 88. Number of Individual Fish Captured from Four Stations on Horse Creek from 2003 - 2008.

5.4.2 Shannon-Wiener Diversity Index

Diversity of individual fish samples in 2008 ranged from 0.31 (HCSW-2, April) to 2.98 (HCSW-4, April) (Figure 89), similar to 2003 to 2007 ranges. When fish samples were combined across all sampling events, HCSW-1 had the highest species diversity in 2004 - 2006, but it had lower diversity in 2003 and 2007 - 2008 (Figure 90). HCSW-4 had high diversity in 2003, lower diversity in 2004 and 2005 after the hurricanes, and higher diversity in 2006 through 2008 as it recovered to approach previous levels. HCSW-3 followed the same pattern as HCSW-4 until 2008, where it experienced a steep drop in diversity back to levels similar to years with high hurricane activity. Fish diversity at HCSW-2 has been decreasing over time, as rainfall and streamflow decline.

At all stations except HCSW-1, Shannon-Wiener Diversity Index values are lower for all sampling events after November 2004 after the hurricanes affected the three downstream stations (Figure 90); the diversity value was primarily affected by the lowered species richness after the hurricanes, as opposed to the number of individuals. Diversity was not significantly different between dates when stations were combined (ANOVA F = 1.32, p = 0.22) (Figure 91). Over all sampling dates combined (Figure 92), fish diversity was significantly lower at HCSW-2 than at the other stations (ANOVA F = 6.73, p = 0.0005). In 2003 and early 2004, before the hurricanes, diversity generally increased from upstream to downstream. In 2005 after the hurricanes, diversity was consistently higher at HCSW-1, which was relatively unaffected by the hurricanes. In 2006 and 2007, diversity has recovered at HCSW-3 and HCSW-4 to pre-hurricane levels, decreasing once again in the latter part of 2008. Over all stations combined (Figure 93), fish diversity was slightly lower in 2005 than in other years, but the differences were not significant (ANOVA F = 1.31, p = 0.27.)

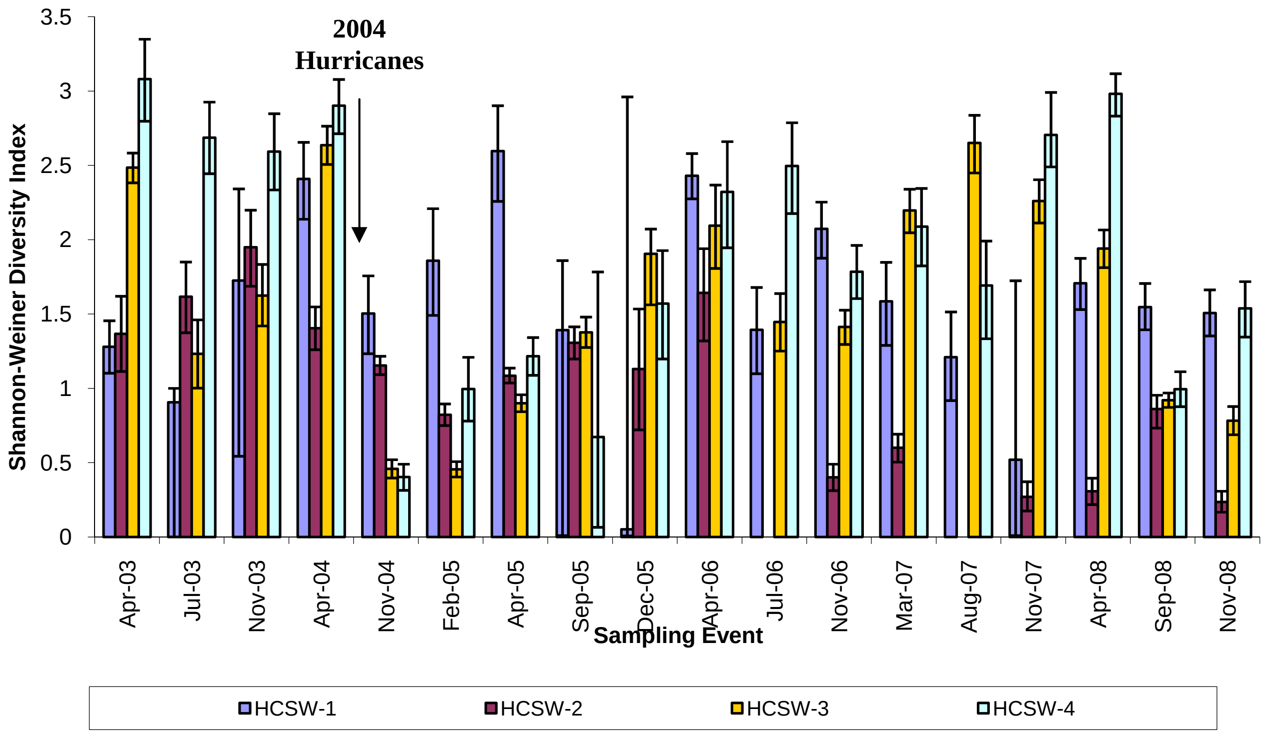

Figure 89. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from Four Stations on Horse Creek in 2003 – 2008 (Ecological Methods v 6.1.1, Exeter Software 2003).

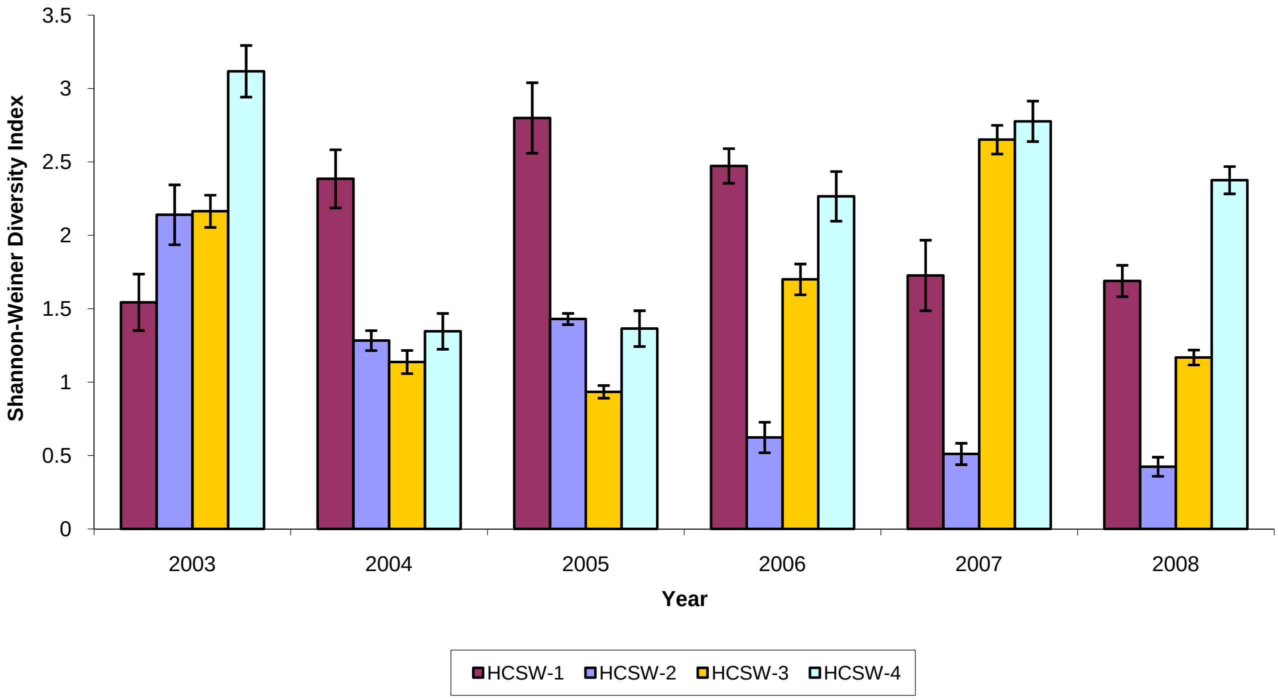

Figure 90. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from Four Stations on Horse Creek summarized over sampling events within each year (Ecological Methods v 6.1.1, Exeter Software 2003).

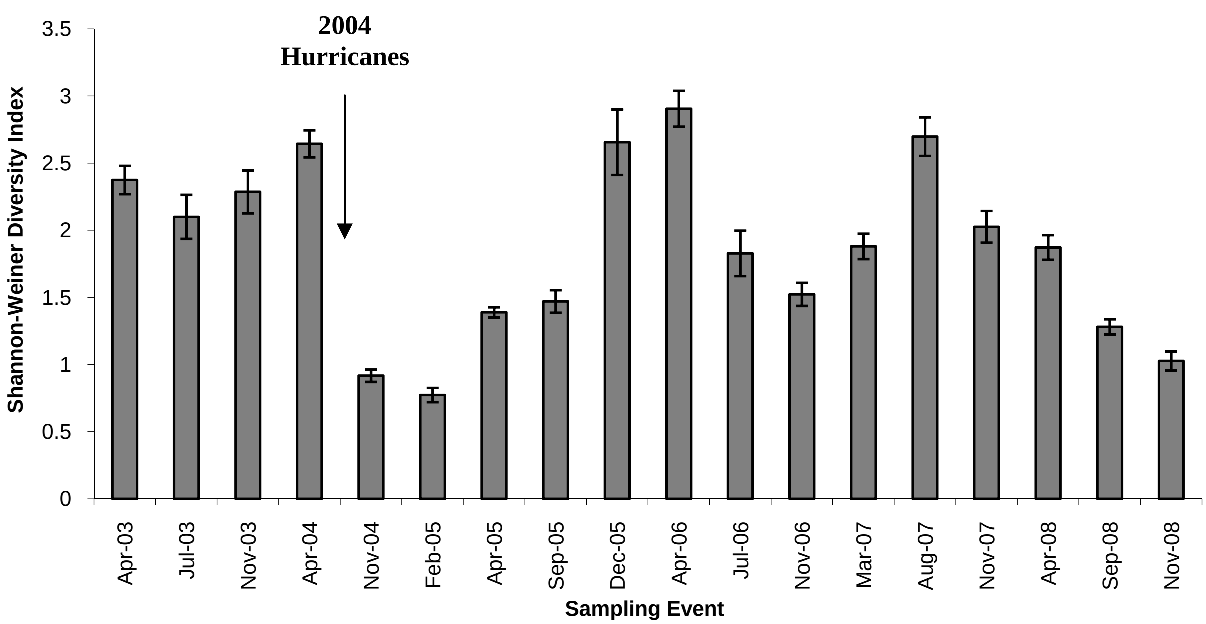

Figure 91. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from Horse Creek summarized over stations (Ecological Methods v 6.1.1, Exeter Software 2003).

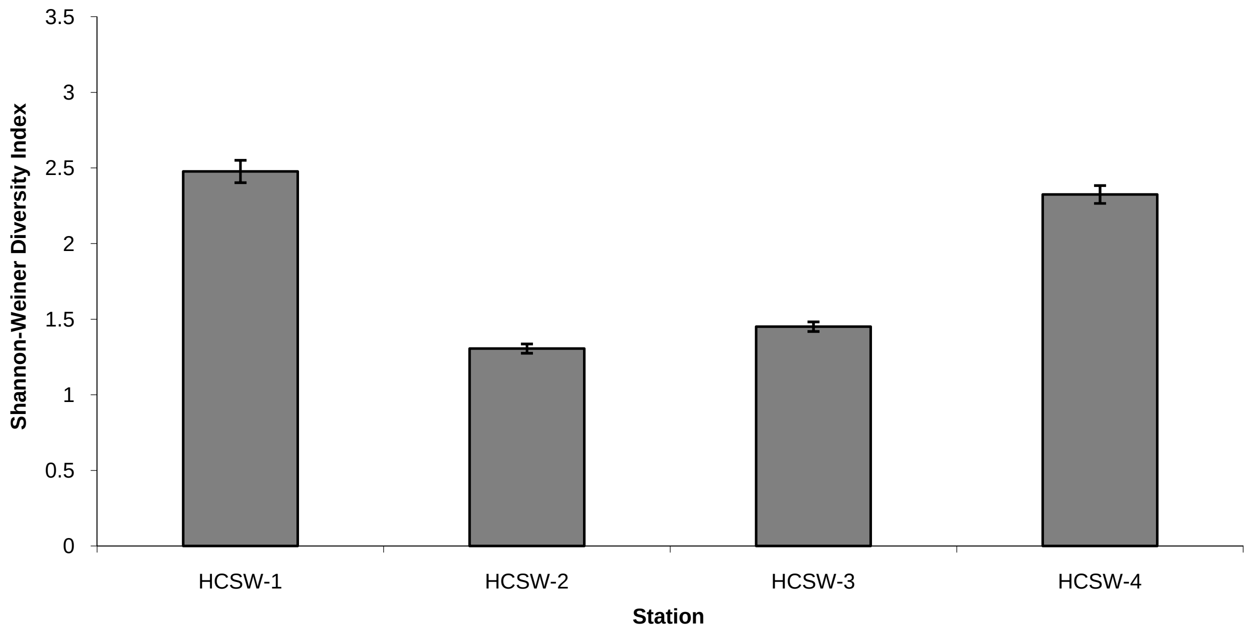

Figure 92. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from Four stations on Horse Creek summarized over sampling dates (Ecological Methods v 6.1.1, Exeter Software 2003).

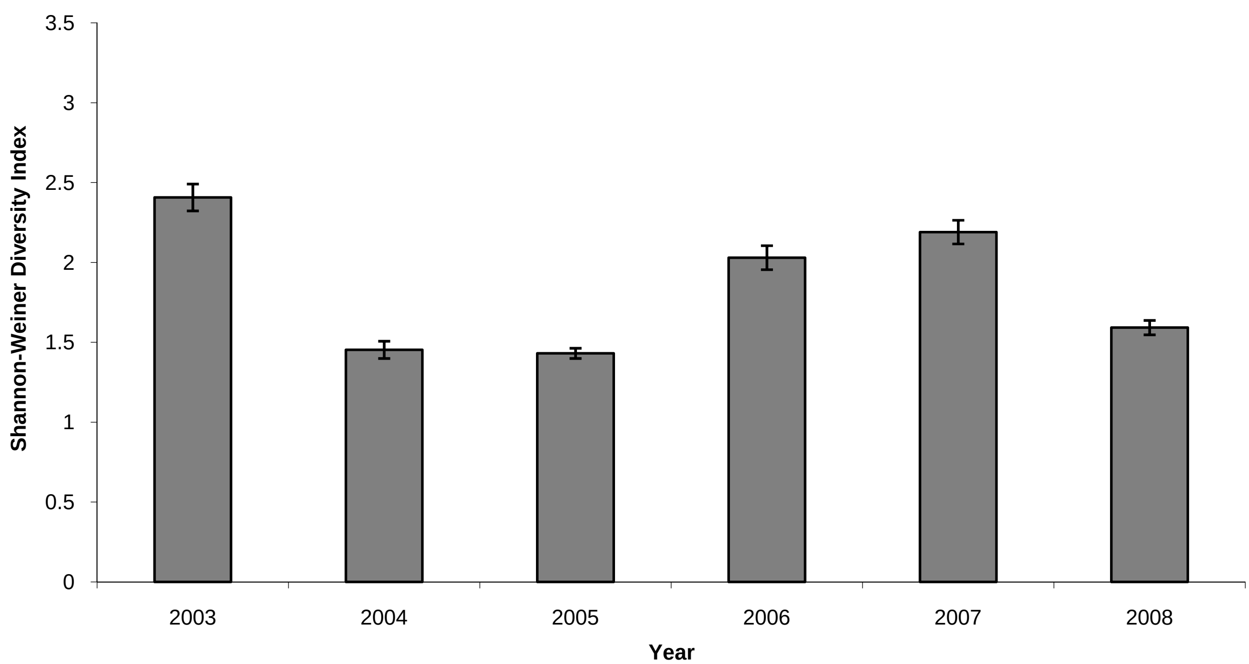

Figure 93. Shannon-Wiener Diversity Indices and 95% Confidence Limits for Fish Samples from Six Years on Horse Creek summarized over stations (Ecological Methods v 6.1.1, Exeter Software 2003).

5.4.3 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 = ΣX_{ij} = Total number of individuals in sample j

N_k = ΣX_{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 21 includes Morisita's Index values combined by year or station, and Table 22 lists the index values for each station by year. When all sampling locations for a given year or station are combined, fish communities were very similar (Table 21). When individual station and year combinations were compared, the fish communities in 2007 were very dissimilar to other stations and years (Table 22).

Table 21. Morisita's Similarity Index Matrix Comparing Sampling Dates within Stations or within Years for 2003 to 2008 Samples.

	HCSW-1	HCSW-2	HCSW-3	HCSW-4		
HCSW-1	1	0.81	0.82	0.90		
HCSW-2		1	0.97	0.95		
HCSW-3			1	0.97		
HCSW-4				1		
	2003	**2004**	**2005**	**2006**	**2007**	**2008**
2003	1	0.96	0.96	0.99	0.99	0.97
2004		1	0.98	0.99	0.95	1
2005			1	0.98	0.94	0.98
2006				1	0.99	0.99
2007					1	0.97
2008						1

Table 22. Morisita's Similarity Index Matrix Comparing Stations within Sampling Years for 2003 to 2008 Samples.

		HCSW-1						HCSW-2						HCSW-3						HCSW-4					
		2003	2004	2005	2006	2007	2008	2003	2004	2005	2006	2007	2008	2003	2004	2005	2006	2007	2008	2003	2004	2005	2006	2007	2008
HCSW-1	2003	1	0.8	0.86	0.82	0.39	0.83	0.96	0.95	0.72	0.95	0.95	0.94	0.96	0.97	0.96	0.98	0.86	0.96	0.84	0.98	0.96	0.97	0.52	0.97
	2004		1	0.97	0.83	0.78	0.96	0.75	0.7	0.59	0.66	0.65	0.64	0.86	0.7	0.68	0.79	0.89	0.7	0.86	0.73	0.71	0.78	0.79	0.82
	2005			1	0.88	0.6	0.9	0.83	0.78	0.66	0.72	0.71	0.7	0.91	0.76	0.74	0.85	0.94	0.77	0.94	0.79	0.78	0.87	0.77	0.9
	2006				1	0.44	0.79	0.88	0.86	0.9	0.75	0.74	0.72	0.93	0.78	0.77	0.83	0.91	0.82	0.85	0.82	0.83	0.84	0.57	0.89
	2007					1	0.8	0.26	0.25	0.21	0.24	0.23	0.23	0.45	0.28	0.24	0.36	0.51	0.26	0.45	0.29	0.25	0.32	0.74	0.36
	2008						1	0.75	0.73	0.57	0.72	0.71	0.71	0.87	0.76	0.73	0.83	0.86	0.75	0.8	0.77	0.74	0.77	0.76	0.82
HCSW-2	2003							1	0.99	0.86	0.95	0.94	0.93	0.97	0.96	0.96	0.97	0.87	0.98	0.83	0.98	0.99	0.95	0.41	0.97
	2004								1	0.87	0.97	0.97	0.95	0.95	0.97	0.98	0.96	0.84	0.99	0.78	0.99	0.99	0.92	0.38	0.95
	2005									1	0.75	0.75	0.71	0.83	0.75	0.76	0.75	0.75	0.82	0.67	0.79	0.82	0.73	0.32	0.79
	2006										1	1	1	0.9	0.99	0.99	0.95	0.76	0.99	0.71	0.99	0.98	0.89	0.35	0.91
	2007											1	1	0.89	0.99	0.99	0.95	0.75	0.99	0.7	0.99	0.98	0.88	0.35	0.9
	2008												1	0.87	0.99	0.99	0.94	0.73	0.98	0.68	0.98	0.97	0.87	0.34	0.89
HCSW-3	2003													1	0.93	0.92	0.97	0.96	0.94	0.91	0.95	0.95	0.96	0.58	0.99
	2004														1	1	0.98	0.81	0.99	0.76	1	0.99	0.92	0.4	0.94
	2005															1	0.97	0.8	0.99	0.75	0.99	0.99	0.91	0.37	0.93
	2006																1	0.9	0.97	0.85	0.98	0.98	0.96	0.52	0.98
	2007																	1	0.83	0.98	0.83	0.84	0.91	0.7	0.94
	2008																		1	0.77	1	1	0.92	0.39	0.95
HCSW-4	2003																			1	0.78	0.79	0.93	0.7	0.92
	2004																				1	1	0.93	0.41	0.95
	2005																					1	0.93	0.39	0.96
	2006																						1	0.53	0.99
	2007																							1	0.56
	2008																								1

Species Accumulation Curves

One way to determine when enough individuals in a community have been sampled to accurately estimate species diversity with some level of confidence is to plot the cumulative number of species collected through the sampling period. The result should be a curve that increases steeply at first when new species are continually being found, then gradually levels off when new species become very rare. The asymptote of the curve suggests the point at which additional sampling will provide no additional species. The total number of species in a community, as well as the number of rare species, strongly influences the sampling effort needed to offer some certainty that most species have been reported. As indicated by the curves plotted for each of the sampling locations, as well as that for all stations combined, we continue to collect very few new species with subsequent sampling events, and the curves shown have also leveled off for each station (Figure 94). This suggests that very few, if any, additional species will be collected in the future.

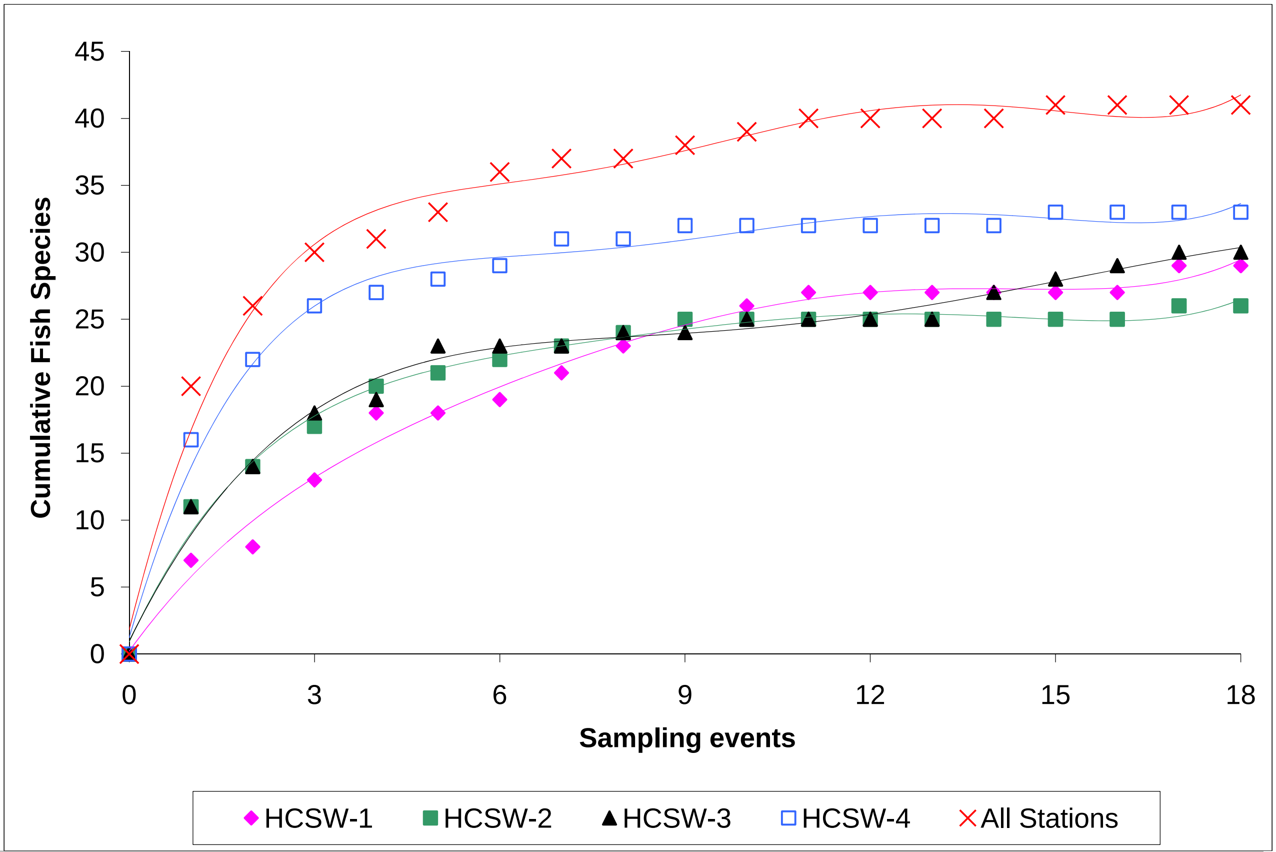

Figure 94. Cumulative Numbers of Fish Species Collected at Horse Creek Stations During 2003 -2008. (Species accumulation curves were fit for visual purposes only.)

5.4.4 Summary of Fish Results

Forty-one species of fish were collected in 2003 to 2008, with most captured individuals belonging to one of five families (Table 23). We expect to add very few additional species during future monitoring events, because the species accumulation curves based on the samples collected in 2003 to 2008 have leveled off. Several native species are almost certainly present in Horse Creek but were not collected in 2003 to 2008. These include the American eel (*Anguilla rostrata*) and black crappie (*Pomoxis nigromaculatus*). Samples collected included seven introduced species: walking catfish, African jewelfish, brown hoplo, suckermouth catfish, oriental weatherfish, sailfin catfish, and blue tilapia. Introduced species rank second only to habitat destruction in their effects on native species, communities, and ecosystems (Wilson 1992, Parker et al. 1999). Over 30 species of introduced 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, we expect to continue to collect additional introduced species in Horse Creek during future monitoring events as new introductions occur and as such species expand their ranges in Florida.

Table 23. Percentage of individual fish captured per year for most abundant fish families in Horse Creek during 2003 – 2008 as part of the Horse Creek Stewardship Program.

Fish Family	HCSW-1	HCSW-2	HCSW-3	HCSW-4	Total
Poeciliidae	53 %	96 %	91 %	75 %	88 %
Centrarchidae	9%	1%	2%	7%	3%
Cyprinidae	28%	0.02%	3%	6%	4%
Cyprinodontidae	1%	1%	1%	4%	2%
Athernninidae	3%	0%	1%	3%	1%

For 2008 sampling, the effects of Hurricane Charley have little impact on fish abundance and diversity at stations in Horse Creek. Before Hurricane Charley, species richness and diversity were lowest at HCSW-1 and highest at HCSW-4. This pattern of longitudinal zonation of increasing species diversity with increasing stream order is typical of stream systems (Harrel et al. 1967, Whiteside and McNatt 1972, Sheldon 1988). In 2008, fish diversity exhibited this zonation, with exception of HCSW-2, which had the lowest fish diversity in all years. Fish communities were similar for all events when locations were combined and for all locations when events were combined, although the fish community in 2007 was somewhat different than other stations and years.

SECTION 6

CONCLUSIONS

6.1 WATER QUANTITY

For 2008, temporal patterns of average daily stream flow and stage were similar across all stations, with the majority of high flows and stages occurring during the rainy season (June through October). The late dry season (April – May) was extremely dry, resulting in periods of little to no flow. Therefore, Mosaic's NPDES-permitted discharges upstream of HCSW-1 only discharged for portions of four months of the year. Rainfall and discharge in 2006, 2007, and 2008 were well below the long-term average (Durbin and Raymond 2006). Three consecutive years of low rainfall and streamflow in Horse Creek have likely had significant impacts on the water quality and biological communities of the stream.

6.2 WATER QUALITY

Water quality parameters in 2008 were always within the desirable range relative to trigger levels and water quality standards at the station closest to mining (HCSW-1, Table 17). All stations in Horse Creek were affected by the low rainfall and streamflow of 2006 to 2008. Algal blooms in warm months when streamflow was low contributed to trigger level exceedances of chlorophyll a, fatty acids, total nitrogen, total ammonia and dissolved oxygen. Dissolved ions (calcium, sulfate, TDS, iron, and fluoride) exceeded the trigger levels during the dry season when rainfall and streamflow were very low, and groundwater baseflow and agricultural irrigation were high.

There was no evidence of temporal trends that could be attributed to anything other than general wet season/dry season fluctuations or longer-term climatic oscillations (Figure 75). Alkalinity and specific conductance show a significant increasing trend at HCSW-1, but these potential trends are heavily influenced by the abnormally low rainfall and streamflow of 2006 - 2008. Orthophosphate shows a significant increasing trend and dissolved oxygen a decreasing trend at HCSW-4. These trends may have been influenced by the last two dry years, and it is also likely that cumulative impacts of agricultural landuse may also be contributing to changes in water quality at this downstream station.

Significant differences between stations were evident for several parameters. Overall, HCSW-2 was the most dissimilar from the other three stations, especially in pH, dissolved oxygen, and some dissolved ions. Some nutrients (nitrate + nitrite and orthophosphate) and dissolved ions (specific conductivity, calcium, sulfate) had higher concentrations downstream in Horse Creek, probably because of increased groundwater seepage and agricultural runoff in the lower Horse Creek basin.

In general, pH, dissolved oxygen, and most dissolved ions are higher when the overall quantity of water in the Horse Creek system is low. Conversely, turbidity, color, iron, and some nutrients are high when the water quantity is also high. Total radium was correlated with increased NPDES discharge but not streamflow or rainfall. When water quantity in Horse Creek is low, the stream may be 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, an increased amount of sediment and organic debris is washed into the stream, leading to increases in turbidity, color, iron, and nitrogen.

6.3 BENTHIC INVERTEBRATES

Benthic invertebrate habitat scores were "Optimal" to "Sub-optimal" and SCI scores were "Healthy" or "Impaired" at all stations in 2008; these scores are typical of southwestern Florida streams, including those used to develop the Habitat Assessment and SCI indices. Species diversity in Horse Creek exhibits both seasonal and year-to-year variation. When considered over time from 2003 to 2008, the SCI scores were variable over time at each station, but showed no monotonic trend. SCI scores and invertebrate diversity were significantly lower overall at HCSW-2.

6.4 FISH

Forty-one species of fish have been collected from 2003 to 2008. For 2008 sampling, the effects of Hurricane Charley are no longer affecting fish abundance and diversity at downstream stations, but the fish diversity shows the affects of the low rainfall and streamflow condition in 2006 and 2007. Before Hurricane Charley, species richness and diversity were lowest at HCSW-1 and highest at HCSW-4. In 2008, fish diversity exhibited this zonation, with exception of HCSW-2, which had the lowest fish diversity in most years. Fish communities were similar for all events when locations were combined and for all locations when events were combined.

SECTION 7

RECOMMENDATIONS

7.1 PREVIOUS ANNUAL REPORT RECOMMENDATIONS

During the 12 March 2009 meeting of the HCSP TAG for the 2007 annual report, the TAG made several recommendations for modifications to the existing program. These recommendations were tabled to be addressed in the 2008 annual report or during the 2009-2010 monitoring year. These recommendations are as follows:

The new clay settling area in the Horse Creek Watershed called FM-1 will be equipped with real-time telemetry of water levels.

Three parameters (FL-PRO, Total Fatty Acids, and Total Amines) were removed from the HCSP based on data presented by Mosaic, and a new sampling location at Brushy Creek at State Road 64 was added to the program in September 2009.

Mosaic provided a literature review of the Seasonal Kendall Tau method for the 2007 report (Appendix D), and began using the method for analysis in the 2008 report.

7.2 PREVIOUS TAG RECOMMENDATIONS

During the 16 June 2008 meeting of the HCSP TAG for the 2006 annual report, the TAG made several recommendations for modifications to the existing program. These recommendations were tabled to be addressed in the 2007 annual report. These recommendations are as follows:

The data range used in the historical water quality comparisons should be static instead of a moving window, beginning somewhere between 1990 and 1993. This recommendation has resulted in a change in the water quality section of the 2007 report to include historical data from 1990.

Some of the water quality parameters have been detected very few times over the course of the program. These parameters and recommendations for possible reduction in sampling frequency or overall discontinuation were effective September 2009.

During the 27 July 2007 meeting of the HCSP TAG for the 2005 annual report, the TAG made several recommendations for modifications to the existing program. These recommendations and their current status are as follows:

The PRMRWSA would pursue negotiations with Mosaic and/or CFI to add additional monitoring stations on Brushy Creek to address concerns about the affect of CFI mining activities on the Horse Creek Basin.

> Mosaic has no obligation under the HCSP plan document to include additional monitoring stations. The Authority's negotiations are still ongoing with CFI. Mosaic started sampling Brushy Creek in September 2009.

HCSP annual reports should include language that states the HCSP has inherent limitations and is designed to only evaluate the impacts of Mosaic's mining activities on Horse Creek.

This language has been included in annual reports.

The PRMRWSA should alert SWFWMD to declining water quality in the lower Horse Creek Basin that it likely linked to agriculture.

The Authority has requested and SWFWMD has begun an investigation into groundwater quality in the southern Horse Creek Basin, updates are presented at subsequent TAG meetings.

The PRMRWSA will discuss the possibility of uploading HCSP data into the FDEP STORET database with Mosaic.

There are two outstanding issues regarding this recommendation: the cost of the STORET upload and the TMDL implications of including data from HCSW-2, a station that is not representative of Horse Creek water quality.

7.3 CURRENT ANNUAL REPORT RECOMMENDATIONS

There are no current report recommendations at this time.

SECTION 8

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APPENDIX A

Horse Creek Stewardship Program

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 exceedence 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.

1 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.

2 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.

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

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.

4 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.

5 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.

6 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 exceedences 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 exceedences 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 exceedence 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 exceedences 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 exceedence 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 exceedence 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	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

Pollutant Category	Analytical Parameters	Analytical Method	Reporting Units	Monitoring Frequency	Trigger Level	Basis for Initiating Corrective Action Process
	acid.					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 Abundance Percent Diptera Number of Chironomid Taxa Shannon Weaver Diversity[a] Florida Index EPT Index Percent Contribution of Dominant Taxon Percent Suspension Feeders/Filterers	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
Biological Indices: Fish	Total Number of Taxa Abundance Shannon-Weaver Diversity[a] Species Turnover (Morisita Similarity Index[a] Rarefaction/Species Accumulation Curves[b]	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

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.

APPENDIX B

Cumulative Chronological List of Procedural Changes to the HCSP

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 on going 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: Final acceptance of the 2007 report.

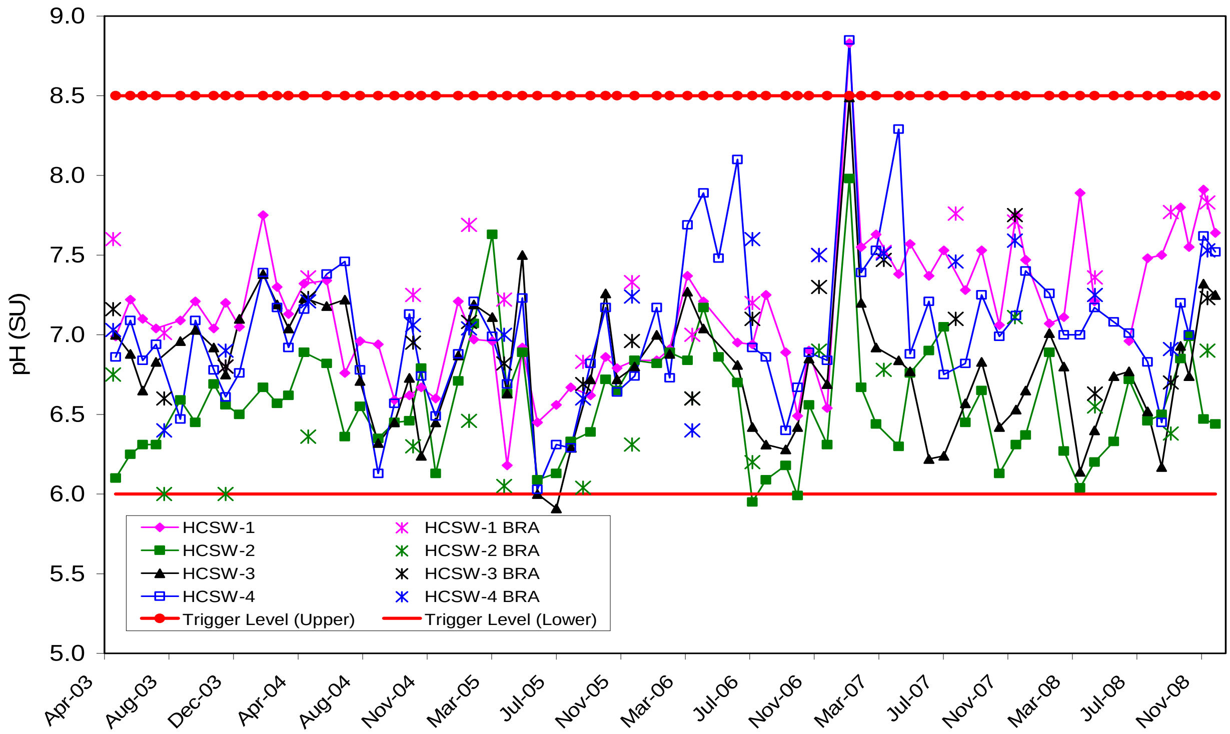
Change 9: Add clay settling area (CSA) FM-1 to existing monitoring program.
Year Implemented: Prior to 2009 wet season.
Comments: Recently constructed SCA FM-1 will be added to existing CSA's providing real time monitoring to Authority.
Provisional Acceptance: March 2009
Final Acceptance: Final acceptance of 2007 report.

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: Final acceptance of 2007 report.

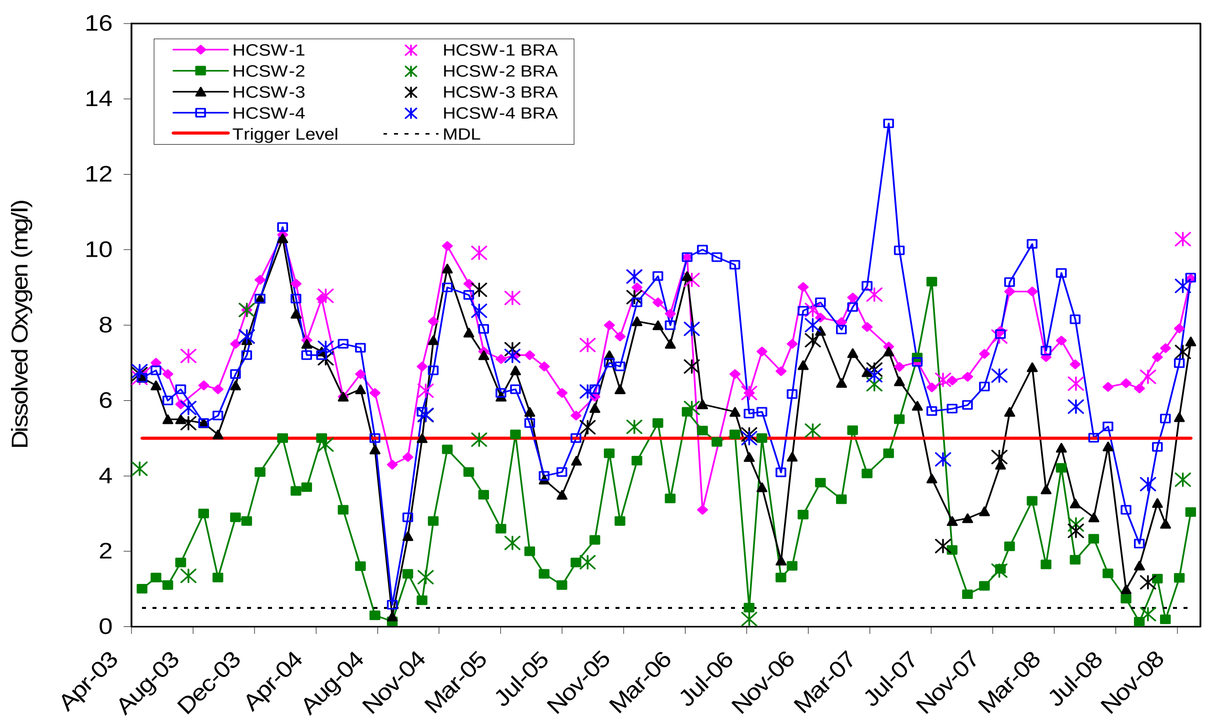
Change 11: Addition of new water quality sample location for Brushy Creek @ Hwy 64.
Year Implemented: 2009
Comments: In lieu of deleted three parameters Mosaic will collect samples and provide data monthly from this location minus trigger levels and impact assessments.
Provisional Acceptance: March 2009
Final Acceptance: Final acceptance of 2007 report.

APPENDIX C

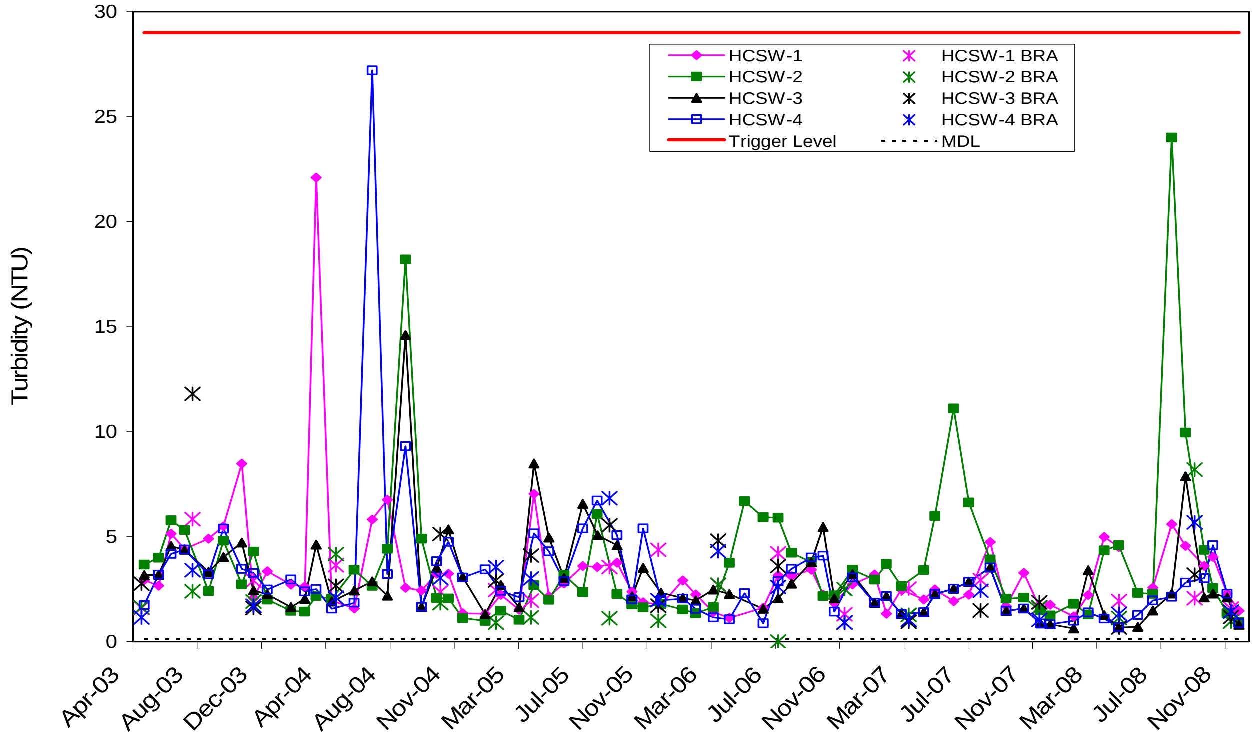
Horse Creek Stewardship Program Water Quality from 2003-2008



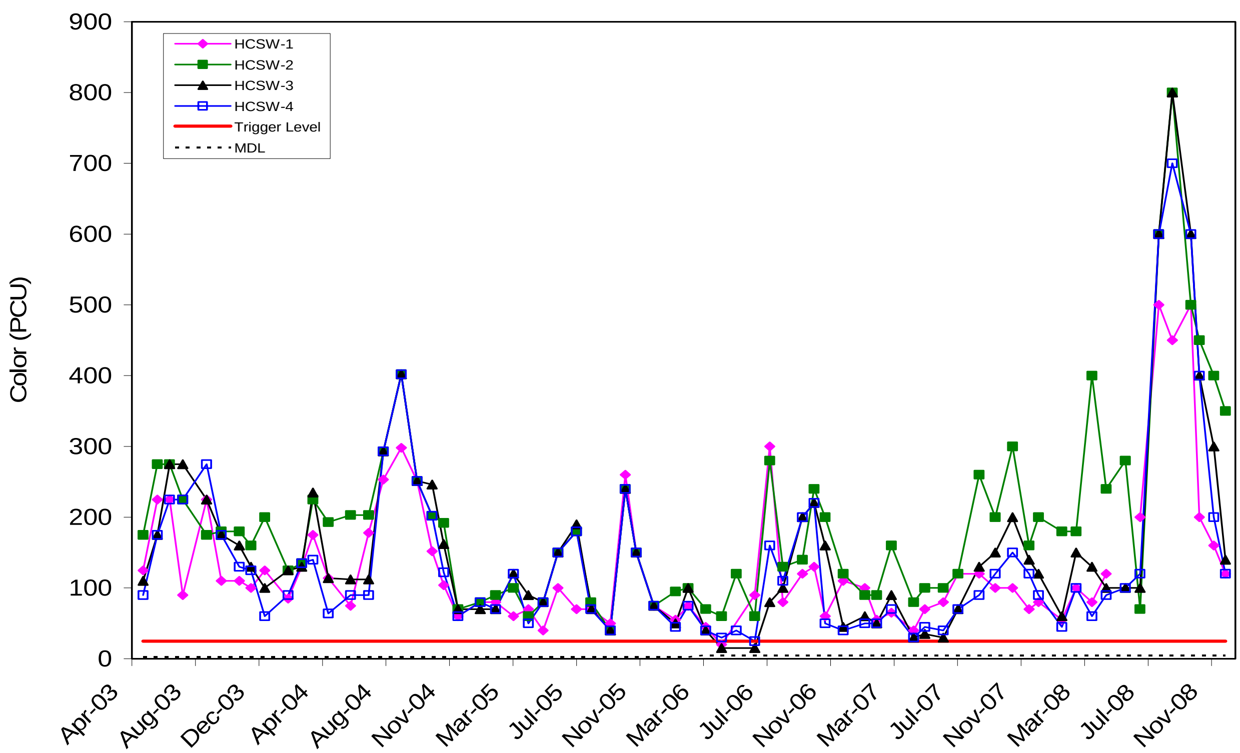
C-1. **Values of pH Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events from 2003-2008. Minimum Detection Limit – 1 su.**



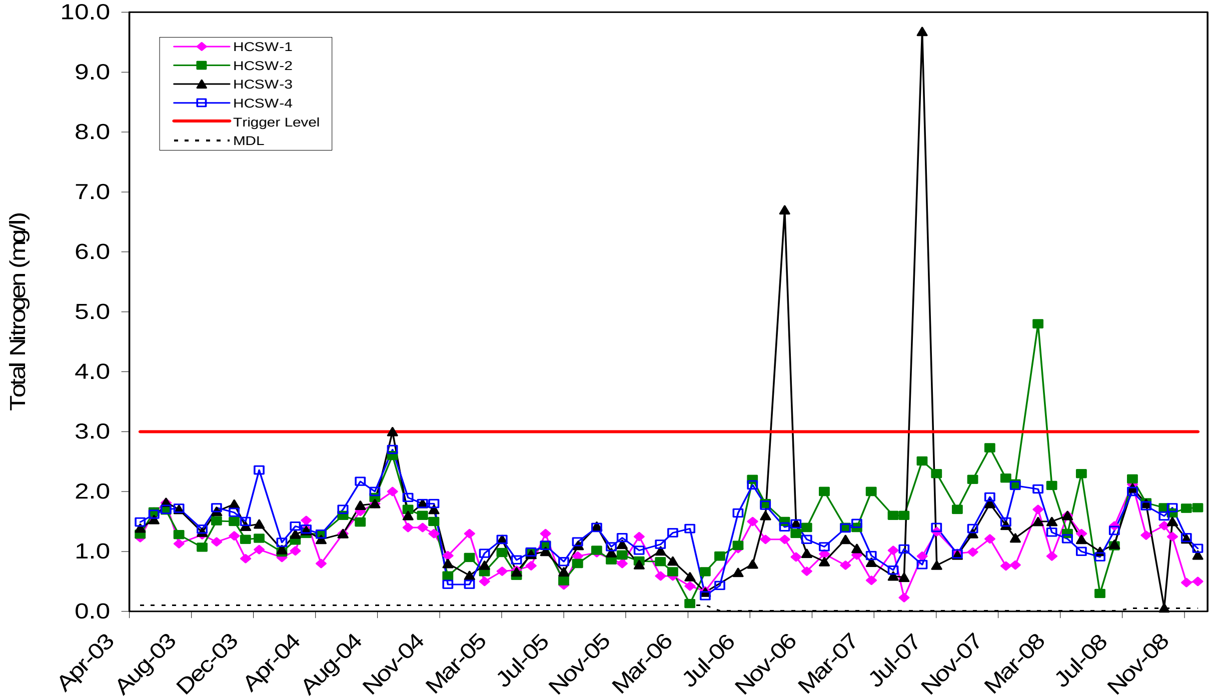
C-2. **Dissolved Oxygen Levels Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events from 2003-2008.**



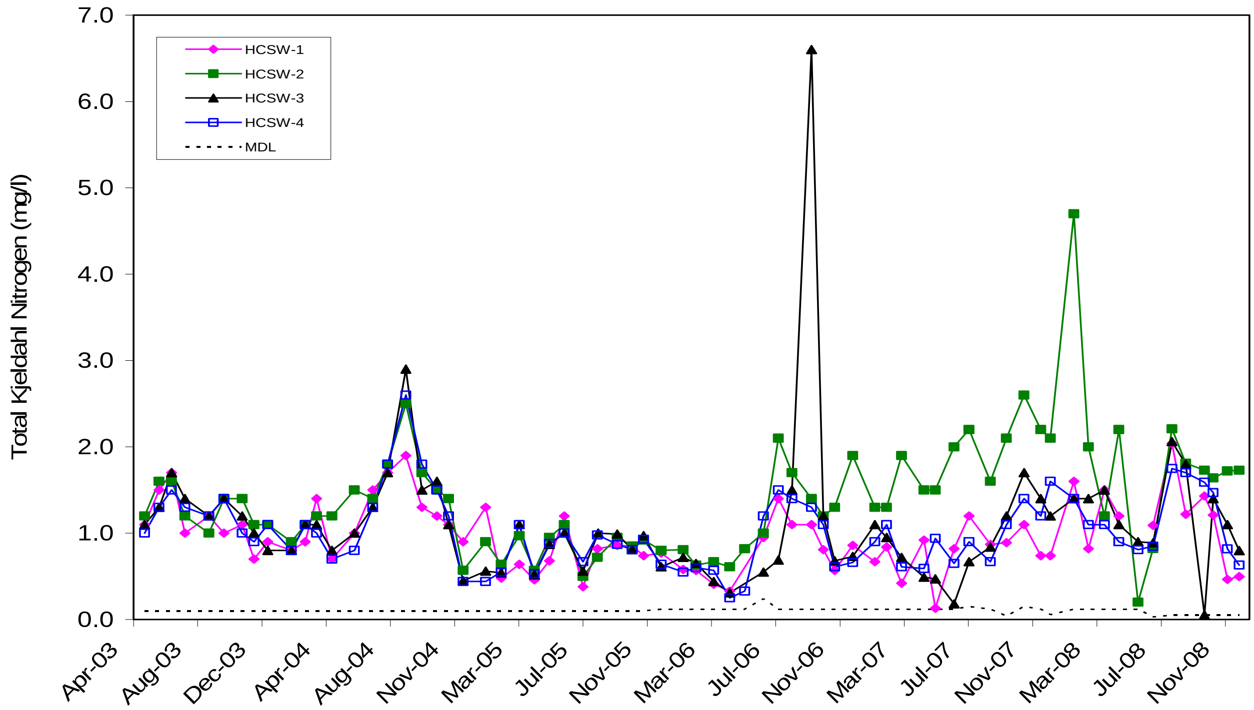
C-3. **Turbidity Levels Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events from 2003-2008.**



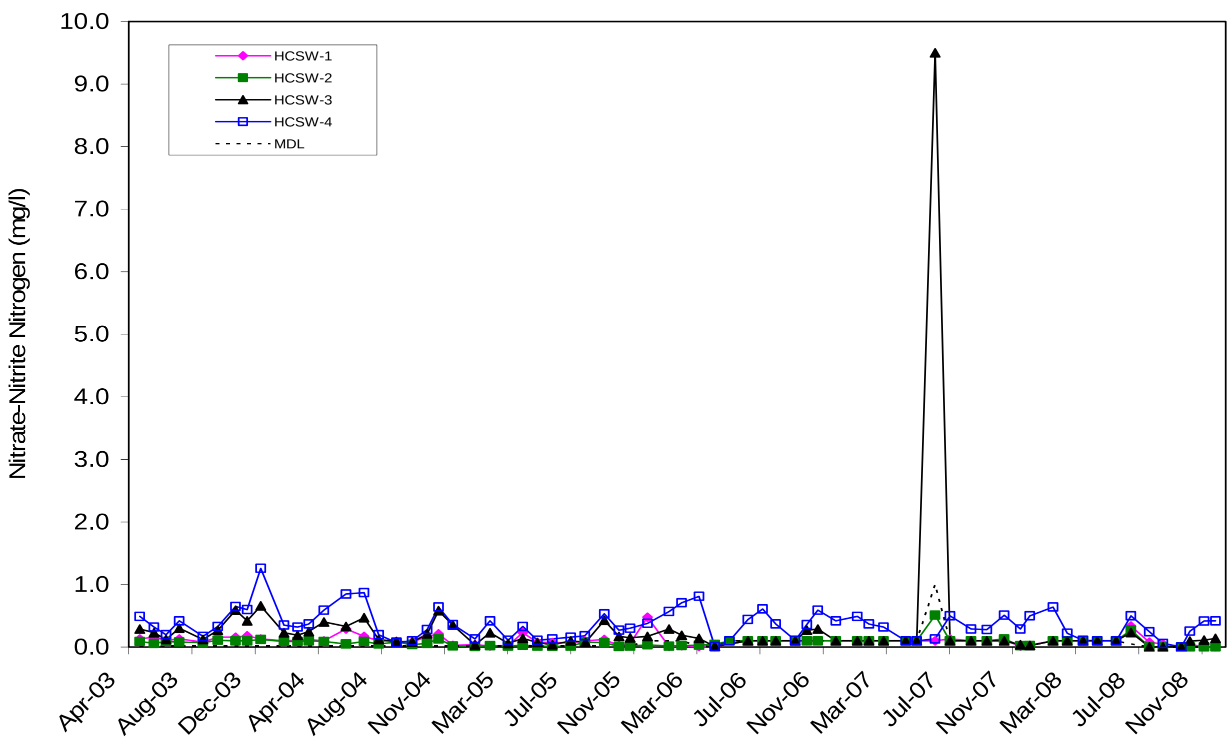
C-4. **Color Levels Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.**



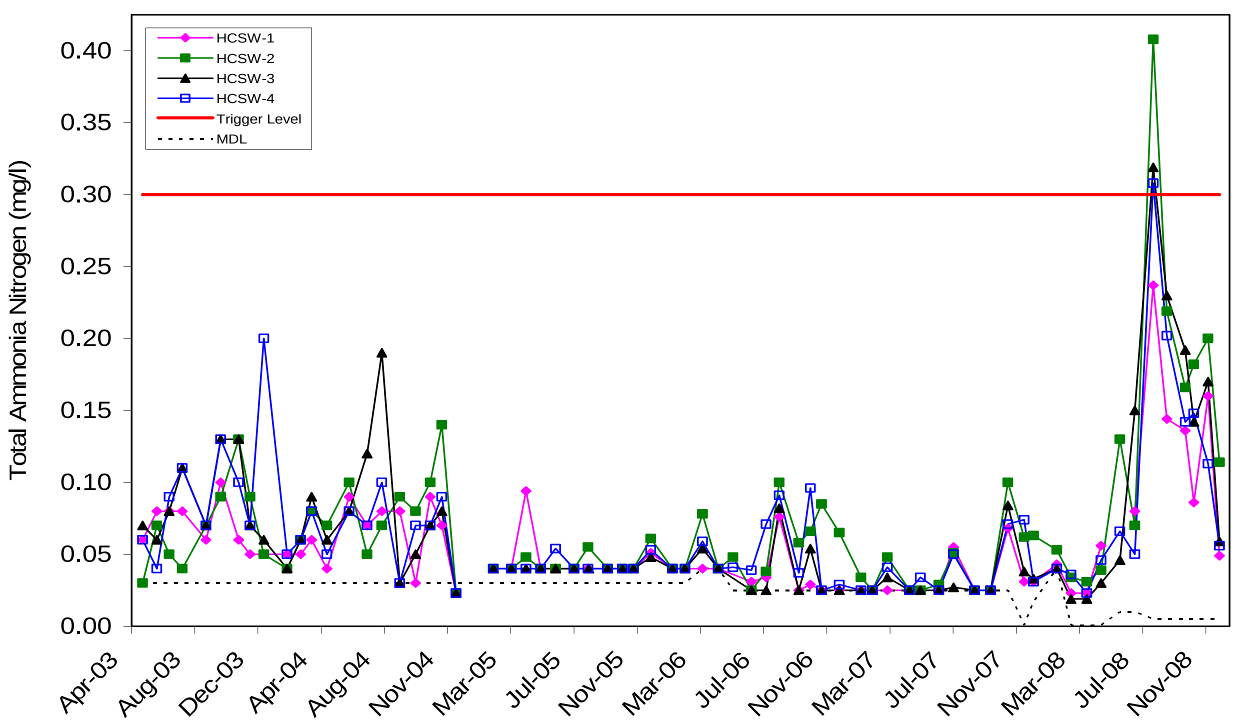
C-5. Total Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.



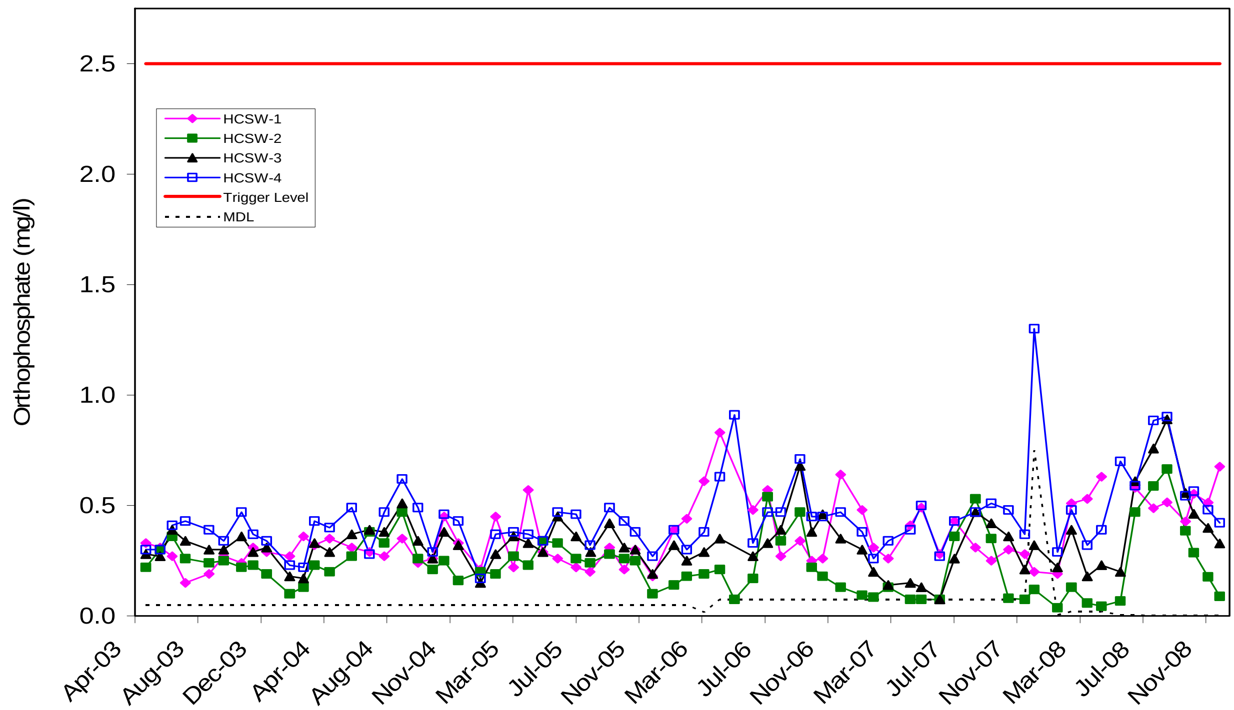
C-6. Total Kjeldahl Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.



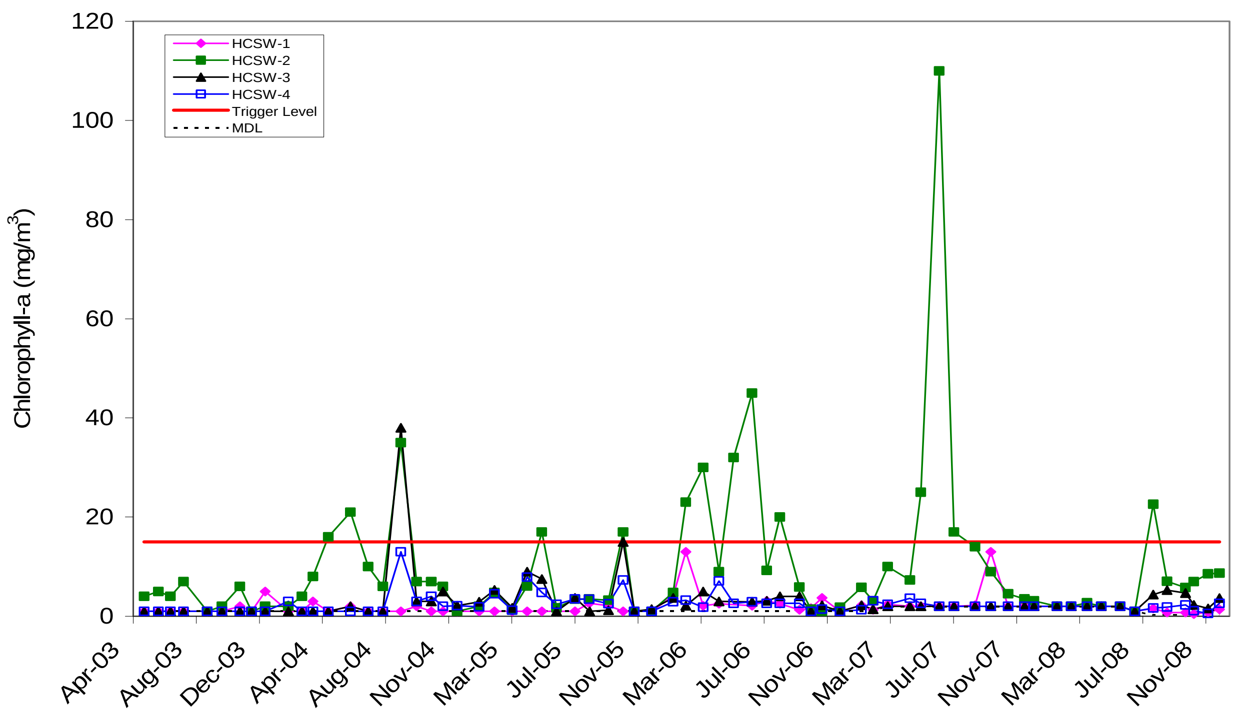
C-7. **Nitrate-Nitrite Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.**



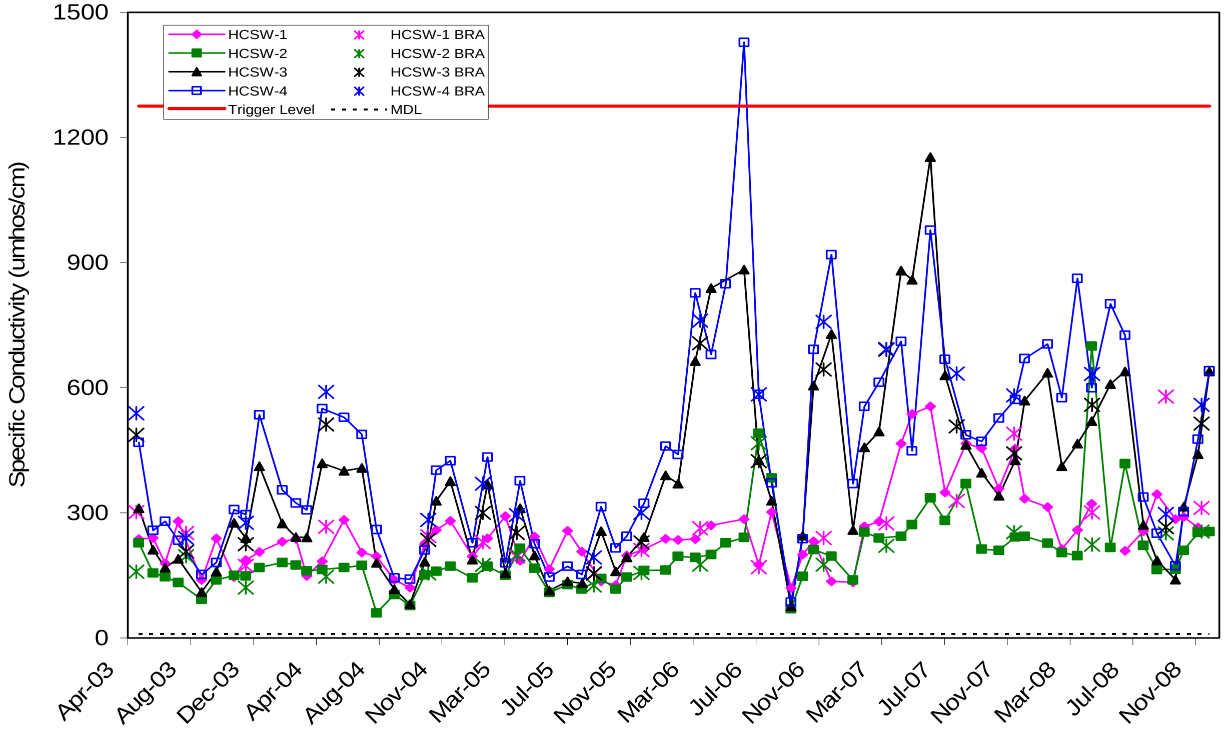
C-8. **Total Ammonia Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.**



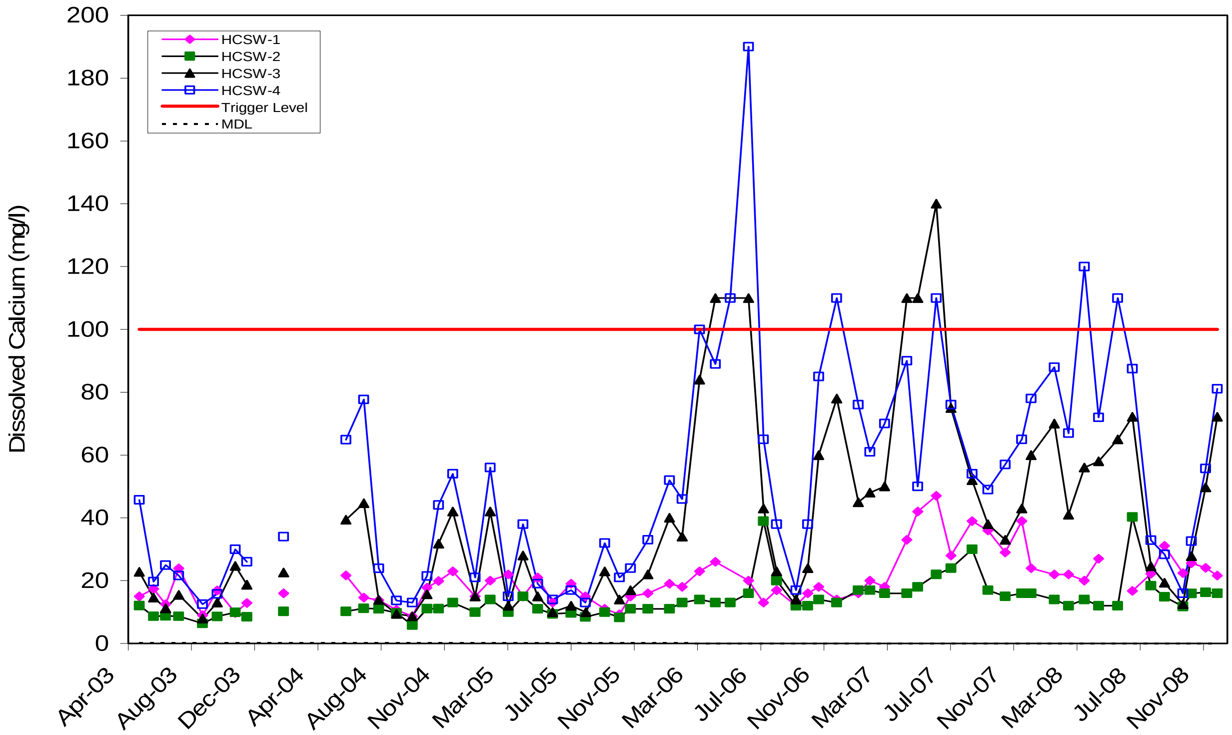
C-9. Orthophosphate Concentrations Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.



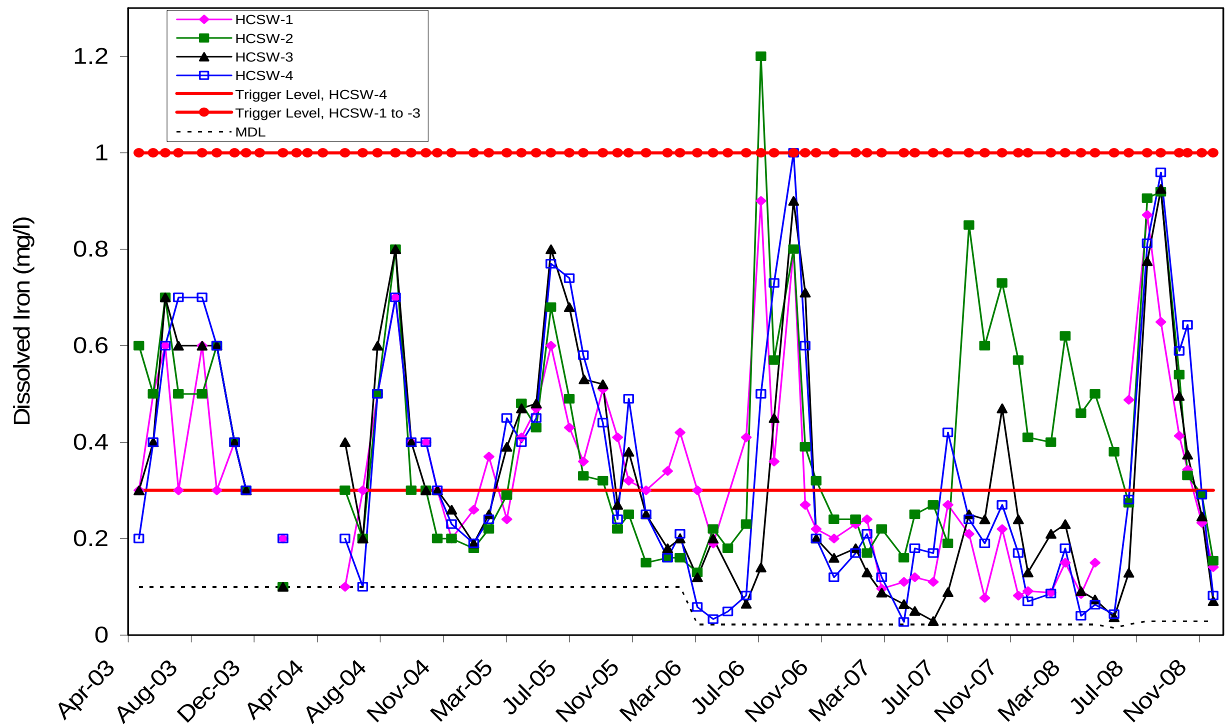
C-10. Chlorophyll-a Concentrations Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.



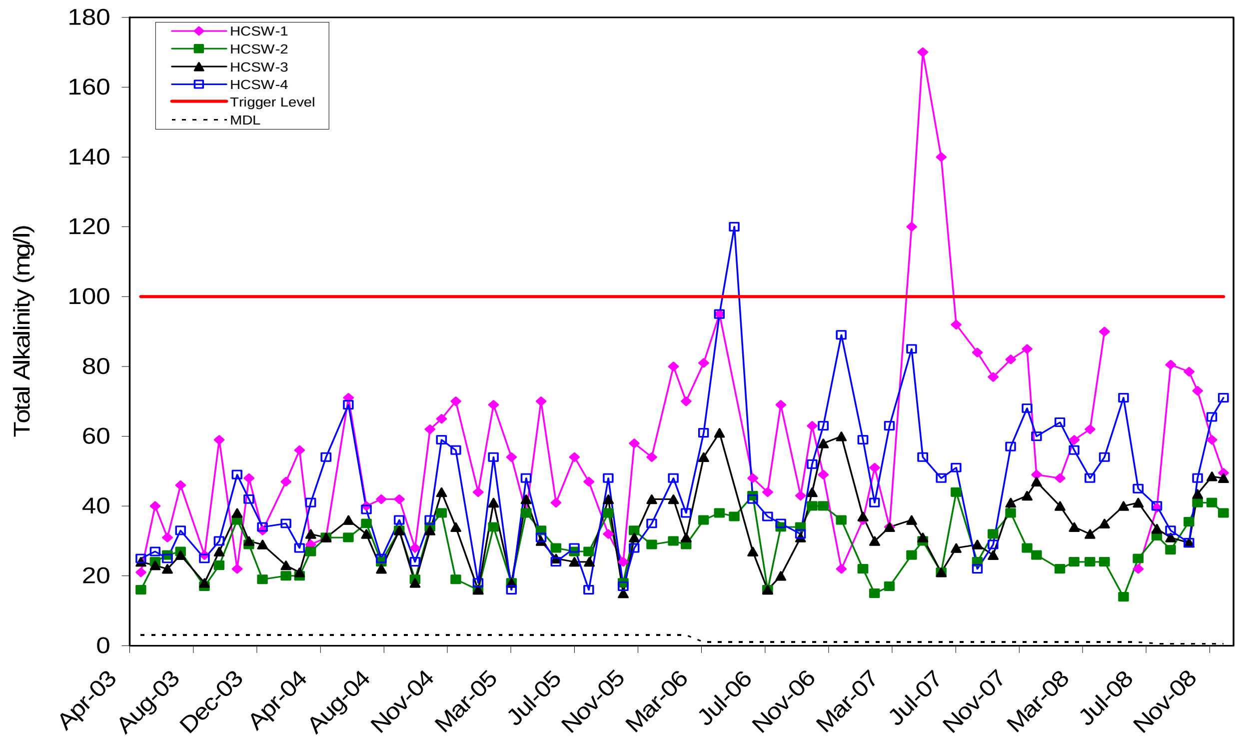
C-11. Levels of Specific Conductivity Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events from 2003-2008.



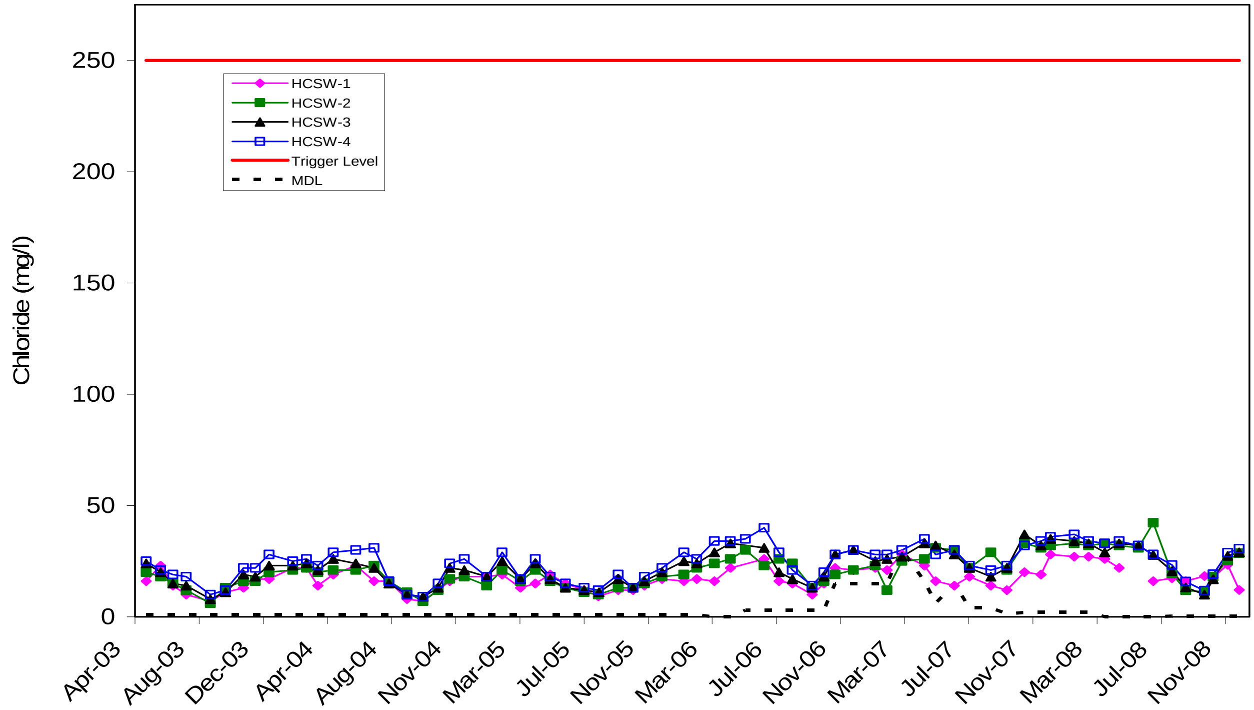
C-12. Dissolved Calcium Concentrations Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.



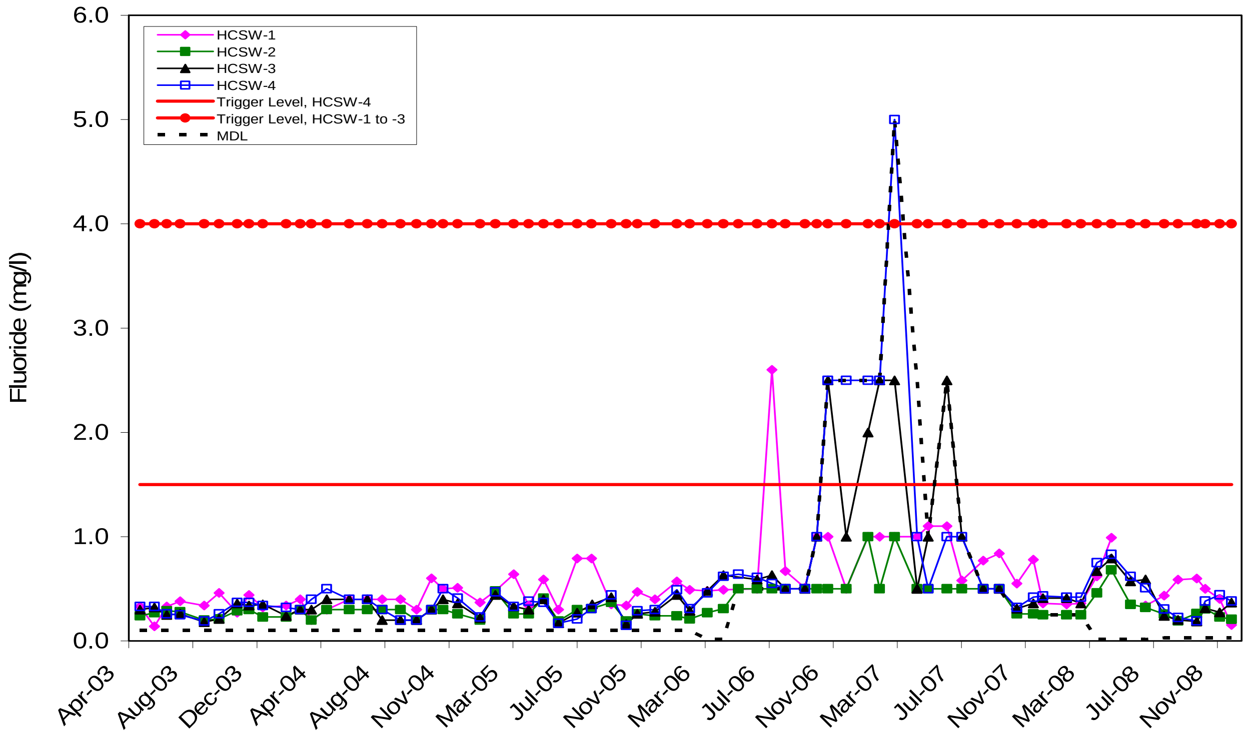
C-13. Dissolved Iron Concentrations Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.



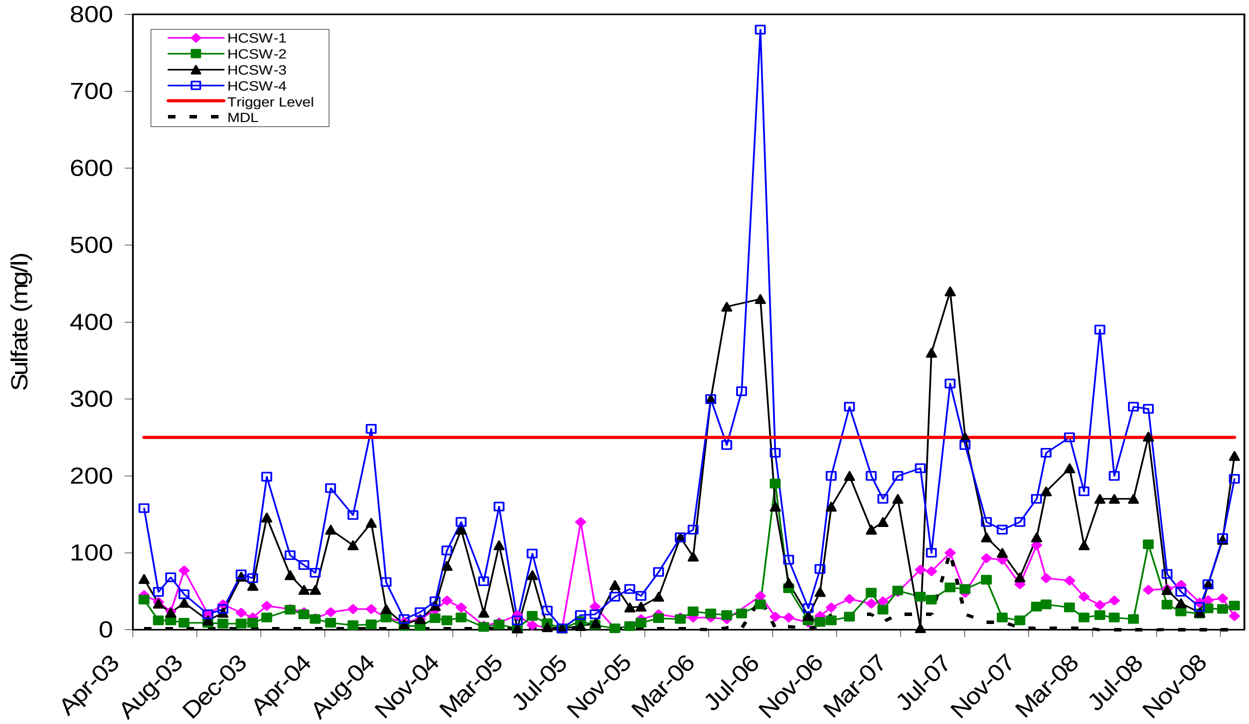
C-14. Total Alkalinity Concentrations Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.



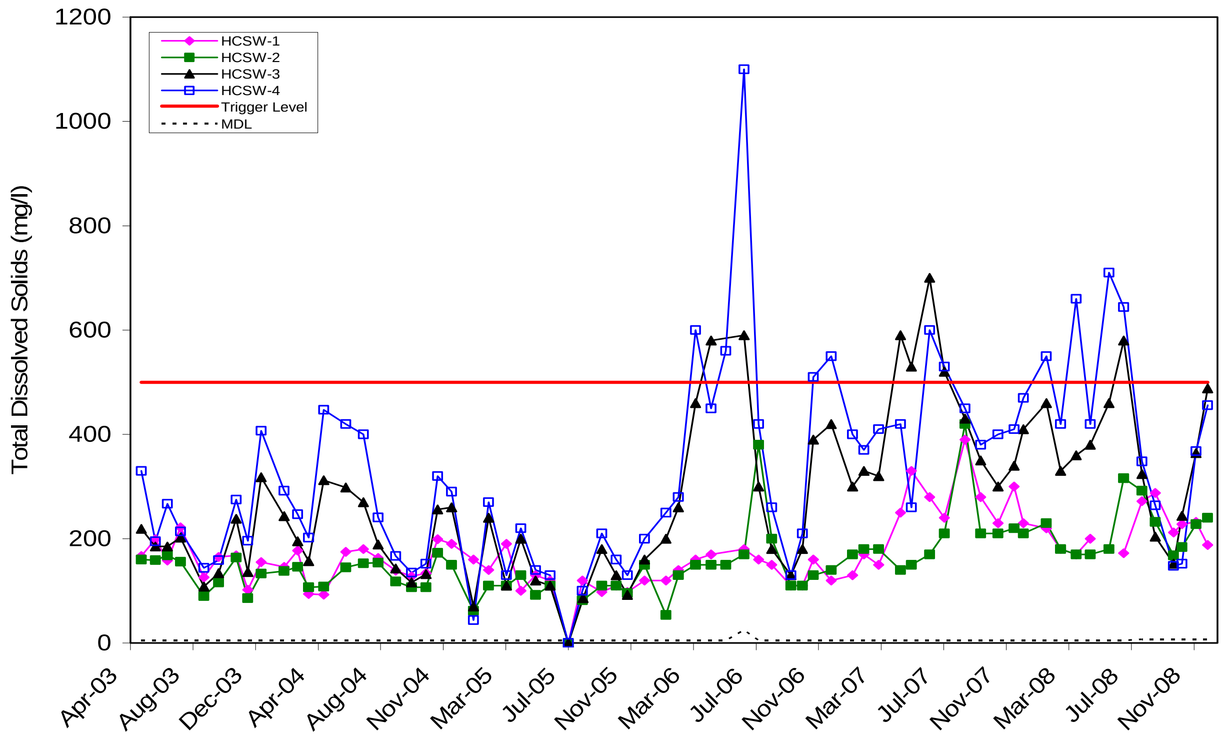
C-15. **Chloride Concentrations Obtained During Monthly HCSP Water Quality Sampling from 2003-2008. (HCSP trigger value for Chloride is 250 mg/L.)**



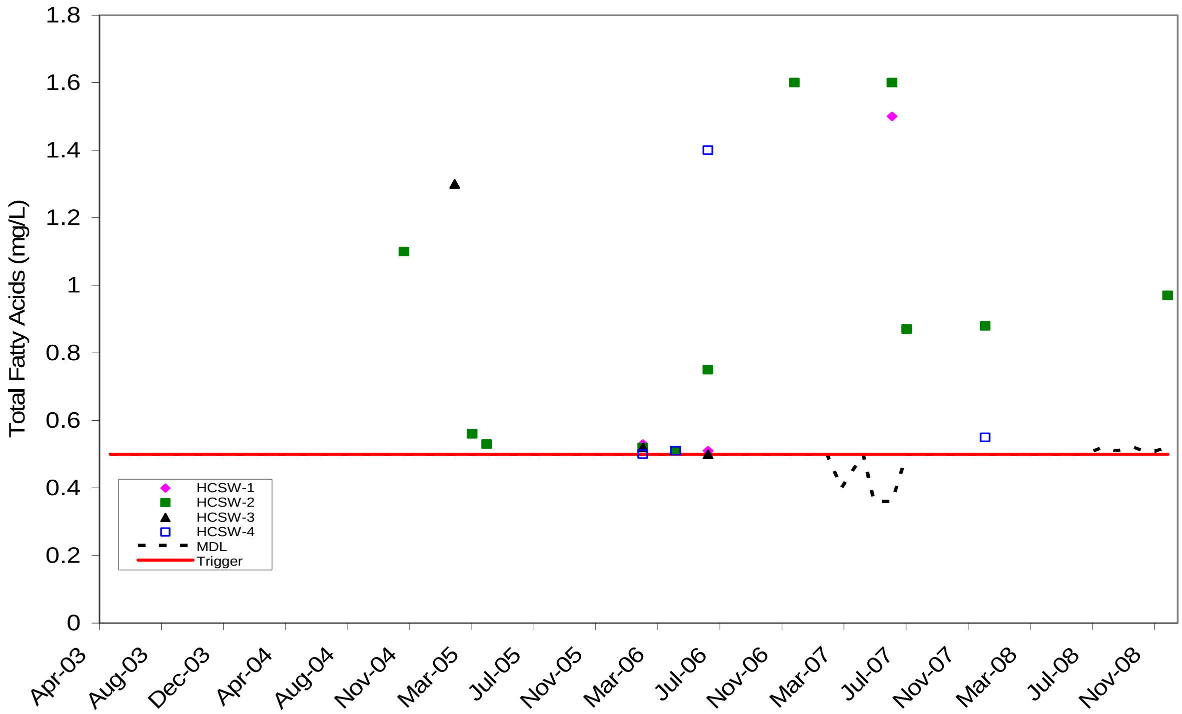
C-16. **Fluoride Concentrations Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.**



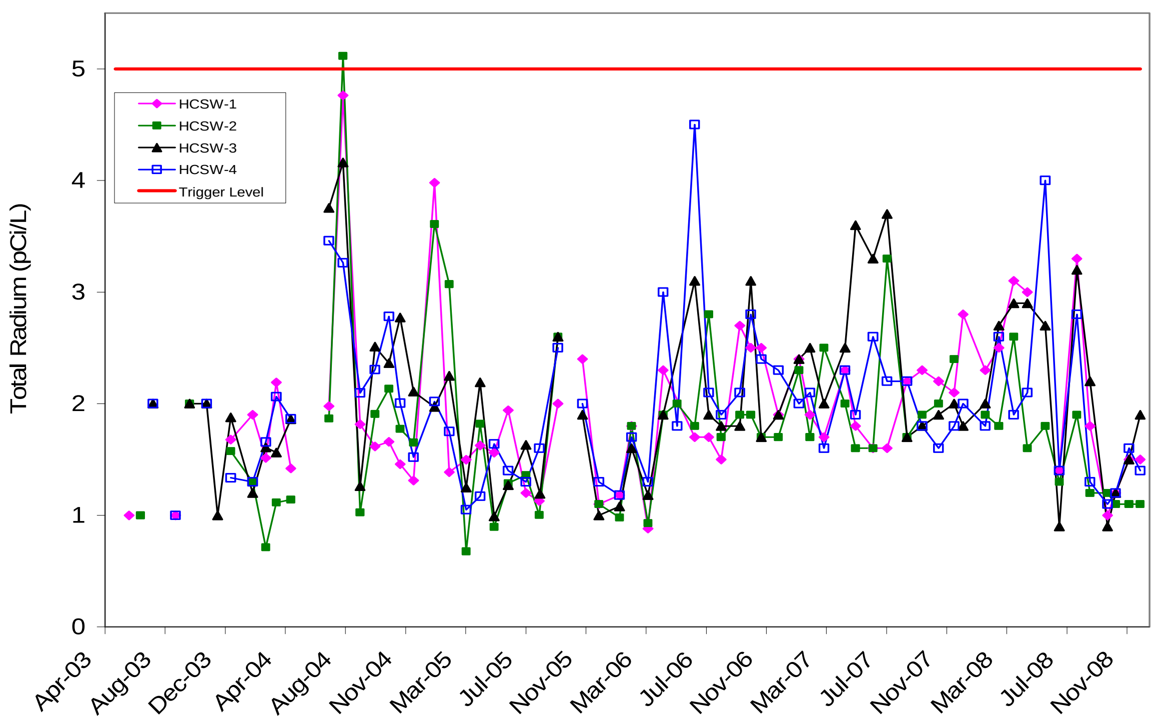
C-17. Sulfate Concentrations Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.



C-18. Levels of Total Dissolved Solids Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.



C-19. Levels of Total Fatty Acids (Above MDL only) Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.



C-20. Levels of Total Radium (Combination of Radium 226 and Radium 228) Obtained During Monthly HCSP Water Quality Sampling from 2003-2008.

APPENDIX D

Listed 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. 2005).

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. 2005). 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. 2005). 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	0.020	0.60	0.31
5	0.050	0.97	0.83

5	0.200	1.00	1.00
5	0.500	1.00	1.00
10	0.002	0.12	0.10
10	0.005	0.45	0.32
10	0.020	0.98	0.95
10	0.050	0.99	0.99
10	0.200	1.00	1.00
10	0.500	1.00	1.00

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.

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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.

APPENDIX E

Tag Meeting Summary

Horse Creek Stewardship Program
Technical Advisory Group
Meeting Summary for August 4, 2010

Draft 2008 Annual Report

TAG Panel
No TAG Panel Members were Present

Presenters

Kris Robbins	Entrix
Bill Lewelling	SWFWMD

Attendees

Sam Stone	PRMRWSA
Santino Provenzano	Mosaic
Jeff Clark	EarthBalance
Doug Durbin	Entrix
Carol Kraft	SWFWMD
Bill Orendorff	SWFWMD

1.District's Investigation of Ground Water Impacts to Horse Creek.

Bill Lewelling provided a power point presentation to the group showing the steps taken by District staff to investigate the source of high sulfate water found in the lower Horse Creek basin. In this up date report the District also discussed the recent progress made while working with Bethel Farms to add an irrigation tail recovery system. This system should provide a reduction in use of ground water for irrigation and also reduce high sulfate water runoff downstream to Horse Creek.

2. Report Overview

Due to the lack of TAG members present it was decided that Kris Robbins of Entrix would not provide a formal presentation of the Report. Instead the group agreed to go over questions provided by Earth Balance and the Authority which resulted in a thorough review of the report as it related to specific questions raised by the group.

Action:
Entrix will provide as a word document all the review questions and responses to the Authority for transmittal to TAG members.

In the 2009 report and subsequent reports Entrix will provide a list of exceedences experienced during the program.

In the 2009 report and subsequent reports Entrix will provide a summary table that describes the impact assessments (exceedence, action taken, and brief conclusion) completed during the program.

In the 2009 report and subsequent reports Entrix will provide the acres and a map of reclaimed land that has been re-connected to the affected drainage basin.

The Authority will provide copies of final impact assessments to TAG members in the future.

In the 2008 report Entrix will provide a summary discussion and in subsequent reports provide a summary table showing trends found in the report and how those trends have been addressed.

In the 2009 report and subsequent reports Entrix will provide a table and discussion on the native versus exotic fish population found in Horse Creek.

In the 2009 report and subsequent reports Entrix will provide single station plots showing the SCI index results.

For the 2009 draft report Entrix and Mosaic will investigate the possibility of eliminating a sit down meeting to review draft reports and have scheduled events in real time over the web with TAG members.

3. Clay Settling Area (CSA) Monitoring
Mosaic suggested that a real field test of the system be planned and run on some regular basis in order to test both the Mosaic and Authority personnel's response time to an alarm.

Action.
Sam Stone agreed that it was a good idea and needed to discuss the test with Authority staff.

5. Timeline for 2008 Annual Report
Sam will provide by email a reminder to TAG members to provide written review comments by 8/13/10.

6. Timeline for 2009 Annual Report
Mosaic and Entrix thought that this draft report could be sent to the Authority in 2010.