Biological Research Associates
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Horse Creek Stewardship Program
2004 Annual Report

Prepared for:

Mosaic™

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EXECUTIVE SUMMARY

INTRODUCTION

This is the second annual report summarizing the status of the Horse Creek Stewardship Program (HCSP). 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, and a series of legal challenges to the required permits. 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 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.

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.

MINING AND RECLAMATION

About 638 acres were mined in the Horse Creek Basin at the Mosaic Fort Green Mine in 2004. An average of 50 acres were mined each month, and mining rates varied by month from a low of 40 acres in October 2004 to a maximum of 74 acres in November 2004. It is Mosaic's understanding that some additional phosphate mining was conducted by CF Industries in a Horse Creek tributary basin (Brushy Creek) in 2004, but Mosaic is not aware of the extent or timing of that mining.

There are two clay settling areas in the Horse Creek Basin at the Fort Green Mine. The FGH-3 clay settling area, completed in 1999, is located predominantly in Sections 5, 8, and 9, T33S, R23E. The FGH-4 clay settling area, completed in 2001, is located predominantly in Section 31, T33S, R23E. Both settling areas have real-time monitoring of the liquid level in the ponds, with monitoring level data relayed to the PRMRWSA.

About 320 acres were reclaimed through revegetation in 2004 at the Fort Green Mine. Earthwork, including spreading of overburden of land backfilled with tailings and final contouring of the ground surface, was completed on 298 acres.

MONITORING PROGRAM COMPONENTS

Monitoring for the HCSP began in April 2003, and this report, which is the second of a series of Annual Reports, presents the results of the first and second year of monitoring. Approximately 8,000 acres of land in the Upper Horse Creek Basin had been mined by Mosaic at the time the HCSP was initiated, located upstream of all HCSP monitoring stations on land controlled by Mosaic. In 2003 and 2004, a total of 981 acres of land located upstream of the northernmost Horse Creek monitoring location was mined by Mosaic. 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 USGS 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 conducted in April, July, and November 2003 and April and November 2004. A series of hurricanes affecting southwest Florida in the Summer 2004 made biological sampling impossible during that time period.

WATER QUANTITY

Temporal patterns of average daily stream flow and stage were similar at both USGS gauging stations in Horse Creek, with highest flows and stages occurring during the rainy season (June through September) in 2003. A similar pattern was observed for Mosaic's National Pollutant Discharge Elimination System (NPDES)-permitted discharges upstream of northernmost monitoring location. As indicated by the 2003 - 2004 rainfall data, an unusually high rainfall event occurred in late June 2003 and three hurricanes dropped large amounts of rain in August, September, and October 2004. The effects of these events were apparent in all the water quantity data, and negatively affected the November biological sampling effort.

WATER QUALITY

Reported water quality constituents were compared with HCSP trigger levels. Water quality parameters were almost always well within the desirable range relative to trigger levels, with trigger levels exceeded for six parameters, but only three parameters more than once. Dissolved oxygen concentrations were consistently below the trigger level of 5 mg/l at HCSW-2, the station located on Horse Creek at County Road 663A/Goose Pond Road. HCSW-2 is located downstream of a segment of the creek known as Horse Creek Prairie, an area of very slow-moving water known to contain low dissolved oxygen levels (Durbin and Raymond 2006). Dissolved oxygen exceedances at other stations are limited to periods of high temperatures or rainfall, as were other exceedances (chlorophyll a, total nitrogen, sulfate, and radium). Several parameters (e.g., dissolved ions, oxidized nitrogen and phosphate) were consistently higher at the lower end of the study area than in the upper segment; this is attributed to contributions of groundwater entering the stream as runoff or seepage from irrigated agricultural areas.

BENTHIC MACROINVERTEBRATES

Optimal benthic macroinvertebrate habitat conditions, as determined through the DEP Habitat Assessment Procedure, were present during sampling events from April 2003 – April 2004 at all locations, and total Stream Condition Index (SCI) scores indicated that the benthic community was Fair or Poor during that time. In November 2004, both the Habitat and SCI scores were lower than in previous samples as a result of changes in habitat quality as a result of three fall 2004 hurricanes. Most of the occasions when the benthic community was found to be in the Poor or Very Poor categories occurred in July 2003 or November 2004, almost certainly the result of poor sampling conditions during high water from the large amount of rainfall received in previous months. During future monitoring events, we anticipate higher benthic community index scores as the system recovers from hurricane impacts.

FISH

Thirty-six species of fish were collected in 2003 and 2004. We expect to add more species during future monitoring events, because the species accumulation curves have not leveled off, based on the five samples collected in 2003 - 2004. Additional native species are expected to occur in Horse Creek but were not collected in 2003 and 2004. Over 30 species of introduced fish have established reproducing populations in Florida, so we expect to continue to collect additional introduced species in Horse Creek during future monitoring events as new introductions occur and as introduced species continue to expand their ranges in Florida. High flows during the July 2003 and November 2004 sampling events resulted in the fewest number of species and individual fish collected relative to the other sampling events. This trend was similar to what was observed for benthic macroinvertebrates. The lowest number of fish species was collected and lowest diversity was calculated for the most upstream Horse Creek station (HCSW-1), while the most species were collected and the highest diversity calculated for the station farthest downstream (HCSW-4) in 2003, but not 2004. The presence of more fish species downstream than upstream is likely the result of several factors: (1) the closer proximity to the Peace River which presumably provides opportunity for movement of species upstream from the river, (2) the overall larger size of the stream channel which provides more room for various types of fish habitat, and (3) the fact that the lower reaches of Horse Creek are not as prone to very low discharge (or going dry) as the more upstream segments of the channel. In 2004, species diversity was highest at the most upstream and downstream sites, presumably because the upstream site was the least affected by 2004 hurricanes. Aside from the several introduced species which have not been documented in Horse Creek in the scientific literature, no unexpected fish taxa were found during the 2003 – 2004 sampling, and no reduction was indicated in fish diversity or abundance as a result of mining activities in the watershed.

CONCLUSIONS

Although this report covers only the second year of an ongoing monitoring program, and only two biological sampling events were possible during 2004, some general conclusions can be drawn. Expected relationships between rainfall, runoff and stream flow were observed in the 2004 water quantity data. Water quality parameters were almost always well within the desirable range relative to trigger levels, with trigger levels exceeded for five parameters, but only two parameters more than once. The benthic macroinvertebrate and fish communities found in Horse Creek in 2003 - 2004 were typical of those found in a Southwest Florida stream, and no impacts from mining were apparent, but very clear and prounced effects were apparent from the 2004 hurricanes.

RECOMMENDATIONS

Water quantity, water quality and aquatic biological monitoring should proceed in the same manner, including the adjustments to the biological sampling schedule recommended in the 2003 Annual Report That is, the window for the summer biological sampling event should include all of July/August/September and the fall window should encompass October/November/December, to maximize the opportunity for having suitable sampling conditions. Every effort should be made to space the biological sampling events at least six weeks apart to try to capture seasonal variation.

Biological sampling should not be undertaken during times when the stream stage is above 10 feet at HCSW-1 and 4 feet at HCSW-4. This recommendation lowers the suitable sampling stage at HCSW-4 by 1 foot from the previous guideline; this adjustment is the result of significant morphometric changes at that station resulting from Hurricane Charley.

NOTE TO TAG – These recommendations came from the meeting on the Historical Report:

Mosaic and the PRMRWSA should investigate the availability and cost of LIDAR rainfall data for the Horse Creek Basin because of its ability to more accurately represent widespread rainfall amounts.

Future reports should adopt a standard set of agency water quality databases from which to draw ongoing monitoring data for Horse Creek. These should include the SWFWMD, FDEP STORET and the USGS, to the extent that each of these agencies continues to collect Horse Creek data. Such data should be presented and discussed in relation to the monitoring data produced by the HCSP.

In general, presentation of period-of-record data recent data in graphics is preferable to single-year data, except where a more limited presentation of data is necessary to illustrate a point. Where data extend back more than ten years, only the most recent decade of data may be presented if it provides better resolution of the information being presented, although longer periods of record may be presented to indicate trends or temporal changes beyond the last decade.

This report, and future HCSP annual reports, should include a list of formal changes to the HCSP methodology. The list should reflect only additions, deletions and revisions which have been addressed by the HCSP TAG (either through presentation within an annual report, separate recommendation by Mosaic, or recommendation by the TAG itself), and not all recommendations made in annual reports would necessarily constitute changes to the HCSP methodology. At the end of the list would be the recommended changes within the current year's report to allow the TAG and the PRMRWSA to consider the specific methodology changes proposed in the report. Changes to the methodology would not be implemented until they have been reviewed by the TAG and the annual report has been accepted by the PRMRWSA Board. In the case of minor changes to the protocol, the PRMRWSA and/or the TAG could give provisional approval of a change to allow for its implementation before final approval of the annual report by the PRMRWSA Board. The list of changes should stand as a separate appendix, with each item identifying the monitoring year the change is implemented, and whether the change is provisional or final. The list should be cumulative and chronological to reflect the adaptive nature of the methodology. This report contains such a list (Appendix B) in the recommended format. No changes should be made to the original HCSP methodology document, which is a component of the legal settlement agreement and comprises a separate appendix of each annual report.

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1.0 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 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 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 8,000 acres of land in the Upper Horse Creek Basin had been mined on land controlled by Mosaic, lying upstream of all but the northernmost monitoring location. In 2004, a total of 638 acres was 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 second of a series of Annual Reports, presents the results of monitoring conducted in 2004. Additionally, monitoring results from 2003, the first year of the HCSP, are also included to allow comparisons between years. As the HCSP monitoring continues, however, future annual reports will be limited to raw data for only the current year, with summaries and trend analyses representing the data for previous years and non-HCSP historical data. A separate report contains a review and summary of all available historical water quality and biological information for Horse Creek (Durbin and Raymond 2006).

2.0 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 (Figure 1). Horse Creek is a major tributary of the Peace River that drains the south-western 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).

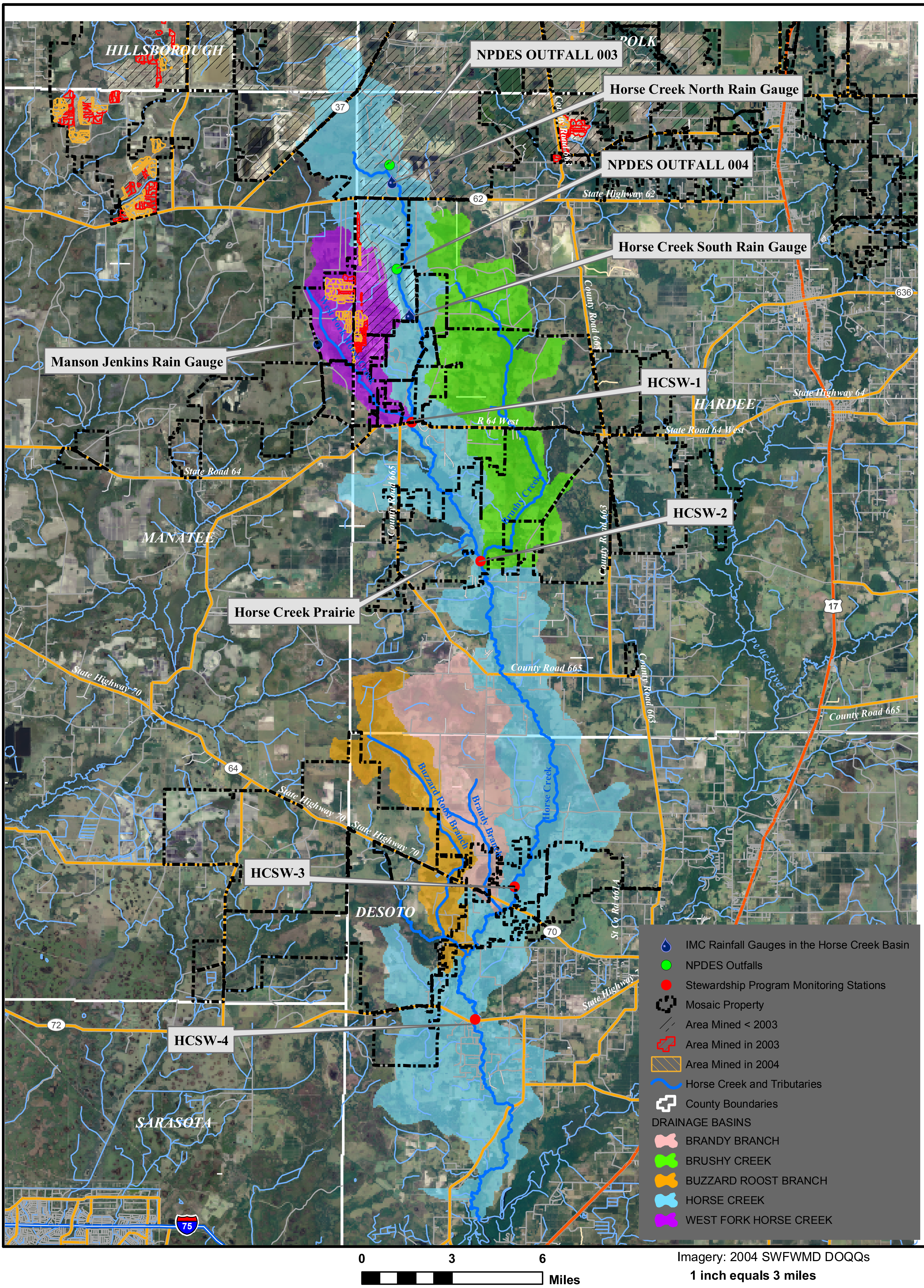
The climate of Horse Creek Basin is subtropical and humid with an average temperature of about 72 º F. Summer temperatures average 80 ºF, and winter temperatures average 60 ºF (Hammett 1990). The average daily temperatures in Hardee County, in the northern Horse Creek Basin, range from is 52 º F to 91 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 in, 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).



Preparation Date:	Revision Date:	Project Number:
29 November 2005	29 November 2005	2476-065-b22
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DJD	KMNR	
ArcMap Name:	Plot File:	
horsecreek_aerial.mxd	horsecreek_aerial.pdf	

Figure 1. Overview of drainage basins, HCSP sampling locations, and phosphate mining ownership in the Horse Creek Basin.

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3.0 SUMMARY OF MINING AND RECLAMATION ACTIVITIES

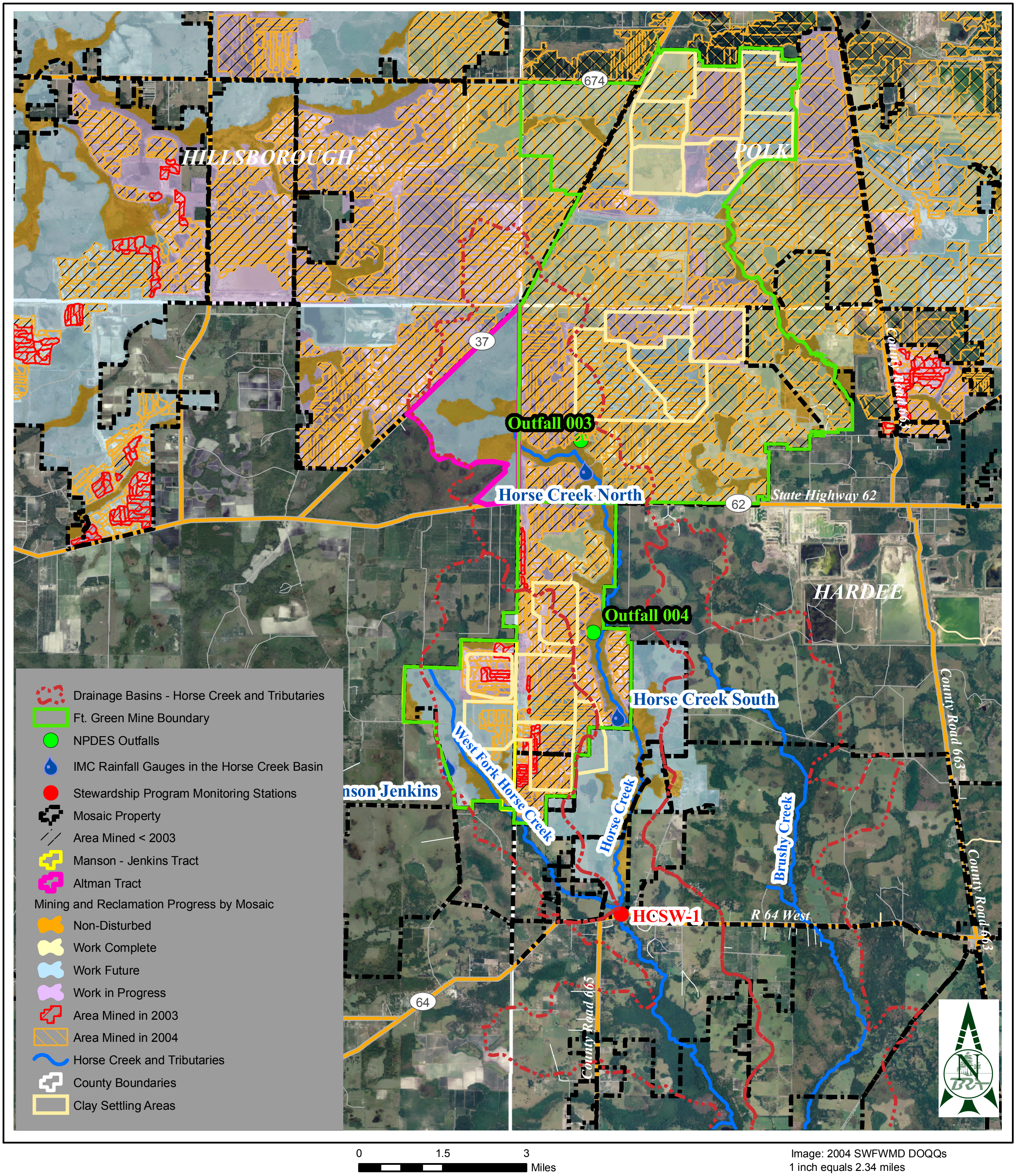
3.1 MINING

About 638 acres were mined in the Horse Creek Basin at the Mosaic Fort Green Mine in 2004 (Figure 2). Mining occurred in the basin during all months in 2004, with an average of 50 acres mined per month. Mining rates varied by month from a low of 40 acres in October to a maximum of 74 acres in November. Mining was split between the Fort Green Tract (176 acres mined in Hardee County) and the Manson Jenkins Tract (462 acres mined in Manatee County). There have been, and will be in the future, mining activities in the Horse Creek Basin outside of those performed by the Mosaic Corporation. It is Mosaic's understanding that some additional phosphate mining was conducted by CF Industries in a Horse Creek tributary basin (Brushy Creek) in 2004, 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 a 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 two 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, to 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. Pond elevations in 2004 have ranged from a low of approximately 142.0 ft. NGVD in March to a high of approximately 145.6 ft. NGVD in September.

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 was put into service a 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. Clays are introduced into the settling area at the southwest corner, and at a point approximately midway on the west wall the dam. The settling area is also used to store mine pit water, which is pumped into the settling area at the northwest corner and at approximately the center of the south wall. Pond elevations in 2004 ranged from a low of approximately 129.7 ft. NGVD in June, to a high of approximately 142.0 ft. NGVD in October.

No repairs have been required on either settling area, aside from routine maintenance. Both 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.



Preparation Date: 29 November 2005	Revision Date: 29 November 2005	Project Number: 2476-065-b22
Project Manager: DJD	GIS Operator: KMNR	GIS QA/ QC:
ArcMap Name: horsecreek-mined.mxd	Plot File: horsecreek-mined.pdf	

Figure 2. Mining and reclamation areas in the Horse Creek Basin.

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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.

About 320 acres were reclaimed through revegetation in 2004 at the Fort Green Mine. Earthwork, which included spreading of overburden onto land backfilled with tailings and final contouring of the ground surface, was completed on 298 acres. In 2004, 100 acres were planted in wetland plants and 220 acres were planted in upland plants in reclamation projects within the Horse Creek Basin at the Fort Green Mine.

4.0 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 was conducted monthly, while biological sampling events were conducted twice in 2004 (Table 1). Biological sampling was not conducted in Summer 2004 because stream stage was prohibitively high.

Table 1. Schedule of Water Quality and Biological Sampling Events of the HCSP in 2004.

Date	Water Quality Sampling Events	Macroinvertebrate and Fish Sampling Events
29 January 2004	X	
24 February 2004	X	
16 March 2004	X	
14 April 2004	X	
22 April 2004		X
26 May 2004	X	
29 June 2004	X	
27 July 2004	X	
30 August 2004	X	
29 September 2004	X	
27 October 2004	X	
03 November 2004		X
18 November 2004	X	
15 December 2004	X	

4.2 WATER QUANTITY

Provisional discharge data for 2004 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 2004 (Figure 1). Daily rainfall data for 2004 were obtained from the USGS for HCSW-1, as well as 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. The HCSP Historical 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. These data provide 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.

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 sample 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 BRA in association with the three biological sampling events employed a HydroLab Quanta multiparameter unit with the same measuring methods and acceptance limits listed in Table 2. BRA also employed a Hack 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 Hydrolab Quanta. All sampling was conducted according to the Florida Department of Environmental Protection's (DEP's) Standard Operating Procedures (SOPs) for field sampling. Laboratory analyses were performed by experienced personnel according to National Environmental Laboratory Accreditation Council (NELAC) protocols, including quality assurance/quality control (QA/QC) considerations contained in the QA/QC plan developed for this program (currently in review). There were no substantial problems during water quality sampling events or laboratory analysis of samples during the 2004 monitoring.

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 - 2004 Monthly Water Quality Samples.

Parameter	Method	Hold Time	Preservation	Minimum Detection Limit	Container
Color	110.2	48 hours	Unpreserved	2.5 PCU	Clear HDPE bottle
Total Kjeldahl Nitrogen	351.2	28 days	Sulfuric Acid, pH < 2	0.1 mg/l	Clear HDPE bottle
Nitrate-Nitrite Nitrogen	353.2	28 days	Sulfuric Acid, pH < 2	0.02 mg/l	Clear HDPE bottle
Nitrate Nitrogen	SM 4500E	48 hours	Unpreserved	0.02 mg/l	Clear HDPE bottle
Total Ammonia Nitrogen	350.1	28 days	Sulfuric Acid, pH < 2	0.03 mg/l	Clear HDPE bottle
Orthophosphate	365.1	48 hours	Unpreserved	0.05 mg/l	Clear HDPE bottle
Chlorophyll *a*	SM 10200H	48 hours	Unpreserved	1 mg/l	Opaque plastic bottle
Specific Conductivity	120.1	28 days	Unpreserved	10 uS/cm	Clear HDPE bottle
Total Alkalinity	310.1	14 days	Unpreserved	mg/l CaCO3	Clear HDPE bottle
Dissolved Calcium*	200.7	28 days	Unpreserved	0.1 mg/l	Clear HDPE bottle
Dissolved Iron*	200.7	28 days	Unpreserved	0.1 mg/l	Clear HDPE bottle
Chloride	300.0	28 days	Unpreserved	1 mg/l	Clear HDPE bottle
Fluoride	300.0	28 days	Unpreserved	0.1 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	1 mg/l	Clear HDPE bottle
Total Dissolved Solids	160.1	7 days	Unpreserved	5 mg/l	Clear HDPE bottle
Petroleum Range Organics	FL-PRO	7 days	Hydrochloric Acid, pH < 2	0.1 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

- If a field conductivity measurement exceeded 1,400 umhos/cm, the laboratory performed an analysis of specific conductivity.
- All water samples were preserved at 4C while awaiting analysis.
- Ortho-phosphate 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 will be field-filtered.
- * - The analytical method for iron and calcium was changed during the 2003 – 2004 monitoring period; see results section for details.

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 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)	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
Biological Indices: Fish	Total Number of Taxa Abundance Shannon-Wiener Diversity(a) Species Turnover (Morisita Similarity Index(a) 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
(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.,
(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 22 April 2004 and 3 November 2004. Biological sampling was not conducted during the summer of 2004 because the stream stage was well above the levels at which sampling could be safely and effectively performed; many invertebrate habitats were submerged during those months. 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 various metrics listed for benthic macroinvertebrates in the HCSP plan; however, the plan itself anticipated such changes in methodology and the use of the revised protocol is consistent with the plan.

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 Taxon	10-(10[(X-10)/44])
Percent Tanytarsini	10[ln(X+1)/3.3]
Sensitive Taxa	10X/9
Percent Very Tolerant Taxa	10-(10[ln(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 is no need to retroactively adjust SCI values from previous years' sampling results. Changes made to the calculation protocol are 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
Good	73-100	Similar to natural conditions, up to 10% loss of taxa expected
Fair	46-73	Significantly different from natural conditions; 20-30% loss of Ephemeroptera, Trichoptera and long-lived taxa; 40% loss of clinger and sensitive taxa; percentage of very tolerant individuals doubles
Poor	19-46	Very different from natural conditions; 30% loss of total taxa; Ephemeroptera, Trichoptera, long-lived, clinger and sensitive taxa uncommon or rare; Collector-Filterer and Tanytarsini individuals decline by half; 25% of individuals are very tolerant
Very Poor	0-19	Extremely degraded; 50% loss of expected taxa; Ephemeroptera, Trichoptera, long-lived, clinger, and sensitive taxa missing or rare; 60% of individuals are very tolerant

4.5 FISH

Fish sampling was conducted concurrently with the benthic macroinvertebrate sampling at each station on 22 April 2004 and 3 November 2004. Biological sampling was not conducted during the summer of 2004 because the stream gage height was well above the recommended 5 ft; many fish habitats were submerged during those months and electrofishing was not possible. Fish were collected with a 4-foot x 8-foot seine (3 mm mesh size) and by electrofishing, using a generator-powered Smith-Root, Inc. backpack electrofishing 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. Future annual reports will compare catch per unit effort information among stations and over time.

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 1991). 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 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 is available.

The presence of more fish species downstream in Horse Creek than upstream is assumed to be the combined result of several factors: (1) the closer proximity to the Peace River which presumably provides opportunity for movement of species upstream from the river, (2) the overall larger size of the stream channel which provides more room for various types of fish habitat, and (3) the fact that the lower reaches of Horse Creek are not as prone to very low discharge (or going dry) as the more upstream segments of the channel.

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 3). 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 3). 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 3). 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 over the stream is low (approximately 25 percent); so, the area receives considerable direct sunlight.

At HCSW-4, the sampling segment is less sinuous (Figure 3). 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 POST-HURRICANE HABITAT CONFIGURATION AT MONITORING STATIONS

Because Hurricane Charley effectively traveled up the Horse Creek basin in mid-2004, the stream and its floodplain were left visibly different in a number of ways (Figure 4). Loss of tree canopy was the primary change through much of the floodplain, primarily through the loss of a large portion of tree limbs and foliage, as well as the downing of many mature trees. The channel itself was altered through the combined effects of the large discharge brought about by Charley (and subsequent storms in 2004), as well as the sudden introduction of massive amounts of vegetation debris and sediment into the stream. The vegetation debris ranged from fresh leaves blown from trees (and many still attached to branches), to woody material varying in size from small twigs to entire trees. Introduction of this material obviously had a powerful effect on in-stream hydraulics, leading to changes in channel configuration, local velocity patterns, and erosion/deposition patterns. As the floodplain continues to 'recover' from hurricane effects (i.e., through re-growth of damaged vegetation), and as organic material (primarily wood) breaks down and is transported into the stream and longitudinally downstream, it can be assumed that Horse Creek will see further changes in its morphometry, and probably its ecology, over and above typical year-to-year changes that might otherwise be expected.

At Stations HCSW-2, 3 and 4, there was severe damage to the riparian and floodplain forest, with trees of all sizes and species damaged or destroyed. For example, the live oak hammock in the floodplain at HCSW-3, which previously provided nearly 90 percent canopy cover, suffered so much tree and branch loss that the forest floor was in virtually full sun.

The instream effects were most notable at Stations HCSW-3 and HCSW-4, which apparently lie within the area struck by the eye of Charley. Both stations had trees and large branches lying in the stream channel which complicated the use of fish and invertebrate sampling equipment. The very high flows resulting from the hurricanes' rainfall combined with the altered hydraulics brought about by the new debris in the stream caused major shifts in the locations of sandbars, pools, runs, etc. These changes, along with reduced visibility caused by somewhat cloudy water made wading in the stream difficult compared to previous sampling events. Since the area has seen no rainfall in the past several weeks and stream flows have been steadily declining, the suspended material in the water is assumed to have been the result of decomposition of the trees, leaves and other organic matter thrown into the stream by the hurricanes, rather than suspended sediment contributed by runoff. Many areas along the stream had a distinct odor indicating rotting vegetation and/or accumulations of muck and decaying material.

Farther upstream, Station HCSW-2 had marked floodplain forest damage, but the stream channel segment that is sampled was not dramatically changed. Station HCSW-1 was only minimally affected in terms of either its floodplain or the channel. This is because the path of Charley was several miles to the east of that station, and because the stream is very deeply incised at HCSW-1, so the channel and its riparian canopy lie somewhat below the surrounding landscape, presumably resulting in lower localized wind speeds as the hurricanes went through.

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

Figure 4. Photographs of HCSP Sampling Locations after 2004 Hurricanes. Photos taken 5 February 2005.

5.0 RESULTS AND DISCUSSION

Below we present a summary of water quantity and quality data collected as part of the HCSP in 2004. In addition, results of the 2004 benthic macroinvertebrate and fish sampling are presented.

5.1 WATER QUANTITY

5.1.1 Rainfall

Continuous rainfall data are collected by the USGS at HCSW-1 (USGS Station 2297155). Figure 5 includes 2003 - 2004 daily rainfall data for HCSW-1, as well as data from the two Mosaic rain gauges located in the Horse Creek watershed (see Figure 1 for locations). Rainfall was variable at the different locations; however, heavy rainfall was observed on the same days at all four locations. Seasonality of daily rainfall was also similar among locations (Figure 6), with all stations showing highest daily rainfall during the wet season (June – September). During other months in 2003, daily rainfall was usually near zero at all locations. In 2004, however, January - April rainfall was greater than in 2003 or historic conditions (Durbin and Raymond 2006). Total annual rainfall was about 60 inches for both 2003 and 2004, well within the historic range for that station (Durbin and Raymond 2006).

5.1.2 Stream Stage

Figure 7 illustrates the relationship between the staff gauge readings made during each 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). The correlation of stage values among the stations is fairly close, as indicated in Table 7.

Patterns of daily stage levels, based upon monthly readings by Mosaic and data collected continuously by the USGS, were clearly related temporally among the four stations (Figure 7). Stage height (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). Spearman's rank correlation procedure, a nonparametric procedure, was used because three of the six stations (HCSW-1 (IMC) and both USGS stations) had gage heights that were not distributed normally (Shapiro-Wilk test for normality, $p < 0.05$). Gage heights showed a strong and significant correlation between all Mosaic stations and USGS stations (Table 7). Such close correspondence is not unexpected for a fairly small watershed in a low gradient setting like peninsular Florida.

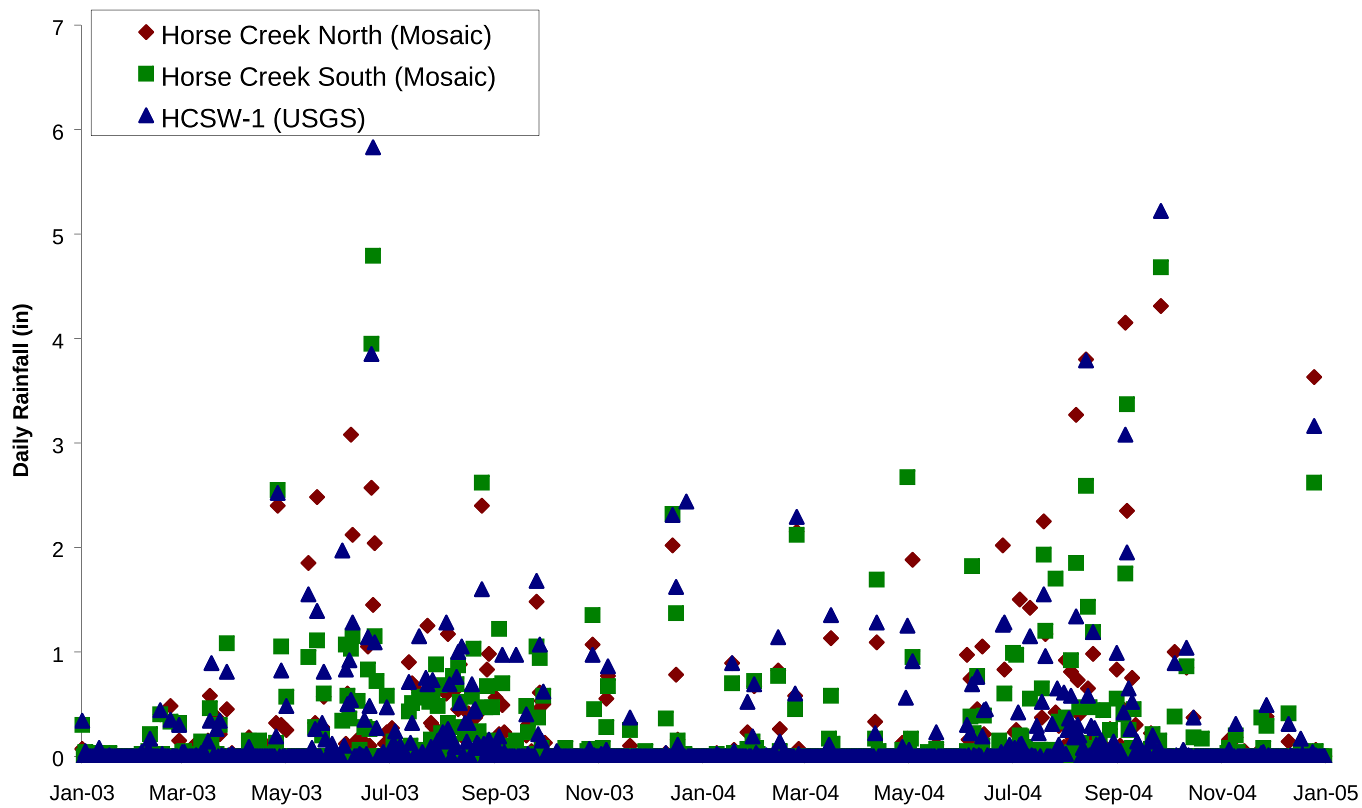


Figure 5. Daily Rainfall From Gauges in the Horse Creek Watershed in 2003-2004 (Figure uses provisional data from USGS website).

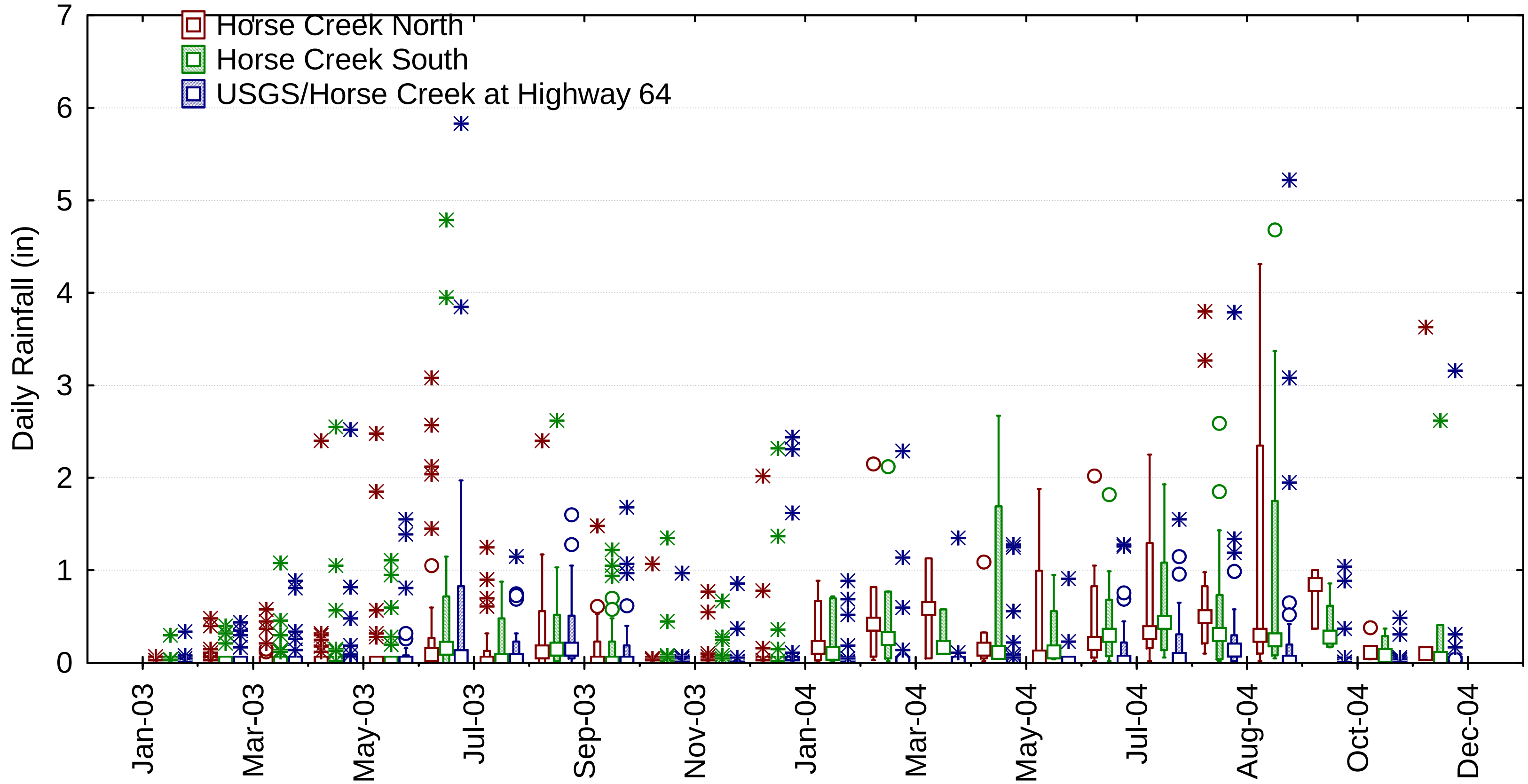
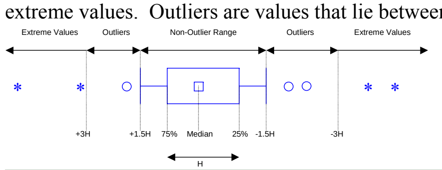


Figure 6. Monthly Median Box-and-whisker plots[1] of Daily Rainfall Summaries From Gauges in the Horse Creek Watershed in 2003-2004 (Figure uses provisional data from USGS website).

[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).



Mean daily stage levels were highest on 22 - 23 June 2003 and 14 August, 6 September, and 27 September 2004, corresponding with high streamflow as a result of an extremely large rainfall event or hurricanes (Charley, Frances, and Jeanne in 2004). Stage duration curves for 2003 and 2004 were developed for HCSW-1 and HCSW-4 (Figures 8 and 9) to indicate the percentage of time stream stage was above particular elevations. Stage at HCSW-1 varied only three to four feet between the curve's P10 and P90 in both years, indicating that stream height is 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). Stages reached above the P10 show that a few rain events caused the stream at HCSW-1 to rise up to ten feet higher for short periods of time in 2003 and 2004. Stream stage at HCSW-4 is more variable than at HCSW-1 between the P10 and P90 (about nine feet), but that station still showed considerable rises in stage beyond the P10 level as a result of large rain events in both years. Stage duration was very similar between years, but stream elevation did remain at its highest levels for more days in 2004 than in 2003, probably because of three hurricanes.

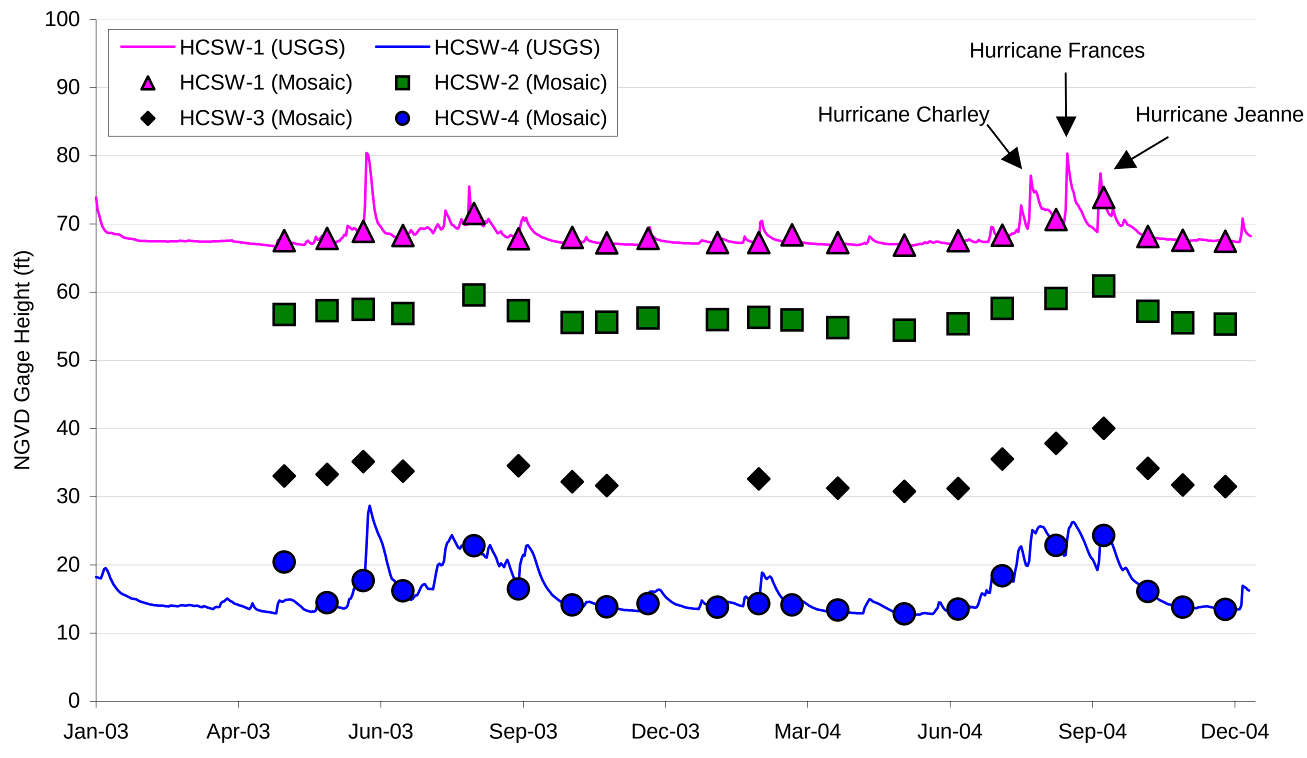


Figure 7. Stream Stage at HCSP Monitoring Stations in 2003 - 2004. Individual data points are from Mosaic's monthly monitoring; continuous lines are average daily stage from USGS (Stations 02297155 and 02297310). HCSW-3 is missing three gage heights; water was above the gage in August 2003 and below the limits of detection in December 2003 – January 2004 and March 2004 (Figure uses provisional data from USGS website).

Table 7. Coefficients of Rank Correlation (r_s) for Spearman's Rank Correlations of Monthly Gage Height (NGVD) for 2003-2004 ($p < 0.05$).

	HCSW-2 (Mosaic)	HCSW-3 (Mosaic)	HCSW-4 (Mosaic)	HCSW-1 (USGS)	HCSW-4 (USGS)
HCSW-1 (IMC)	0.77	0.89	0.78	0.93	0.83
HCSW-2 (IMC)		0.97	0.95	0.85	0.98
HCSW-3 (IMC)			0.94	0.90	0.99
HCSW-4 (IMC)				0.85	0.98
HCSW-1 (USGS)					0.88

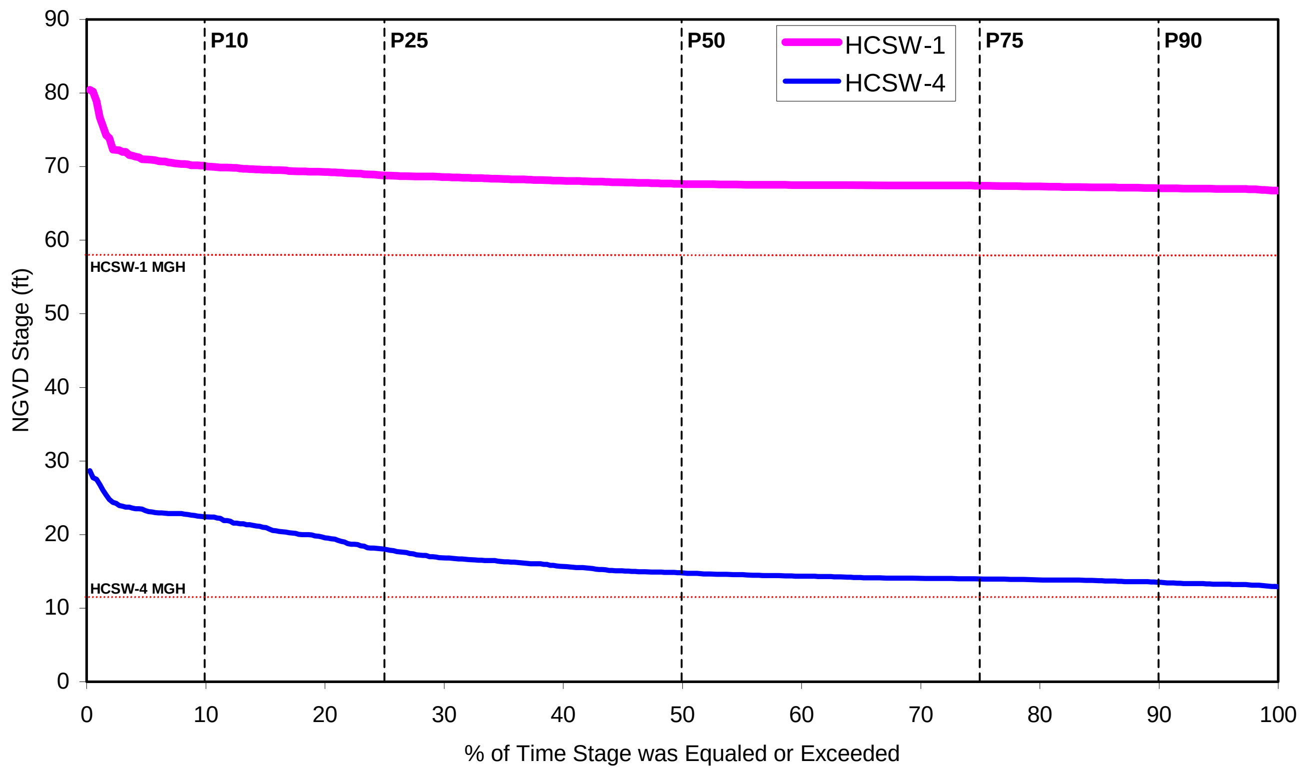


Figure 8. Stage Duration Curves for HCSW-1 and HCSW-4 in 2003, showing percent of year water levels were at or above a given stage. Typical reference points of 10% (P10), 25% (P25), 50% (P50), 75% (P75), and 90% (P90) are indicated on the graph, as well as the minimum gage heights of HCSW-4 (10.96 ft, NGVD) and HCSW-1 (58.12 ft NGVD). (Figure uses provisional data from USGS website, USGS Stations 02297155 and 02297310).

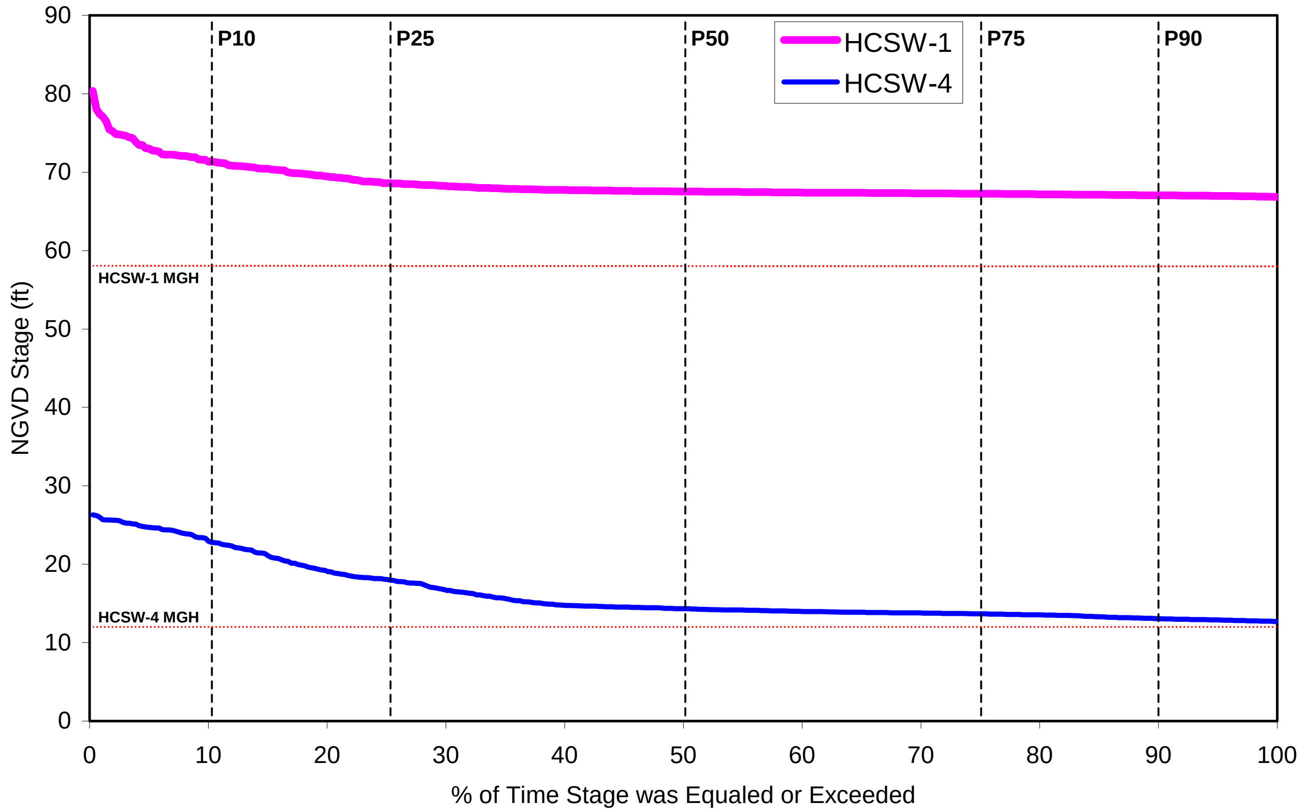


Figure 9. Stage Duration Curves for HCSW-1 and HCSW-4 in 2004, showing percent of year water levels were at or above a given stage. Typical reference points of 10% (P10), 25% (P25), 50% (P50), 75% (P75), and 90% (P90) are indicated on the graph, as well as the minimum gage heights of HCSW-4 (10.96 ft, 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 HCSP requires that staff gauges be installed at HCSW-2 and HCSW-3, but does not mandate that discharge be measured at those stations. Thus, all discharge results and discussion are based upon USGS data from HCSW-1 and HCSW-4. The average daily stream flow, obtained from the USGS continuous recorder data for HCSW-1 and HCSW-4, is presented in Figure 10 and Table 8. The seasonal pattern of streamflow seen in 2003-2004 is similar to historical monthly patterns (Durbin and Raymond 2006). The highest flows occurred during the wet-season months of June through September, with extremely high flows occurring in late June 2003 and August – October 2004, following unusually large rainfall events. The three peaks in discharge in August, September, and October 2004 correspond with Hurricanes Charley, Frances, and Jeanne passing over central Florida. Average daily stream flows exhibited a similar pattern at both HCSW-1 and HCSW-4 (Figure 10); 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. For both stations, yearly total stream discharge in 2003 and 2004 was higher than the historical average but not outside the historical range of stream discharge at these stations (Durbin and Raymond 2006).

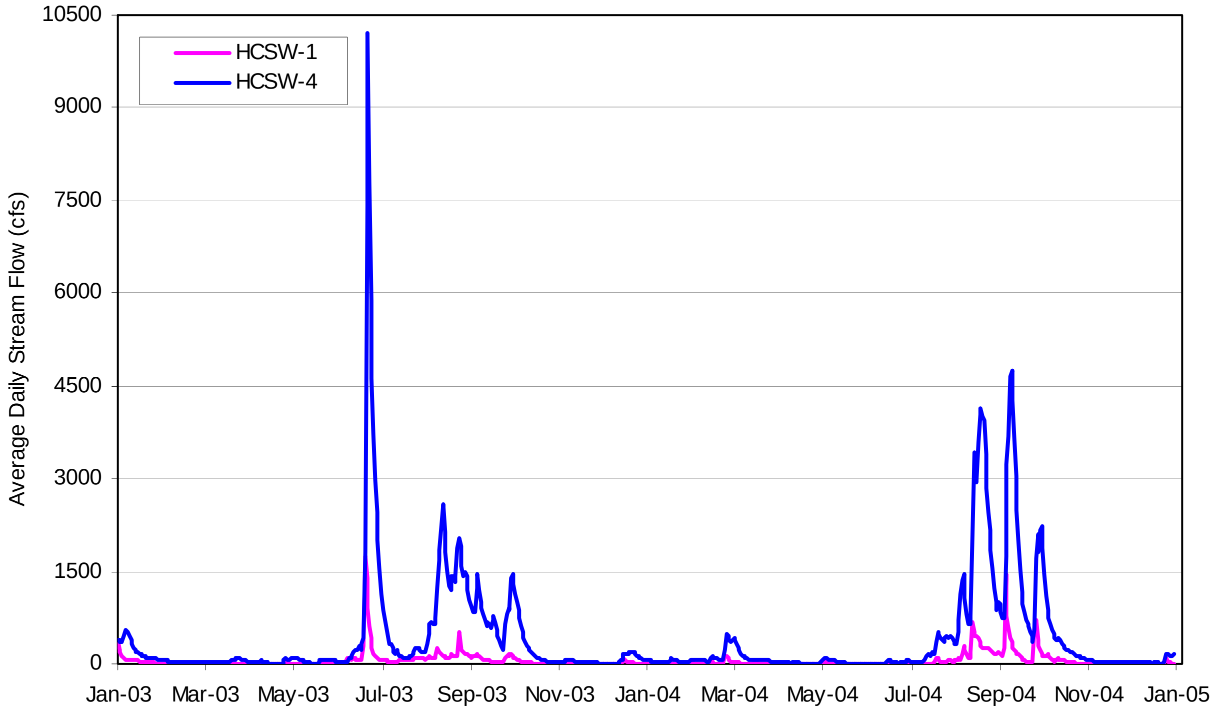


Figure 10. Average Daily Stream Flow for HCSW-1 and HCSW-4 in 2003 - 2004 (Figure uses provisional data from USGS website).

Table 8. Median, 10th Percentile, and 90th Percentile, and Total Annual Stream Discharge at HCSW-1 and HCSW-4 in 2003 - 2004, Based upon Provisional Data from USGS Website.

	HCSW-1	HCSW-4
10th percentile	1.5 cfs	16 cfs
Median	12 cfs	65 cfs
90th percentile	144 cfs	1215 cfs
2003 Total Annual	20891 cfs	149354 cfs
2004 Total Annual	19896 cfs	147688 cfs

5.1.4 Rainfall-Runoff Relationship

Stream discharge at HCSW-1 and the average daily rainfall for 2003 - 2004 (average of daily rainfall at HCSW-1 (USGS) and two Mosaic rain gauges upstream of Highway 64) were compared in Figure 11. Higher stream discharge was usually associated with high rainfall, especially during the wet season; the pattern, however, was not consistent, because rainfall events of one inch or more often corresponded in little or no change in stream discharge at HCSW-1.

To further examine the strength of covariation between daily stream discharge and rainfall, Spearman's rank correlation procedure was used (Zar 1999). Stream discharge at HCSW-1 was compared to rainfall at HCSW-1 (USGS) and the two Mosaic rain gauges, as well the average of all rainfall gauges. Spearman's rank correlation procedure, a nonparametric procedure, was used because stream discharge and rainfall at Horse Creek were not distributed normally (Shapiro-Wilk test for normality, $p < 0.0001$ for all data). The correlation between stream discharge at HCSW-1 and rainfall was statistically significant for each rainfall gauge (Table 9). Although these results suggest that stream discharge and rainfall in Horse Creek covary more than would be expected by chance alone, the correlation coefficients are low ($0.20 > r < 0.31$), indicating that the relationship between the two variables is not very strong. The lag between rainfall and runoff, as well as other antecedent condition factors, are strongly affecting this relationship. Historical rainfall and discharge are also significantly correlated, but the relationship is much stronger ($r \sim 0.6$) because the lag influences the relationship less when considered over time (Durbin and Raymond 2006).

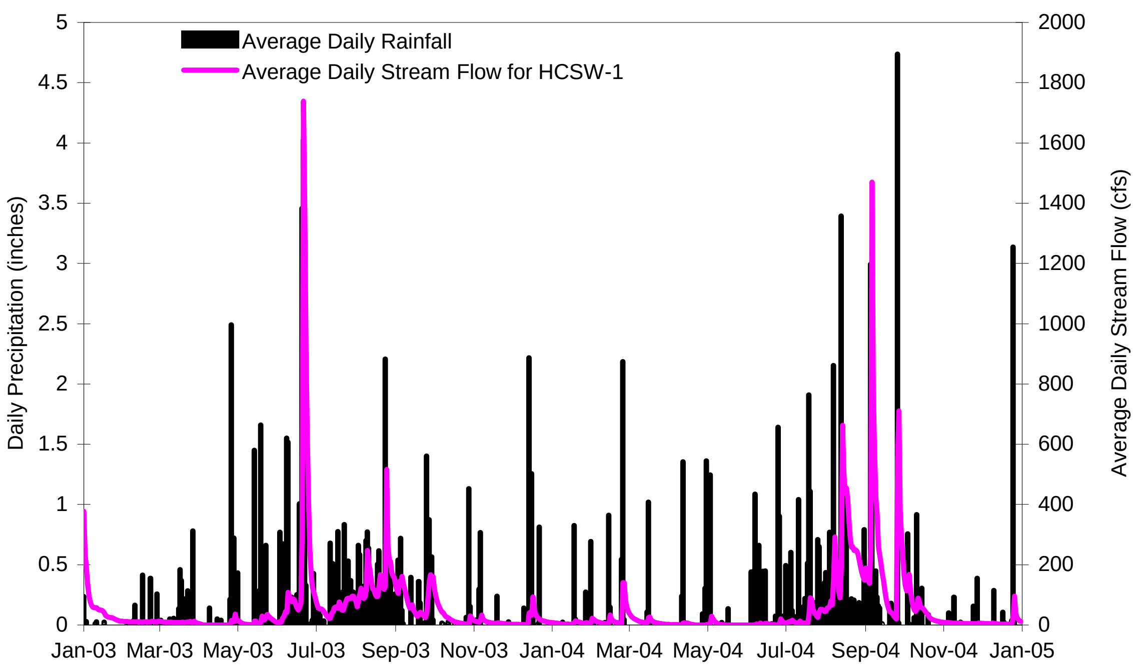


Figure 11. Average Daily Stream Flow and Average Daily Rainfall in the Horse Creek Watershed in 2003 - 2004 (Figure uses provisional data from USGS website).

Table 9. Coefficients of Rank Correlation (r_s) for Spearman's Rank Correlations of HCSW-1 Daily Stream Discharge and Daily Rainfall at USGS Gauge and Two Mosaic Gauges in 2003 - 2004.

Rainfall Gauge	r_s (with HCSW-1 Streamflow)	p value	N (Sample Size)
Horse Creek North	0.2062	< 0.0001	440
Horse Creek South	0.2341	< 0.0001	442
HCSW-1 (USGS)	0.3159	< 0.0001	712
Average Rainfall	0.3027	< 0.0001	423

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 12 illustrates the relationship between cumulative daily discharge at HGSW-1 and rainfall from the gauges at HCSW-1 and the average of all gauges in the Horse Creek Basin upstream of Highway 64. Comparison of the curves shows that 2004 saw less discharge at the beginning of the year than in 2003, but the cumulative discharge over the years were similar.

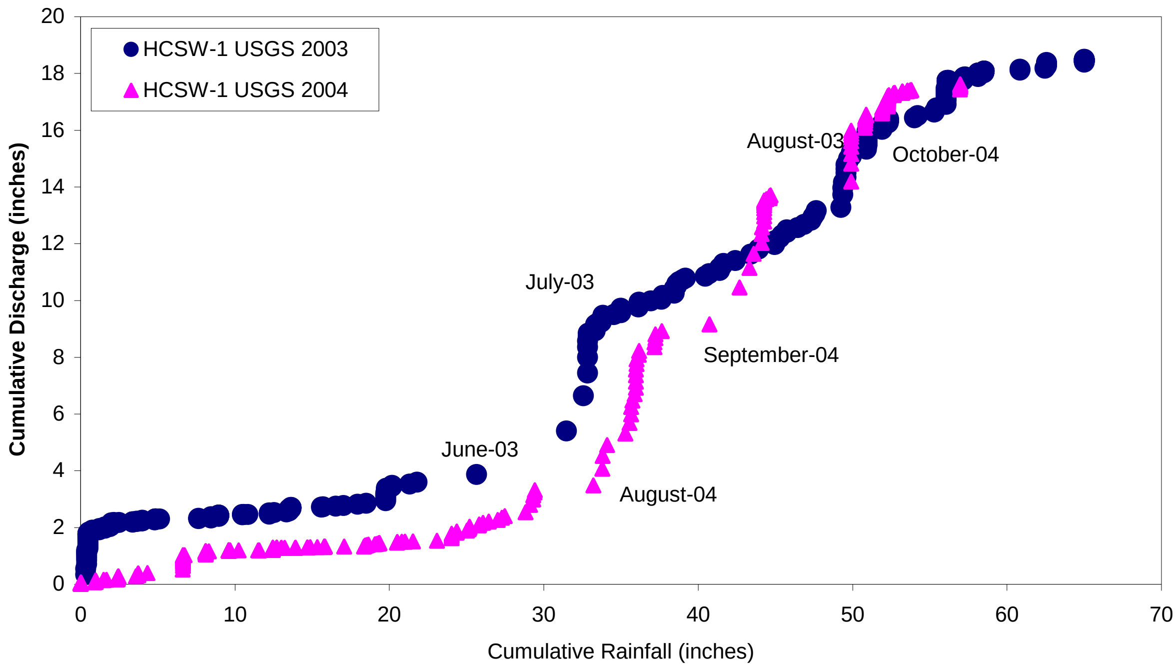


Figure 12. Double Mass Curve of Cumulative Daily Runoff and Rainfall (USGS) in the Horse Creek Watershed in 2003 and 2004 (Figure uses provisional data from USGS website).

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, Figure 1). Both outfalls are twenty-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 2003 - 2004 (Figure 13). The Horse Creek outfalls, however, are not the major discharge points of the mine, so this data represents only a portion of the mine's rainfall-discharge relationship (Table 10). 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 2003 - 2004 daily discharge of two Mosaic NPDES outfalls (Outfalls 003 and 004) located upstream of HCSW-1 was plotted against the 2003 - 2004 daily flow for HCSW-1 (Figure 14). Peak NPDES discharge corresponds with the highest flows in Horse Creek, but the total flow at HCSW-1 commonly included water discharged from the NPDES outfalls. Comparing HCSW-1 stream discharge and NPDES discharge in 2003 - 2004 using a Spearman's rank correlation procedure (Zar 1999) indicates they covary strongly ($r_s = 0.6410$, $p < 0.0001$, $N = 712$). Thus, an increase in one parameter will correspond to an increase in the other. This does not necessarily suggest a causal relationship between NPDES discharge and stream discharge. Just as stream discharge at HCSW-1 was weakly correlated with rainfall (Table 9), so too is NPDES discharge (Table 11), with lagtimes and antecedent conditions affecting this relationship.

As indicated in Figure 14, during July 2003, NPDES outfall discharge is larger than streamflow at HCSW-1. Although this reduction in stream volume as the water moved downstream could indicate that Horse Creek is a "losing stream" in this area, it is more likely that the equipment at the USGS gage malfunctioned. 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. If the cross section of the stream at or near the gage changed during the period in question (e.g., debris became lodged or dislodged near the gage) the cross-sectional area could have changed sufficiently to give erroneous readings. 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 (R. Franklin, *pers. comm.*).

Table 10. 2004 Average monthly Mosaic Industrial Wastewater Discharge (NPDES) to Horse Creek (Outfalls 003 and 004) and Payne Creek (Outfall 001 and 002) from the Fort Green Mine.

Month	Discharge to Payne Creek (MGD)	Discharge to Horse Creek (MGD)
January	0.4	0.0
February	0.0	0.0
March	0.0	0.0
April	0.0	0.0
May	1.9	0.0
June	0.0	0.0
July	2.0	0.0
August	20.8	8.8
September	53.7	24.8
October	7.8	27.7
November	1.2	7.4
December	3.1	4.0

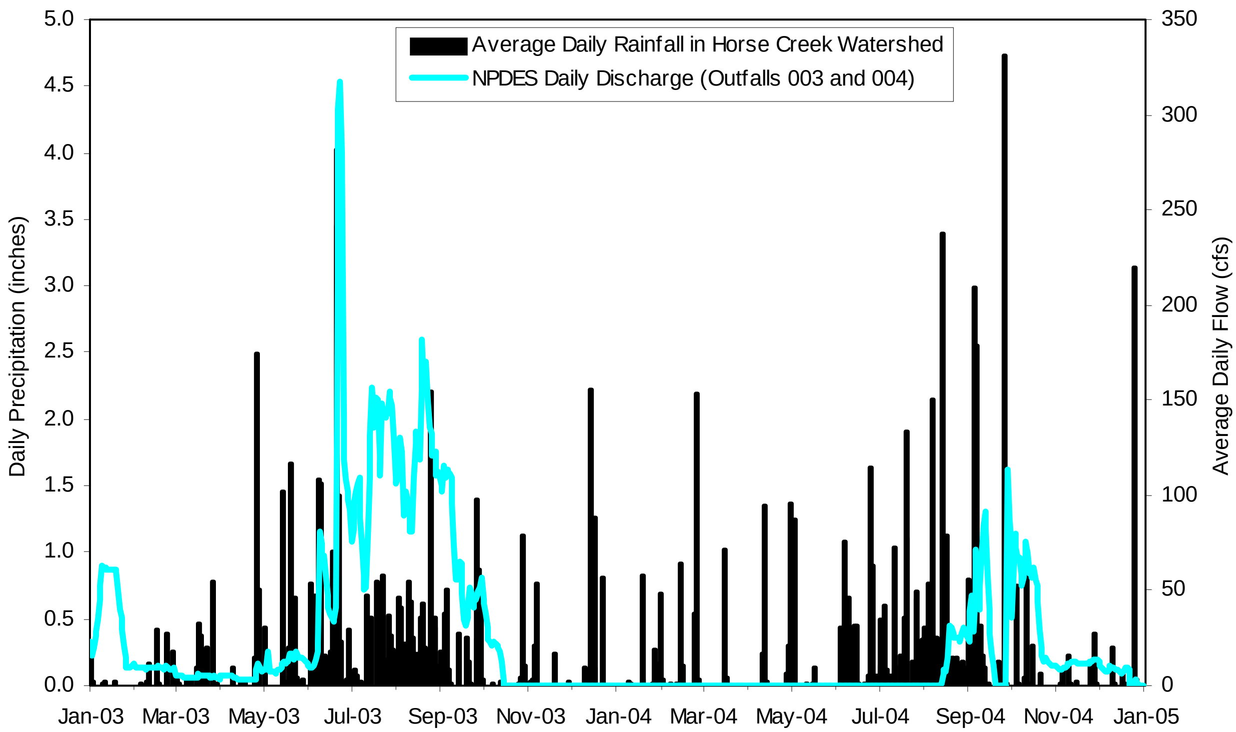


Figure 13. Combined Mosaic NPDES Discharge and Average Daily Rainfall in the Horse Creek Watershed in 2003 – 2004 (Figure uses provisional data from USGS website).

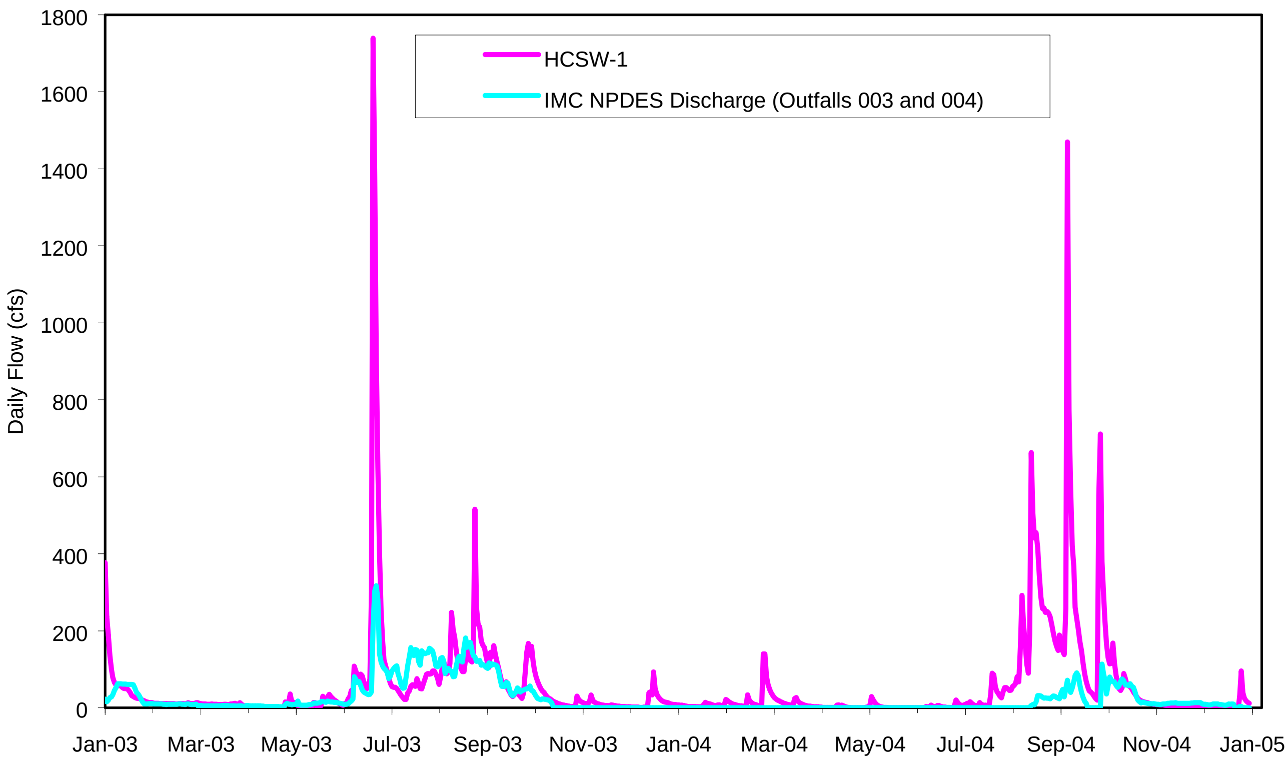


Figure 14. Daily Flow at HCSW-1 and Combined Mosaic NPDES Discharge for 2003 – 2004 (Figure uses provisional data from USGS website).

Table 11. Coefficients of Rank Correlation (r_s) for Spearman's Rank Correlations of NPDES Daily Discharge and USGS Daily Discharge and Daily Rainfall at USGS Gauge and Two Mosaic Gauges in 2003 - 2004

Gauge	r_s (with NPDES Outfall)	p value	N (Sample Size)
HCSW-1 (USGS Discharge)	0.6410	< 0.0001	712
Horse Creek North (Rain)	0.0133	0.7766	459
Horse Creek South (Rain)	0.0579	0.2139	461
HCSW-1 (USGS Rain)	0.1832	< 0.0001	731
Average Rainfall	0.1309	0.0058	442

5.1.6 Summary of Water Quantity Results

For 2003 - 2004, temporal patterns of average daily stream flow and stage were similar across all stations, with highest flows and stages occurring during the rainy season (June through September). Mosaic's NPDES-permitted discharges upstream of HCSW-1 exhibited a similar pattern, contributing more water to Horse Creek during wet periods than dry. An unusually high rainfall event occurred in late June 2003, and three hurricanes affected the region in August and September 2004. The effects of these rainfall events and hurricanes were apparent in all the water quantity data. Rainfall and discharge in 2003 and 2004 were within historical ranges for the region, although total annual discharge was higher during these two years than the historical average (Durbin and Raymond 2006).

5.2 WATER QUALITY

The results of field measurements and laboratory analyses of water samples obtained monthly from April 2003 through December 2004 at each HCSP monitoring station are presented below. 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 25 April 2003, 29 July 2003, 20 November 2003, 22 April 2004, and 3 November 2004. Water quality raw data are included in a database on the attached CD-ROM.

Line graphs were used to display water quality measurements for each parameter, 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, the daily mean is plotted with high-low lines representing the daily minimum and maximum. Water quality data for 2003–2004 were compared to historic ranges (Durbin and Raymond 2006) for each station.

Trends in water quality parameters are not specifically addressed in this report because only two years of HCSP monitoring data have been collected. Differences in water quality between stations for each water quality parameter were evaluated using ANOVA and Duncan's post hoc test (or the non-parametric Kruskal-Wallis ANOVA and Mann-Whitney U test if normality assumptions were not met). This analysis will help to identify potential differences among stations that can be examined in more detail as the HCSP continues. Water quality parameters were also correlated with streamflow and/or rainfall using Pearson's or Spearman's correlation coefficient. All statistics calculated for this report represent exploratory analyses and are not intended to imply broad conclusions about water quality in Horse Creek. Further years of study are needed to identify any trends that may be present in this data.

Water quality of NPDES discharge was obtained periodically when water was discharged from Outfalls 003 and 004. The frequency and number of parameters monitored is determined by Mosaic's NPDES permits and does not correspond to the monitoring schedule of the HCSP. Therefore, links between water quality in Horse Creek and NPDES discharge are exploratory only. A summary of water quality for the NPDES outfalls during 2003 - 2004 is presented in Table 12. Water quality at the outfalls in 2003 and 2004 was within the HCSP trigger values for almost all parameters. Only one parameter, chlorophyll *a* at Outfalls 003 and 004, reached or exceeded the HCSP trigger values. Chlorophyll *a* was measured eight times in 2003-2004, and exceeded the HCSP trigger value four times (June and July 2003 and August 2004). Chlorophyll *a* concentrations at HCSW-1, the HCSP station closest to the outfalls, was very low during the months surrounding the high NPDES values (May-August 2003, July-September 2004). This suggests that the higher chlorophyll a values in the NPDES discharge did not affect water quality in Horse Creek. At other HCSP stations, chlorophyll *a* levels were very low in 2003, but they were high in August 2004. Although the cholorphyll *a* peak at downstream stations corresponds with the high concentration of chlorophyll *a* in NPDES discharge, it seems unlikely that NPDES discharge is the cause, considering that *a)* station nearest the discharge was not affected and *b)* the three stations with high concentrations were also affected by Hurricane Charley at that time.

Table 12. Water quality summary of NPDES discharge into Horse Creek during 2003 - 2004 at Outfalls 003 and 004.

	2003							
	Outfall 003 (June-July)				**Outfall 004 (April – October)**			
Constituent	Avg	Count	Min	Max	Avg	Count	Min	Max
pH (su)	7.39	5	6.78	8.00	6.80	28	6.40	7.22
Conductivity (umhos/cm)	353.50	2	244.00	463.00	447.29	7	364.00	571.00
Temperature (degrees C)	29.95	2	29.90	30.00	27.61	7	26.00	29.20
Turbidity (NTU)	13.60	1	13.60	13.60	1.70	1	1.70	1.70
Dissolved Oxygen (mg/L)	6.15	2	5.70	6.60	5.21	7	5.00	5.60
TSS	15.40	5	11.00	20.00	2.36	28	1.00	6.00
Fixed Suspended Solids	3.40	5	1.00	9.00	1.29	28	1.00	3.00
Total Phosphorus (mg/L)	1.00	5	0.62	1.36	0.12	28	0.05	0.32
Total Kjeldahl Nitrogen (mg/L)	2.50	5	1.80	2.70	0.49	28	0.30	0.90
Nitrate-Nitrite (mg/L)	0.08	5	0.05	0.10	0.08	28	0.05	0.11
Total Nitrogen (mg/L)	2.58	5	1.88	2.80	0.56	28	0.36	0.99
Fluoride (mg/L)	1.15	2	0.80	1.49	0.64	3	0.42	0.86
Sulfate (mg/L)	25.50	2	24.00	27.00	145.67	3	93.00	216.00
Chlorophyll *a* (mg/m^3)	**69.50**	2	**25.00**	**114.00**	2.33	3	1.00	5.00
	2004							
	Outfall 003 (August – October)				**Outfall 004 (August – December)**			
Constituent	Avg	Count	Min	Max	Avg	Count	Min	Max
pH (su)	7.33	6	7.13	7.74	6.60	16	6.22	7.00
Conductivity (umhos/cm)	362.50	2	338.00	387.00	402.00	5	360.00	447.00
Temperature (degrees C)	29.90	2	29.00	30.80	24.42	6	16.80	31.20
Turbidity (NTU)	16.40	1	16.40	16.40	7.85	2	3.60	12.10
Dissolved Oxygen (mg/L)	6.70	2	6.00	7.40	5.28	5	5.00	5.90
TSS	8.83	6	5.00	18.00	1.81	16	1.00	5.00
Fixed Suspended Solids	6.00	6	2.00	14.00	1.00	16	1.00	1.00
Total Phosphorus (mg/L)	0.64	6	0.37	1.05	0.08	16	0.05	0.13
Total Kjeldahl Nitrogen (mg/L)	0.83	6	0.70	1.00	0.82	16	0.60	1.20
Nitrate-Nitrite (mg/L)	0.08	6	0.06	0.11	0.08	16	0.02	0.10
Total Nitrogen (mg/L)	0.92	6	0.79	1.07	0.89	16	0.62	1.26
Fluoride (mg/L)	1.00	1	1.00	1.00	0.60	2	0.50	0.70
Sulfate (mg/L)	74.00	1	74.00	74.00	100.00	2	96.00	104.00
Chlorophyll *a* (mg/m^3)	**16.00**	1	**16.00**	**16.00**	**17.00**	2	5.00	**29.00**

5.2.1 Physio-Chemical Parameters

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 sampling events at all stations (Figure 16) and within historic ranges (5 – 8.5) (Durbin and Raymond 2006). The upper and lower ranges of pH values established as trigger levels are identical to those for Florida Class III Surface Water Quality Standards. Values obtained during biological sampling events were consistent with pH levels determined during the monthly water quality sampling events (Figure 16). Continuous pH data obtained daily at HCSW-1 was within a range similar to that obtained during monthly water quality sampling (Figure 17). Mean daily continuous pH values at HCSW-1 were always within the range of the trigger levels [6.0 to 8.5 standard units (SUs)] (Figure 17), although several minimum daily values were below 6.0 (SU). The lowest values from the continuous pH recorder were measured from August – October 2004, when three hurricanes increased streamflow (Figure 18), flooded the area, and washed more acidic runoff from area wetlands into Horse Creek. The continuous recorder shows an apparent increase in pH variability in 2004 compared to 2003. This could be attributed to a replaced pH probe, but the recorder calibrated correctly during both 2003 and 2004, indicating that the data should be accurate.

Levels of pH were significantly different among stations (ANOVA $F(3,80) = 13.3$, $p < 0.0001$), with HCSW-2 significantly lower than other stations (Duncan's post hoc test, $p < 0.05$). Station HCSW-2 lies just downstream of a large swamp complex (Figures 15 and 19) that has the potential to add substantial organic acids from plant decomposition that will tend to decrease the pH (Reid and Wood 1976). Additional inflows from wetland areas further downstream may serve to maintain the lower pH regime at HCSW-3 and HCSW-4. Levels of pH were not significantly correlated with streamflow at either HCSW-1 or HCSW-4, where streamflow data was available (Spearman's rank correlation procedure).

Figure 15. 2005 photograph of Horse Creek Prairie, a 160-acre swamp lying 1.5 km upstream of HCSW-2 on Horse Creek.

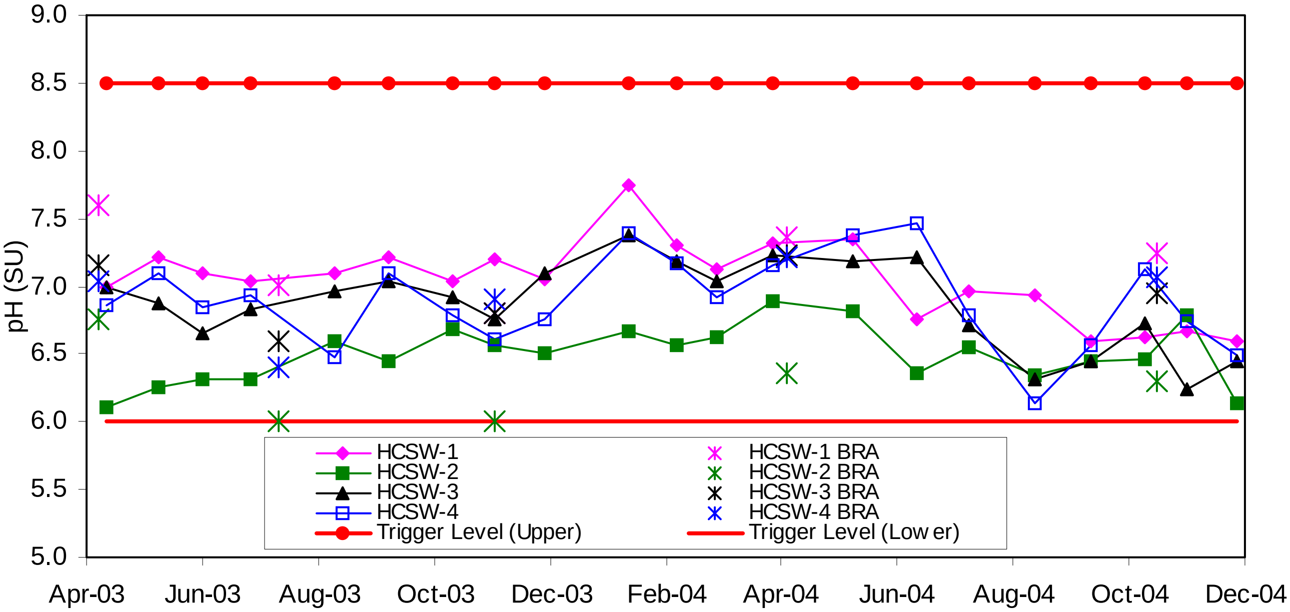


Figure 16. Values of pH Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2003 - 2004. Minimum Detection Limit = 1 su.

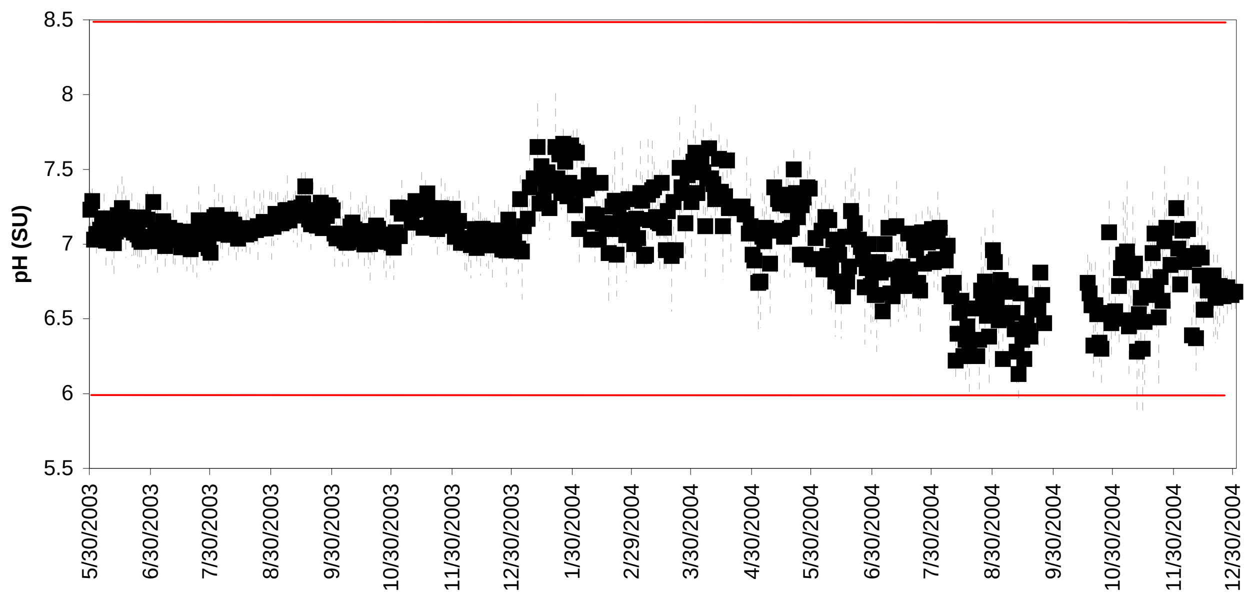


Figure 17. Daily Mean pH (With Daily Min. and Max. pH as Grey-Dashed High-Low Lines) Obtained from the Continuous Recorder at HCSW-1 for 2003- 2004. Minimum Detection Limit = 1 su. Red Lines are HCSP Trigger Values.

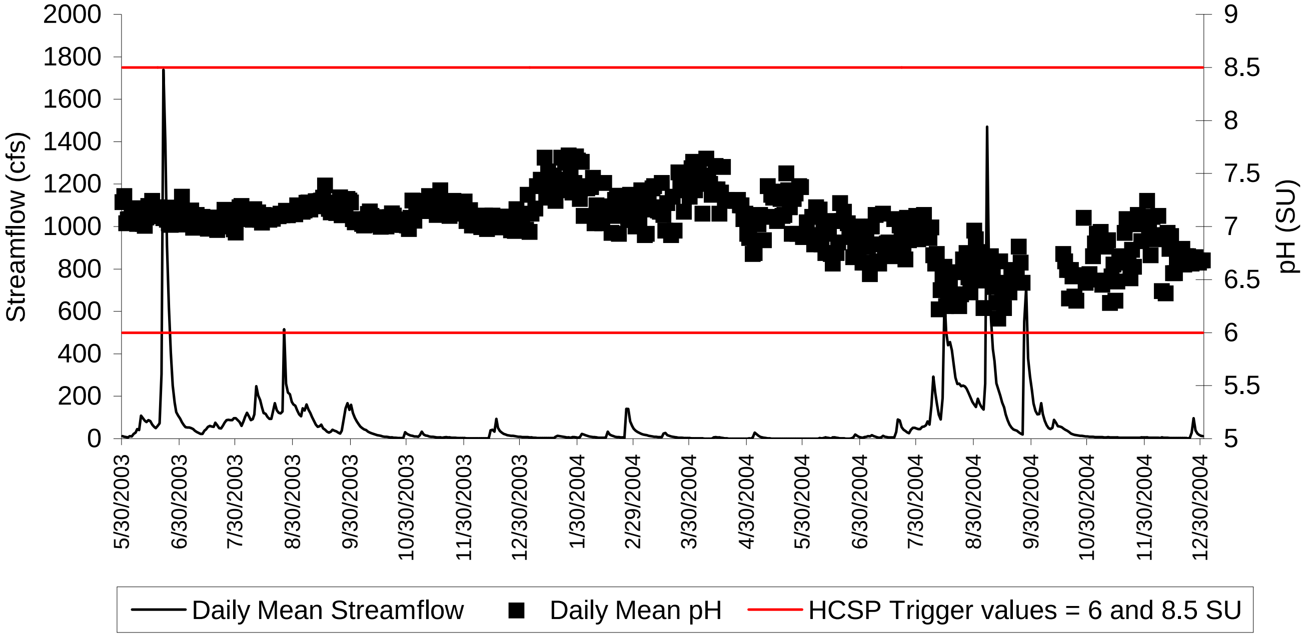
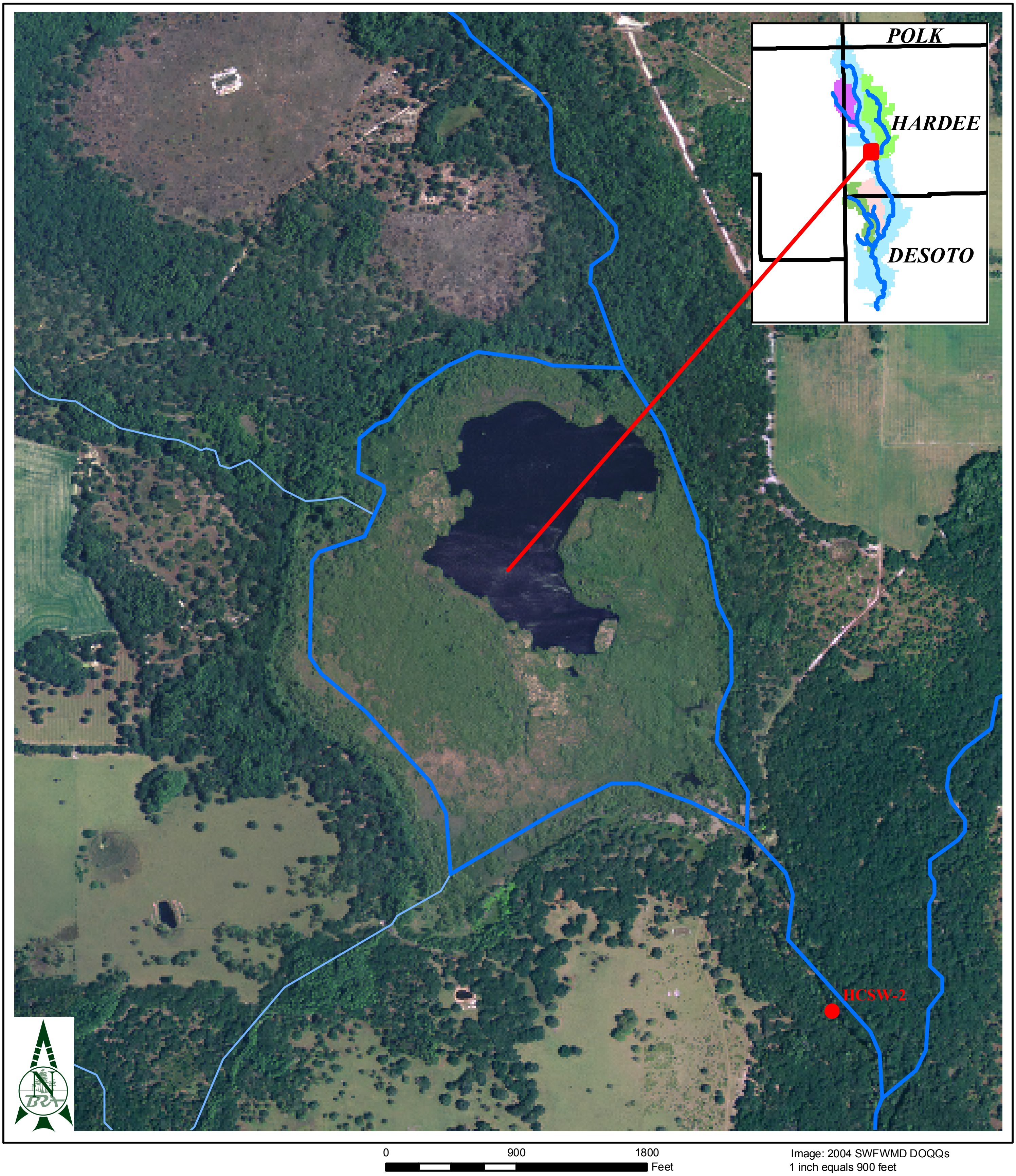


Figure 18. Relationship Between Daily Mean pH (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow (from USGS Provisional Data) for 2003 - 2004. Minimum pH Detection Limit = 1 su. Red Lines are HCSP Trigger Values.



Preparation Date: 20 May 2005	Revision Date: 07 June 2005	Project Number: 2476-065-b21
Project Manager: DJD	GIS Operator: LBS	GIS QA/ QC:
ArcMap Name: horsecreek-prairie.mxd	Plot File: horsecreek_prairie.pdf	

Figure 19. 2004 aerial photography of Horse Creek Prairie, a 160-acre swamp lying 1.5 km upstream of HCSW-2 on Horse Creek.

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Dissolved oxygen (DO) concentrations were above the trigger level and Class III Standard of 5.0 mg/l (indicating desirable conditions) during sampling events in 2003 and most of 2004 at HCSW-1, HCSW-3, and HCSW-4 (Figure 20). However, levels of DO were consistently below 5.0 mg/l at HCSW-2; this station receives water from the Horse Creek Prairie (Figures 15 and 19), a blackwater swamp that typically has low DO concentrations. In addition, DO was below the trigger value at all four stations from August – October 2004, corresponding to times of high streamflow from hurricanes and high temperatures**.** DO was negatively correlated with streamflow at both HCSW-1 and HCSW-4 (Spearman's rank correlation $r = -0.63$, $p = 0.002$ and $r = -0.81$, $p < 0.001$, respectively). DO was within the historical range for all stations (4 – 11); historical data include several very low values for DO, especially at HCSW-2, (Durbin and Raymond 2006). Levels of dissolved oxygen were significantly different among stations (Kruskal-Wallis ANOVA by ranks test, $H = 39.2$, $p < 0.0001$), with HCSW-2 significantly lower than other stations (Mann-Whitney U test, $p < 0.05$).

DO concentrations at HCSW-1, HCSW-3, and HCSW-4 obtained during biological sampling events were consistent with those found during the monthly water quality sampling. Because biological sampling occurs upstream of water sampling in a more channelized, faster flowing reach, concentrations of DO determined at HCSW-2 during the biological sampling events in April and November 2003 were higher than levels found during Mosaic's monthly water quality sampling events (Figure 20).

The continuous DO concentrations obtained at HCSW-1 occasionally fell below the trigger level during the summer months when the water's potential for holding DO is low, which is not unexpected for a stream of this type in peninsular Florida (Figure 21). Usually, only minimum daily DO was below the trigger level, but the mean daily DO concentration was also below the trigger value when streamflow was high, especially during the August-October 2004 hurricane season (Figure 22).

Turbidity levels as measured monthly were not significantly different among stations in 2003 - 2004 (Kruskal -Wallis ANOVA by ranks, $H = 0.788$, $p = 0.852$) (Figure 23). With the exception of HCSW-3 during July 2003, turbidity levels obtained during biological sampling events were similar to those found during monthly water quality sampling events. Turbidity levels at all stations in 2003 - 2004 were below the trigger level and Class III Surface Water Quality Standard of 29 nephelometric turbidity units (NTUs). Higher than usual turbidity levels did occur at HCSW-1 in March 2004, at HCSW-4 in June 2004, and at HCSW-2, HCSW-3, and HCSW-4 in August 2004. High turbidity levels in 2004 corresponded with hurricanes that passed through the area, causing increased sediment and debris to runoff into Horse Creek. All turbidity measurements were within historic ranges (0 – 20 NTU), and most were near the historic median (< 5 NTU) (Durbin and Raymond 2006). Turbidity was weakly correlated with streamflow at HCSW-1 (Spearman's rank correlation $r = 0.45$, $p = 0.04$).

The continuous turbidity data for HCSW-1 indicated that turbidity levels occasionally were higher than those obtained during the monthly water quality sampling events, but the trigger level was only exceeded once, on 19 July 2004 (Figures 24). The highest values for continuous turbidity were measured when rainfall was low, suggesting that dry conditions increase the turbidity of the stream. Perhaps during dry spells, cattle may be more prone to wade in the stream, thereby making it more turbid.

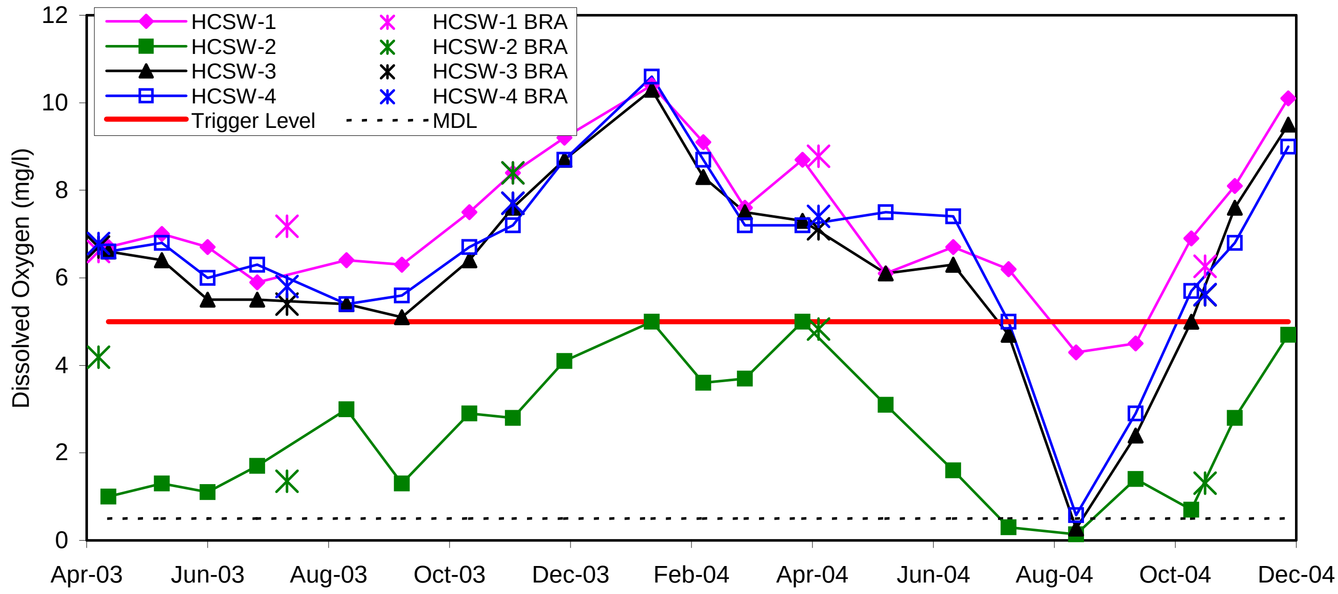

Figure 20. Dissolved Oxygen Levels Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2003 - 2004.

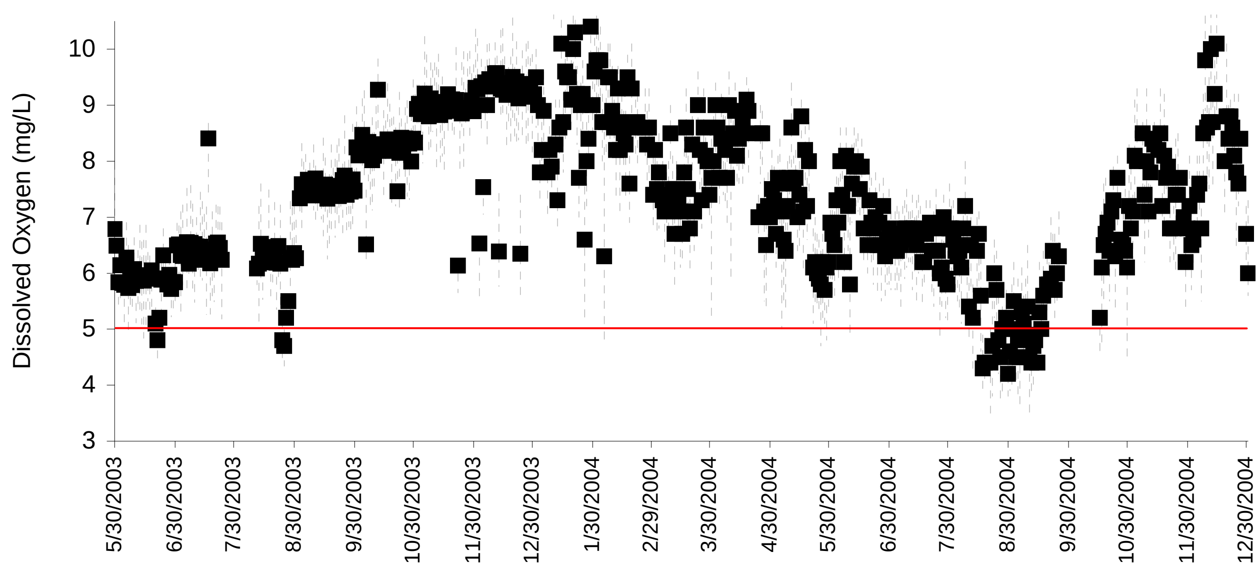

Figure 21. Daily Mean Dissolved Oxygen (With Daily Minimum and Maximum as Grey-Dashed High-Low Lines) Obtained From the Continuous Recorder at HCSW-1 for 2003- 2004. Minimum Detection Limit = 0.5 mg/L). The Red Line is the HCSP Trigger Value.

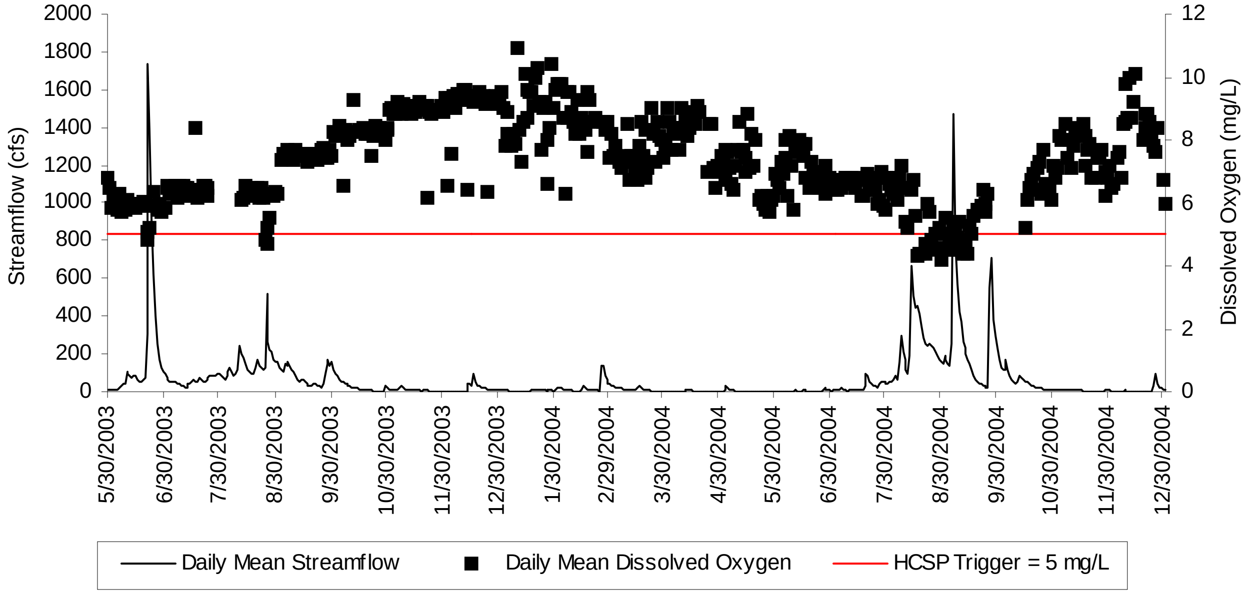

Figure 22. Relationship Between Daily Mean DO (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow (from USGS Provisional Data) for 2003 - 2004. Minimum pH Detection Limit = 0.5 mg/L. The Red Line is the HCSP Trigger Value.

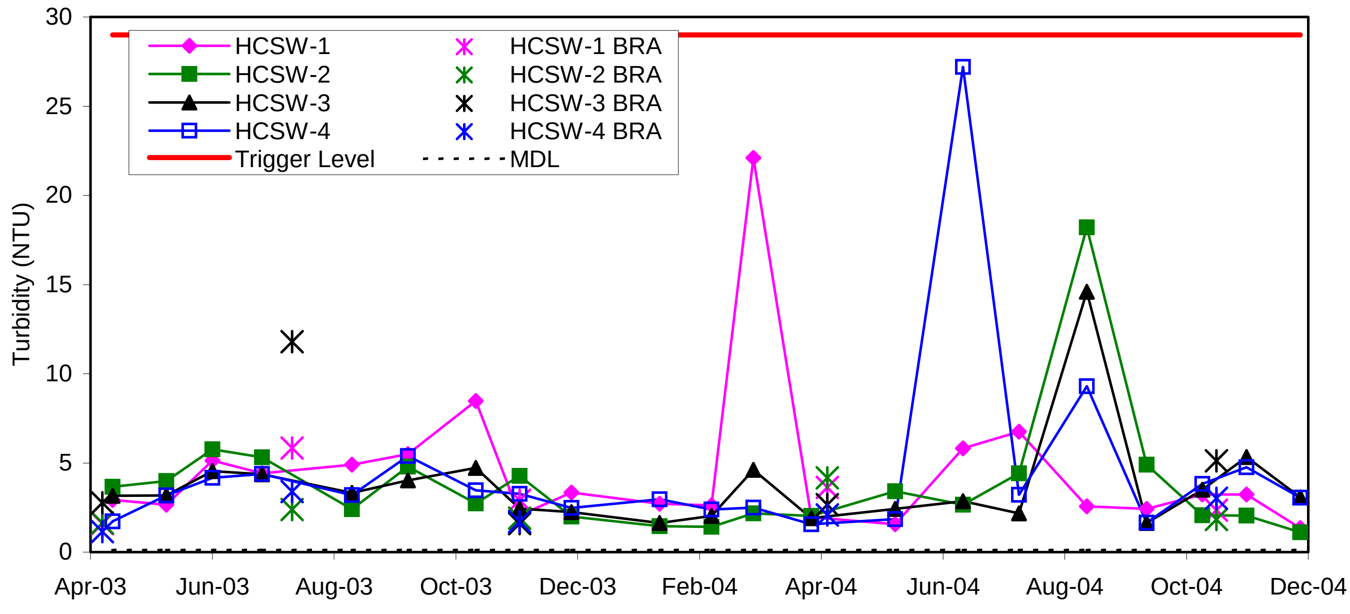

Figure 23. Turbidity Levels Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2003 - 2004

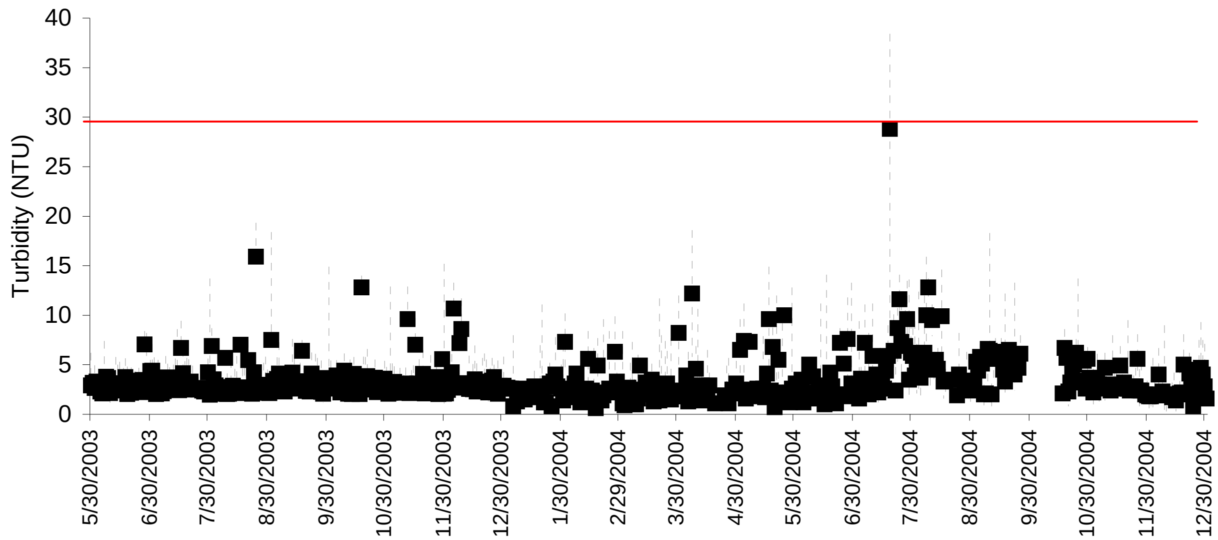

Figure 24. Daily Mean Turbidity (With Daily Minimum and Maximum as Grey-Dashed High-Low Lines) Obtained From the Continuous Recorder at HCSW-1 for 2003- 2004. Minimum Detection Limit = 0.1 NTU). The Red Line is the HCSP Trigger Value.

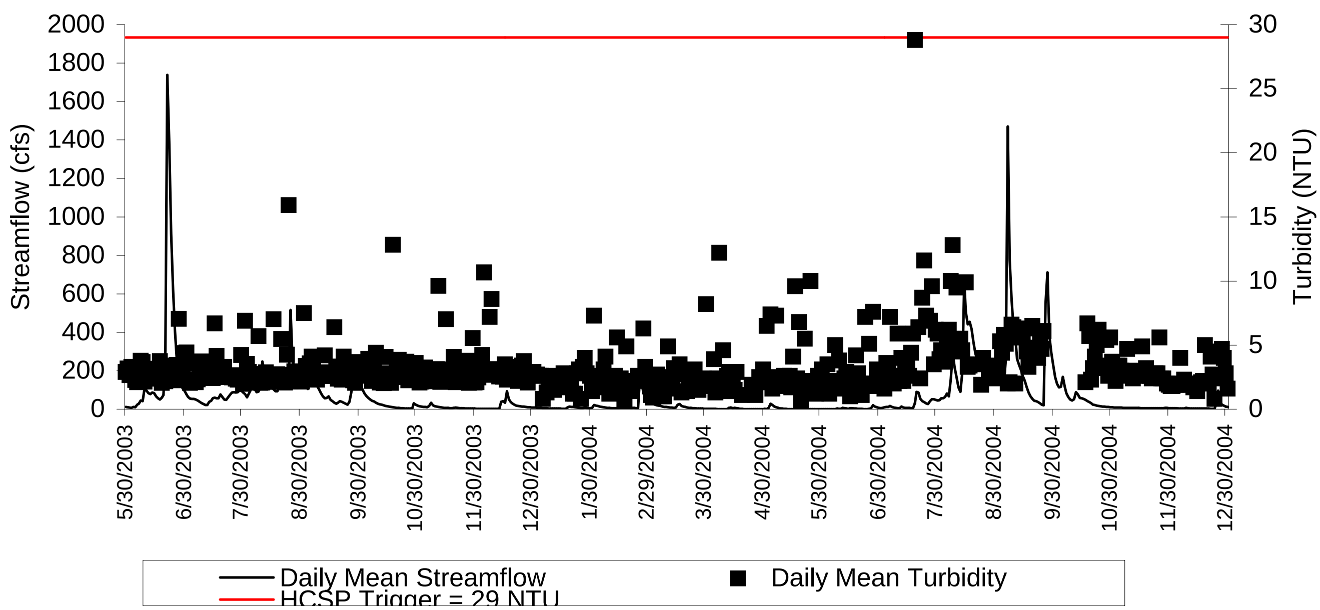

Figure 25. Relationship Between Daily Mean Turbidity (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow (from USGS Provisional Data) for 2003 - 2004. Minimum pH Detection Limit = 0.1 NTU. The Red Line is the HCSP Trigger Value.

All color values were above the trigger level of 25 Platinum-Cobalt units (PCU) (indicating desirable conditions) during all events at all stations (Figure 26). The highest color levels (~400 PCU) were measured in August 2004, during a peak in chlorophyll a, organic nitrogen, and streamflow. Color was significantly correlated with streamflow at both HCSW-1 (Spearman's $r = 0.68$, $p < 0.001$) and HCSW-4 (Spearman's $r = 0.82$, $p <0.001$). Color levels were not significantly different among stations in 2003 - 2004 (one-factor-ANOVA on log Color, $F = 2.63$, $p = 0.05$). The similar pattern among the stations, with higher color in the summer months and lower levels in the 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). As the dry season begins, groundwater seepage provides a proportionally higher contribution and contributes 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. This agricultural factor is also noted below with respect to several other parameters. Ranges and seasonal patterns of color levels in 2003 and 2004 were within historical ranges of 50 – 500 PCU (Durbin and Raymond 2006).

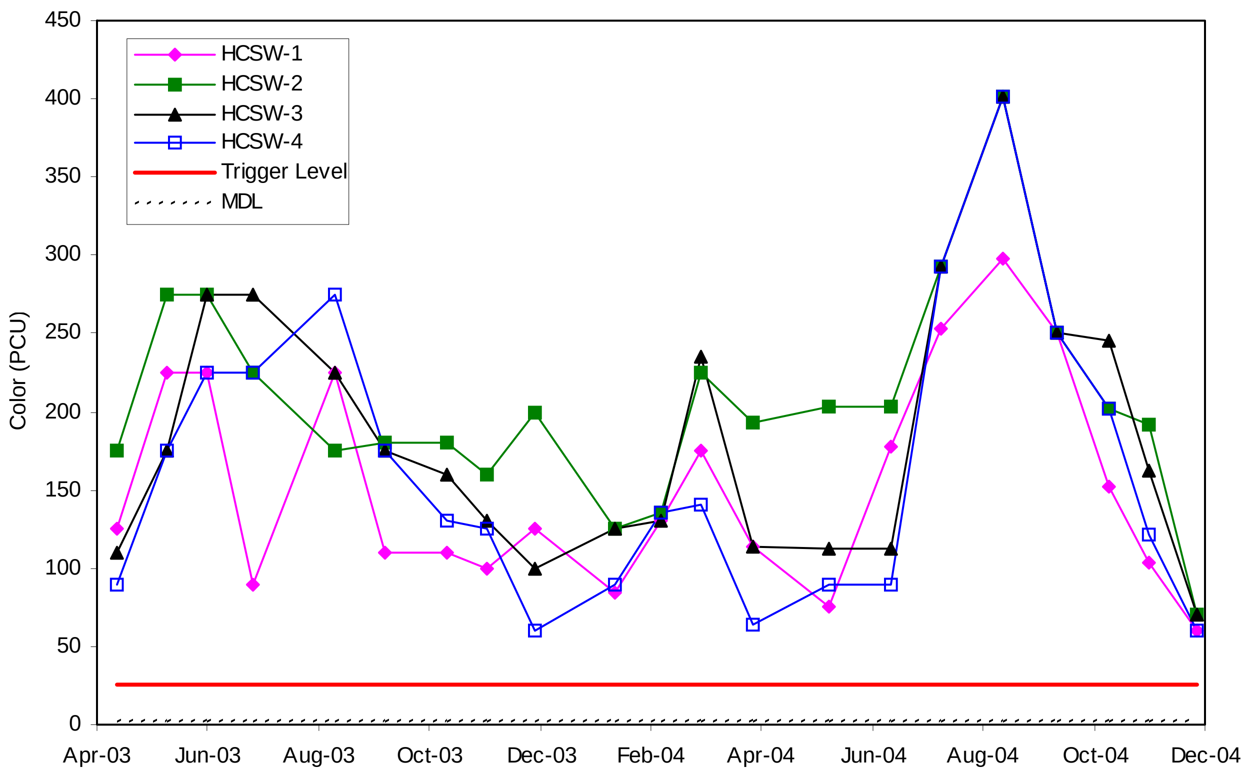

Figure 26. Color Levels Obtained During Monthly HCSP Water Quality Sampling in 2003 – 2004.

5.2.2 Nutrients

Total nitrogen concentrations were between 1 and 2 mg/l during most sampling events at all stations (Figure 27). During 2003 - 2004, total nitrogen was consistently below the trigger value of 3.0 mg/l, except in August 2004 at HCSW-3 (total nitrogen concentrations were consistently higher during this month at all stations). The major component of total nitrogen in nearly all samples was organic nitrogen. Nitrogen concentrations in surface waters may increase during times of high rainfall when plant debris, animal waste, and other nitrogen sources are washed into streams with force (Reid and Wood 1976). December 2003 also had higher than usual total nitrogen concentrations at HCSW-4, but this peak indicated an excess of inorganic nitrogen. Nitrogen was positively correlated with stream discharge at both HCSW-1 (Spearman's $r = 0.46$, $p = 0.03$) and HCSW-4 (Spearman's $r = 0.44$, $p = 0.05$). Total nitrogen concentrations were significantly different among stations (ANOVA on log TN, $F = 2.80$, $p = 0.045$), with a general pattern of increasing total nitrogen levels from upstream to downstream stations (Duncan's post hoc test, $p < 0.05$). Without extensive further investigation, this can only be tentatively attributed to inputs of agricultural fertilizers (SWFWMD 2000, Durbin and Raymond 2006) or biosolids application along the waterway. Total nitrogen levels in Horse Creek in 2003 and 2004 may be slightly higher than the historical median nitrogen concentrations (0.5 – 2.0 mg/L), but little data for total nitrogen is available prior to 1990, leaving a small historic sample size (Durbin and Raymond 2006).

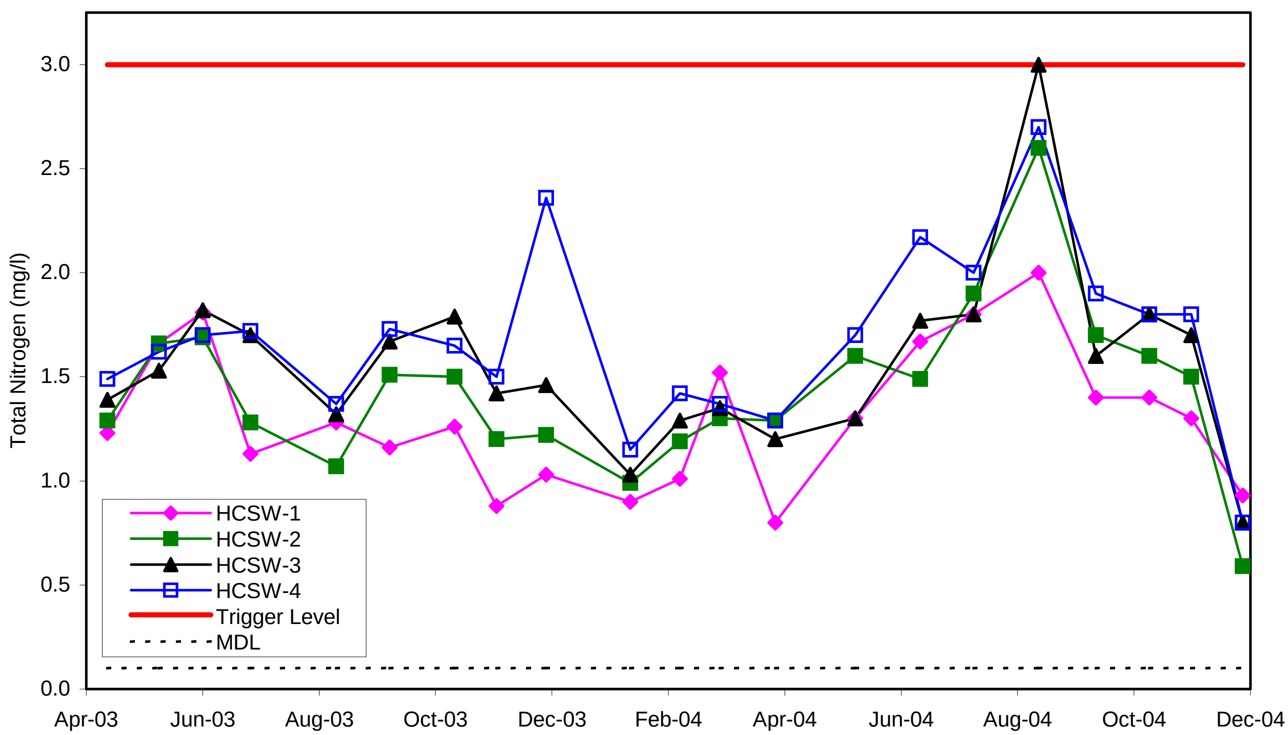

Figure 27. Total Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 – 2004.

As noted above, total Kjeldahl nitrogen (TKN) comprised the majority of total nitrogen in most samples (Figure 28, compare with Figure 27). An independent trigger value was not established for TKN. Concentrations of TKN were not significantly different among stations (ANOVA on log TKN, $F = 0.736$, $p = 0.533$). Streamflow and TKN concentration were significantly correlated at HCSW-1 (Spearman's $r = 0.57$, $p = 0.007$) and HCSW-4 (Spearman's $r = 0.82$, $p < 0.001$). Total Kjedahl Nitrogen concentrations, like total nitrogen, were highest in August 2004, corresponding with high streamflow. Because nitrate-nitrite nitrogen and ammonia nitrogen do not have the same peak, the peak in nitrogen during August 2004 indicates an excess of organic nitrogen in Horse Creek. Flood waters from hurricanes Charley and Jeanne probably washed extensive plant debris and animal waste into Horse Creek that was subsequently decomposed yielding organic nitrogen (Reid and Wood 1976). Concentrations of TKN for 2003-2004 were within the historical range for Horse Creek (0.5 – 2.5 mg/L), which also includes some isolated elevated values, (Durbin and Raymond 2006).

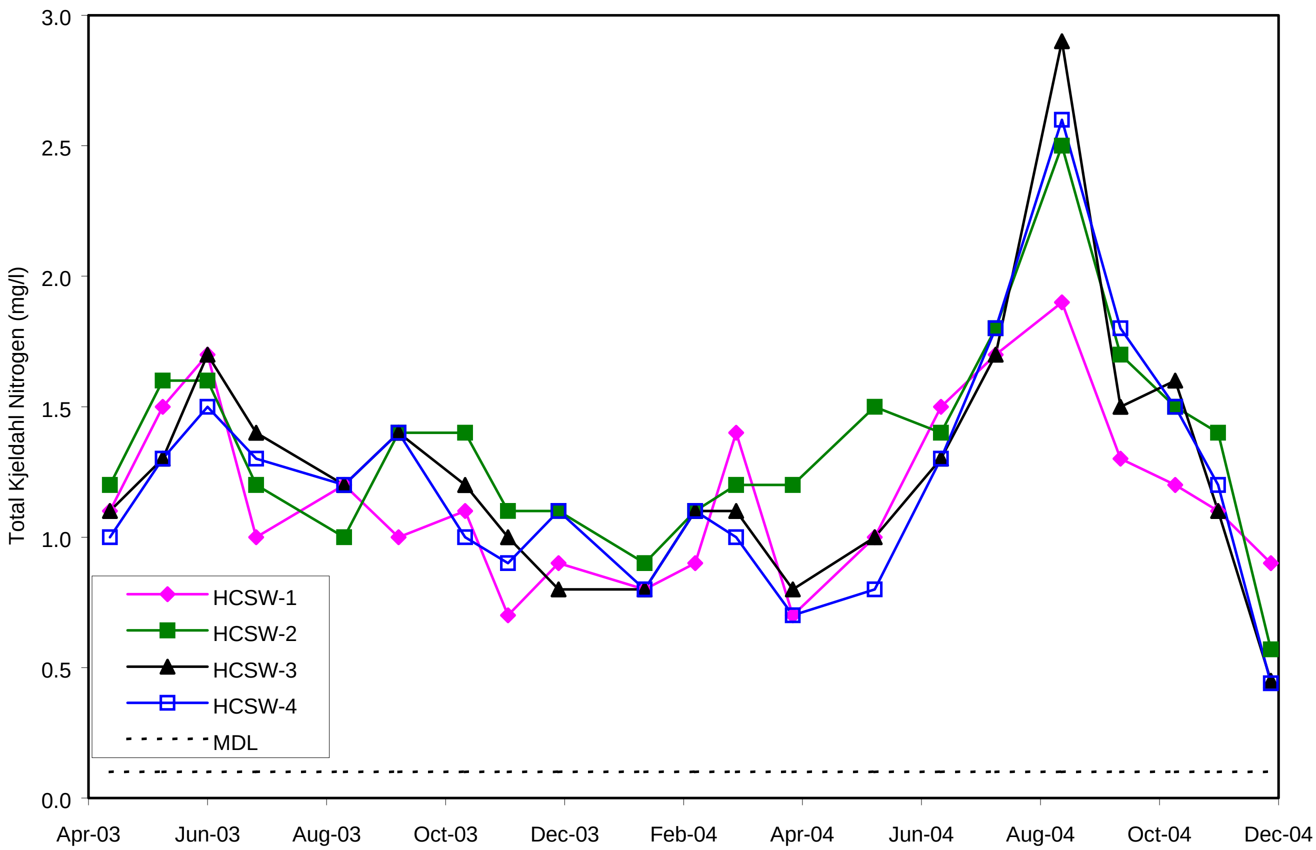

Figure 28. Total Kjeldahl Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004.

Nitrate+nitrite nitrogen levels were significantly different among stations (Kruskal-Wallis ANOVA by ranks test, $H = 47.49$, $p < 0.0001$), with concentrations lower at HCSW-1 and HCSW-2 and higher at HCSW-3 and HCSW-4 (Mann-Whitney U test, $p < 0.05$) (Figure 29). Nitrate+nitrite nitrogen levels increased at HCSW-3 and HCSW-4 through spring 2004 and late 2003 and 2004, probably because of fertilizer inputs from irrigation runoff or groundwater seepage during the dry season. Nitrate-nitrite levels were highest during times of low stream flow at HCSW-4 (Spearman's rank correlation r = -0.74, $p<0.001$), but not at upstream sites where groundwater seepage is less likely. An independent trigger value was not established for nitrate-nitrite nitrogen, but concentrations during 2003-2004 were well within historical ranges of 0 – 2.5 mg/L (Durbin and Raymond 2006).

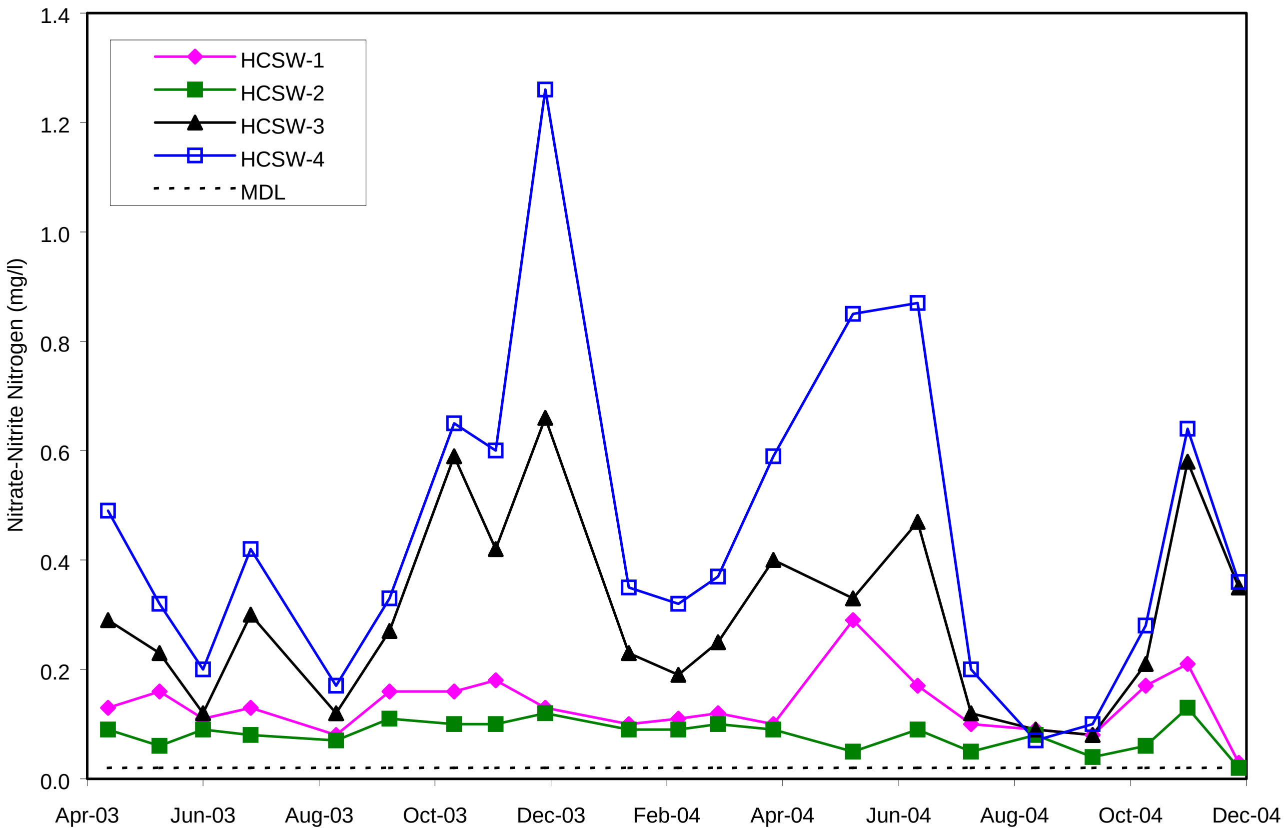

Figure 29. Nitrate-Nitrite Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004.

Total ammonia nitrogen levels were within a similar range during all sampling events at all stations (Kruskal-Wallis ANOVA by ranks test, $H = 1.659$, $p = 0.646$) (Figure 30). Ammonia levels were below the HCSP trigger value of 0.3 mg/L. Current ammonia levels are consistent with historical data for Horse Creek (0 – 0.2 mg/L) (Durbin and Raymond 2006). Ammonia was not correlated with streamflow at HCSW-1 or HCSW-4, where streamflow data was available.

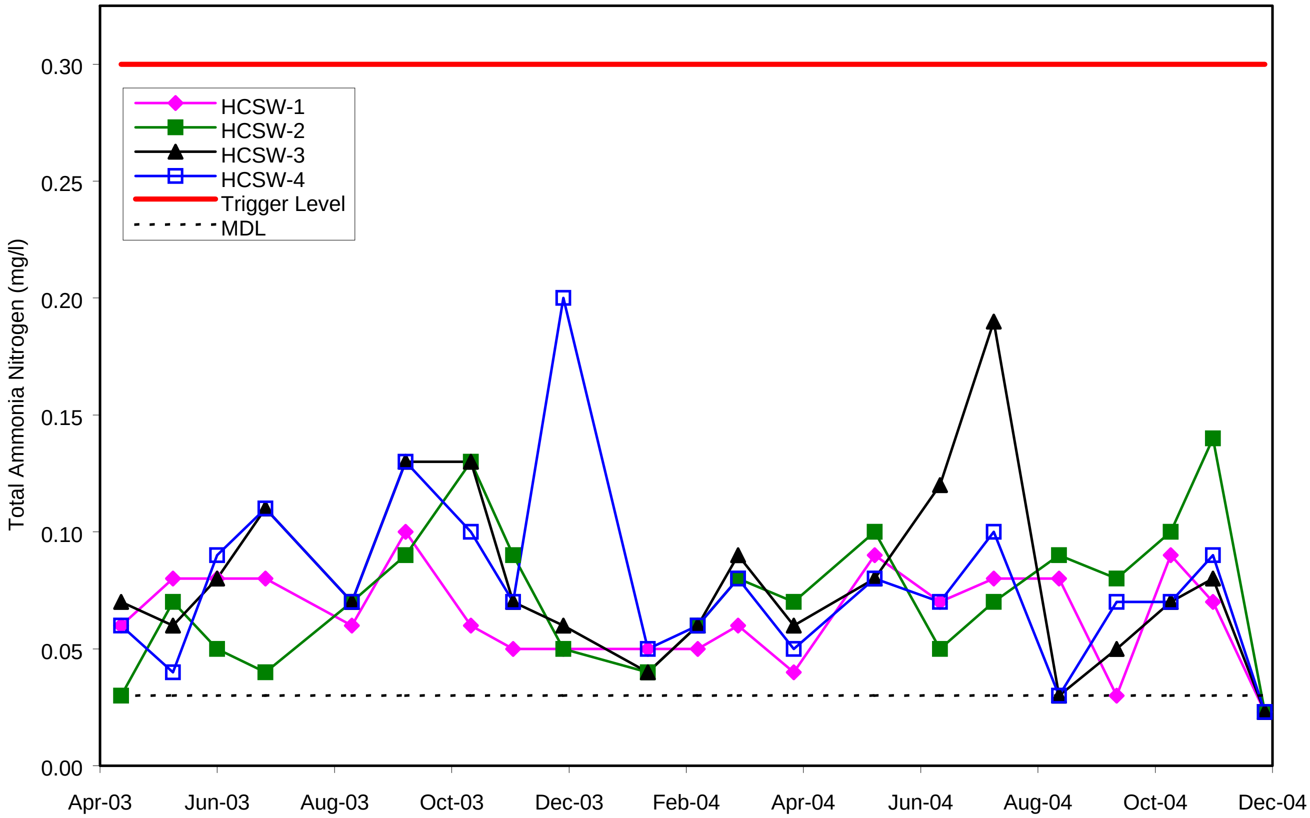

Figure 30. Total Ammonia Nitrogen Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004.

Levels of orthophosphate were well below the trigger level of 2.5 mg/l (Figure 31). Orthophosphate concentrations were significantly different among stations (ANOVA, $F = 10.72$, $p < 0.0001$), with concentrations at HCSW-1 and HCSW-2 (closer to mines) significantly lower and HCSW-4 significantly higher than other stations (Duncan's post hoc test, $p < 0.05$). 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. Current phosphate levels in Horse Creek are lower than concentrations prior to the beginning of phosphate mining in the basin (0.5 – 6.0 mg/L) and are consistent with values from the last decade (~ 0.5 mg/L) (Durbin and Raymond 2006). Orthophosphate was negatively correlated with streamflow at HCSW-1 (Spearman's rank correlation $r = -0.59$, $p = 0.005$).

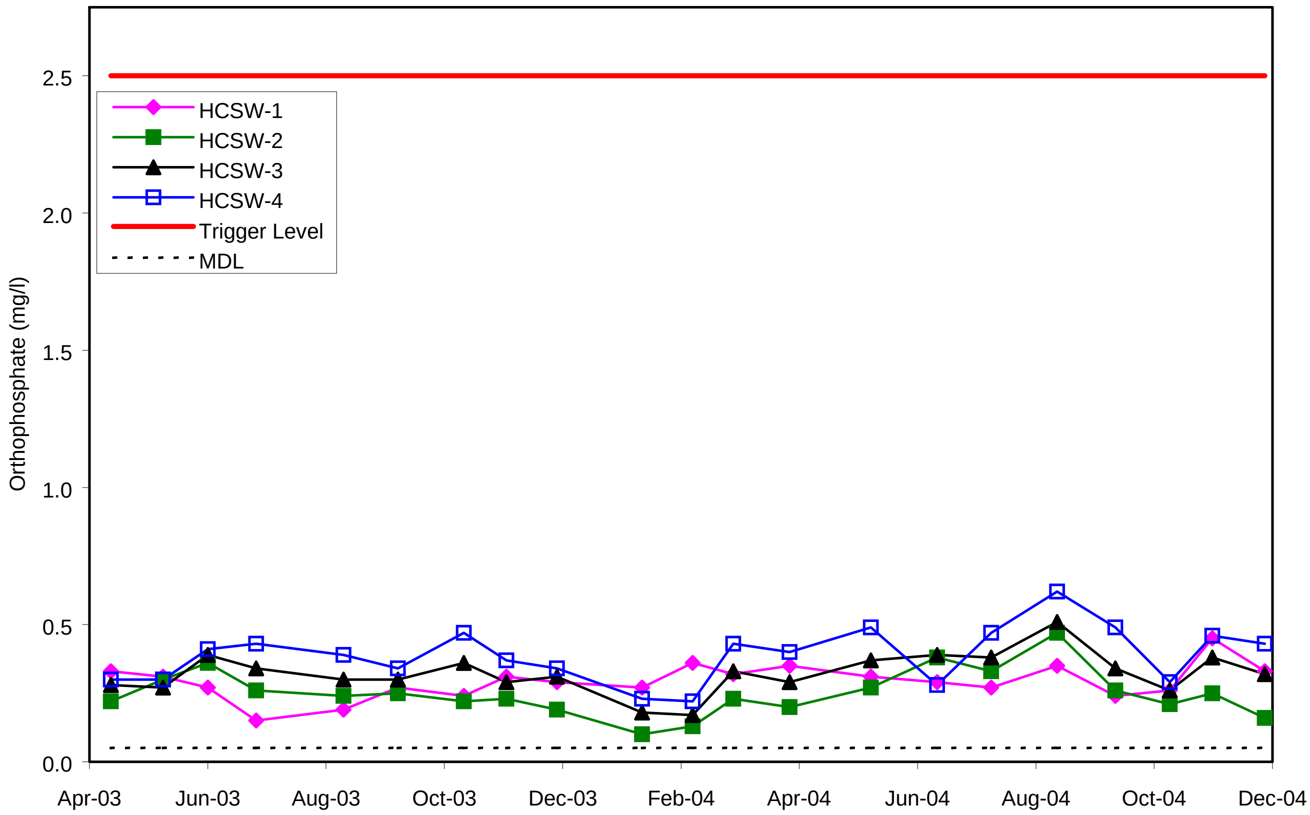

Figure 31. Orthophosphate Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004.

Chlorophyll *a* values were well below the trigger level of 15 mg/m^3 during all sampling events at all stations in 2003, but not in 2004 (Figure 32). In 2004, two stations, HCSW-2 (April, May, and August) and HCSW-3 (August), exceeded the trigger values for chlorophyll *a*. During these events, stations also had high organic nitrogen concentrations, high color, and high stream discharge, although chlorophyll concentrations were not correlated with discharge overall (Spearman's rank correlation). The levels of chlorophyll *a* seen in 2003 and 2004 were consistent with the historical pattern of low background levels (< 15 ug/L) interspersed with brief peaks. Chlorophyll *a* concentrations were significantly higher at the most lentic (slow-moving) station, HCSW-2, than at other stations (Kruskal-Wallis ANOVA by ranks test, $H = 28.84$, $p < 0.0001$; Mann-Whitney U, $p < 0.05$). Horse Creek Prairie, upstream of HCSW-2 (Figures 15 and 19), produces natural conditions that may encourage phytoplankton growth, such as slow-moving waters and decaying plant material.

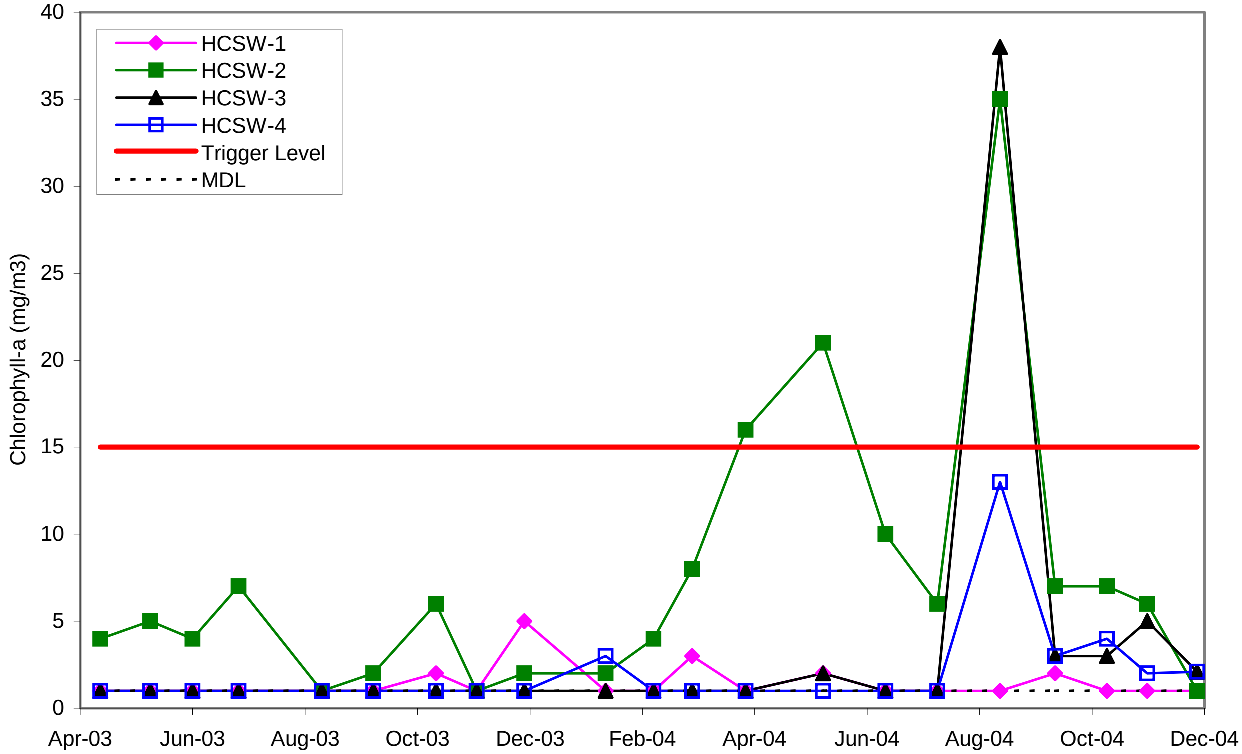

Figure 32. Chlorophyll-a Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004. Minimum Detection Limit = 1 mg/m^3.

5.2.3 Dissolved Minerals, Mining Reagents, and Radionuclides

During all sampling events and at all stations, specific conductivity levels were well below the trigger level of >1275 µmhos/cm^2 (Figure 33). Specific conductivity was significantly different among stations (ANOVA of log specific conductance, $F = 14.21$, $p < 0.00001$), with the lowest concentrations at HCSW-2 and the highest at HCSW-4 (Duncan's post hoc test, $p < 0.05$). Levels of specific conductivity determined during each biological sampling event were consistent with those obtained during monthly water quality sampling events (Figure 33). 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 34). Mean daily specific conductivity was lowest during the 2004 wet season (Figure 35), when three hurricanes brought abnormal amounts of surface runoff with low conductivity compared to groundwater or other sources. Specific conductivity was negatively correlated with streamflow at both HCSW-1 and HCSW-4 (Spearman's rank correlation $r = -0.63$, $p = 0.002$ and $r = -0.77$, $p < 0.001$, respectively). Current specific conductivity levels in Horse Creek are consistent with historical values from the last decade (100 – 1000 umhos/cm) (Durbin and Raymond 2006).

The fact that conductivity was usually higher at HCSW-4 than at the other stations is probably the cumulative result of contributions of groundwater that has either seeped into Horse Creek directly or has run off from 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 the HCSP Historical Report (Durbin and Raymond 2006). It is also possible that some of the conductivity differential may simply be the result of spatial changes in geology of the watershed from the upper part of the basin toward the Peace River. Groundwater, which contains more concentrated dissolved ions that surface water, is closer to the surface in the lower Horse Creek Basin, making seepage into the stream more likely.

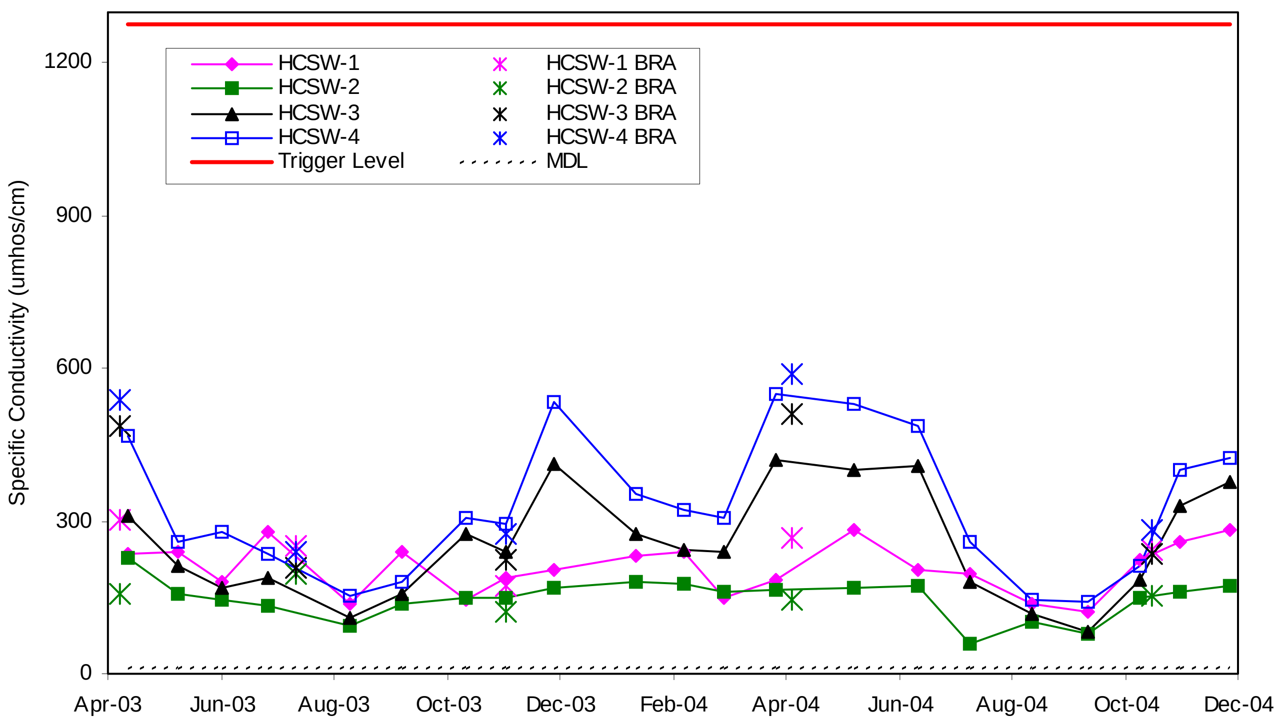

Figure 33. Levels of Specific Conductivity Obtained During Monthly HCSP Water Quality Sampling and Biological Sampling Events in 2003 - 2004.

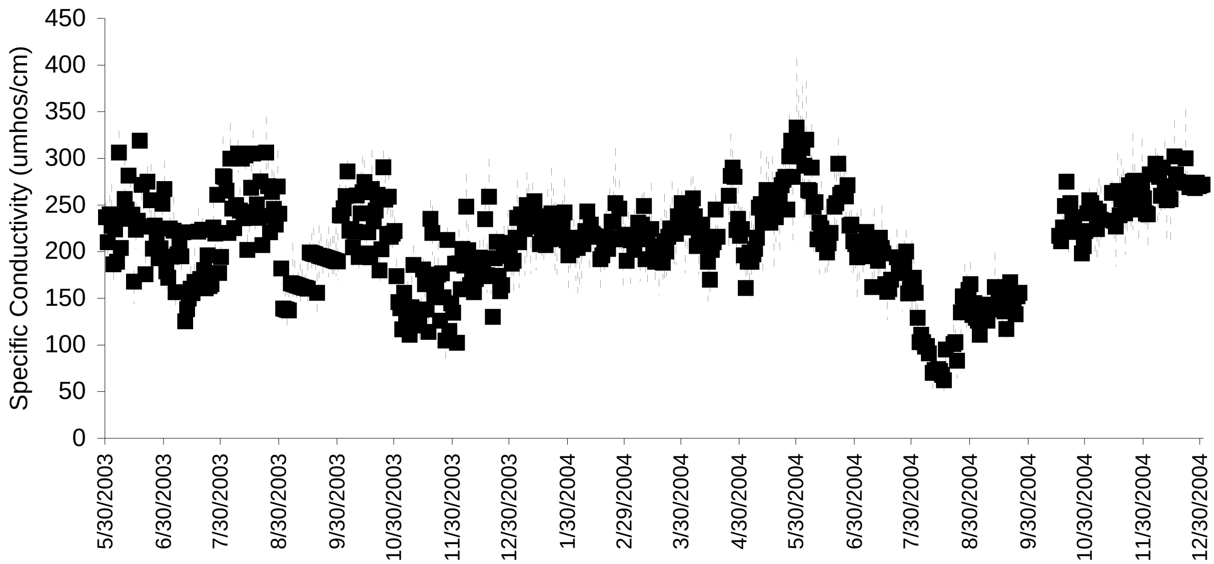

Figure 34. Daily Mean Specific Conductivity (With Daily Min. and Max. as Grey-Dashed High-Low Lines) Obtained From the Continuous Recorder at HCSW-1 for 2003- 2004. Minimum Detection Limit = 100 umhos/cm). The Red Line is the HCSP Trigger Value.

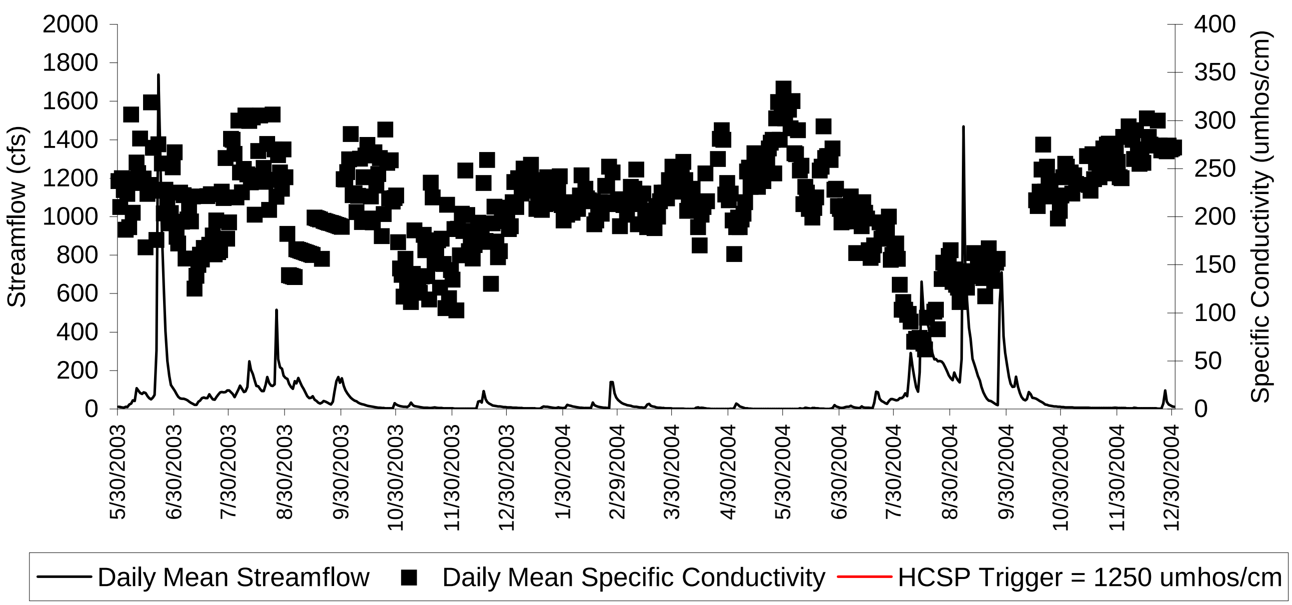

Figure 35. Relationship Between Daily Mean Specific Conductivity (Obtained From the Continuous Recorder at HCSW-1) and Daily Mean Streamflow (from USGS Provisional Data) for 2003 - 2004. Min. Detection Limit = 100 umhos/cm. The Red Line is the HCSP Trigger Value.

Concentrations of calcium were significantly different between stations (Kruskal-Wallis ANOVA by ranks, $H = 32.39$, $p < 0.0001$), with significantly lower levels at HCSW-2 and higher levels at HCSW-4 (Duncan's post hoc test, $p < 0.05$) (Figure 36). As with specific conductivity, calcium levels were higher downstream where the groundwater contribution to baseflow is higher. Dissolved calcium was negatively correlated with streamflow at both HCSW-1 and HCSW-4 (Spearman's rank correlation $r = -0.65$, $p = 0.005$ and $r = -0.81$, $p < 0.001$, respectively). Calcium levels were lower than the trigger value of 100 mg/l at all stations during all events and are within the low range of historical values (10 – 140 mg/L) (Durbin and Raymond 2006). The analytical procedure for calcium and iron changed during the 2003-2004 monitoring period, although the change did not affect the general magnitude or interpretation of results.[2]

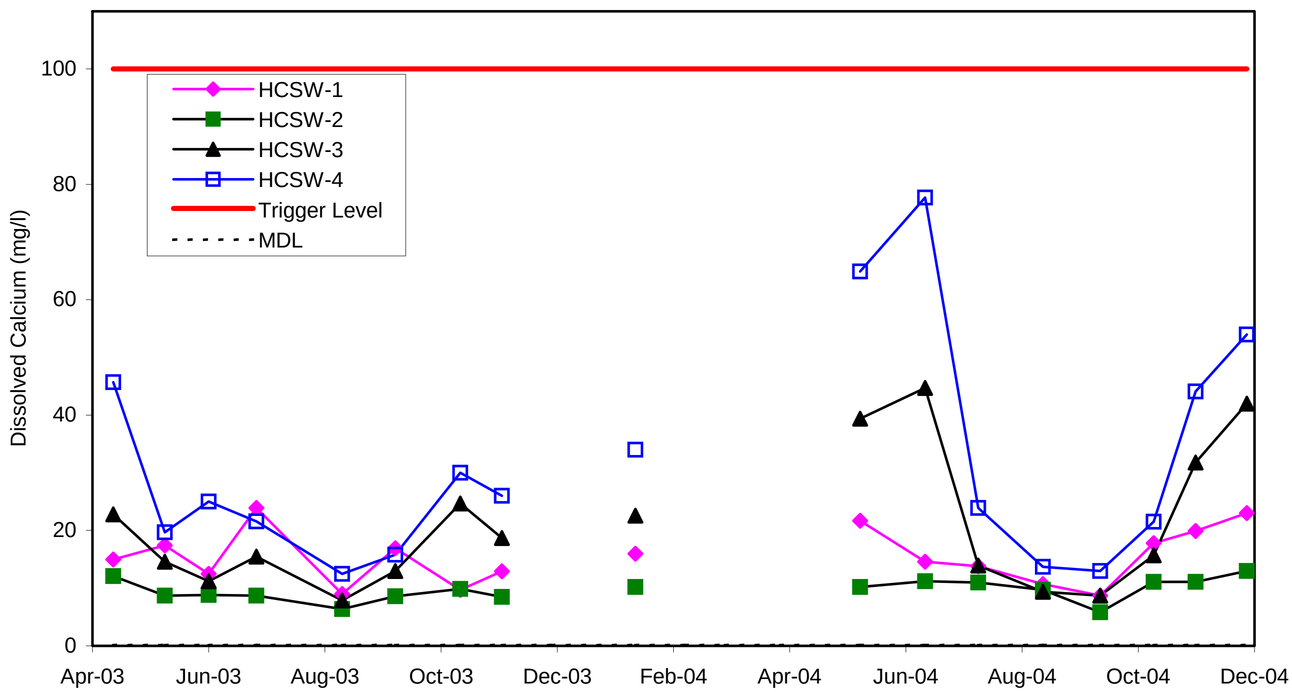

Figure 36. Dissolved Calcium Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004. Minimum Detection Limit = 0.1 mg/l.

[2] The Program began with sampling of dissolved iron and calcium (April – November 2003). At a meeting with the PRMRWSA and EarthBalance, it was requested that Mosaic begin sampling for total metals since the text in the body of the HCSP methodology specifies only "Calcium" and "Iron," so sub-samples for iron and calcium were not filtered before analysis in November and December 2003 and February to April 2004. Later the PRMRWSA noted that Table 1 of the Agreement has "Iron" and "Calcium" listed with a row heading of "Dissolved Minerals" and requested that the analysis be switched back to dissolved iron and calcium. Samples from January 2004 and May 2004 to the present have been analyzed for dissolved iron and calcium. All iron and calcium data (both total and dissolved) is included on the attached CD-ROM. As total iron and total calcium should by definition be equal or greater than the dissolved fractions alone, the months with total iron and calcium represent a conservative determination of the iron and calcium concentrations and in no way are any less protective than measuring dissolved concentrations. For the 20 November 2003 sampling event, during which measurements of both Total and Dissolved Calcium and Iron were made, the measurements for each mineral were very similar, regardless of the method used (12.9 mg/l calcium, both methods; 0.3 mg/l dissolved iron and 0.297 mg/l total iron).

Levels of dissolved iron at all stations were below the trigger level of 1 mg/l during all sampling events (Figure 37) and are within historical ranges (0 – 0.8 mg/l) (Durbin and Raymond 2006). Dissolved iron was positively correlated with streamflow at both HCSW-1 and HCSW-4 (Spearman's rank correlation r = 0.79, $p < 0.001$ and r = 0.74, $p < 0.001$, respectively). Dissolved iron concentrations were not significantly different among stations (Kruskal-Wallis ANOVA by ranks, H = 0.514, p = 0.915). With few exceptions, dissolved iron concentrations at HCSW-4 exceeded the HCSP trigger value of 0.3 mg/l established for that sampling station. HCSW-4 originally has a different trigger level for iron because of its location upstream of a segment of Horse Creek that is designated as Class I waters, which carry a lower standard value for iron (0.3 mg/l) than Class III waters (1.0 mg/l). The HSCP has provisionally accepted that the trigger value for HCSW-4 for iron is too low.

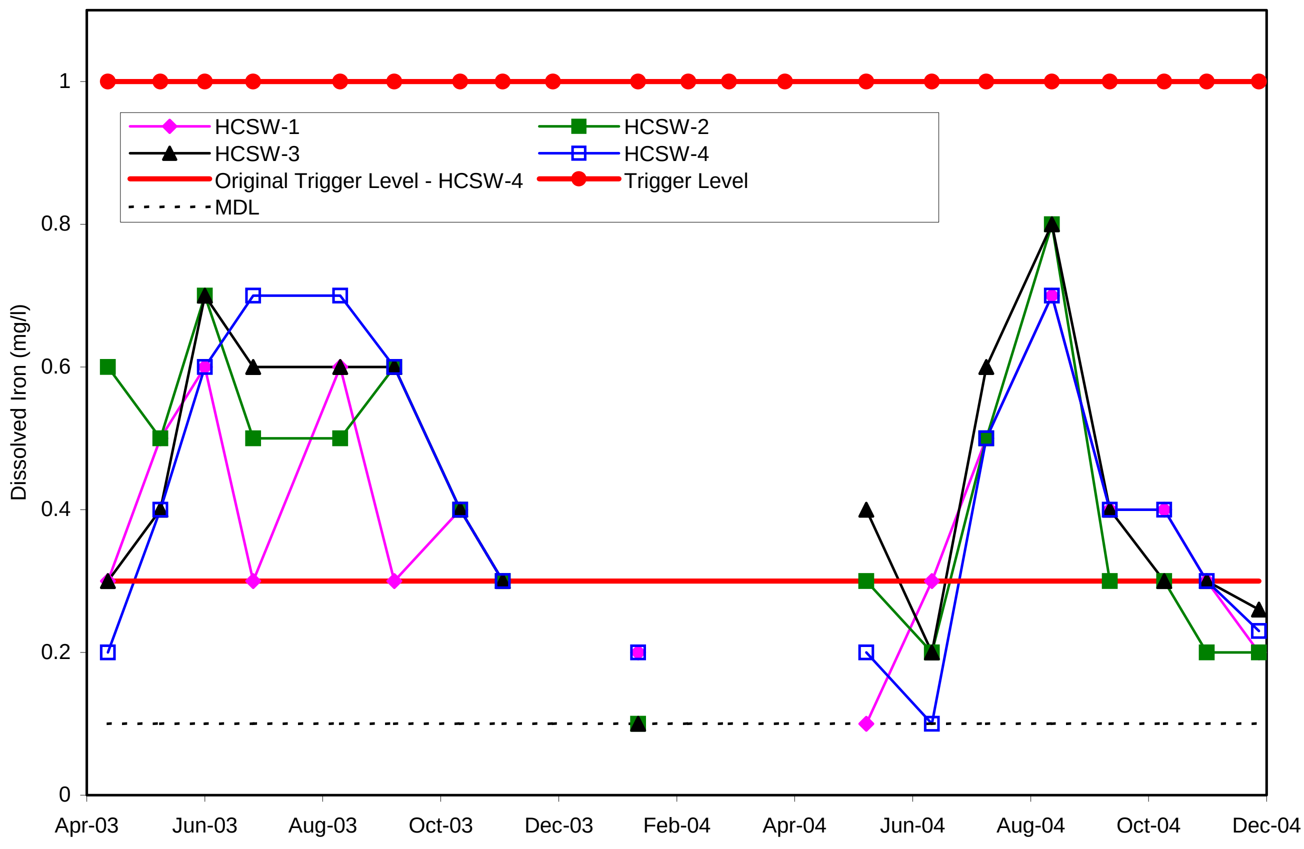

Figure 37. Dissolved Iron Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004.

Total alkalinity was significantly different among stations (one-factor ANOVA of log alkalinity, F = 11.108, $p < 0.00001$), with highest levels at HCSW-1 and HCSW-4 (Duncan's post hoc test) (Figure

38). Levels of total alkalinity were well below the trigger value of 100 mg/l during 2003 – 2004 and are within historical ranges (10 – 60 mg/L) (Durbin and Raymond 2006). Alkalinity was negatively correlated with streamflow at both HCSW-1 and HCSW-4 (Spearman's rank correlation r = -0.59, p = 0.005 and r = -0.84, p < 0.001, respectively), 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.

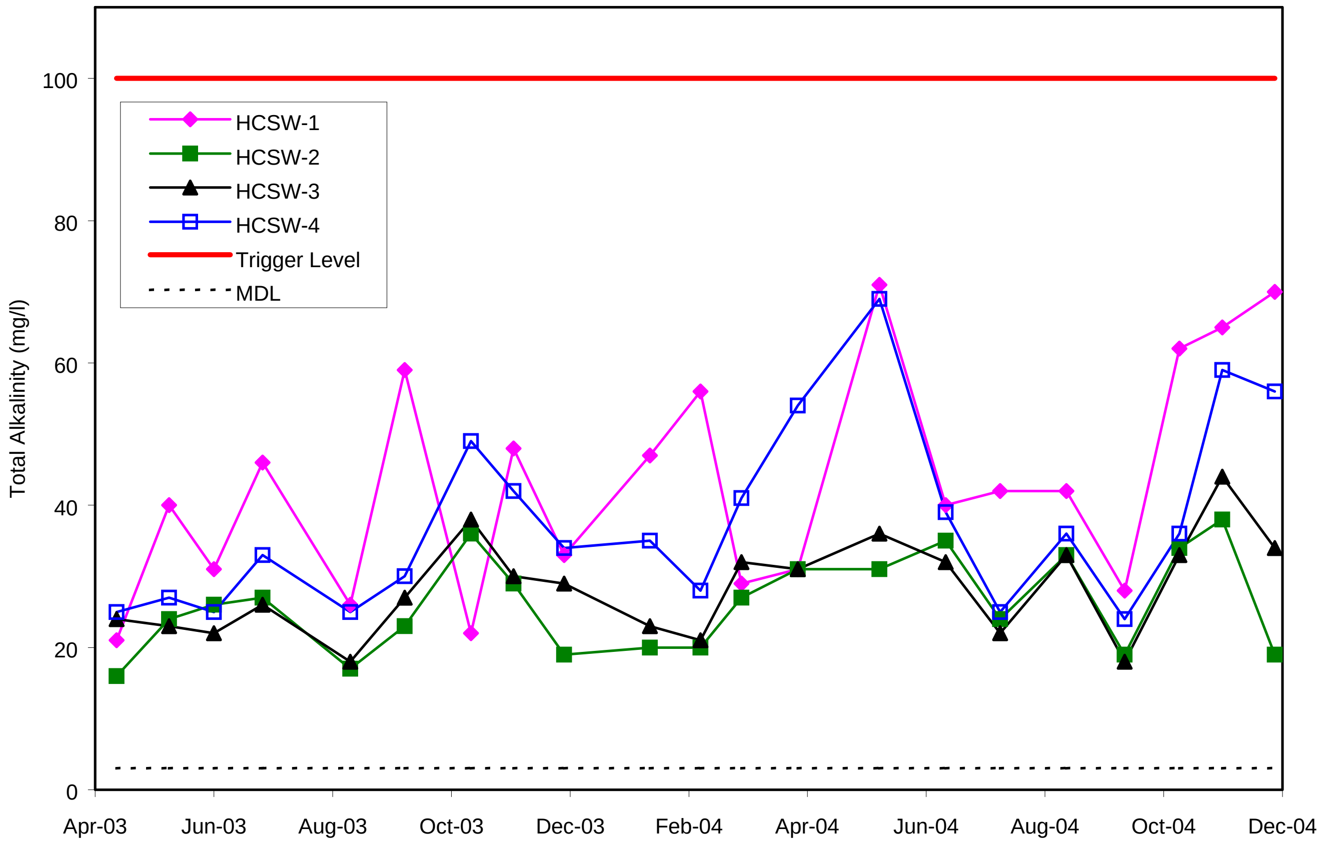

Figure 38. Levels of Total Alkalinity Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004.

Chloride concentrations were significantly different among stations during all sampling events (one-factor ANOVA, F = 4.132, p = 0.0089), with a pattern of slightly increasing concentration downstream. (Figure 39). Levels of chloride were below 30 mg/l during 2003 - 2004, considerably lower than the trigger level of 250 mg/l. The historical range of chloride concentration in the Horse Creek Basin is less than 70 mg/L, so current levels are normal for the area. Chloride was negatively correlated with streamflow at both HCSW-1 and HCSW-4 (Spearman's rank correlation r = -0.79, p < 0.001 and r = -0.80, p < 0.001, respectively).

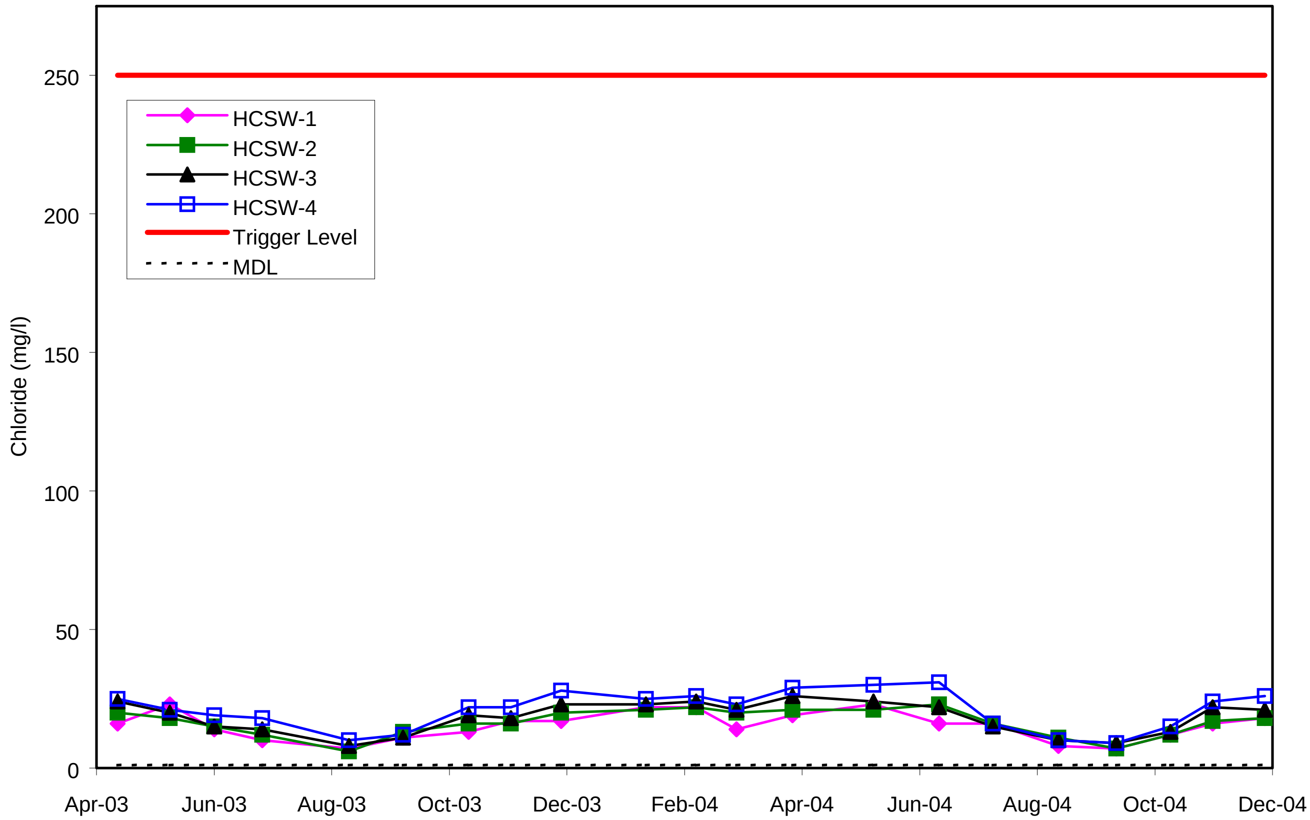

Figure 39. Chloride Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004.

Fluoride levels were below 0.5 mg/l during all sampling events at all stations and were significantly different among sites (Kruskal-Wallis ANOVA by ranks, $H = 17.52$, $p = 0.0005$), with HCSW-2 having the lowest values (Figure 40). Concentrations of fluoride were well below the trigger levels of 4.0 and 1.5 mg/l, established for HCSW-1, HCSW-2, and HCSW-3 and HCSW-4, respectively. HCSW-4 has a different trigger level for fluoride than the other stations because of its proximity to Class I waters. Current fluoride levels in the Horse Creek Basin are equal to or less than historical concentrations (0.3 – 1.0 mg/l) (Durbin and Raymond 2006). Fluoride was negatively correlated with streamflow at HCSW-4 (Spearman's rank correlation $r = -0.91$, $p < 0.001$).

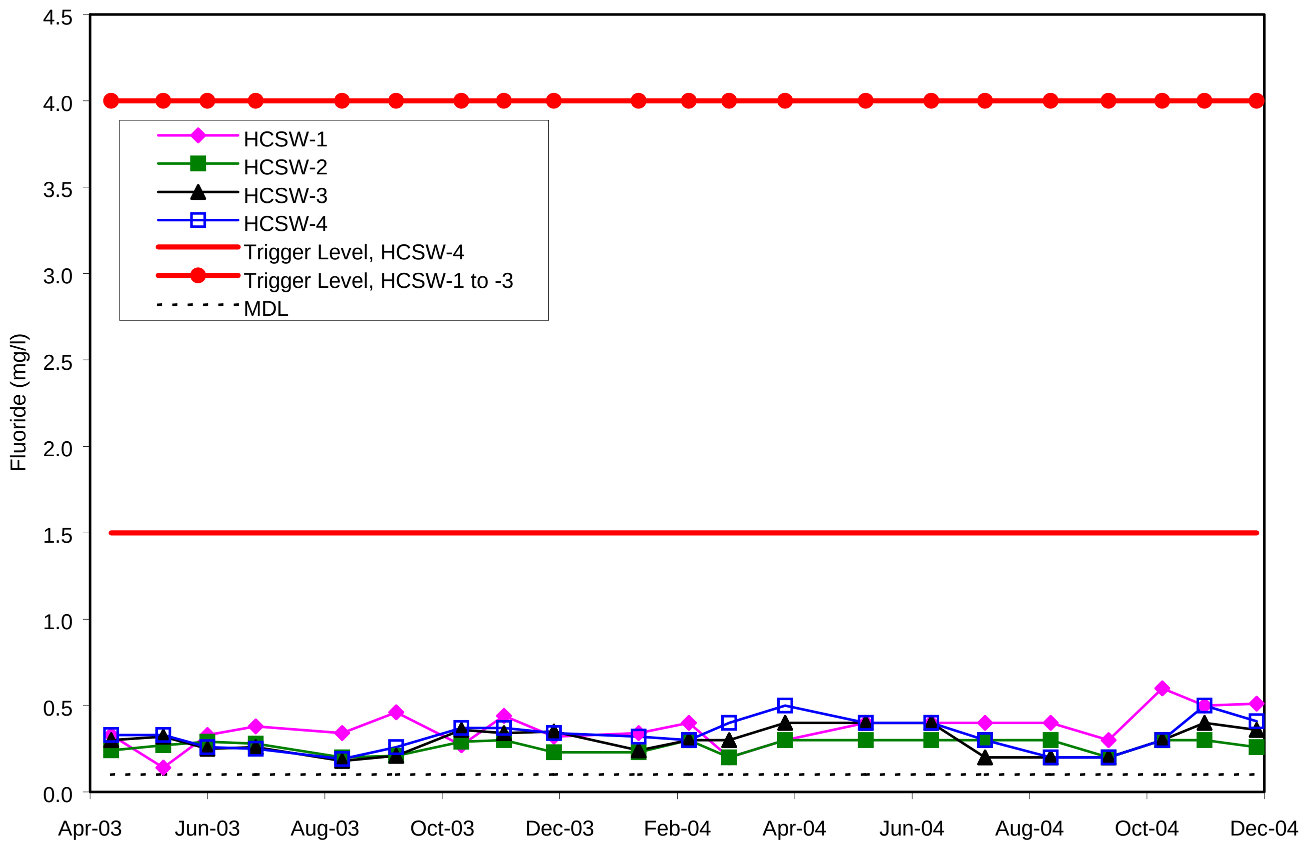

Figure 40. Fluoride Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004.

Sulfate concentrations were below the trigger level of 250 mg/l at all sampling stations during all sampling events (Figure 41), except at HCSW-4 during June 2004, when stream discharge was low. Sulfate concentrations were negatively correlated with stream discharge at the downstream station, HCSW-4 (Spearman's $r = -0.71$, $p < 0.001$). In 2003 and 2004, levels of sulfate were significantly different among stations (one-factor ANOVA of log sulfate, $F = 28.232$, $p < 0.0001$), with lowest levels at HCSW-2 and highest at HCSW-3 and HCSW-4 (Duncan's post hoc test, $p < 0.05$). As with specific conductivity and calcium, sulfate concentrations may be higher downstream because of increased groundwater seepage or irrigation runoff. Low sulfate concentrations upstream and wider ranging concentrations downstream in 2003-2004 are consistent with historical patterns for Horse Creek (0 – 100 mg/l for HCSW-1 and 0 – 500 mg/L for HCSW-4) (Durbin and Raymond 2006).

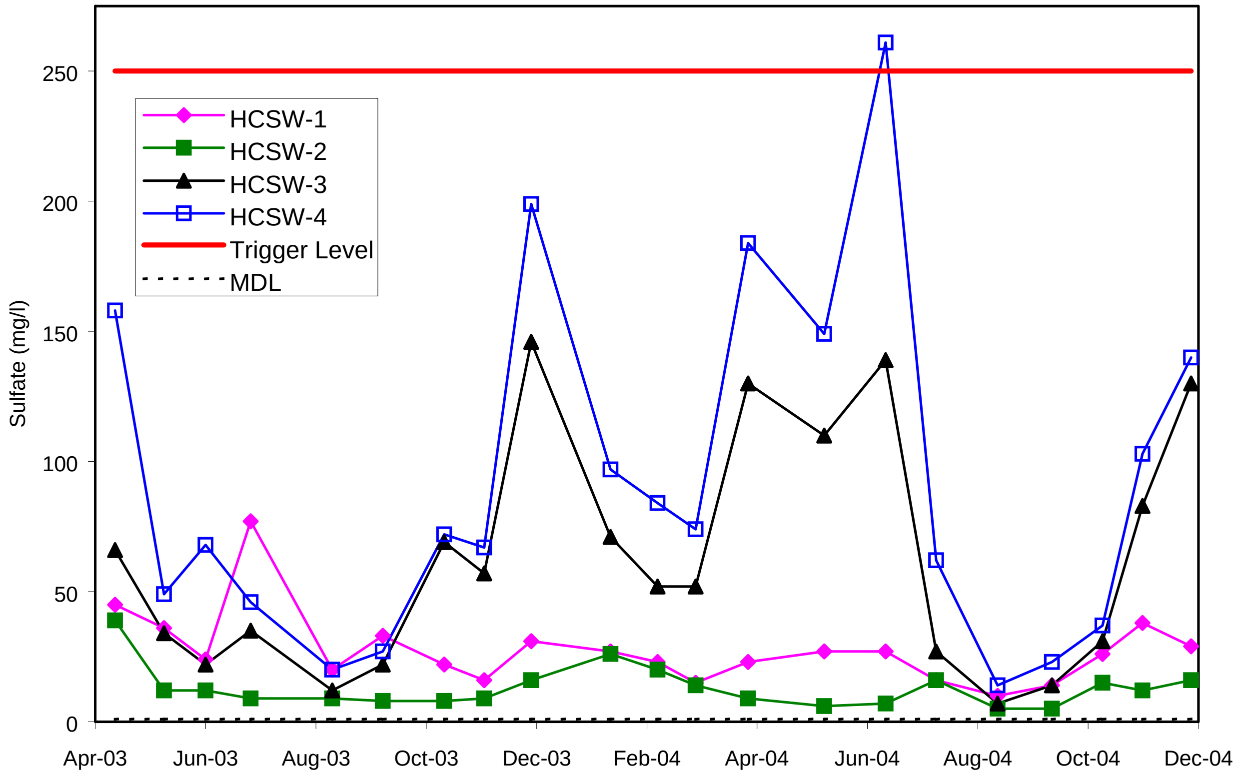

Figure 41. Sulfate Concentrations Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004.

As with sulfate concentrations, total dissolved solids levels were lowest at HCSW-1 and HCSW-2 and highest at HCSW-3 and HCSW-4 (one-factor ANOVA of log TDS, $F = 17.8$, $p < 0.00001$; Duncan's post hoc test, $p < 0.05$) (Figure 42). Total dissolved solids levels were below the trigger level of 500 mg/l during all sampling events in 2003 and 2004. As expected, concentrations of TDS were highest during times of low stream discharge at HCSW-4 (Spearman's rank correlation, $r = -0.68$, $p < 0.001$). 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.

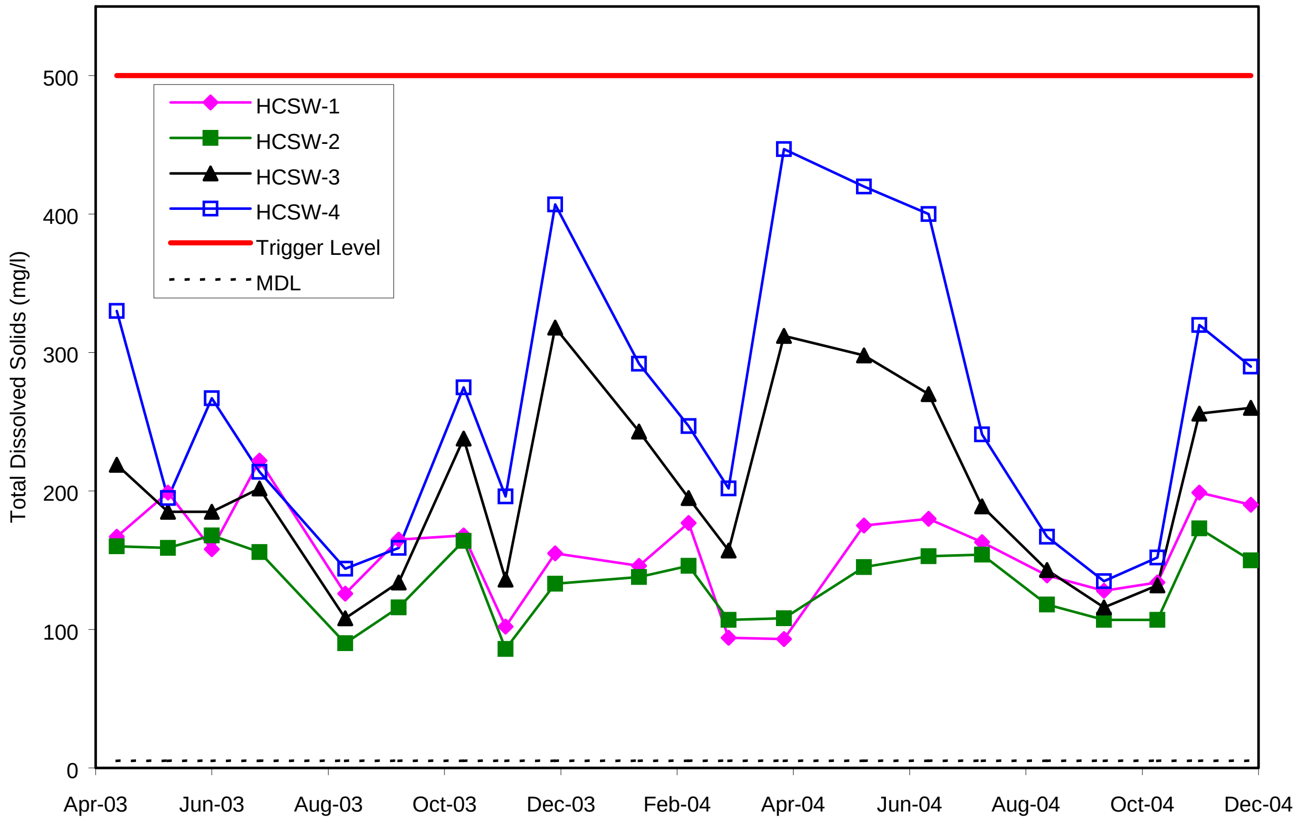

Figure 42. Levels of Total Dissolved Solids Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004.

The phosphate benefication 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). 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 and total amines were not detected at any sampling station in 2003 - 2004. Total fatty acids were detected during one event (representing an exceedance of the trigger level): the 18 November 2004 sample at HCSW-2.

Phosphate ore is a source of radioactivity as naturally occurring uranium-238 disintegrates into isotopes of radium and radon, which emit alpha waves in water. A water quality study of unmined and reclaimed basins in phosphate-mining areas found that radium concentrations of surface waters were higher in unmined areas than in reclaimed basins, probably because of undisturbed phosphate deposits on unmined lands (Lewelling and Wylie 1993). Clay-settling areas may trap radioactive chemicals associated with clay slurry, but release only small amounts of radioactive chemicals into surface waters (Lewelling and Wylie 1993). In Horse Creek during 2003 - 2004, total radium[3] levels were below the trigger level of 5 pCi/1 during 2003 (Figure 43), except at HCSW-2 during July 2004, a time of low rainfall and stream flow. This trigger level exceedance is questionable because lab analysis of Radium 226 for July 2004 was coded as "J" for "estimated." Radium levels at all stations were higher during July 2004 than any other month. Total radium levels were not significantly different among stations (Kruskal-Wallis ANOVA by ranks test, $H = 5.191$, $p = 0.158$) or correlated with streamflow.

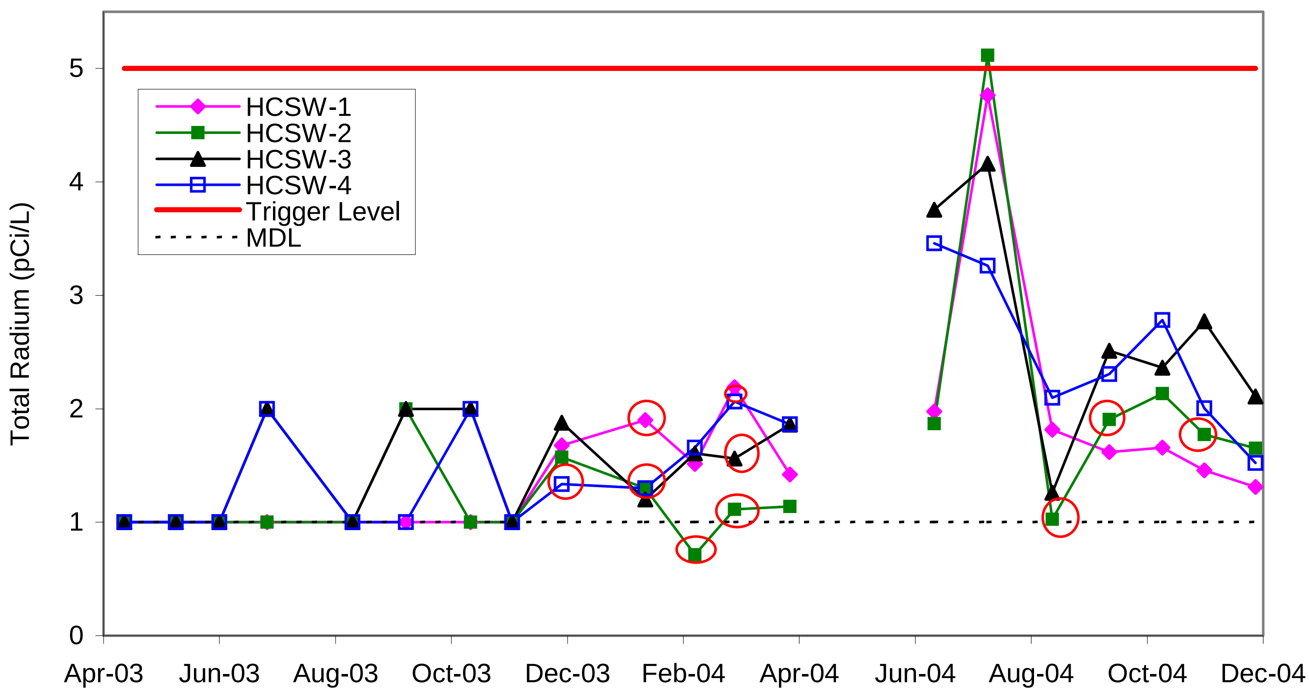

Figure 43. Levels of Total Radium Obtained During Monthly HCSP Water Quality Sampling in 2003 - 2004. *Red circles indicate estimated values with at least one component undetected. (Lab failed to complete radium analysis on May 2004 samples.)*

[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. From December 2003 to the present, the data has been analyzed and reported as Radium 226 and Radium 228 separately and the sum of Radium 226 and Radium 228. If one or both of the components of Radium is undetected, PRMRWMA has requested that the MDL be used as the value for that component, thereby overestimating total Radium. Total Radium values estimated this way are indicated by a red circle in Fig. 43.

5.2.4 Summary of Water Quality Results

Water quality trends toward the established trigger levels were evaluated in the historical report (Durbin and Raymond 2006) but not enough HCSP data has been collected to reevaluate those trends in this annual report. However, we did evaluate whether HCSP trigger levels were exceeded. Water quality parameters were usually within the desirable range relative to trigger levels and water quality standards. Trigger levels were exceeded at least once for five parameters: dissolved oxygen, chlorophyll *a*, dissolved iron, sulfate, fatty acids, and radium (Table 13). Dissolved oxygen was below the trigger level during all sampling events at HCSW-2. Based upon historical conditions in Horse Creek (Durbin and Raymond 2006), the reported values for dissolved oxygen at HCSW-2 are the result of natural conditions (proximity to hypoxic swamp) and are not related to mining activities. Dissolved oxygen triggers were also exceeded at the other three stations during hot and rainy months of 2004, when high temperatures reduce the oxygen carrying capacity of the stream and several hurricanes caused runoff and organic debris to enter Horse Creek. Chlorophyll *a* trigger values were exceeded in 2004 three times at HCSW-2 and once at HCSW-3. Several of these events are probably related to the organic debris that entered the stream after Hurricane Charley in August 2004. In addition, HCSW-2 is a slow-moving section of Horse Creek located immediately downstream of a swamp, thereby creating conditions that would naturally foster algal growth. The dissolved iron trigger level exceedances at HCSW-4 are related to the lower trigger value set for that station. The TAG committee of the HCSP has provisionally agreed that a trigger level of 0.3 mg/L dissolved iron may be too low for historical levels at that station; the trigger level for the other three stations (1.0 mg/L) was not exceeded at any station in 2004. The other four exceedances (sulfate at HCSW-4, fatty acids at HCSW-2, and radium at HCSW-2) were isolated events. Those events occurred during the summer months prior to the beginning of Mosaic's NPDES discharge period to Horse Creek in 2004.

From the limited data available (Figure 44) after only nine months of sampling, there was no evidence of temporal trends that could be attributed to anything other than general wet season/dry season fluctuations, including the effect of irrigation water inflows, as just mentioned for color at HCSW-2. Several water quality parameters were highest during periods of high rainfall and streamflow (positive correlation), including color, organic nitrogen, turbidity, dissolved iron, and to a lesser extent, chlorophyll *a*. These parameters are most likely to exceed the HCSP trigger values during the wet season months (June – September) because of intrinsic relationships with hydrology, not mining activities. Other parameters were lowest during the wet season (negative correlation), including dissolved oxygen, pH, nitrogen oxides, orthophosphate, and most dissolved ions. DO and pH are most likely to exceed trigger values in the wet season when acidic runoff and organic decomposition is high and oxygen carrying capacity is low. Orthophosphate, nitrogen oxides, and dissolved ions are highest during the dry season, when groundwater seepage and irrigation runoff are highest (SWFWMD 2000, Wade et al 2003, SWFWMD 2001, PBSJ 1999).

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 (Wade et al 2003) and agricultural runoff in the lower Horse Creek basin (SWFWMD 2000, Coastal Environmental 1996, Hammett 1990). Differences in topology, 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). Note that many of the statistics calculated for this report represent exploratory analyses and are not intended to imply broad conclusions about water quality in Horse Creek. These analyses are the first steps to evaluating trends in water quality or correlations with water quantity in Horse Creek.

Table 13. Instances of Trigger Level Exceedance Observed in 2004 HCSP Monthly Monitoring (HCSW-1 Continuous Monitoring Not Included).

Sampling Location	Station_ID	Date	Analyte	Concentration	Trigger Level
Horse Creek at State Road 64	HCSW-1	8/30/04	Dissolved Oxygen (mg/l)	4.3	5.0
Horse Creek at State Road 64	HCSW-1	9/29/04	Dissolved Oxygen (mg/l)	4.5	5.0
Horse Creek at Goose Pond Road	HCSW-2	1/29/04	Dissolved Oxygen (mg/l)	5	5.0
Horse Creek at Goose Pond Road	HCSW-2	2/24/04	Dissolved Oxygen (mg/l)	3.6	5.0
Horse Creek at Goose Pond Road	HCSW-2	3/16/04	Dissolved Oxygen (mg/l)	3.7	5.0
Horse Creek at Goose Pond Road	HCSW-2	5/26/04	Dissolved Oxygen (mg/l)	3.1	5.0
Horse Creek at Goose Pond Road	HCSW-2	6/29/04	Dissolved Oxygen (mg/l)	1.6	5.0
Horse Creek at Goose Pond Road	HCSW-2	7/27/04	Dissolved Oxygen (mg/l)	0.3	5.0
Horse Creek at Goose Pond Road	HCSW-2	8/30/04	Dissolved Oxygen (mg/l)	0.14	5.0
Horse Creek at Goose Pond Road	HCSW-2	9/29/04	Dissolved Oxygen (mg/l)	1.4	5.0
Horse Creek at Goose Pond Road	HCSW-2	10/27/04	Dissolved Oxygen (mg/l)	0.7	5.0
Horse Creek at Goose Pond Road	HCSW-2	11/18/04	Dissolved Oxygen (mg/l)	2.8	5.0
Horse Creek at Goose Pond Road	HCSW-2	12/15/04	Dissolved Oxygen (mg/l)	4.7	5.0
Horse Creek at State Road 70	HCSW-3	7/27/04	Dissolved Oxygen (mg/l)	4.7	5.0
Horse Creek at State Road 70	HCSW-3	8/30/04	Dissolved Oxygen (mg/l)	0.27	5.0
Horse Creek at State Road 70	HCSW-3	9/29/04	Dissolved Oxygen (mg/l)	2.4	5.0
Horse Creek at State Road 72	HCSW-4	8/30/04	Dissolved Oxygen (mg/l)	0.58	5.0
Horse Creek at State Road 72	HCSW-4	9/29/04	Dissolved Oxygen (mg/l)	2.9	5.0
Horse Creek at Goose Pond Road	HCSW-2	4/14/04	Chlorophyll a (mg/m^3)	16	15
Horse Creek at Goose Pond Road	HCSW-2	5/26/04	Chlorophyll a (mg/m^3)	21	15
Horse Creek at Goose Pond Road	HCSW-2	8/30/04	Chlorophyll a (mg/m^3)	35	15
Horse Creek at State Road 70	HCSW-3	8/30/04	Chlorophyll a (mg/m^3)	38	15
Horse Creek at State Road 72	HCSW-4	7/27/04	Dissolved Iron (mg/L)	0.5	0.3
Horse Creek at State Road 72	HCSW-4	8/30/04	Dissolved Iron (mg/L)	0.7	0.3
Horse Creek at State Road 72	HCSW-4	9/29/04	Dissolved Iron (mg/L)	0.4	0.3
Horse Creek at State Road 72	HCSW-4	10/27/04	Dissolved Iron (mg/L)	0.4	0.3
Horse Creek at State Road 72	HCSW-4	6/29/04	Sulfate (mg/l)	261	250
Horse Creek at Goose Pond Road	HCSW-2	11/18/04	Fatty Acids (mg/L)	1.1	0.5
Horse Creek at Goose Pond Road	HCSW-2	7/27/04	Radium (pCi/l)	5.1	5.0

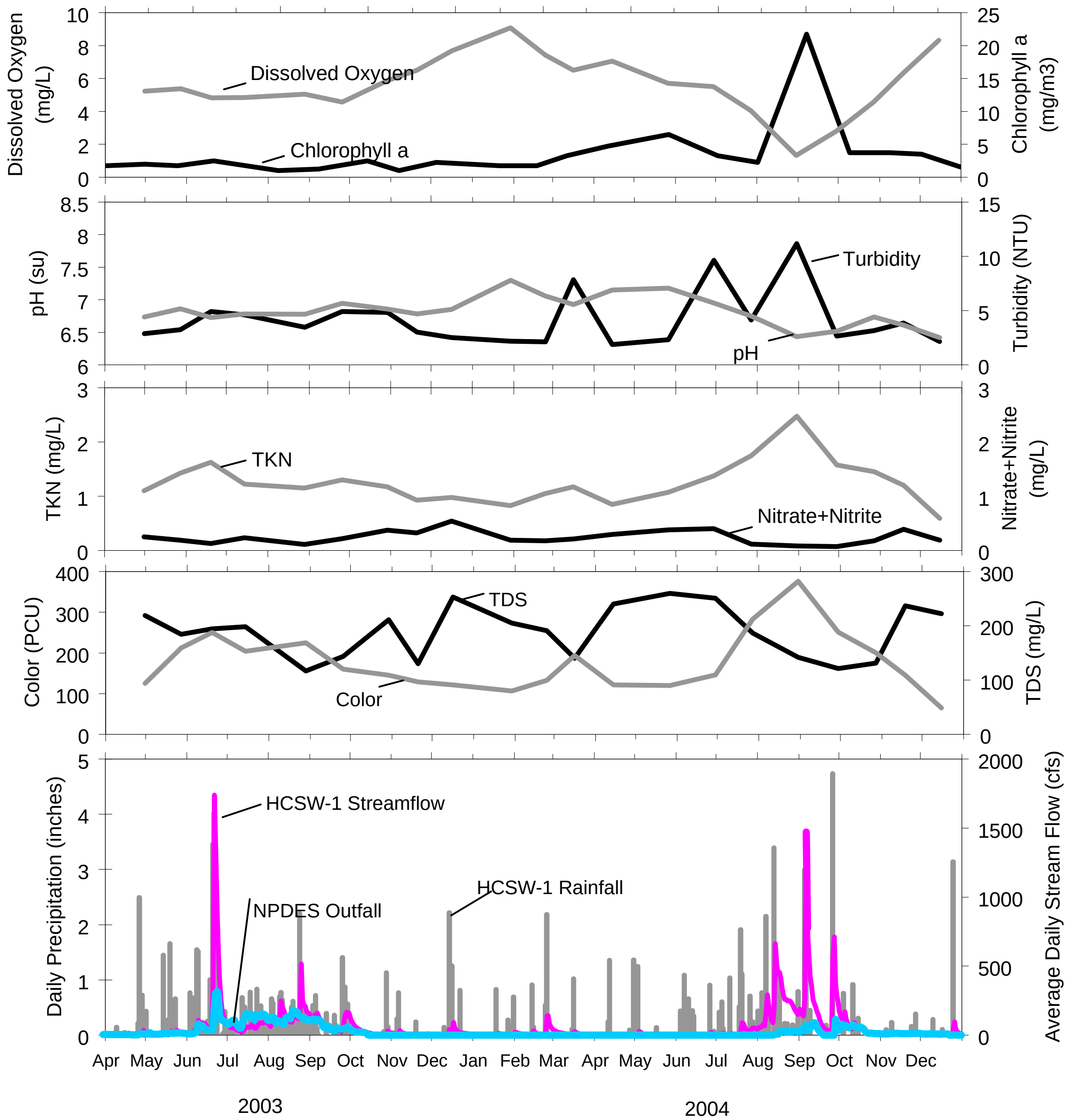

Figure 44. HCSP Water Quality Correlations With NPDES Discharge, Streamflow, and Rainfall at HCSW-1 in 2003 and 2004.

5.3 BENTHIC MACROINVERTEBRATES

Biological sampling and aquatic habitat assessment were only possible two times in 2004 because of the occurrence of Hurricane Charley. This storm, and to a lesser extent, Hurricanes Frances and Jeanne, had a powerful and lasting effect on the Horse Creek system.

5.3.1 Stream Habitat Assessment

The majority of the habitat assessment parameters 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. Although water velocity and habitat smothering were slightly higher when NPDES discharge was elevated (July 2003, August – October 2004), this also coincides with heavy rainfall and overall high discharge in Horse Creek (Figure 11). Biological sampling was not conducted during the summer of 2004 because the stream gage height was well above the recommended 5 ft.

The habitat quality of Horse Creek was within the optimal or sub-optimal range during all sampling events in 2003 and 2004 (Table 14). The minor variation among the sampling events for a given station during this time period 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. In November 2004, however, stations affected by hurricanes (HSCW-2 to HCSW-4) scored much lower than during the previous sample. Vegetation quality and substrate diversity were affected the most severely by the hurricanes at those stations, dropping from optimal or sub-optimal levels to marginal (Table 14).

Because Hurricane Charley effectively traveled up the Horse Creek basin in mid-2004, the stream and its floodplain were visibly different in a number of ways. Loss of tree canopy was the primary change through much of the floodplain, primarily through the loss of a large portion of tree limbs and foliage, as well as the downing of many mature trees. The channel itself was altered through the combined effects of the large discharge brought about by Charley (and subsequent storms in 2004), as well as the sudden introduction of massive amounts of vegetation debris and sediment into the stream. The vegetation debris ranged from fresh leaves blown from trees (and many still attached to branches), to woody material varying in size from small twigs to entire trees. Introduction of this material obviously had a powerful effect on in-stream hydraulics, leading to changes in channel configuration, local velocity patterns, and erosion/deposition patterns. As the floodplain continues to 'recover' from hurricane effects (i.e., through re-growth of damaged or destroyed vegetation), and as organic material (primarily wood) breaks down and is transported into the stream and longitudinally downstream, it can be assumed that Horse Creek will see further changes in its morphometry, and probably its ecology, over and above typical year-to-year changes that might otherwise be expected.

5.3.2 Stream Condition Index

A database containing a list of the benthic macroinvertebrate taxa collected during 2003 and 2004 is on the attached CD-ROM. Tables 15 and 16 provide the SCI metrics, resulting SCI values, and total SCI scores calculated for the benthic macroinvertebrates collected at the four stations during each sampling event. Please note that the number of individuals included in Tables 15 and 16 represents 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. Biological sampling was not conducted during the summer of 2004 because the stream gage height was well above the recommended 5 ft, such that the habitats targeted for sampling were inaccessible.

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 45 illustrates the number of taxa collected at each of the proposed receiving-waters stations during the quarterly events. For all stations, the highest number of benthic macroinvertebrates species was collected during April 2003 or 2004. The fewest number of species were collected in July 2003 or November 2004 at all stations but HCSW-2 as a result of very high water levels from the large amount of rainfall received in previous months. Low taxa collected in July is largely a sampling artifact and does not reflect lessened habitat quality in the stream. 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).

Table 14. Habitat Scores Obtained During HCSP Biological Sampling Events in 2003 and 2004.

	HCSW-1					HCSW-2					HCSW-3					HCSW-4				
	25 Apr 2003	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004	25 Apr 2003	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004	25 Apr 2003	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004	25 Apr 2003	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004
Substrate Diversity	15	10	10	10		18	15	15	16	10	15	18	10	12	9	20	15	15	16	11
Substrate Availability	18	20	13	20		20	20	14	17	15	20	20	18	18	15	20	20	18	17	14
Water Velocity	10	20	17	17		10	18	13	13	16	13	18	17	16	16	15	18	17	15	18
Habitat Smothering	18	18	15	18		15	15	7	17	16	18	19	10	16	5	17	18	10	18	11
Artificial Channelization	20	20	20	20		15	15	15	15	15	20	20	20	20	20	19	19	19	19	19
Bank Stability																				
Right Bank	8	8	9	8		8	8	9	8	8	8	8	8	8	5	8	8	8	8	6
Left Bank	8	8	9	8		8	8	8	8	8	8	8	8	8	3	8	8	8	8	4
Riparian Buffer Zone Width																				
Right Bank	10	10	10	10		10	10	10	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	10	10	10	10	10	10	10
Riparian Zone Vegetation Quality																				
Right Bank	9	9	10	9		10	10	10	10	5	10	10	10	10	3	10	10	10	10	4
Left Bank	8	8	10	8		10	10	10	10	4	10	10	10	10	3	10	10	10	10	4
Total Score*	**133**	**141**	**133**	**138**	**†**	**134**	**139**	**121**	**134**	**117**	**142**	**151**	**131**	**138**	**99**	**149**	**148**	**135**	**141**	**111**
Habitat Descriptor	Optimal	Optimal	Optimal	Optimal		Optimal	Optimal	Optimal	Optimal	Sub-optimal	Optimal	Optimal	Optimal	Optimal	Sub-optimal	Optimal	Optimal	Optimal	Optimal	Sub-optimal

- * - The maximum possible score under this protocol is 160 (120-160 Optimal, 80-119 Suboptimal, 40-79 Marginal, <40 Poor).
- † - Habitat scores inadvertently were not recorded by the sampling team on 3 November 2004 at station HCSW-1, but because that site was not affected by hurricanes in the early fall, the November 2004 scores should be very similar to those of previous samples at that site.

Table 15. SCI Metrics Calculated for Benthic Macroinvertebrates Collected at Four Locations on Horse Creek for the HCSP During 2003.

SCI Metric	HCSW-1						HCSW-2					
	25 April 2003		29 July 2003		20 November 2003		25 April 2003		29 July 2003		20 November 2003	
	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value
Total Taxa	28	**4.8**	22	**2.4**	27	**4.4**	34	**7.2**	22	**2.4**	31	**6.0**
Ephemeropteran Taxa	4	**8.0**	2	**4.0**	2	**4.0**	3	**6.0**	0	**0.0**	1	**0.0**
Trichopteran Taxa	2	**2.9**	2	**2.9**	3	**4.3**	3	**4.3**	0	**0.0**	0	**0.0**
Percent Collector-Filterer Taxa	34.3	**8.5**	78.2	**10**	34.6	**8.6**	44	**10**	68.2	**10**	20.7	**5.0**
Long-lived Taxa	4	**10**	5	**10**	4	**10**	4	**10**	2	**5.0**	3	**7.5**
Clinger Taxa	3	**3.8**	7	**8.8**	5	**6.3**	2	**2.5**	0	**0.0**	0	**0.0**
Percent Dominant Taxon	28.6	**5.8**	71.4	**0.0**	29	**5.7**	25.7	**6.4**	66.2	**0.0**	17.9	**8.2**
Percent Tanytarsini	8.6	**6.8**	0	**0.0**	2.8	**4.0**	4.2	**5.0**	0	**0.0**	6.8	**6.2**
Sensitive Taxa	4	**4.4**	6	**6.7**	3	**3.3**	1.0	**1.1**	0	**0.0**	0	**0.0**
Percent Very Tolerant Taxa	0.7	**8.7**	2	**7.3**	0.0	**10**	5.4	**5.5**	17.1	**2.9**	21.0	**2.5**
Total SCI Score	**70.8**		**57.7**		**67.4**		**64.4**		**22.6**		**37.4**	
Interpretation	**Fair**		**Fair**		**Fair**		**Fair**		**Poor**		**Poor**	
Total Number of Individuals	1,120		147		214		668		1,332		972	

SCI Metric	HCSW-3						HCSW-4					
	25 April 2003		29 July 2003		20 November 2003		25 April 2003		29 July 2003		20 November 2003	
	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value
Total Taxa	30	**5.6**	13	**0**	29	**5.2**	34	**7.2**	28	**4.8**	27	**4.4**
Ephemeropteran Taxa	3	**6.0**	0	**0**	3	**6.0**	4	**8.0**	5	**10**	4	**8.0**
Trichopteran Taxa	3	**4.3**	0	**0**	2	**2.9**	2	**2.9**	3	**4.3**	2	**2.9**
Percent Collector-Filterer Taxa	71.5	**10**	77.1	**10**	14.7	**3.5**	34.2	**8.5**	13.3	**3.2**	17.5	**4.2**
Long-lived Taxa	2	**5.0**	3	**7.5**	4	**10**	4	**10**	2	**5.0**	4	**10**
Clinger Taxa	4	**5.0**	1	**1.3**	6	**7.5**	3	**3.8**	5	**6.3**	5	**6.3**
Percent Dominant Taxon	61.1	**0.0**	77.1	**0**	23.9	**6.9**	30.8	**5.3**	15.2	**8.8**	25.8	**6.4**
Percent Tanytarsini	1.4	**2.6**	0	**0**	0.0	**2.0**	2.3	**3.6**	5.1	**5.5**	1.7	**3.0**
Sensitive Taxa	2	**2.2**	0	**0**	4	**4.4**	2	**2.2**	5	**5.6**	4	**4.4**
Percent Very Tolerant Taxa	10.1	**4.1**	2.4	**7**	1.8	**7.5**	0.8	**8.6**	15.2	**3.2**	1.7	**7.6**
Total SCI Score	**49.8**		**28.6***		**62.0**		**66.7**		**62.8***		**63.5**	
Interpretation	**Fair**		**Poor**		**Fair**		**Fair**		**Fair**		**Fair**	
Total Number of Individuals	2,368		83		327		1,064		79		720	

* Number of invertebrates from sorted portion 15 % less than target of 125 individuals.

Table 16. SCI Metrics Calculated for Benthic Macroinvertebrates Collected at Four Locations on C.R. Horse Creek for the HCSP During 2004.

SCI Metric	HCSW-1				HCSW-2			
	22 April 2004		4 November 2004		22 April 2004		4 November 2004	
	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value	Raw Score	SCI Value
Total Taxa	26	**4**	22	**2.4**	21	**2**	23	**2.8**
Ephemeropteran Taxa	1	**2**	5	**10**	2	**4**	1	**2**
Trichopteran Taxa	1	**1.4**	2	**2.8**	0	**0**	0	**0**
Percent Collector-Filterer Taxa	18.9	**4.6**	23.3	**5.7**	2.3	**0.3**	0	**0**
Long-lived Taxa	2	**5**	4	**10**	2	**5**	0	**0**
Clinger Taxa	3	**3.8**	5	**6.3**	3	**3.8**	0	**0**
Percent Dominant Taxon	18.9	**8.0**	29.1	**5.7**	64.2	**0**	51.1	**0.6**
Percent Tanytarsini	0	**0**	0	**0**	2.0	**3.3**	0	**0**
Sensitive Taxa	2	**2.2**	6	**6.7**	2	**2.2**	0	**0**
Percent Very Tolerant Taxa	15.9	**3.1**	3.5	**6.3**	16.6	**3.0**	72.5	**0**
Total SCI Score	**37.9**		**62.1***		**26.3**		**6.1**	
Interpretation	**Poor**		**Fair**		**Poor**		**Very Poor**	
Total Number of Individuals	264		344		604		524	
SCI Metric	**HCSW-3**				**HCSW-4**			
	22 April 2004		**4 November 2004**		**22 April 2004**		**4 November 2004**	
	Raw Score	**SCI Value**	**Raw Score**	**SCI Value**	**Raw Score**	**SCI Value**	**Raw Score**	**SCI Value**
Total Taxa	26	**4**	11	**0**	29	**5.2**	22	**2.4**
Ephemeropteran Taxa	0	**0**	0	**0**	0	**0**	5	**10**
Trichopteran Taxa	1	**1.4**	1	**1.4**	3	**4.3**	0	**0**
Percent Collector-Filterer Taxa	9.7	**2.2**	18.8	**4.6**	25.5	**6.3**	6.0	**1.3**
Long-lived Taxa	4	**10**	0	**0**	5	**10**	0	**0**
Clinger Taxa	2	**2.5**	2	**2.5**	5	**6.3**	3	**3.8**
Percent Dominant Taxon	36.1	**4.1**	18.8	**8.0**	14.6	**9.0**	26.3	**6.3**
Percent Tanytarsini	0	**0**	0	**0**	7.3	**6.4**	1.5	**2.8**
Sensitive Taxa	1	**1.1**	1	**1.1**	1	**1.1**	3	**3.3**
Percent Very Tolerant Taxa	5.6	**5.4**	12.5	**3.7**	9.1	**4.4**	31.58	**1.5**
Total SCI Score	**34.2***		**23.6***		**58.7***		**34.8**	
Interpretation	**Poor**		**Poor**		**Fair**		**Poor**	
Total Number of Individuals	72		16		220		133	

* Number of invertebrates from sorted portion 15 % less than target of 125 individuals.

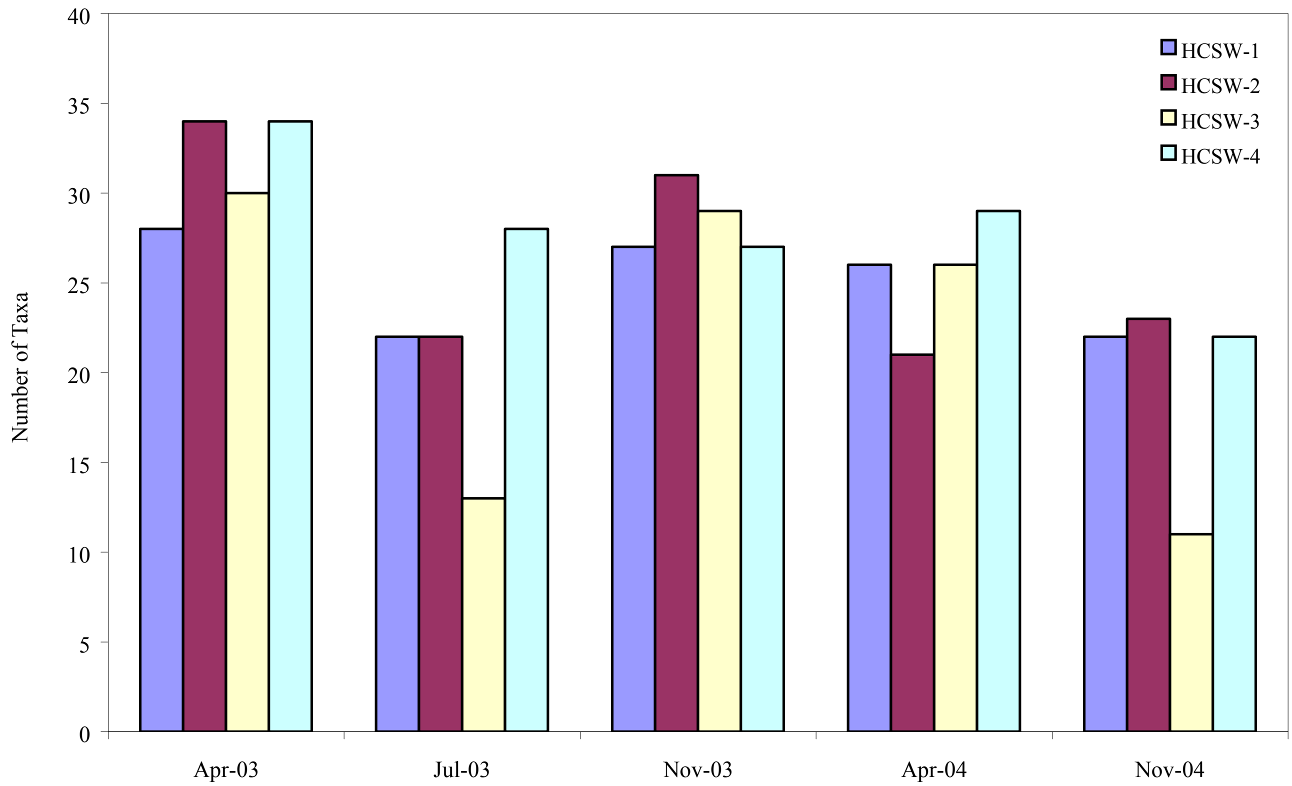

Figure 45. Number of Invertebrate Taxa Collected from the Horse Creek Stewardship Project in 2003 - 2004.

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. None were collected during the July 2003 event at HCSW-2 and HCSW-3, the April and November 2004 events at HCSW-3, or the April 2004 event at HCSW-4; therefore, those stations received a zero for the metric on those dates. The greatest number of mayfly taxa collected at any station during any event was seven. 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 (Tables 15 and 16).

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 for HCSW-2 in July 2003 November 2003, and April 2004, for HCSW-3 in July 2003, and for HCSW-4 in November 2004. The greatest number of caddisfly taxa in any sample was three (in each of four samples representing all three sampling events). 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 2003 (Tables 15 and 16).

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 2003 event were composed of at least 15 percent collector-filterers, with a maximum of 78 percent (Tables 15 and 16). In 2004, however, scores were lower at most stations, reaching as low as 0. This is within the range reported by Fore (2004) in developing the SCI calculation protocol. For all stations except HCSW-4, the highest percentage of filter-collectors was found in the July samples; the basis for this difference is unclear.

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; each station met this threshold during each event, except during November 2004. The observed range of long-lived taxa (0 - 5 taxa) in samples collected from Horse Creek in 2003 (Tables 15 and 16) corresponds with the range used to develop the SCI methodology (Fore 2004). Overall, the greatest number of long-lived taxa was collected from HCSW-1, but the small number of taxa collected and small sample size make it difficult to show differences among the stations for this group. Unlike all prior sampling events, no long-lived taxa were found at HCSW-2, 3 or 4 in November 2004, suggesting that such species may have been displaced by high flows following Hurricane Charley, Frances and Jeanne and had not yet recovered.

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 the July 2003 or November 2003 or 2004 events, and only 2-3 species were found there during April 2003 and 2004 (Tables 15 and 16). 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 all sampling events, with the most in any sample being seven (Tables 15 and 16). 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.

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 three of the four stations in July 2003. Overall, 14 of the 20 samples had a single taxon representing more than one fourth of the invertebrate community (Tables 15 and 16). For nine of the 20 samples, a mollusk dominated the sample; the exotic clam *Corbicula fluminea* was dominant at three stations during at least one sampling event, and the snail *Pisidium* sp. and fingernail clam *Musculium lacustre* were dominant at HCSW-2 during the April 2003 and July 2003 events, respectively. Beetles (Coleoptera) dominated the November 2003 samples from HCSW-2, 3 and 4, April and November 2004 samples from HCSW-1, and April 2004 samples from HCSW-3. The mayfly *Stenonema exiguum* dominated the relatively small sample from HCSW-4 in July. Dipterans were the dominant group in November 2004 at HCSW-2 and HCSW-4, while amphipods were dominant during April 2004 at HCSW-2 and November 2004 at HCSW-3.

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; this occurred at three of the four stations in July 2003 and November 2004, and at half the stations in April 2004. The contribution by Tanytarsini was less than ten percent in all 2003 – 2004 samples (Tables 15 and 16).

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 2003 ranged from zero (in four samples) to six (Tables 15 and 16). That only two sensitive taxa were collected from HCSW-2 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.

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 did not occur during the 2003 sampling periods at any station, with the highest value being 21 percent; in November 2004 at HCSW-2, however, 73 percent of the taxa were classified as very tolerant (Tables 15 and 16).

5.3.2.11 SCI Overall Score

Final SCI scores for the samples ranged from about 22 to 73 in 2003 and from 6 to 62 in 2004 (Tables 15 and 16 and Figure 46). In 2003, eight of the samples are interpreted as indicating "Fair" conditions, two as "Poor," and one as "Good" (see Table 6 for interpretation of scores). In 2004, SCI scores were lower than in the same months of 2003, with one sample with "Very Poor" conditions, five samples with "Poor" conditions, and 2 samples with "Fair" conditions (Figure 46). Simply taking the mean of the SCI scores for each station would imply that HCSW-1 (59.2) and HCSW-4 (55.8) harbor more desirable communities than HCSW-2 (31.4) or HCSW-3 (39.4). However, the poor sampling conditions during the July event make such a comparison unreliable. Future sampling will improve the relevance of comparisons across the stations to allow for more robust conclusions. The generally lower SCI scores from November 2004 are attributed to stream impacts from Hurricane Charley, with the higher score for HCSW-1 from that event reflective of the lower hurricane impacts seen at that station. Some samples did not have the target number of invertebrates in the sorted portion (* in Figure 46), so those results may not be comparable with over events.

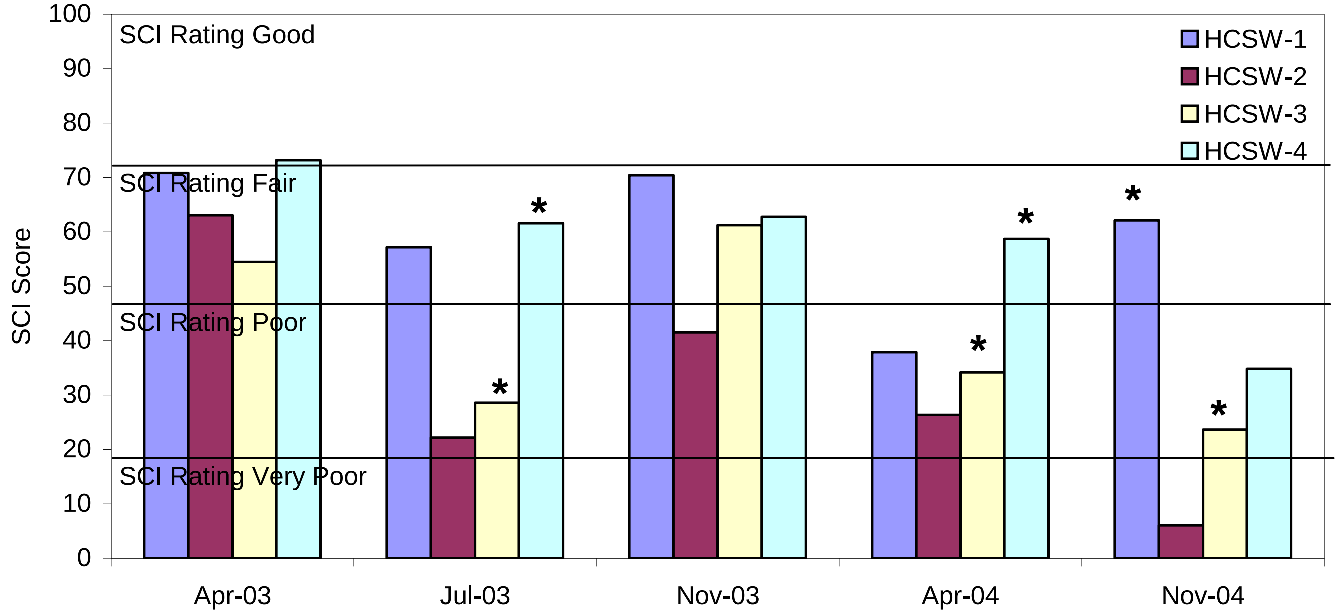

Figure 46. SCI Scores for Samples Collected from Horse Creek, 2003 - 2004. Samples marked by * had 15 % fewer than the target number of 125 invertebrates in the sorted portion.

5.3.3 Shannon-Wiener Diversity Index

Although not a component of the SCI protocol, the Shannon-Wiener Diversity Index was calculated for each benthic macroinvertebrate sampling event at each location. This index, one of the most popular measures of species diversity, is based on information theory and is a measure of the degree of uncertainty in predicting what species will be drawn at random from a collection of species and individuals (Ludwig and Reynolds 1988). The Shannon-Wiener Index assumes that all species 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 species diversity,
S = Number of species, and
p_i = Proportion of total sample belonging to ith species.

The Shannon-Wiener Index, H', increases with the number of species 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 species and their relative abundance; a greater number of species and a more even distribution of individuals across species both increase diversity as measured by *H'*. For example, consider two communities, each with 100 individuals of 10 species captured. Community A is dominated by one species (91 of 100 individuals), while only one individual was captured for each of the other nine species. Community B, however, is even, with 10 individuals captured for each of the ten species. 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 species.

In Horse Creek in 2003, the Shannon-Wiener Diversity Index ranged from 1.4 to 3.9, with higher diversity values occurring for the April and November events than for July (because of high water inhibiting the July sample collection) (Figure 47). Results in 2004 were similar to 2003 results from the same months, with slightly lower diversity at a few stations in November 2004. Hurricanes affecting the region in August – October 2004 probably negatively affected the invertebrate community of Horse Creek. When results from all events in 2003 and 2004 were combined by station (Figure 48), HCSW-4 showed the highest benthic macroinvertebrate diversity (5.0) and HCSW-3 the lowest (3.0).

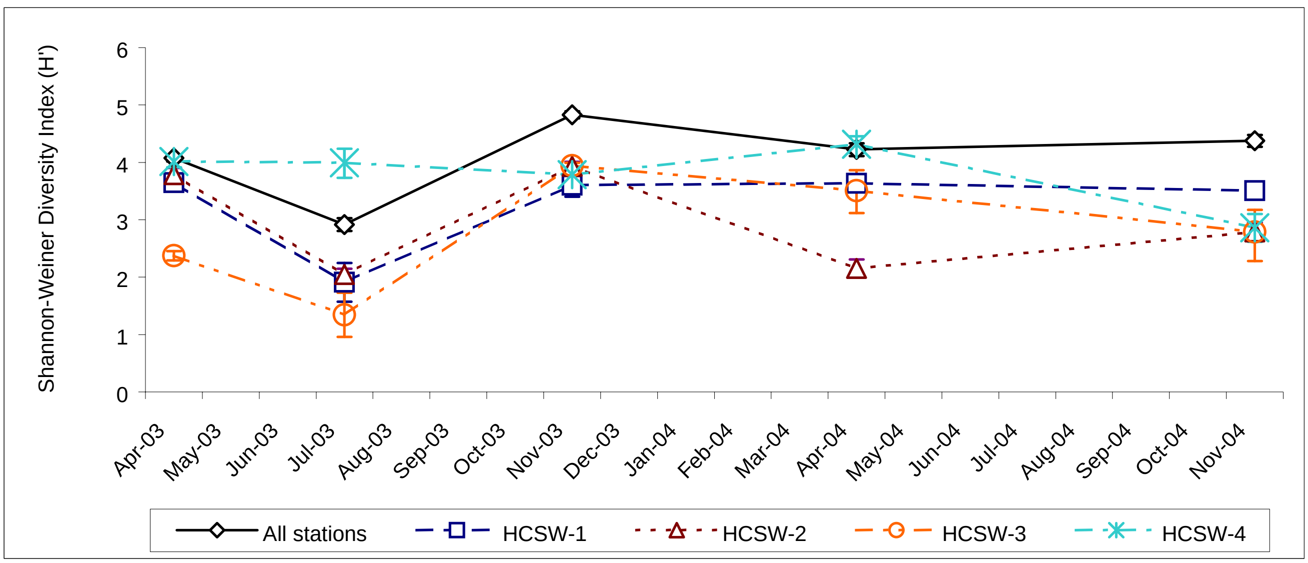

Figure 47. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrates from Four Stations on Horse Creek on 25 April 2003, 29 July 2003, 20 November 2003, 22 April 2004, and 3 November 2004. (90% confidence limits are automatically provided by the software used to calculate the index values (Ecological Methods v 6.1.1, Exeter Software 2003).

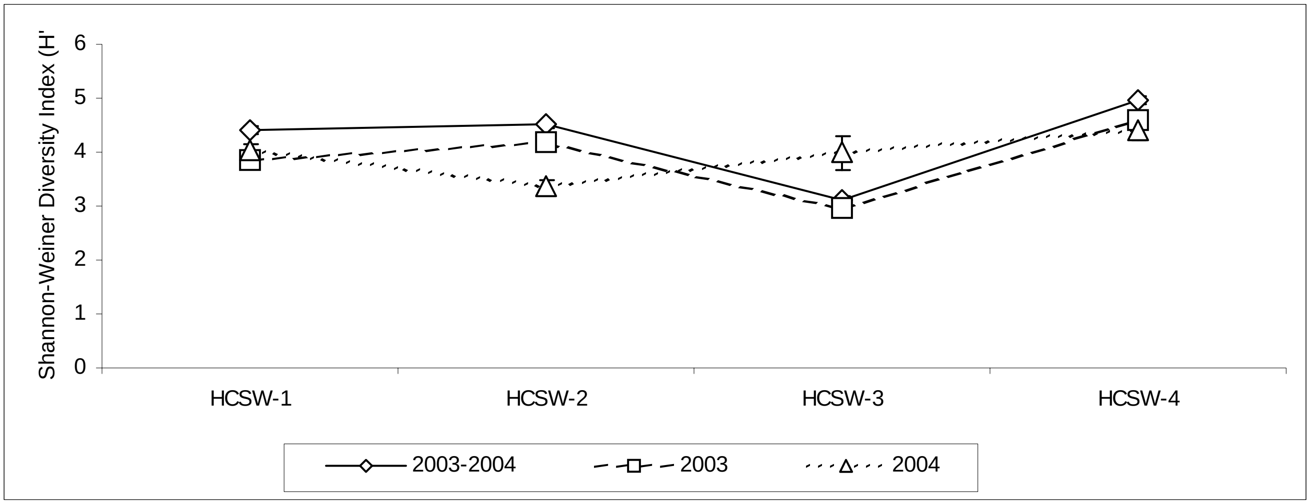

Figure 48. Shannon-Wiener Diversity Indices for Benthic Macroinvertebrates from Four Stations on Horse Creek for combined sample dates. (90% confidence limits are automatically provided by the software used to calculate the index values (Ecological Methods v 6.1.1, Exeter Software 2003).)

5.3.4 Taxa Abundance

Although it is not a component of the SCI protocol, the total number of specimens from each station was also evaluated as a supplemental ecological measure (Figure 49 and Tables 15 and 16). From Figure 49, the wide variation in sample size is evident, and reviewing this figure along with data in the attached CD-ROM indicates the manner in which one or two taxa can dramatically increase the overall sample size (e.g., 181 of the 296 specimens picked from the April 2003 HCSW-3 sample were *Corbicula fluminea*).

It is important to keep in mind that the SCI metric calculations were developed for samples that contain at least 100 to 125 individuals, and samples with fewer individuals are not expected to yield valid SCI results. If the target range of 100 to 125 individuals was not reached in a given sample, as occurred at HCSW-3 and HCSW-4 during July of 2003 and HCSW-3 in April and November 2004, the SCI results cannot be considered to be comparable to those for larger samples. This may explain why HCSW-3 was evaluated as “Poor” by the SCI index in July 2003, April 2004, and November 2004.

5.3.5 Summary of Benthic Macroinvertebrate Results

The SCI value calculated for each individual metric, as well as the total SCI scores, was always lowest during the November 2004 sample at stations affected by hurricanes (HCSW-2 – HCSW-4). High water levels and stream alteration (see Section 5.4.5) as a result of the several hurricanes passing through the area in August-October 2004 probably lowered SCI scores and benthic macroinvertebrate species diversity. Macroinvertebrates may be washed from the stream during high streamflow, resulting in lower invertebrate diversity during and after high rainfall events. In addition, many productive invertebrate habitats were smothered by sediment or washed downstream during the storms.

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 ranging 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.

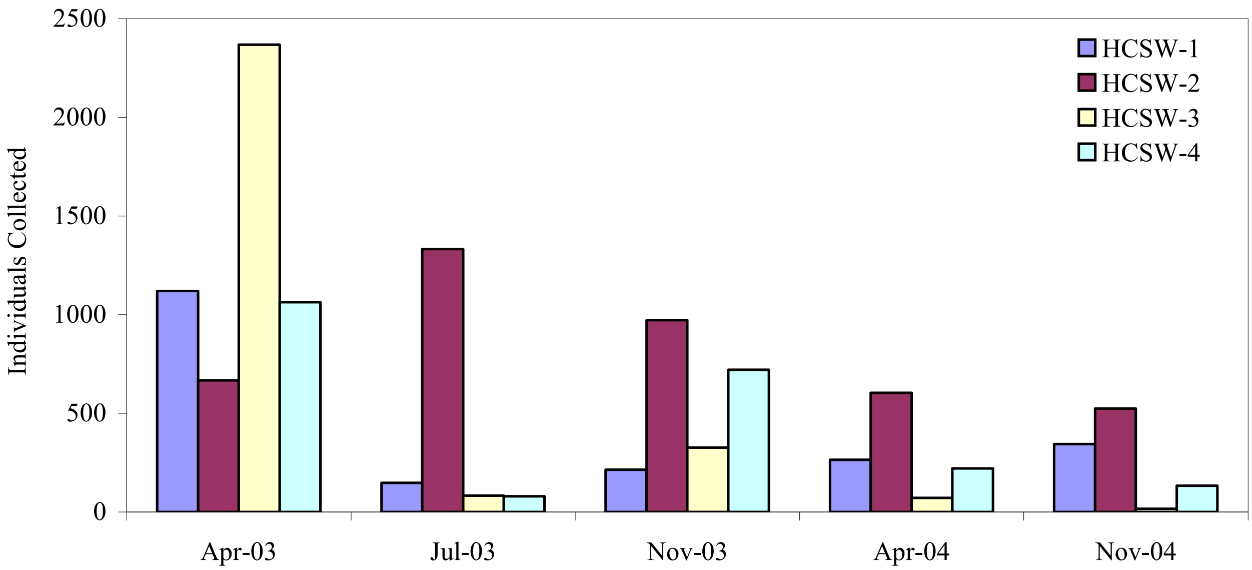

Figure 49. Invertebrate Abundances in Samples Collected from Horse Creek in 2003 - 2004 (values are extrapolated based upon numbers of individuals sorted from known proportions of samples).

The general quality of the macroinvertebrate community at the Horse Creek stations was within the range commonly observed by BRA in similarly-sized natural streams in this region of Florida, although the generally lower diversity, abundance and SCI scores attributed to the effects of Hurricane Charley are at the lower end of the expected ranges for healthy streams in this region. It may appear inconsistent that when the Habitat Assessment scores indicated optimal conditions, the total SCI scores indicated that the benthic communities were Fair or Poor. 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 Fair 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.

5.4 FISH

Biological sampling was not conducted during the summer of 2004 because the stream gage height was well above the recommended 5 feet, making the safe and effective use of sampling equipment impossible. During 2003 - 2004, 36 species of fish were collected from the four Horse Creek sampling stations; they are listed in Table 17 (the attached CD-ROM provides the scientific nomenclature for the species in the database). Of the native species collected, most were quite common regionally and none were unexpected for this portion of Florida. Catfishes, killifishes, shiners and sunfishes were the most commonly collected groups. Six of the 36 species are not native to Florida: the walking catfish (*Clarias batrachus*), African jewelfish (*Hemichromis letourneauxi*), brown hoplo (*Hoplosternum littorale*), suckermouth catfish (*Hypostomus plecostomus*), oriental weatherfish (*Misgurnus anguillicaudatus*), and sailfin catfish (*Pterygoplichthys multirandians*).

5.4.1 Taxa Richness and Abundance

The greatest numbers of individual fish were collected in April 2003, April 2004, November 2004 (Table 17), and more species of fish were collected during November 2003 and April 2004 as compared to the other sampling events. Compared to the other sampling events, the least number of individuals and species were collected on 29 July 2003 (Table 17), primarily because of poor sampling conditions.

Usually, 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. The fewest fish species were collected at HCSW-1 during all sampling events (Table 17). Generally, more species were found at HCSW-4 as compared to the other stations, except in November 2004 (Table 17), when Hurricane Charley had dramatically changed the lower reaches of Horse Creek.

Small numbers (as few as one) of individual fish were collected for most of the species found in 2003 and 2004 (Table 17). Warmouth (*Lepomis gulosus*), bluegill (*Lepomis macrochirus*), spotted sunfish (*Lepomis punctatus*), least killifish (*Heterandria formosa*), and coastal shiners (*Notropis petersoni*) were collected at all four sampling stations the majority of the time. Eastern mosquitofish was the only species collected at all sampling stations during all 2003 and 2004 sampling events.

Table 17. Fish Collected from Horse Creek through HCSP Sampling in 2003 and 2004.

	HCSW-1					*HCSW-2*					*HCSW-3*					*HCSW-4*				
Common Name	**25 Apr 2003**	**29 Jul 2003**	**20 Nov 2003**	**22 Apr 2004**	**3 Nov 2004**	**25 Apr 2003**	**29 Jul 2003**	**20 Nov 2003**	**22 Apr 2004**	**3 Nov 2004**	**25 Apr 2003**	**29 Jul 2003**	**20 Nov 2003**	**22 Apr 2004**	**3 Nov 2004**	**25 Apr 2003**	**29 Jul 2003**	**20 Nov 2003**	**22 Apr 2004**	**3 Nov 2004**
African jewelfish													1					14	3	
bluefin killifish							4		18			1	1				3			
bluegill	7					2	2		2		2	2	3			5	1		5	
bluespotted sunfish								1	3											
brook silverside			2		2						5	10	9	7		2	4	6	2	
brown bullhead	3						1									1		1		
brown hoplo										2										
channel catfish													1					2		
coastal shiner	19	1	2	10	46	1					79	5	25	56		11	9	11	27	
dollar sunfish									1											
eastern mosquitofish	170	2	9	52	19	116	86	83	335	993	112	171	239	71	138	10	57	59	58	573
Everglades pygmy				3					1	2		1					1		1	
flagfish								7	1	30					3			2	1	1
Florida gar														1		1				
golden topminnow				7				3	1			1		2			3		5	
hogchoker											4		7	40		1	2	1	14	
lake chubsucker				1		1														
largemouth bass		1									2	3	1	2		1		1		
least killifish				6		18	28	12	82	242	80	15	2	3	46	1	6	1	40	19
longnose gar																1				
oriental weatherfish						1		2							10				1	
redear sunfish						1												2		
sailfin catfish			1														1			
sailfin molly				1		3		17	5	78	36	1	13	68	35	10	21	7	7	16
Seminole killifish											12	3	9	3		3	12			
spotted sunfish	26		7	9	5	5	1	1	1		27	2	6	17		11	10	12	17	
suckermouth catfish															3					2
swamp darter	1					1	2	2	8		1		2	2		2	1		1	
tadpole madtom			1						2							1			2	
taillight shiner													5				1			
walking catfish			1		1		1								1					
warmouth	3		2	9	3	6	12	10	7	1			1	5			1	8	5	
yellow bullhead			1	9												1				
Total Taxa	**7**	**3**	**9**	**10**	**6**	**11**	**9**	**10**	**14**	**7**	**11**	**12**	**16**	**13**	**7**	**16**	**16**	**14**	**16**	**5**
Total Individuals	**229**	**4**	**26**	**107**	**76**	**155**	**137**	**138**	**467**	**134**	**360**	**215**	**325**	**277**	**148**	**62**	**133**	**127**	**189**	**611**

5.4.2 Shannon-Wiener Diversity Index

Diversity of individual fish samples in 2003 ranged from 0.7 (HCSW-1, July) to 3.1 (HCSW-4, April) and in 2004 ranged from 0.5 (HCSW-3 and HCSW-4, November) to 2.8 (HCSW-4, April) (Figure 50). When fish samples were combined across all sampling events in 2003, the highest species diversity was calculated for HCSW-4, and HCSW-1 had the lowest diversity. In 2004, however, HCSW-1 had the highest diversity (Figure 50). When all sampling dates were combined, fish diversity was higher at HCSW-1 and HCSW-4 than at the midstream stations. When all stations were combined, Shannon-Wiener Diversity Index values were fairly similar for all sampling events except November 2004, after the hurricanes (Figure 51). In 2003 diversity generally from upstream to downstream, but not in 2004.

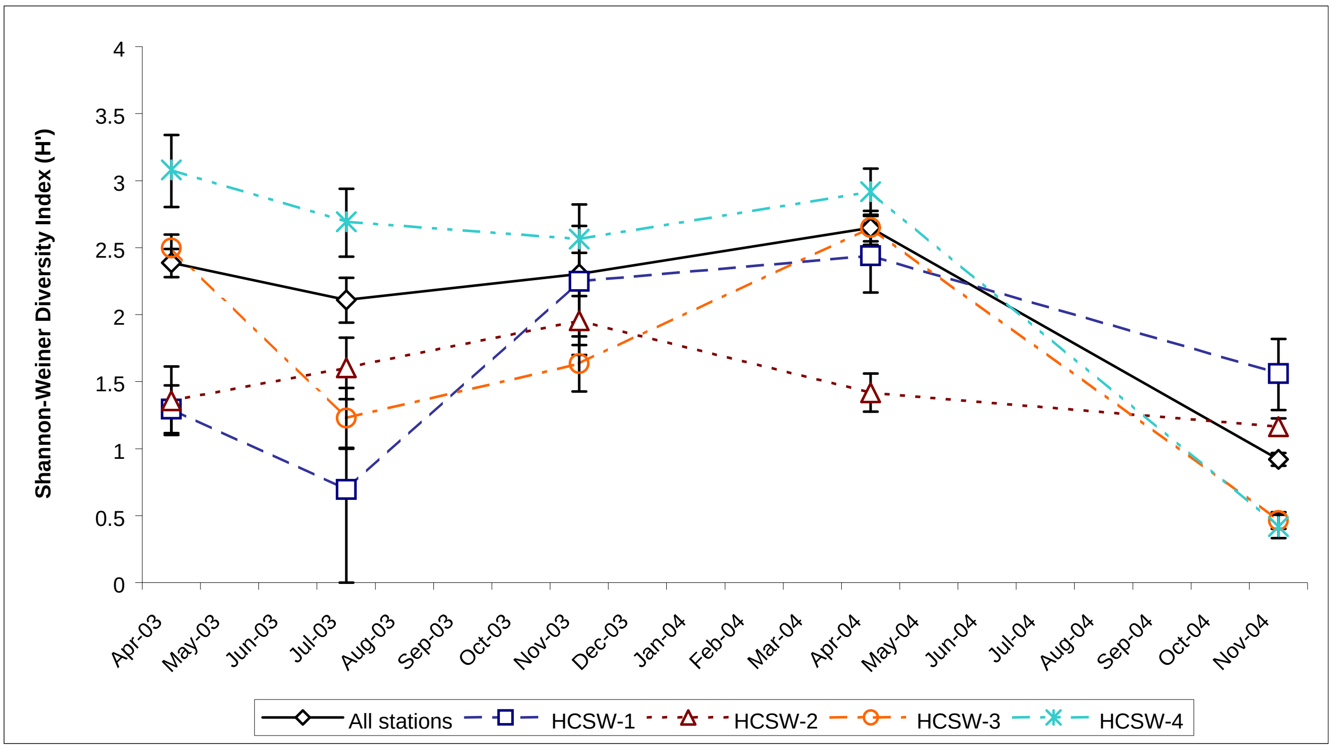

Figure 50. Shannon-Wiener Diversity Indices and 90% Confidence Limits for Fish Collected from Four Stations on Horse Creek on 25 April 2003, 29 July 2003, 20 November 2003, 22 April 2004, and 3 November 2004. (90% confidence limits are automatically provided by the software used to calculate the index values (Ecological Methods v 6.1.1, Exeter Software 2003).

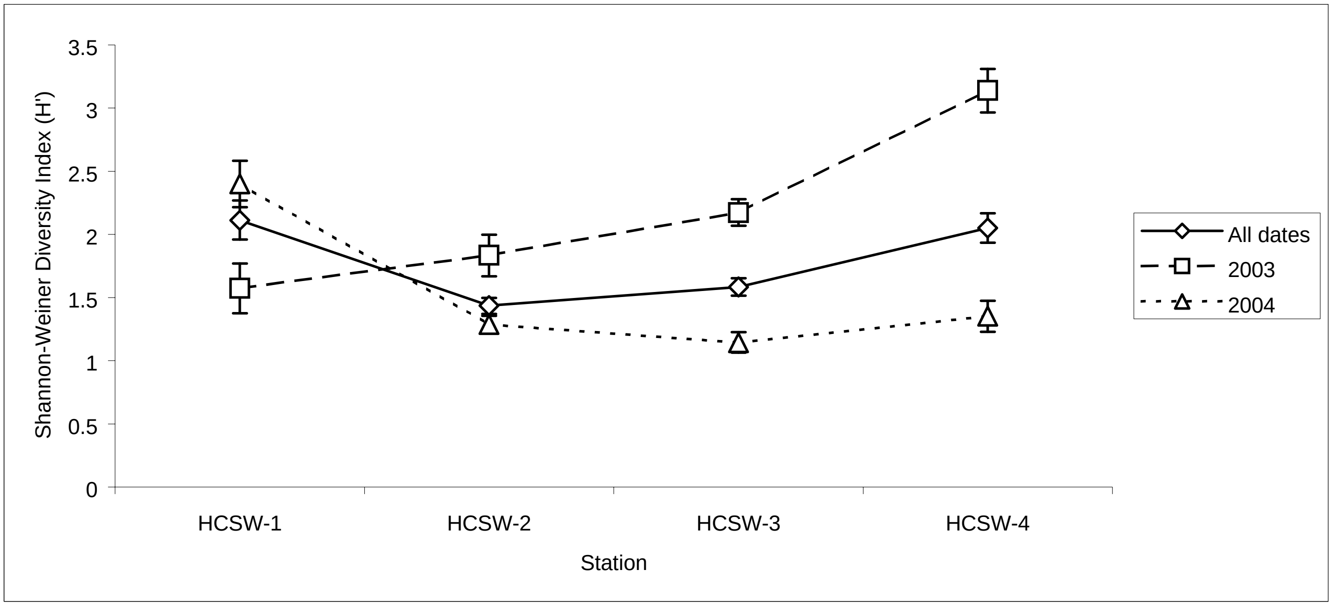

Figure 51. Shannon-Wiener Diversity Indices and 90% Confidence Limits for Fish Collected from Four Stations on Horse Creek summarized over sampling events. (90% confidence limits are automatically provided by the software used to calculate the index values (Ecological Methods v 6.1.1, Exeter Software 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). The index was formulated for counts of individuals and not for other abundance estimates based on biomass, productivity, or cover.

Table 18 includes Morisita's Indices calculated for each station, as well as all stations combined, by sampling event. Values ranged from 0.31 (HCSW-4, comparing April 2003 and November 2004) to 0.99 (many comparisons). When combining all sampling locations, fish communities were similar for all sampling events, although November 2004 had the least similarity to other communities. The fish community at HCSW-2 was similar throughout 2003, while at other stations the communities in July 2003 and November 2003 and 2004 were more similar to each other than to the April 2003 and 2004 communities. Although Morisita's Index is robust to differences in sample size, the number of individuals at HCSW-1 in July 2003 was four, thereby inflating similarity measures of this sample with other dates or stations.

Values of Morisita's Index were also calculated for each sampling event, as well as all events combined, for each station (Table 19). The lowest value of 0.37 was calculated when comparing HCSW-1 to the other three stations during November 2004 (reflecting the effects of the hurricane on the downstream stations), while the highest reasonable value of 0.98 was calculated comparing HCSW-1 to HCSW-2 in April 2003. Fish communities were very similar at all stations when sampling events were combined. Stations were most dissimilar in April 2003 and November 2004.

Table 18. Morisita's Similarity Index Values Comparing Sampling Dates within Stations for 2003 - 2004 Samples.

Event	HCSW-1				HCSW-2				HCSW-3				HCSW-4				All Stations Combined			
	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004	29 Jul 2003	20 Nov 2003	22 Apr 2004	3 Nov 2004
25 Apr 2003	1.06	0.78	0.90	0.49	0.98	0.97	1.00	0.99	0.64	0.67	0.79	0.55	0.75	0.65	0.73	0.31	0.95	0.95	0.99	0.86
29 Jul 2003		1.09	1.23	0.93		0.97	0.99	0.98		0.99	0.51	0.99		0.94	0.83	0.74		0.99	0.96	0.96
20 Nov 2003			0.82	0.51			0.96	0.97			0.59	0.97			0.82	0.77			0.95	0.95
22 Apr 2004				0.54				1.00				0.46				0.56				0.87

Table 19. Morisita's Similarity Index Values Comparing Stations within Sampling Dates for 2003 –2004 Samples.

Station	25 April 2003			29 July 2003			20 November 2003			22 April 2004			3 November 2004			All Dates Combined		
	HCSW-2	HCSW-3	HCSW-4	HCSW-2	HCSW-3	HCSW-4	HCSW-2	HCSW-3	HCSW-4	HCSW-2	HCSW-3	HCSW-4	HCSW-2	HCSW-3	HCSW-4	HCSW-2	HCSW-3	HCSW-4
HCSW-1	0.98	0.68	0.60	1.06	1.09	1.20	0.92	0.93	1.00	0.93	0.88	0.86	0.37	0.37	0.37	0.90	0.94	0.96
HCSW-2		0.71	0.55		0.97	0.94		0.98	0.94		0.75	0.80		0.96	0.96		0.98	0.98
HCSW-3			0.86			0.95			0.95			0.83			1.00			0.99

5.4.4 Species Accumulation Curves

One way to determine when enough individuals in a community have been sampled for accurately estimating species diversity with some level of confidence is to plot the cumulative number of species collected across the sampling events. 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 indicates 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 how many species must be collected 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 add species with each sampling event and the curve has not completely leveled off (Figure 52). This suggests that additional species will likely be collected in the future. In fact, the more apparent leveling-off of the curve for HCSW-4 may be more a product of low numbers of individuals and species after the 2004 hurricanes than of hearing the total number of species at that location.

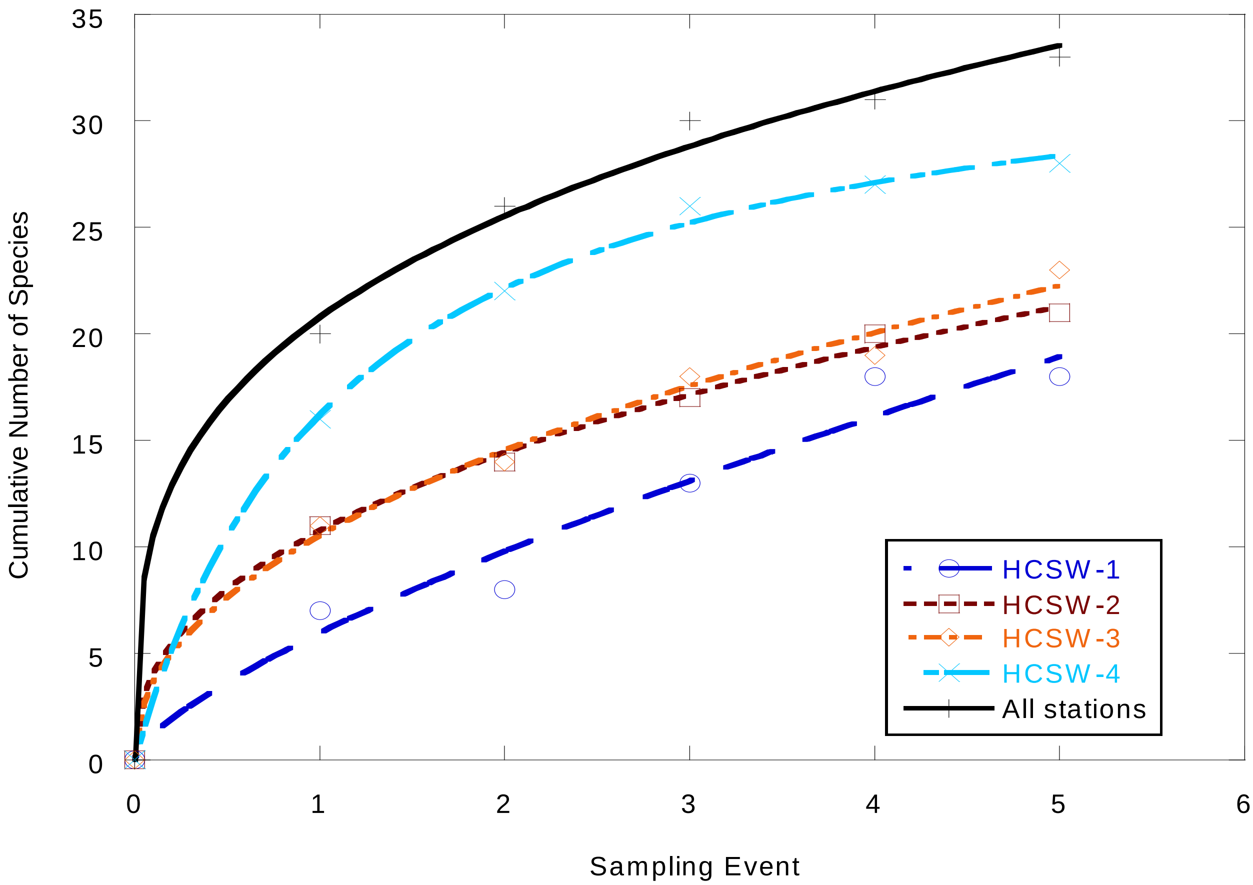

Figure 52. Cumulative Numbers of Fish Species Collected at Horse Creek Stations During 2003 - 2004. Species accumulation curves were fit for visual purposes only using KaleidaGraph 4.0.

5.4.5 Summary of Fish Results

Thirty-six species of fish were collected in 2003 – 2004, with most captured individuals belonging to one of four families (Table 20). We expect to add more species during future monitoring events, because the species accumulation curves based on the five samples collected in 2003 – 2004 have not leveled off. Several native species are almost certainly present in Horse Creek but were not collected in 2003 - 2004. These include species such as the American eel (*Anguilla rostrata*), bowfin (*Amia calva*), white catfish (*Ameiurus catus*), pirate perch (*Aphredoderus sayanus*), and black crappie (*Pomoxis nigromaculatus*). The species collected included six introduced species: walking catfish, African jewelfish, brown hoplo, suckermouth catfish, oriental weatherfish, and sailfin catfish. 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 20. Percentage of individual fish captured for three fish families in Horse Creek during 2003 – 2004 as part of the Horse Creek Stewardship Program.

Fish Family	HCSW-1	HCSW-2	HCSW-3	HCSW-4	Total
Poeciliidae	54 %	96 %	95 %	85 %	92 %
Cyprinodontidae	2 %	2 %	1 %	2 %	1 %
Centrarchidae	15 %	1 %	1 %	4 %	2 %
Cyprinidae	17 %	0 %	3 %	3 %	2 %

High flows (July 2003) or hurricanes (Fall 2004) in the months preceding sampling, led to the fewest number of species and individual fish being collected during July 2003 and November 2004, compared to the other sampling events. This trend was similar to what was observed for benthic macroinvertebrates. Species richness and diversity were lowest at HCSW-1 and highest 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 2004, fish diversity was highest at the upstream and downstream station, probably because of unusual sampling conditions after Hurricanes Charley, Jeanne, and Frances. The central stations were the most affected by the hurricances of 2004. Fish communities were similar for all events when locations were combined and for all locations when events were combined.

Results of the sampling, as well as observations by the ecologists conducting the sampling, indicated a dramatic reduction in overall fish biomass and species diversity at the end of 2004. The samples were dominated by *Gambusia holbrooki*, with smaller numbers of *Poecilia latipinna*. The two upstream stations produced a few more species, including *Heterandria formosa* and several exotic fishes. Obviously missing from the samples (and not observed in the stream as they had been in previous sampling) were adult sunfishes. One small *Lepomis* sp. was taken at HCSW-2, and several more were taken at HCSW-1, but no sunfish larger than about 10 cm was seen. Similarly, no native catfish species, gar or darters were collected. The virtual absence of these species must be somehow related to physical and/or water quality changes in the stream resulting from the hurricanes. It will be interesting to chart their recolonization of the system in the coming sampling events.

6.0 CONCLUSIONS

6.1 WATER QUANTITY

During 2003 and 2004, rainfall, streamflow, gage height, and NPDES discharge showed expected relationships within the Horse Creek Basin. Rainfall varied between gauges, but showed similar seasonality at all sites. Stream stage height was also similar among sites, with the highest stage levels maintained for only 10 to 20 percent of 2003 and 2004. Logically, stream discharge was higher at the downstream USGS gauging station than the upstream station, but streamflow patterns were similar at both sites. Streamflow, NPDES discharge, and rainfall were significantly correlated, preventing the relative magnitude of the effects of each on water quality and biological parameters from being clearly determined. Abnormally high streamflow, gage heights, and rainfall resulted from three hurricanes that affected the area in August – October 2004.

6.2 WATER QUALITY

Trigger levels were exceeded at least once for four water quality parameters: dissolved oxygen, total nitrogen, chlorophyll a, sulfate, and radium. Based upon historical conditions in Horse Creek (Durbin and Raymond 2006), these exceedances were probably the result of natural conditions (proximity to hypoxic swamp, high temperatures, high streamflow, organic debris and runoff from hurricanes) and are not related to mining activities. Some seasonal patterns in water quality parameters were evident. Other landscape factors, such as the proximity of agriculture, biosolid application, prairies, or larger river systems, may also have an effect on such water quality parameters as pH, nutrients (nitrogen oxides and orthophosphate), and dissolved ions (calcium and sulfate). Land use analysis in the HCSP Historical Report (Durbin and Raymond 2006) may provide a means of gaging the effect of these landscape factors on water quality in Horse Creek, but an extensive investigation to precisely quantify the effects of non-mining land use is beyond the scope of the Horse Creek Stewardship Program.

6.3 BENTHIC INVERTEBRATES

Benthic invertebrate habitat scores were "Optimal" and SCI scores were "Good", "Fair", or "Poor" at all stations from April 2003 to April 2004; these scores are typical of southwestern Florida streams, including those used to develop the Habitat Assessment and SCI indices. Macroinvertebrate diversity was similar among stations, but was lower at most locations when rainfall was heavy during the summer, primarily as a result of poor sampling conditions in July 2003 and November 2004. After three hurricances affected the area in fall 2004, the November 2004 sampling event had lower habitat assessment scores, SCI scores, and species diversity than other samples at most sites. This decline in habitat quality must be somehow related to physical and/or water quality changes in the stream resulting from the hurricanes.

6.4 FISH

Fish species richness and diversity was higher in the more downstream locations in 2003, likely because of their proximity to the species-rich Peace River. In 2004, species diversity was highest in the most upstream and downstream stations; the upstream station was not as affected by 2004 hurricanes as the three downstream stations were. In July 2003 and November 2004, fish diversity was lower than on other sampling dates, because of high stream stage that complicated sampling efforts. Fish diversity at the most downstream station (HCSW-4) was least affected by the increase in rainfall because its stage height and discharge rates were already higher than upstream locations. Fish communities were fairly similar between stations and between dates at each station. Although the lowest fish and macroinvertebrate diversity (July 2003 and November 2004) corresponded with peaks in NPDES discharge, the covariation of NPDES discharge and rainfall supports the conclusion that diversity is more affected by precipitation and other meteorological phenomena than mining activities.

6.5 HURRICANE EFFECTS

Biological sampling on 3 November 2004 was substantially hampered by the after-effects of Hurricanes Charley, Frances and Jeanne. At HCSW-2, 3 and 4, there was severe damage to the riparian and floodplain forest, with trees of all sizes and species damaged or destroyed. For example, the live oak hammock in the floodplain at HCSW-3, which previously provided nearly 90 percent canopy cover suffered so much tree and branch loss that the forest floor was in virtually full sun for the remainder of 2004.

The instream effects were most notable at Stations HCSW-3 and HCSW-4, which apparently lie within the area struck by the core of Charley. Both stations had trees and large branches lying in the stream channel which complicated the use of fish and invertebrate sampling equipment. The very high flows resulting from the hurricanes' rainfall combined with the altered hydraulics brought about by the new debris in the stream caused major shifts in the locations of sandbars, pools, runs, etc. These changes, along with reduced visibility caused by somewhat cloudy water made wading in the stream difficult and even dangerous compared to previous sampling events. Since the area had seen no rainfall in the past several weeks and stream flows have been steadily declining, the suspended material in the water is assumed to have been the result of decomposition of the trees, leaves and other organic matter thrown into the stream by the hurricanes, rather than suspended sediment contributed by runoff. Many areas along the stream had a distinct odor indicating rotting vegetation and/or accumulations of muck and decaying material.

Farther upstream, HCSW-2 had marked floodplain forest damage, but the stream channel segment that is sampled was not dramatically changed. HCSW-1 was only minimally affected in terms of either its floodplain or the channel. This is because the path of Charley was several miles to the east of that station, and because the stream is very deeply incised at HCSW-1, so the channel and its riparian canopy lie somewhat below the surrounding landscape, presumably resulting in lower localized wind speeds as the hurricanes moved through.

In addition to complications from hurricane damage, the water depth at HCSW-3 and HCSW-4 was still approximately one foot too deep to allow for adequate fish sampling. The electrofishing backpack must be kept above the water to operate, but in most portions of the sampling area at these two stations, limited sampling area was present where this depth restriction was met. Steep or slippery shorelines, and the presence of woody debris, prevented using the equipment from the bank. Likewise, seining is very difficult in water that is more than waist-deep. The USGS web site reported a stage of 4.0 feet at HCSW-4 on this sampling date. It appears likely that the relationship between the USGS stage reading and the water depths in the sampling segment has been altered by the hurricanes. Based on conditions present during this sampling, BRA recommends that biological sampling not be undertaken (or at least be assumed to be sub-optimal) when the stage at HCSW-4 is above 4 feet, rather than the 5-foot limit previously discussed. Water depth at the upper stations were adequate for the sampling (USGS reported a stage of 9.75 feet for the sampling date), so the upper sampling limit of 10 feet for HCSW-1 is still appropriate.

6.6 TRENDS AND PATTERNS

As monitoring continues and sufficient data accumulates to allow for interpretation of apparent temporal patterns, it will become possible, in at least some cases, to address specific changes within certain parameters. In addition, the incorporation of historical water quality and hydrologic data from the HCSP Historical Report (Durbin and Raymond 2006) will allow for comparisons of current conditions with those reported in past years using trend analysis. Sampling for benthic macroinvertebrates and fish parameters may take longer to show trends, especially with the limited amount of historical biological data available for Horse Creek.

For the purposes of this second annual report, it is merely possible to report that the water quality, hydrologic patterns, and aquatic biota of Horse Creek do not display evidence of adverse impacts associated with phosphate mining operations in the watershed.

Beginning with the 2005 Annual Report, historical data from other monitoring programs (e.g., SWFWMD, FDEP, USGS) will be used to provide longer timeframes for observing trends and patterns. In part, this will include the presentation of period-of-record type graphics for many parameters to allow visualization of the various data sets available for the stream.

7.0 RECOMMENDATIONS

Biological sampling requires that the stream be accessible by wading. Although some limited sampling for invertebrates may be possible by using D-frame dipnets from the edge of the water, this generally yields few invertebrates when stream stage is high. At the very least, such sampling does not provide a representative sample of the overall invertebrate community because all of the in-stream habitats are not available for sampling. Likewise, fish sampling is compromised by high stream stage. Use of seines is impractical if the stream cannot be waded, and the efficacy of backpack electrofishing equipment from the shoreline is limited in the same way as dipnetting for invertebrates.

Based upon our experience during considerable sampling on Horse Creek during the last ten years, biological sampling becomes hindered, with commensurate reductions in data quality, as the stream stage rises above about 10 feet (68.12 ft NGVD) at HCSW-1 and about 4 feet at HCSW-4 (15.96 ft NGVD). Therefore, we recommend that biological sampling not be undertaken during times when the stream stage is above 10 feet at HCSW-1 and 4 feet at HCSW-4. Because USGS stage data is available in real time via the Internet, sampling conditions on a given day can be easily determined from the office.

In light of this sampling restriction, and based upon the observed distribution of Horse Creek flows in the 2003 and 2004 wet seasons, the summer biological sampling window should include all of July/August/September and the fall window should encompass October/November/December, to maximize the opportunity for having suitable sampling conditions. However, every effort should be make to space biological sampling events at least six weeks apart.

NOTE TO TAG – These recommendations came from the meeting on the Historical Report:

Mosaic and the PRMRWSA should investigate the availability and cost of LIDAR rainfall data for the Horse Creek Basin because of its ability to more accurately represent widespread rainfall amounts.

Future reports should adopt a standard set of agency water quality databases from which to draw ongoing monitoring data for Horse Creek. These should include the SWFWMD, FDEP STORET and the USGS, to the extent that each of these agencies continues to collect Horse Creek data. Such data should be presented and discussed in relation to the monitoring data produced by the HCSP.

In general, presentation of period-of-record data recent data in graphics is preferable to single-year data, except where a more limited presentation of data is necessary to illustrate a point. Where data extend back more than ten years, only the most recent decade of data may be presented if it provides better resolution of the information being presented, although longer periods of record may be presented to indicate trends or temporal changes beyond the last decade.

This report, and future HCSP annual reports, should include a list of formal changes to the HCSP methodology. The list should reflect additions, deletions and revisions which have been addressed by the HCSP TAG (either through presentation within an annual report, separate recommendation by Mosaic, or recommendation by the TAG itself). Not all recommendations made in annual reports would necessarily constitute changes to the HCSP methodology (e.g., specification of period-of-record data presentation, or acquisition of LIDAR data, as noted above, are preferences of the TAG, but need not be considered a formal change to the HCSP protocol). At the end of the list would be the recommended changes within the current year's report to allow the TAG and the PRMRWSA to consider the specific methodology changes proposed in the report. Changes to the methodology would not be implemented until they have been reviewed by the TAG and the annual report has been accepted by the PRMRWSA Board. In the case of minor changes to the protocol, the PRMRWSA and/or the TAG could give provisional approval of a change to allow for its implementation before final approval of the annual report by the PRMRWSA Board. The list of changes should stand as a separate appendix, with each item identifying the monitoring year the change is implemented, and whether the change is provisional or final. The list should be cumulative and chronological to reflect the adaptive nature of the methodology. This report contains such a list (Appendix B) in the recommended format. No changes should be made to the original HCSP methodology document, which is a component of the legal settlement agreement and comprises a separate appendix of each annual report.

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APPENDICES

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.

1.0 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) gaging stations, with essentially continuous stage and discharge records since 1977 and 1950, respectively.

2.0 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 gages 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 gage readings will be recorded at the time of any sampling efforts at those stations. Data on rainfall will be obtained using IMC's rain gage array (including any additional gages 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.

3.0 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.

4.0 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.

5.0 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.

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

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

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

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

Notes:

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

References:

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

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: Recommended
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: Recommended
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