Recommended Minimum Flows for Horse Creek
Final Report

December 12, 2023

Southwest Florida
Water Management District

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Acronym List Table

Acronym	Definition
AMO	Atlantic Multidecadal Oscillation
AWS	Area Weighted Suitability
BBDA	Black Banded Darter Adult
BLUJ	Juvenile Bluegill
BMAP	Basin Management Plan
CCSP	Spawning Channel Catfish
cfs or (ft^3/s)	cubic feet per second
CLIP	Critical Lands and Waters Identification Project
CWCFGWB	Central West-Central Florida Groundwater Basin
DEM	Digital Elevation Model
DEP	Florida Department of Environmental Protection
District	Southwest Florida Water Management District
DPFA	Deep Fast Habitat Guild
EDP	Environmental Data Portal (of the District)
ENSO	El Niño-Southern Oscillation
F.A.C	Florida Administrative Code
FDACS	Florida Department of Agriculture and Consumer Services
FDOT	Florida Department of Transportation
FEGN	Florida Ecological Greenways Network
FLUCCS	Florida Land Use, Cover, and Forms Classification System
FNAI	Florida Natural Areas Inventory
F.S.	Florida Statutes
FSAID	Florida Statewide Agricultural Irrigation Demand
FWC	Florida Fish and Wildlife Conservation Commission
GIS	Geographic Information System
GLMM	Generalized Linear Mixed Model
HAAc	Habitat Assessment
HCSP	Horse Creek Stewardship Program
HEC-RAS	Hydrologic Engineering Center River Analysis System
HUC	Hydrologic Unit Code
HYDR	Hydropsychidae
IA	Intermediate Aquifer
IAS	Intermediate Aquifer System
ICU	Intermediate Confining Unit
IWR	Impaired Waters Rule
LDI	Landscape Development Index
LFA	Lower Floridan Aquifer
LOESS	Locally Estimated Scatter Plot Smoothing
LWPIP	Lowest Wetted Perimeter Inflection Point
MFL	Minimum Flow and/or Minimum Water Level (as defined in Section 373.042, F.S.)
mgd	Million gallons per day

Acronym	Definition
n	Number, count data
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
No.	Number, for USGS gage designations
NPDES	National Pollutant Discharge Elimination System
NWCFGWB	Northern West-Central Florida Groundwater Basin
NWI	National Wetland Inventory
PHABSIM	Physical Habitat Simulation System
PRIM	Peace River Integrated Model
PSEU	*Psuedocleon ephippiatum*
R^2	Coefficient of determination (for statistical analyses)
ROMP	Regional Observation and Monitor-well Program
SA	Surficial Aquifer
SCI	Stream Condition Index
SEFA	System for Environmental Flow Analysis
SHFA	Shallow Fast Habitat Guild
SIMPER	Similarity Percentages
SR	State Road
SST	Sea Surface Temperature
SWCFGWB	Southern West-Central Floirda Groundwater Basin
SWFWMD	Southwest Florida Water Management District
TDS	Total Dissolved Solids
TINV	Total Invertebrates
TMDL	Total Maximum Daily Load
TVET	Tvetenia vitracies
UF	University of Florida
UFA	Upper Floridan aquifer
USGS	United States Geological Survey / Department of Interior
WBID	Waterbody Identification Numbers (of the DEP)

Conversion Unit Table

Metric to U.S. Customary		
Multiply	By	To Obtain
cubic meters per second (m^3/s)	35.31	cubic feet per second (cfs)
cubic meters per second (m^3/s)	23	million gallons per day (mgd)
millimeters (mm)	0.03937	inches (in)
centimeter (cm)	0.3937	inches (in)
meters (m)	3.281	feet (ft)
kilometers (km)	0.6214	statute miles (mi)
square meters (m^2)	10.76	square feet (ft^2)
square kilometers (km^2)	0.3861	square miles (mi^2)
hectares (ha)	2.471	acres
liters (L)	0.2642	gallons
cubic meters (m^3)	35.315	cubic feet (ft^3)
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
Celsius degrees (°C)	1.8*(°C) + 32	Fahrenheit (°F)
U.S. Customary to Metric		
Multiply	By	To Obtain
inches (in)	25.40	millimeters (mm)
inches (in)	2.54	centimeters (cm)
feet (ft)	0.3048	meters (m)
statute miles (mi)	1.609	kilometers (km)
square feet (ft^2)	0.0929	square meters (m^2)
square miles (mi^2)	2.590	square kilometers (km^2)
acres	0.4047	hectares (ha)
gallons (gal)	3.785	liters (l)
cubic feet (ft^3)	0.02831	cubic meters (m^3)
acre-feet	1233.0	cubic meters (m^3)
Fahrenheit (°F)	0.5556*(°F-32)	Celsius degrees (°C)
U.S. Customary to U.S. Customary		
Multiply	By	To Obtain
acre	43560	square feet (ft^2)
square miles (mi^2)	640	acres
cubic feet per second (cfs)	0.646	million gallons per day (mgd)

EXECUTIVE SUMMARY

The Southwest Florida Water Management District (District) has been directed by the State Legislature to establish minimum flows for flowing watercourses within its boundary. Minimum flows are defined in Section 373.042(1) of the Florida Statutes as “the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.” Each water management district of the state of Florida, or the Florida Department of Environmental Protection, identifies specific metrics or criteria that can be associated with significant harm and used for minimum flows development. Once adopted into the District’s Water Levels and Rates of Flow Rules within the Florida Administrative Code, minimum flows are used for water supply planning, water use permitting, and environmental resource regulation.

This report summarizes minimum flows for Horse Creek developed by the District. Horse Creek originates just north of State Road (SR) 62 in Hardee County and flows to the lower Peace River. Horse Creek is one of six major tributaries to the Peace River that provides a large volume of freshwater inflow to the Charlotte Harbor estuary, which opens to the Gulf of Mexico.

The recommended minimum flows for Horse Creek were based upon the best available information, as required by Florida Statute, and considered all relevant environmental values identified in the Florida Water Resource Implementation Rule. The District’s approach for developing these minimum flows was habitat-based. Resource management goals for the development of minimum flows for Horse Creek included the following:

- Determination of a low flow threshold to provide protection for ecological resources and recreational use of Horse Creek during critical low-flow periods.
- Maintenance of seasonal hydrologic connections between the Horse Creek channel and floodplain to ensure persistence of floodplain structure and function.
- Maintenance of available instream habitat for fish and invertebrates.
- Maintenance of the inundation of instream woody habitat.
- Maintenance of water quality.

The baseline flow record used for the minimum flow analyses was developed for Horse Creek to account for decreases and increases (from excess agricultural runoff) in gaged flows associated with surface and groundwater withdrawals. The Horse Creek baseline flow record extended from May 1, 1950, through December 31, 2021. Flow-based blocks, defined below, were developed from analysis of the minimum flow requirement for fish passage and the sensitivity of floodplain inundation to flow reduction at the United States Geological Survey (USGS) Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage.

- Block 1 – Flows less than or equal to 15 cubic feet per second (cfs)
- Block 2 – Flows greater than 15 cfs and less than or equal to 78 cfs
- Block 3a – Flows greater than 78 cfs and less than or equal to 172 cfs
- Block 3b – Flows greater than 172 cfs and less than or equal to 644 cfs
- Block 3c – Flows greater than 644 cfs

A percent-of-flow approach was used with several block-specific criteria to develop minimum flows for Horse Creek that ensure maintenance of 85% of the most sensitive criteria, and by default, all criteria associated with the resource management goals. In addition, a low flow threshold was identified to protect flow continuity. Assessments were conducted to ensure all relevant environmental values identified by the Florida Water Resources Implementation Rule would be protected by the minimum flows proposed for Horse Creek.

For Horse Creek, the recommended minimum flows for Block 1 and Block 2 maintain available instream habitat and the recommended minimum flows for Block 3a, 3b, and Block 3c maintain floodplain inundation. All proposed minimum flows are derived from baseline flows for the previous day at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage that have been adjusted for withdrawal impacts.

Flow-Based Block	If Previous Day's Flow, Adjusted for Withdrawals, is:	Recommended Minimum Flow is:	Potential Allowable Flow Reduction is:
1	≤ 15 cfs	Flow on the previous day	0 cfs
2	> 15 cfs and ≤ 78 cfs	15 cfs or 88% of the flow on the previous day, whichever is greater	12% of flow on the previous day
3a	> 78 cfs and ≤ 172 cfs	69 cfs or 86% of the flow on the previous day, whichever is greater	14% of flow on the previous day
3b	> 172 cfs and ≤ 644 cfs	88% of the flow on the previous day	12% of flow on the previous day
3c	> 644 cfs	92% of the flow on the previous day	8% of flow on the previous day

The recommended minimum flows for Horse Creek are currently being met and are expected to be met over the next 20 years. Therefore, development of a recovery or prevention strategy is not necessary.

An adaptive management approach will be used by the District to monitor and assess the status of minimum flows established for Horse Creek. Because changes in the Horse Creek watershed related to numerous factors, including climate change, could potentially affect flow characteristics and additional information relevant to minimum flows development may become available, the District is committed to periodic reevaluation, and, if necessary, revision of minimum flows established for Horse Creek.

CHAPTER 1 - INTRODUCTION

This report documents the development of new, recommended minimum flows for Horse Creek, which were formulated by the Southwest Florida Water Management District (District) using the best available information. This chapter provides an overview of the rationale for developing these minimum flows and the legal directives and approaches used by the District. Chapter two provides a description of the Horse Creek watershed, including the location, soils, climate, streamflow, hydrogeology, and aquifer levels. Factors that impact streamflow, with some emphasis on larger scale climatic oscillations, are also summarized in this chapter. Chapter three presents water quality trends and relationships with historic flow patterns. Chapter four identifies and discusses the ecological resources of concern. Chapter five outlines the technical approaches for establishing minimum flows associated with resources of concern. Chapter six presents the results of staff analyses, with minimum flow recommendations for Horse Creek.

1.1. Rationale for Minimum Flows Development

Flowing surface waters provide numerous benefits to society and are an integral part of the natural functioning of ecosystems within Florida. Surface water withdrawals can directly affect the water volume or rate of flow in rivers of the area. Similarly, groundwater withdrawals have the potential to alter groundwater levels and thereby reduce the water volume or flow. These cause-and-effect relationships between water withdrawals and reduced surface water flows have been recognized by the Florida State Legislature in the Florida Water Resources Act of 1972 (Chapter 373, Florida Statutes (F.S.)). As a result of this legislation, the District has the responsibility for establishing minimum flows for all surface watercourses within its boundaries. A minimum flow is defined in Section 373.042(1)(a), F.S., as “the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.”

Based on its importance to the state and region and the existence of withdrawal-related impacts, the District has prioritized the establishment of minimum flows for Horse Creek, a 54-mile watercourse that originates on the northern side of State Road (SR) 62 in Hardee County and flows to the lower Peace River, south of Arcadia in DeSoto County. Horse Creek is one of the six major tributaries to the Peace River that provides a large volume of freshwater inflow to Charlotte Harbor estuary, which opens to the Gulf of Mexico. The creek and its floodplain provide critical habitat for numerous fish, macroinvertebrate, and plant species, which in turn provide food and habitat for various birds, mammals, and other organisms. The District initiated work supporting development of minimum flows for Horse Creek in 2007 and has completed extensive physical, hydrologic and ecological data collection and analysis for the effort over the past sixteen years.

Based on comprehensive analyses, the District has developed recommended minimum flows for Horse Creek. These minimum flows were developed with consideration of and are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule (see Rule 62-40.473, Florida Administrative Code, (F.A.C.)). If adopted by the District's Governing Board, the recommended minimum flows for Horse Creek will be included in the District's Water Levels and Rates of Flow Rules (Chapter 40D-8, F.A.C.). Once effective, the minimum flow rules will support District water-use permitting, environmental resource permitting, water-supply planning and other management activities that afford protection for the creek.

1.2. Legal Directives and Use of Minimum Flows

1.2.1. Relevant Florida Statues and Rules

Flowing surface waters provide numerous benefits to society and are an integral part of the natural functioning of ecosystems within the state of Florida. Surface water withdrawals can directly affect the water volume or rate of flow in rivers. Similarly, groundwater withdrawals have the potential to alter groundwater levels and thereby reduce the water volume or flow in rivers. These cause-and-effect relationships between water withdrawals and reduced flows in surface watercourses have been recognized by the Florida State Legislature through enactment and updates of the Florida Water Resources Act of 1972 (Chapter 373, F.S.) Based on this legislation, the District has the responsibility for establishing minimum flows for all surface watercourses within its boundary. Six primary legal directives guide the District's establishment and implementation of minimum flows:

1. Section 373.042 of The Florida Water Resources Act of 1972 (Chapter 373, F.S.) directs the Department of Environmental Protection (DEP) or the District to establish minimum flows for all surface watercourses in the area. This section states that "the minimum flow and minimum water level shall be calculated by the department and the governing board using the best information available." This statute also establishes the priority list and schedule which is annually updated and approved by the District Governing Board. Section 373.042 also allows for the establishment of an independent scientific peer review panel and use of a final report prepared by a peer review panel when establishing minimum flows and minimum water levels.

2. Section 373.0421, F.S., allows for considerations and exclusions concerning minimum flows or minimum water level establishment, including changes and structural alterations to watersheds, surface waters and aquifers and their effects. In cases where dams, or extensive channelization have altered the hydrology of a system for flood control and water supply purposes, the District attempts to balance protecting environmental values with the human needs that are met by these alterations. This section also requires that recovery and prevention strategies must be adopted and implemented if flows in a water body are not currently meeting or are projected to not meet an applicable minimum flow within the next 20 years. In addition, the periodic and as needed, revision of established minimum flows and minimum water levels is required.

3. Rule 62-40.473 of the Florida Water Resource Implementation Rule (Chapter 62-40, F.A.C.), provides goals, objectives, and guidance regarding the establishment of minimum flows and minimum water levels. This rule identifies the ten environmental values described in section 1.2.2 below that are to be considered when establishing minimum flows and minimum water levels. In recognition of the fact that flows naturally vary, this rule also states that minimum flows should be expressed as multiple flows defining a minimum hydrological regime to the extent practical and necessary.

4. Chapter 40D-8, F.A.C., the District's Water Levels and Rates of Flow Rules, describes the minimum flows established for surface watercourses in the District. Minimimum flows are specifically included in Rule 40D-8.041, F.A.C.

5. Chapter 40D-80, F.A.C., the District's Recovery and Prevention Strategies for Minimum Flows and Levels Rules, sets forth the regulatory portions of the recovery or prevention strategies to achieve or protect, as applicable, the minimum flows and minimum water levels established by the District.

6. Rule 62-41.204(2), F.A.C., the Central Florida Water Initiative Area Uniform Process for Setting Minimum Flows and Minimum Water Levels and Water Reservations Rule, within the Regulation of the Consumptive Use of Water Rules of the DEP (Chapter 62-41, F.A.C.) identifies additional requirements for minimum flow and level prioritization, establishment, and status assessments for certain waterbodies. These water bodies include those within the Central Florida Water Initiative (CFWI) Area, which as defined in Section 373.0465, F.S., includes all of Orange, Osceola, Polk and Seminole counties and southern Lake County. The CFWI is a collaborative water supply planning effort among the St. Johns River, South Florida and Southwest Florida water management districts, the Florida DEP, the Florida Department of Agriculture

and Consumer Services, regional utilities, business organizations, environmental groups, agricultural interests, and other stakeholders (CFWI 2020). Rule 62-41.204(2) (F.A.C.) requires coordination between the DEP, St. Johns River Water Management District, Southwest Florida Water Management District, and the South Florida Water Management District for discussion of water body prioritization for minimum flow, minimum water level and reservation development, and the sharing of information between the three water management districts when seeking to establish or reevaluate minimum flows and levels.

The District's Minimum Flows and Levels Program addresses all relevant requirements expressed in the Water Resources Act of 1972, District rules, and those of the DEP. The District has developed specific methods for establishing minimum flows or minimum water levels for lakes, wetlands, rivers, springs, and aquifers, subjected the methods to independent, scientific peer-review, and in some cases, adopted the methods into its Water Level and Rates of Flow rules. In addition, regulatory components of recovery strategies necessary for the restoration of minimum flows and minimum water levels that are not currently being met have been adopted into the District's Recovery and Prevention Strategies for Minimum Flows and Levels rules (Chapter 40D-80, F.A.C.) and in the District's Consumptive Use of Water rules (Chapter 40D-2, F.A.C.).

A summary of efforts completed for the District's Minimum Flows and Levels Program is provided by Hancock et al. (2010) and SWFWMD (2023b). Additional information pertaining to the establishment and implementation of minimum flows and other related issues is available from the District's Minimum Flows and Levels (Environmental Flows) Program web page at https://www.swfwmd.state.fl.us/projects/mfls, and in CFWI (2020), DEP (2021a), SWFWMD (2020, 2021a,b,c, 2022 and 2023a, b).

1.2.2. Environmental Values

The Florida Water Resource Implementation Rule, specifically Rule 62-40.473, F.A.C., provides additional guidance for the minimum flows and levels establishment, requiring that "…consideration shall be given to natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic and wetlands ecology", including:

a) Recreation in and on the water;
b) Fish and wildlife habitats and the passage of fish;
c) Estuarine resources;
d) Transfer of detrital material;

e) Maintenance of freshwater storage and supply;
f) Aesthetic and scenic attributes;
g) Filtration and absorption of nutrients and other pollutants;
h) Sediment loads;
i) Water quality; and
j) Navigation.

The ways in which these environmental values were considered for development of proposed minimum flows for Horse Creek are discussed in Chapter 6.

1.3. Development of Minimum Flows and Levels

Implementation of the District's Minimum Flows and Levels Program is based on three fundamental assumptions:

1. Alterations to hydrology will have consequences for the environmental values listed in Rule 62.40.473, F.A.C., and Section 1.2.2 of this report.

2. Relationships between some of these altered variables can be quantified and used to develop significant harm thresholds or criteria that are useful for establishing minimum flows and levels.

3. Alternative hydrologic regimes may exist that differ from non-withdrawal impacted conditions but are sufficient to protect water resources and the ecology of these resources from significant harm.

Support for these assumptions is provided by a large body of published scientific work addressing relationships between hydrology, ecology and human-use values associated with water resources (e.g., see reviews and syntheses by Pastor et al. 2014, Poff et al. 1997, Poff and Zimmerman 2010, Postel and Richer 2003, Wantzen et al. 2008). This information has been used by the District and other water management districts within the state to identify significant harm thresholds or criteria supporting development of minimum flows and minimum water levels for over 400 water bodies (DEP 2022a), as summarized in publications associated with these efforts (Flannery et al. 2002, Neubauer et al. 2008) and in minimum flows reports, which may be found at the links provided in Table 1-1.

Table 1-1. Hyperlinks to minimum flows and levels (MFL) documents, including technical reports, from each of the water management districts (WMD) within the state of Florida.

WMD	Hyperlink to MFL Documents
Northwest Florida WMD	https://nwfwater.com/water-resources/minimum-flows-minimum-water-levels/
South Florida WMD	https://www.sfwmd.gov/our-work/mfl
St. Johns River WMD	https://www.sjrwmd.com/documents/mfl/
Suwanee River WMD	https://www.mysuwanneeriver.com/55/Minimum-Flows-and-Minimum-Water-Levels
Southwest Florida WMD	https://www.swfwmd.state.fl.us/projects/mfl/documents-and-reports

With regard to the assumption associated with alternative hydrologic regimes, consider a historic condition for an unaltered river or lake system with no local groundwater or surface water withdrawal impacts. A new hydrologic regime for the system would be associated with each increase in water use, from small withdrawals that have no measurable effect on the historic regime to large withdrawals that could substantially alter the regime. A threshold hydrologic regime may exist that is lower or less than the historic regime, but still protects the water resources and ecology of the system from significant harm. This threshold regime could conceptually allow for water withdrawals, while protecting the water resources and ecology of the area. Thus, minimum flows and minimum water levels may represent minimum acceptable rather than historic or potentially optimal hydrologic conditions.

1.3.1. Flow Definitions and Concepts

To address all relevant requirements of the legal directives associated with minimum flows and aid in the understanding of information presented in this report, we think it is appropriate to elaborate on several flow-related definitions and concepts, including the following.

- Flow or streamflow refers to discharge, i.e., the rate a specified volume of water flows past a point for some unit of time. For minimum flow purposes, flow is typically expressed in cubic feet per second (cfs).

- Long-term, as defined in Rule 40D-8.021, F.A.C., “means an evaluation period used to establish Minimum Flows and Minimum Water Levels, and assess withdrawal impacts on established Minimum Flows and Minimum Water Levels that represents a period which spans the range of hydrologic conditions which can be expected to occur based upon historical records, ranging from high water levels to low water levels." Also, for minimum flow and level purposes, "historic" means a Long-term period when there are no measurable impacts due to withdrawals and Structural Alterations are similar to current conditions."

- Reported flows are directly measured or estimated by a relationship developed using measured flows and water depth or velocity. Examples include measured and estimated flows reported by the United States Geological Survey (USGS) and those available through the District's Environmental Data Portal (EDP). Most reported flows are estimated using velocity and water-depth measurements or regressions or other models developed from empirical measurements. For example, reported flows are typically estimated from measured water levels using rating curves. Reported flows are alternatively referred to as *observed* or *gaged* flows.

- Modeled flows are flows that are derived using a variety of modeling approaches. Examples include flows predicted using numerical groundwater flow models, flows predicted with statistical models derived from either observed or other modeled hydrologic data, and impacted flows adjusted for withdrawal-related flow increases or decreases.

- Impacted flows are flows that include withdrawal-related impacts. Impacted flows can be *reported flows*, and they can also be *modeled flows* based on simulated groundwater withdrawal scenarios.

- Baseline flows are flows that have occurred or are expected in the absence of withdrawal impacts. Baseline flows may be *reported flows* if data exists prior to any withdrawal impacts. More typically, baseline flows are *modeled flows*. Baseline flows are alternatively referred to as *natural, unimpacted, unimpaired* or *historic* flows.

- Minimum flow is defined by the Florida Water Resources Act of 1972 as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area."

- A flow regime is a hydrologic regime characterized by the quantity, timing, and variation of flows in a river. Rule 62-40.473, F.A.C., dictates that "minimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area as provided in Section 373.042(1), F.S."

1.3.2. Baseline Flow Conditions

Use of significant harm criteria for minimum flows development is predicated upon identification of a baseline flow record or records that characterize environmental conditions expected in the absence of withdrawals. For river segments or entire rivers where flows are currently or have not historically been affected by water withdrawals, reported flows for the period without withdrawal effects or, respectively, for the entire period of record can be used as baseline flows. More typically, reported flows are impacted flows that incorporate withdrawal effects, or are available for a limited period, and baseline flows must be modeled.

Once developed, a baseline flow record or records can be used in association with significant harm criteria for identifying potential flow reductions and establishing minimum flows that are not expected to result in significant harm. In some cases, a single baseline flow record is used; in other situations, or for differing analyses, use of two or more baseline flow records is necessary.

1.3.3. Building Block Approach

Building block approaches for environmental flow efforts frequently involve categorization of the flow regime into discrete blocks defined by flow volume and/or day of the year or water year (summarized in Postel and Richter 2003). These blocks are then "assembled" to create a prescribed flow regime that includes necessary elements of the natural flow regime or another specified flow regime.

The District's building block approach has typically involved assessing the potential for significant harm separately within three seasons of the year, including the late spring dry season referred to as Block 1, the summer wet season referred to as Block 3, and an intermediate flow season referred to as Block 2. Our use of these three blocks is based on the typical seasonal variation of flows in streams in west central Florida that are dominated by surface runoff. This seasonal, building block approach allows for the assessment of potential changes in habitat availability and other environmental values for periods of relatively higher or lower flows, when they may be most critical for maintaining ecological structure and function or exhibit increased sensitivity to flow reductions (Flannery et al. 2002).

For some baseflow-dominated systems, for example, short, coastal rivers where discharge from spring vents accounts for much of the flow, use of a seasonal, building block approach may not be necessary. In addition, association of blocks with specific flow ranges, which typically, but not always correspond with seasonal periods, may be appropriate for establishing minimum flows for some systems.

In the past, the building block approach for characterizing flow regimes was based on fixed dates. However, the fixed-date approach for block definition is not currently considered appropriate for representing seasonal flow regimes for a system in years when annual flows remain high or low relative to historical conditions. To address this issue, the District has begun using flow-based blocks that correspond with typical low (Block 1), medium (Block 2), and high (Block 3) flows to develop minimum flows. This approach was successfully used for the reevaluation of minimum flows for the Lower Peace River (Ghile et al. 2021) and was strongly supported by findings of the independent peer review panel that contributed to that effort (Bedinger et al. 2020). The approach is also being used for the recommended minimum flows for the Little Manatee River (Holzwart et al. 2023). As described in Section 5.2 of this report, flow-based blocks were used for the development of proposed minimum flows for Horse Creek.

1.3.4. Low Flow Threshold

Criteria used to establish low flow thresholds in freshwater rivers include fish passage depths or potential changes in wetted perimeter (i.e., the width of the stream bottom and banks in contact with water for a stream channel cross-section). A low flow threshold associated with maintaining adequate freshwater flows to protect numerous environmental values is proposed for Horse Creek.

1.3.5. Significant Harm and 15 Percent Change Criteria

Significant harm is the criterion on which the establishment of minimum flows must be made to protect the water resources and ecology of the area, but no definition of significant harm is provided in the Water Resources Act of 1972 or the Water Resource Implementation Rule. This makes the District or DEP responsible for determining the conditions that constitute significant harm in each priority water body within the District.

Criteria for setting minimum flows are selected based on their relevance to environmental values identified in the Water Resource Implementation Rule and confidence in their predicted responses to flow alterations. The District uses a weight-of-evidence approach to determine if the most sensitive assessed criterion is appropriate for establishing a minimum flow, or if multiple criteria will be considered collectively.

For criteria selection and use, the District uses natural breakpoints, inflections, or thresholds when available. For example, in perennially flowing freshwater systems, a water depth of 0.6 feet (0.18 meters) may be used to establish a minimum low flow threshold for promoting fish passage and flow continuity. Another threshold-based criterion used for flowing freshwater systems is the lowest wetted perimeter inflection point (LWPIP), where inflections in curves relating flow and wetted perimeter are used to determine threshold flows for significant harm.

When natural breakpoints, inflections, or thresholds are not available, the District has used a presumptive 15% habitat or resource-reduction standard as a criterion for significant harm. The basis for the management decision to equate a 15% change to significant harm lies, in part, with a recommendation put forth by the peer-review panel that considered the District's proposed minimum flows for the Upper Peace River. In their report, the panelists note that "In general, instream flow analysts consider a loss of more than 15% habitat, as compared to undisturbed or current conditions, to be a significant impact on that population or assemblage" (Gore et al. 2002). The panel's assertion was based on consideration of environmental flow studies employing the Physical Habitat Simulation System (PHABSIM) for analyzing flow, water depth and substrate preferences that define aquatic species habitat availability. More than twenty peer review panels have evaluated the District's use of the 15% standard for significant harm (review reports are available at https://www.swfwmd.state.fl.us/projects/mfl/documents-and-reports). Although they have questioned its use, these panels have generally been supportive of the use of a 15% change criterion for evaluating effects of potential flow reductions on habitats or resources when determining minimum flows.

Potential loss of habitats and resources in other systems has been managed using methods other than the 15% resource reduction standard. In some cases, resources have been protected less conservatively: habitat loss > 30% compared with historical flows (Jowett 1993) and preventing > 20% reduction to historical commercial fisheries harvests (Powell et al. 2002). Dunbar et al. (1998) note, "… an alternative approach is to select the flow giving the 80% habitat exceedance percentile," which is equivalent to an allowable 20% decrease from baseline conditions. More recently, the Nature Conservancy proposed that in cases where harm to habitat and resources is not quantified, presumptive standards of 10% to 20% reduction in natural flows will provide high to moderate levels of protection, respectively (Richter et al. 2011).

Gleeson and Richter (2017) suggest that “high levels of ecological protection will be provided if groundwater pumping decreases monthly natural baseflow by less than 10% through time.” Presumptive flow-based criteria such as these assume that resources are protected when more detailed relationships between flow and resources of interest are not available. Habitat- or resource-based presumptions of harm are based on data and analyses linking incremental reductions in flow to reductions in resources or habitats. As such, the 15% habitat- or resource-based standard makes more use of the best available information than a presumptive, flow-based criterion would. In the absence of natural breakpoints, inflections, or thresholds, the 15% presumptive habitat or resource-based standard for significant harm represents the District’s best use of the best available information.

1.3.6. Percent-of-flow Method

Through use of 15% habitat or resource-reduction standards, the District has typically incorporated percent-of-flow methods into its building-block approach for establishing minimum flows. The percent-of-flow method is considered a “top-down” approach (Arthington et al. 1998, Brizga et al. 2002, Arthington 2012), in that modeled scenarios involving incremental reductions in baseline flows and resultant changes in important ecological parameters are evaluated to determine the flow reductions that would potentially result in significant harm to the river. The percent-of-flow method is regarded as a progressive method for water management (Alber 2002, Postel and Richter 2003, National Research Council 2005, Instream Flow Council 2002). A goal for use of the percent-of-flow method is to ensure that temporal patterns of the natural flow regime of the river are largely maintained, with some allowable flow reductions for water supply.

The District has successfully used a percent-of-flow method, often in combination with a low flow threshold, to establish minimum flows for numerous flowing systems including the Upper and Lower Alafia River, Upper and Lower Anclote River, Upper Braden River, Chassahowitzka River/Chassahowitzka Spring Group, Crystal River/Kings Bay Spring Group, Gum Slough Spring Run, Homosassa River/Homosassa Spring Group, Upper Hillsborough River, Upper and Lower Myakka River, Middle and Lower Peace River, Upper and Lower Pithlachascotee River, Upper and Lower Manatee River, Lower Shell Creek, Rainbow River/Rainbow Spring Group and Weeki Wachee River/Weeki Wachee Spring Group.

Minimum flows developed using the percent-of-flow method allow permitted surface-water users to withdraw a percentage of streamflow at the time of the withdrawal and permitted groundwater users to potentially reduce baseline flows by prescribed percentages on a longer-term basis. By proportionally scaling water withdrawals to the rate of flow, the percent-of-flow method minimizes adverse impacts that could result from withdrawal of large volumes of water during low flow periods, especially when river systems may be vulnerable to flow reductions. Similarly, larger volumes may not be available for withdrawal during periods of higher flows to protect floodplain inundation.

The percent-of-flow approach has been effectively implemented for numerous permitted surface water withdrawals within the District, including those associated with water-supply withdrawals from the Peace River, Alafia River, and Little Manatee River. These withdrawals are typically based on a percentage of the previous day's average flow. Applications of the percent-of-flow method for regulation of groundwater withdrawals involve different considerations that must account for the gradual and more diffuse manner that changes in groundwater levels are manifested in changes in streamflow. The percent-of-flow method has, however, been successfully implemented to regulate groundwater withdrawals throughout the District.

1.3.7. Adaptive Management

Adaptive management is a standard approach for reducing the inherent uncertainty associated with natural resource management (Williams and Brown 2014) and is recommended by the U.S. Department of the Interior for decision making in the face of uncertainty about management impacts (Williams et al. 2009). Adaptive management is a systematic, iterative approach to meeting management objectives in the face of uncertainty through continued monitoring and refinement of management actions based on consideration of alternatives and stakeholder input (Herrick et al. 2019).

Continued adaptive management will require: ongoing monitoring of water quality, water flows and levels, biological communities, and land use changes in the watershed; status assessments of the current minimum flows and evaluation of compliance with permitted withdrawal requirements; and periodic reevaluation of all minimum flows that are ultimately adopted for Horse Creek.

1.4. Vertical Datums

The District has recently converted from use of the National Geodetic Vertical Datum of 1929 (NGVD 29) to use of the North American Vertical Datum of 1988 (NAVD 88) for measuring and reporting vertical elevations. In some circumstances within this document, elevation data that were collected or reported relative to mean sea level or relative to NGVD 29 are converted to elevations relative to NAVD 88. All datum conversions were derived using the Corpscon 6.0 software distributed by the United States Army Corps of Engineers.

CHAPTER 2 - PHYSICAL AND HYDROLOGIC DESCRIPTION

This chapter describes the Horse Creek watershed including the location, land use, soils, climate, streamflow, hydrogeology and aquifer levels relevant to the development of minimum flows for Horse Creek.

2.1. Description of the Watershed

The Horse Creek watershed (Figure 2-1), as defined by the USGS Hydrologic Unit Code (HUC) 0310010108, encompasses approximately 242.59 square miles (628 square kilometers). It extends from approximately 1.55 miles (2.5 kilometers) northwest of the juncture of Hillsborough, Polk, Manatee, and Hardee counties to the confluence of Horse Creek and the Peace River in DeSoto county, draining the western portion of the Peace River watershed.

The physiographic setting of the watershed is described by the Polk Uplands (100-130 feet in elevation) at the headwaters of the creek, DeSoto Plain (30-100 feet in elevation) throughout the middle of the watershed, and Gulf Coastal Lowlands (30-40 ft) near the creek's confluence with the Peace River (Lewelling 1997, White 1970; Figure 2-2). In general, subbasins within the steeper DeSoto Plain have higher runoff potentials than those in the other physiographic zones (Lewelling 1997). The USGS National Hydrography Dataset identifies seven tributaries to Horse Creek in the Geographic Names Information System, listed from upstream to downstream in the watershed at the point of convergence with Horse Creek: West Fork Horse Creek, Elder Branch, Brushy Creek, Lettis Creek, Osborn Branch, Brandy Branch, and Buzzard Roost Branch (Figure 2-2). Two northern tributaries (West Fork Horse Creek and Brushy Creek are ditched, resulting in rapid flows, while the southern tributaries of Brandy Branch and Buzzard Roost Branch are slower and more meandering (PBS&J, Inc. 2007).

The Horse Creek channel is approximately 54 miles (87 kilometers) long, originating north of Florida SR 62, east of Duette in Hardee County, and joining the Peace River north of County Road 761 in DeSoto county. Its confluence with the Peace River is approximately 2.93 river miles (4.71 kilometers) upstream from the Peace River Water Treatment Facility, operated by the Peace River Manasota Regional Water Supply Authority. Horse Creek is a significant tributary to the Peace River, with a mean daily discharge of 185 cfs as measured from May 1950 through December 2021 at the USGS Horse Creek at SR 72 near Arcadia, FL (Number (No.) 02297310) gage.

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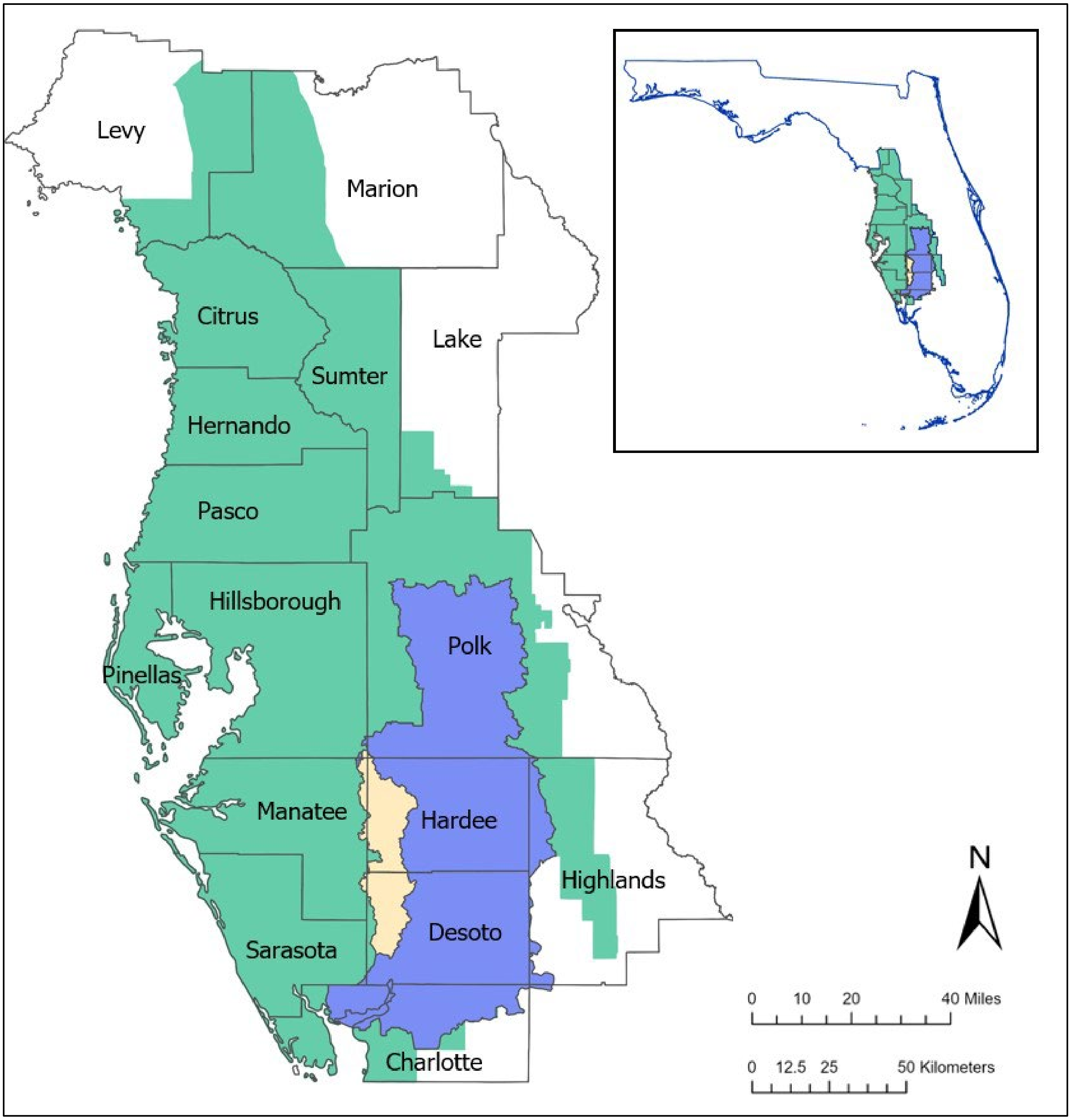

Figure 2-1. Location of the Horse Creek watershed (yellow) within the Peace River watershed (blue), the District boundary (green), and the state of Florida (inset map).

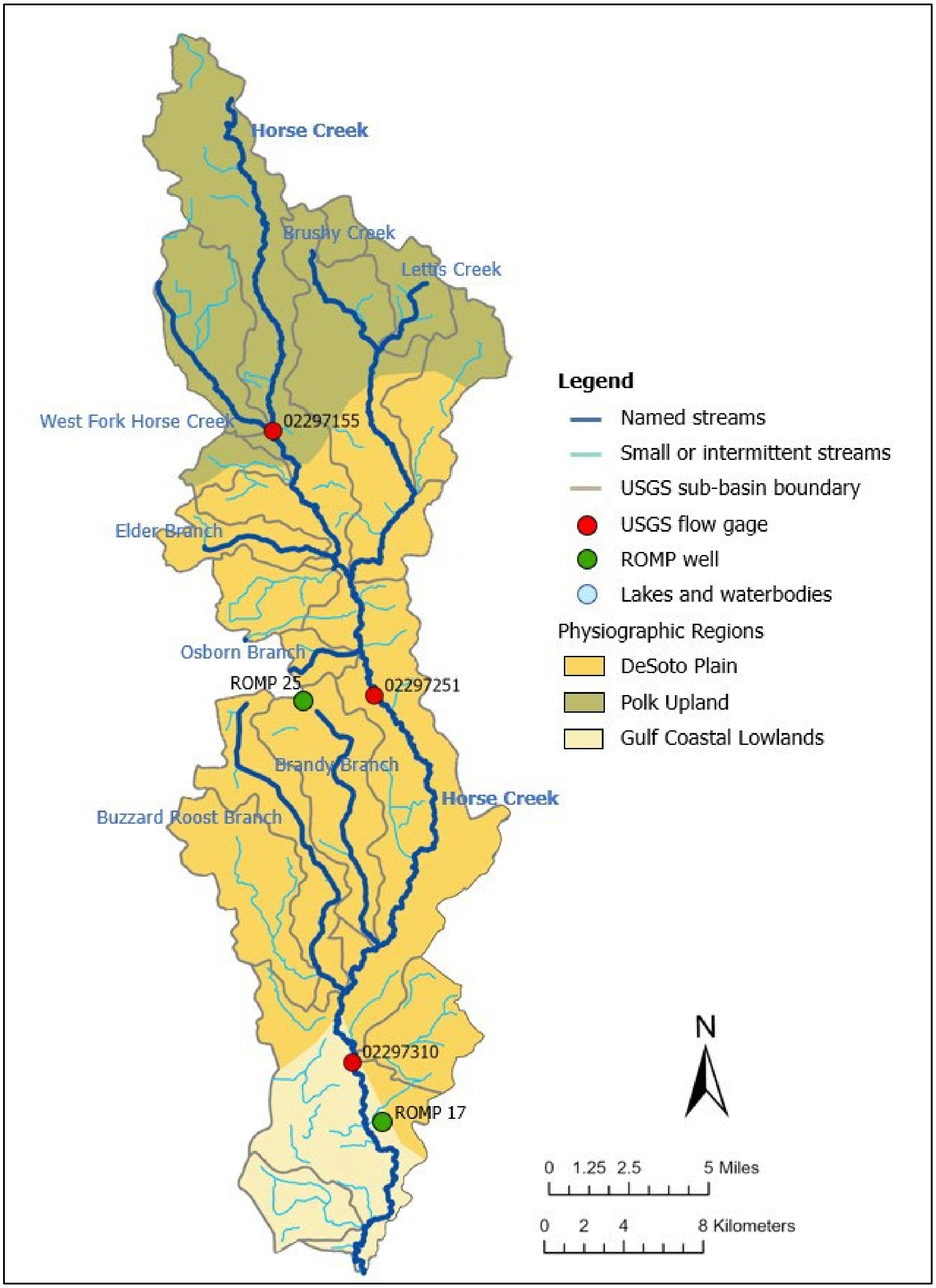

Figure 2-2. Map of the Horse Creek watershed showing the Horse Creek mainstem, named tributaries, smaller and intermittent streams, USGS drainage sub-basins, USGS gage stations, SWFWMD Regional Observation and Monitor-well Program (ROMP) wells, and physiographic regions (source: GIS layer files maintained by the District (SWFWMD 2019b, d)).

2.2. Land Use and Cover

The Florida Land Use, Cover and Forms Classification System (FLUCCS) is a hierarchical method for classifying land information with increasing levels of specificity, derived from photointerpretation of aerial data (FDOT 1999). Level 1 codes divide land use into eight broad categories, including industrial, agricultural, and wetlands. Level 4 codes are more specific and contain subcategories such as extractive mining (within the Level 1 industrial classification) or row crops (under the Level 1 agricultural designation). Since the adoption of FLUCCS by the Florida Department of Transportation (FDOT), different state water management districts have modified their codes slightly, particularly at the finer-scale designations. Details of the classifications used by the District can be found in the Photo Interpretation Key for Land Use Classification (SWFWMD 2014).

In this chapter, FLUCCS Level 1 data are used to coarsely describe the watershed and Level 4 data are used to better describe extractive and reclaimed lands within the Urban Level 1 description and to calculate the Landscape Development Index (LDI). Additional data regarding mandatory phosphate mined units and their reclamation status obtained from the DEP are presented and discussed.

2.2.1. Changes in Land Use Over Time

Agriculture has historically dominated land use in the Horse Creek watershed and as of 2020, 41.22% of land was designated as agricultural (Table 2-1; Figures 2-3 and 2-4). Primary agricultural use includes pastures for cattle grazing, hay, or sod production, and citrus groves, especially orange groves (Figure 2-5; USDA 2022). Other crops grown in the watershed include sweet corn, blueberries, sugarcane, and peaches (USDA 2022).

The Florida Department of Agriculture and Consumer Services (FDACS) Office of Agricultural Water Policy has developed the Florida Statewide Agricultural Irrigation Demand (FSAID) Geodatabase as a repository for agricultural water use projections through 2045 (Balmorial Group 2022, FDACS 2022). Approximately 25.99 square miles of agricultural land within the Horse Creek watershed were irrigated in 2020, primarily for the production of citrus, vegetable crops, and sod (Figure 2-6). In 2045, this irrigated area is projected to decrease by 0.05% (Figure 2-6). The amount of water used in irrigated areas is projected to increase by 0.81 million gallons per day (mgd) from 15.04 mgd in 2020 to 15.85 mgd in 2045.

Approximately 113 water use permits for irrigated areas, issued by the SWFWMD, are active in the Horse Creek watershed, as of August 2023. Of these permits, the majority (n = 92) include citrus, irrigated by low volume spray. The bulk of irrigated fruit and vegetable crops (blueberries, melons, eggplants, tomatoes, and squash) were listed as irrigated by drip with plastic. Permits for commercial hay fields indicated irrigation by seepage and sod permits specified either irrigation by fully enclosed seepage (47% of permitted water for sod irrigation), seepage without plastic (27%) or other methods including low volume spray and center pivot.

The introduction of extractive mining north of SR 64 in the 1980s significantly changed land use classifications in the northern Horse Creek watershed (Figures 2-3, 2-4, and 2-7). This has resulted in the conversion of largely rangeland (scrub and prairie-like habitats) and agricultural land to mined land (Flatwoods Consulting Group (Flatwoods) 2021).

There are seven mines at least partially within the Horse Creek watershed, all of which are active except for the planned DeSoto mine (Figure 2-8). As of 2020, roughly 12% of the the Horse Creek watershed has been mined (Flatwoods 2021; Figure 2-9). Phosphate waste disposal sites, including clay settling areas, can be found throughout the northern portion of the watershed (Figure 2-10).

Since 1975, Florida state law has required the reclamation of land mined for phosphate including contouring, protecting water quality and quantity, revegetation of the area, and returning wetlands to their pre-mining state (Part II of Chapter 378, F.S., and Chapter 62C-16, F.A.C). It typically takes three years for reclaimed herbaceous wetlands to meet reclamation criteria and 15 years for forested wetlands to do so (Flatwoods 2021). As of 2019, approximately 22% of the disturbed mandatory phosphate mined areas had been reclaimed, 11% were in progress, and 67% were designated as future work (Figure 2-11).

Table 2-1. Land use change in the Horse Creek watershed from 1990 to 2020 by Florida Land Use, Cover and Forms Classification System (Level 1) designations in terms of area (in square miles (mi^2)) and as a percentage of the total area. The subset of Level 1 Urban and Built-Up lands classified as "Extractive" and "Reclaimed" according to Level 4 designations are included.

	1990		1999		2010		2020	
Land Use and Cover (Level)	**Area (mi^2)**	**Percent of Total (%)**	**Area (mi^2)**	**Percent of Total (%)**	**Area (mi^2)**	**Percent of Total (%)**	**Area (mi^2)**	**Percent of Total (%)**
Urban (1)	4.65	1.92	16.60	6.84	31.83	13.12	41.36	17.05
Extractive (4)	1.27	0.52	13.09	5.40	18.59	7.66	28.12	11.59
Reclaimed (4)	0.0	0.0	0.0	0.0	4.39	1.81	4.26	1.76
Agriculture (1)	113.18	46.65	113.20	46.66	104.98	43.28	100.00	41.22
Rangeland (1)	41.14	16.96	29.68	12.24	24.72	10.19	22.33	9.20
Upland Forests (1)	37.79	15.58	36.35	14.98	18.63	7.68	18.43	7.60
Water (1)	0.30	0.12	0.61	0.25	1.07	0.44	1.07	0.44
Wetlands (1)	45.33	18.69	45.99	18.96	60.95	25.12	58.75	24.22
Barren Land (1)	0.03	0.01	0.03	0.01	0.21	0.09	0.38	0.16
Transportation, Utilities (1)	0.18	0.07	0.13	0.06	0.20	0.08	0.26	0.11

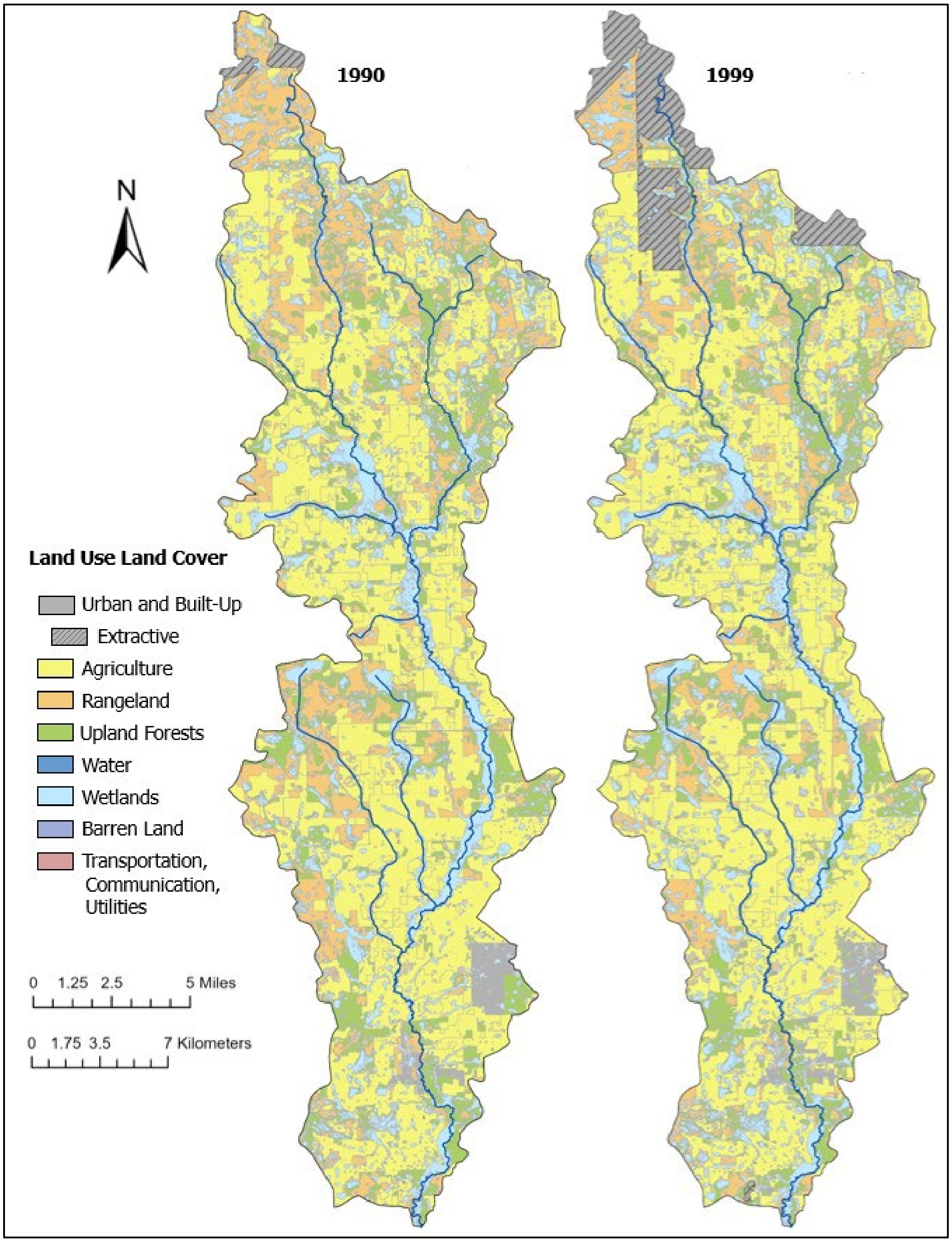

Figure 2-3. The 1990 (left) and 1999 (right) Florida Land Use, Cover and Forms Classification System (Level 1) land designations within the Horse Creek Watershed. The subset of Level 1 Urban and Built-Up lands classified as "Extractive" with Level 4 codes are also shown, to demonstrate the expansion of phosphate mining throughout the northern portion of the watershed over time (source: GIS layer files maintained by SWFWMD (2003a, 2003b)).

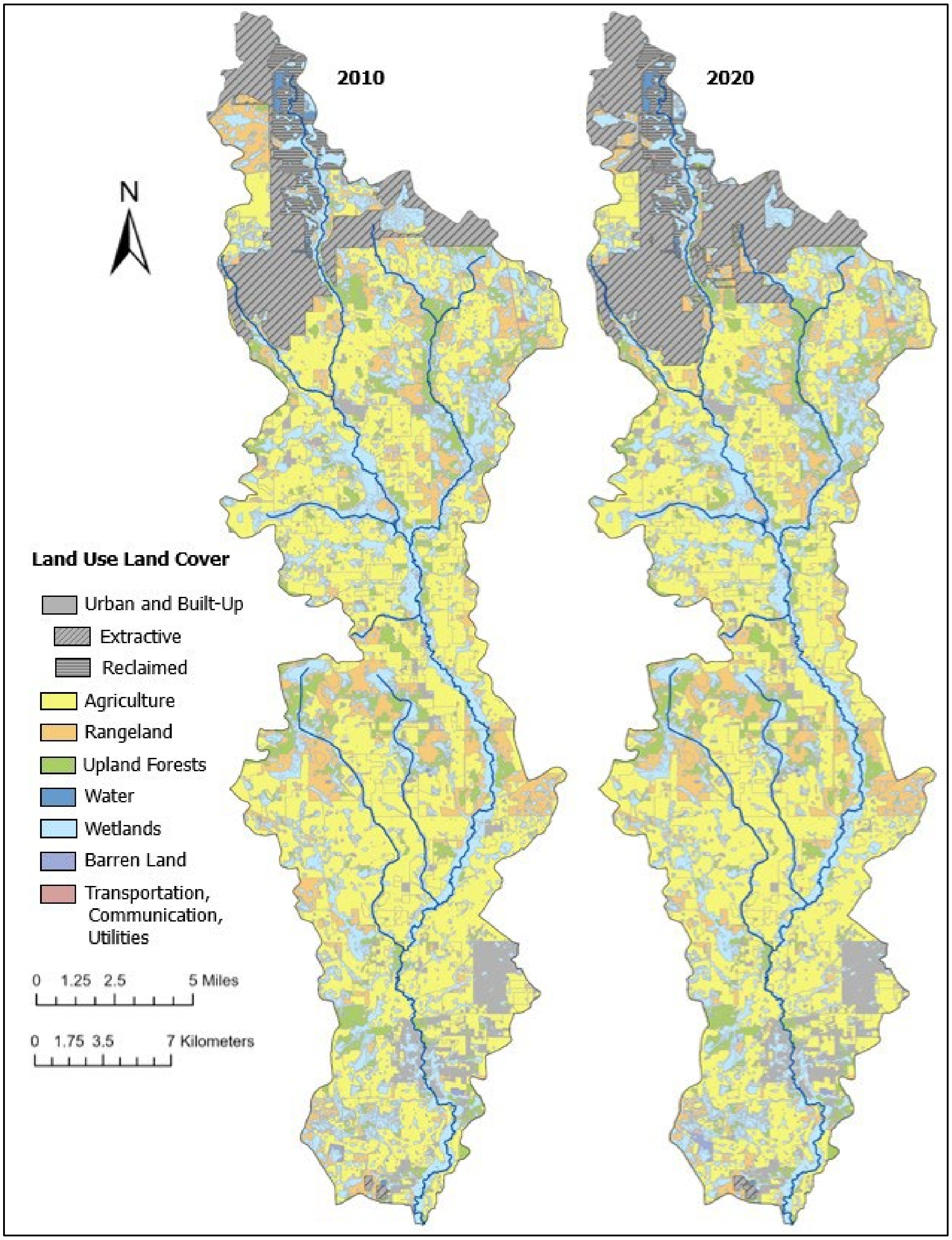

Figure 2-4. The 2010 (left) and 2020 (right) Florida Land Use, Cover and Forms Classification System (Level 1) designations within the Horse Creek Watershed. The subset of Level 1 Urban and Built-Up lands classified as "Extractive" and "Reclaimed" with Level 4 codes are also shown, to demonstrate the expansion of phosphate mining throughout the northern portion of the watershed over time (source: GIS layer files maintained by SWFWMD (2011, 2021d)).

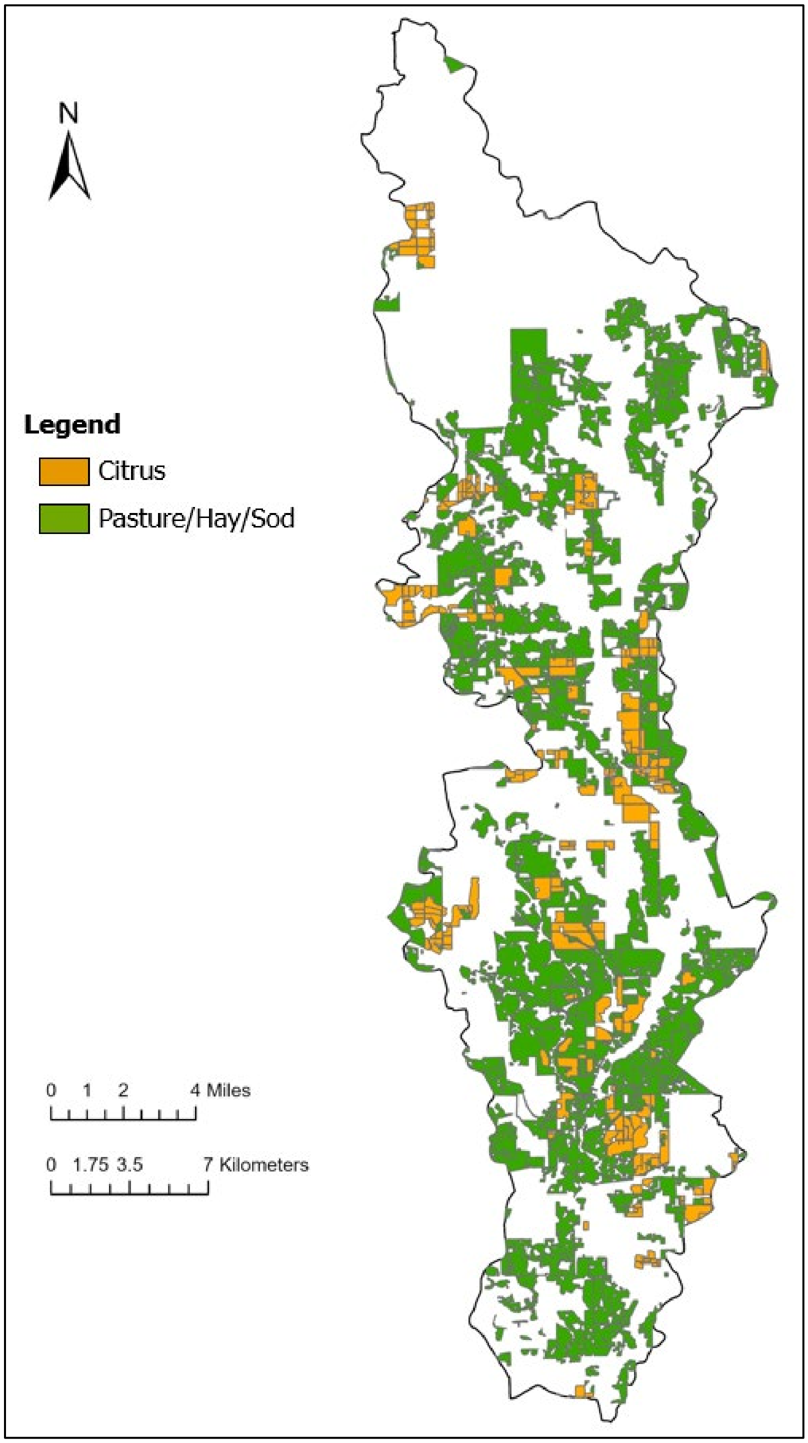

Figure 2-5: Primary agricultural use in the Horse Creek watershed include: pastures for cattle grazing, hay, and sod production (green) and citrus groves (orange; source: GIS layer files maintained by the Florida Department of Agriculture and Consumer Services (FDACS 2022)).

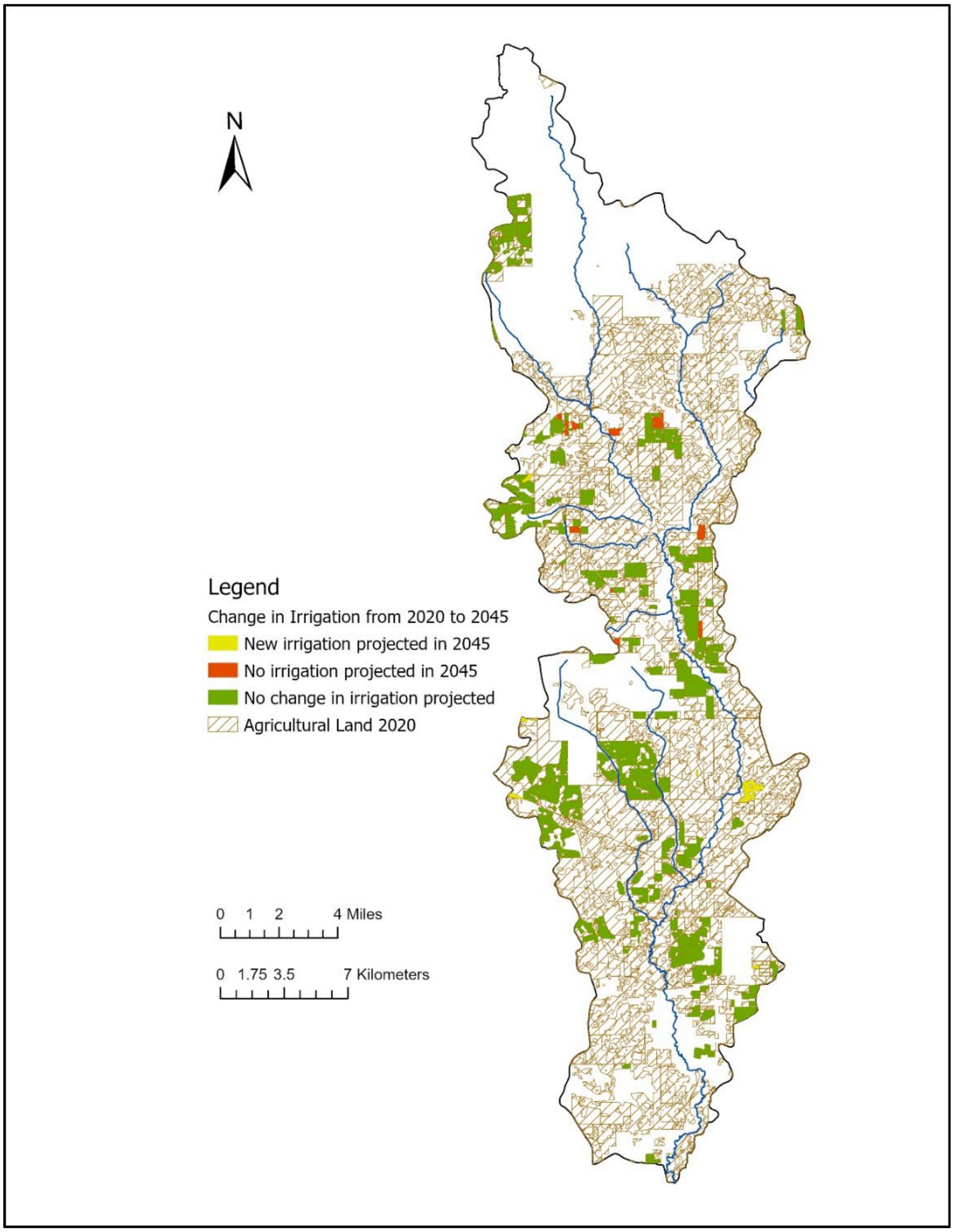

Figure 2-6. Projected changes in irrigated agricultural lands from 2020 to 2045. Irrigated lands identified by the Florida Department of Agriculture and Consumer Services (FDACS) are contained in the yellow, red, and green polygons. The color of these polygons indicates the projected change in irrigation status in 2045 as compared to 2020. All agricultural lands identified by FDACS are shown within the brown hatched polygons (source: GIS files maintained by FDACS (2022)).

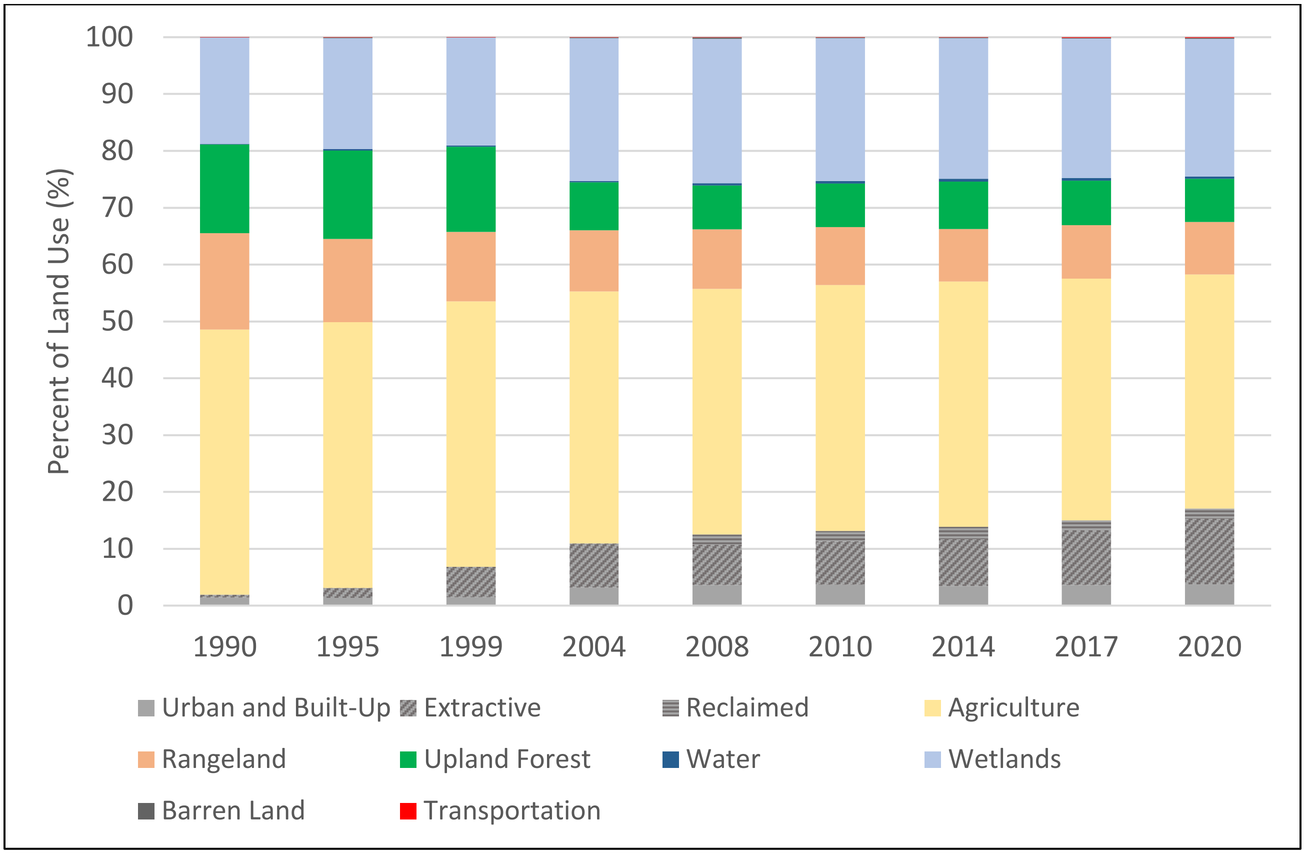

Figure 2-7. The change in percent composition of land use over time in the Horse Creek watershed, derived from Florida Land Use, Cover and Forms Classification System Level 1 Codes. The subset of Level 1 Urban and Built-Up lands classified as "Extractive" and "Reclaimed" with Level 4 codes are also shown, to demonstrate the impact of phosphate mining throughout the watershed over time (source: GIS layer files maintained by SWFWMD).

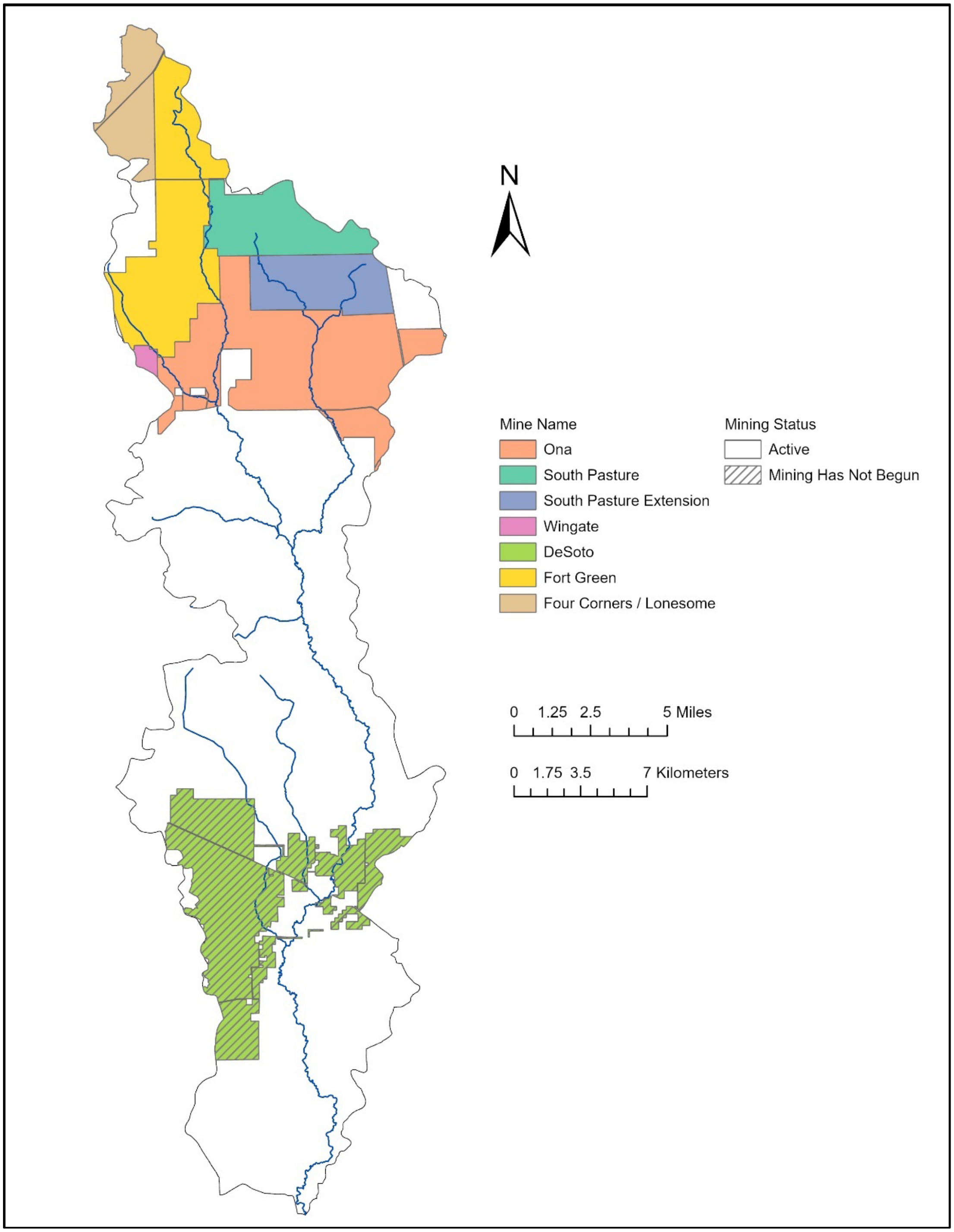

Figure 2-8. Phosphate mine boundaries with their mining status in the Horse Creek watershed (source: GIS layer maintained by the DEP (2021a).

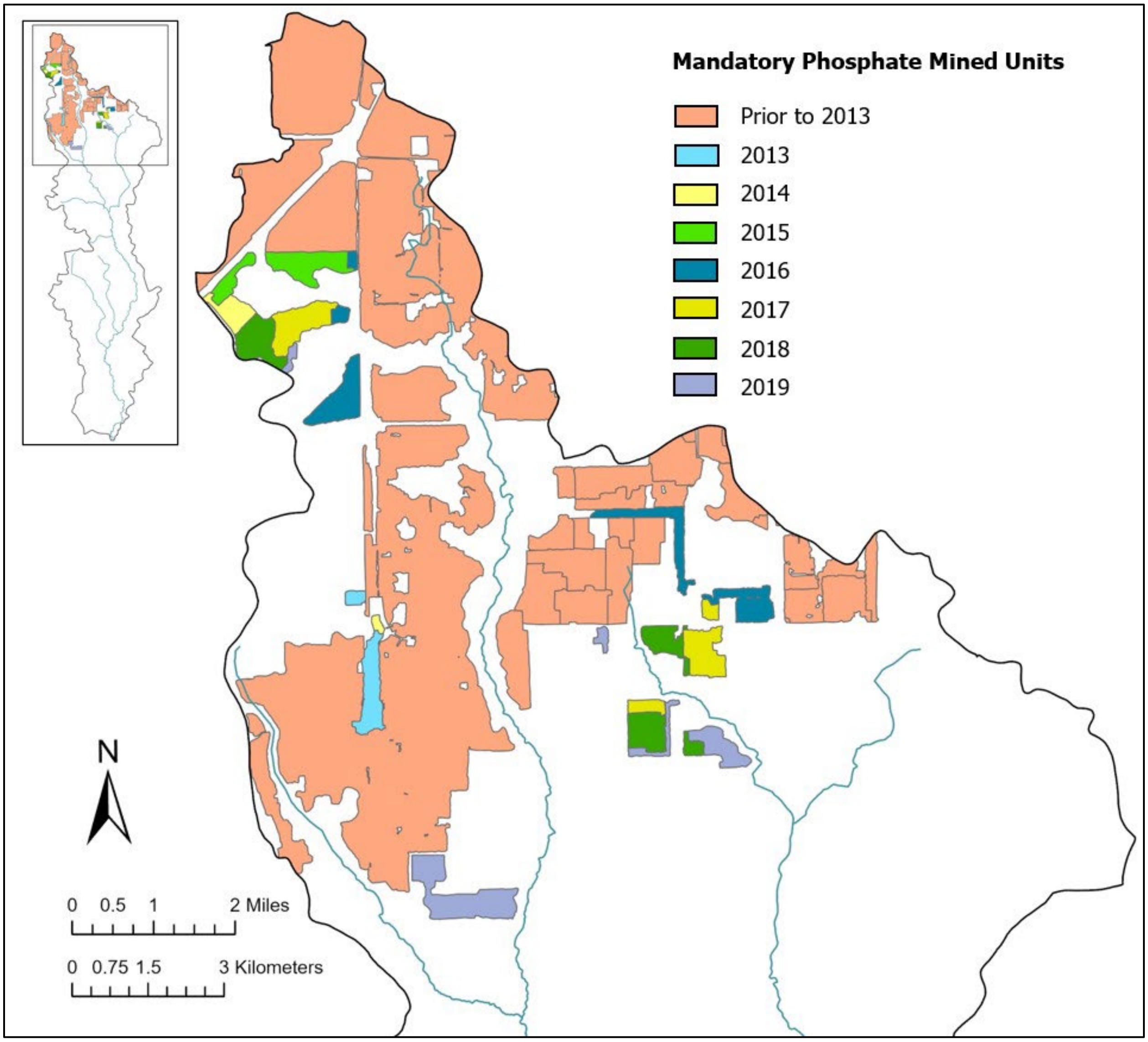

Figure 2-9. The location of conceptual mined area boundaries for all active phosphate mines within the northern Horse Creek watershed and relative to the entire watershed (inset map). "Mandatory" is a designation used by the DEP to indicate the regulatory status of the land and does not specify that the area is required to be mined, though it must be reclaimed should mining occur (source: GIS layer files maintained by DEP (2021b)).

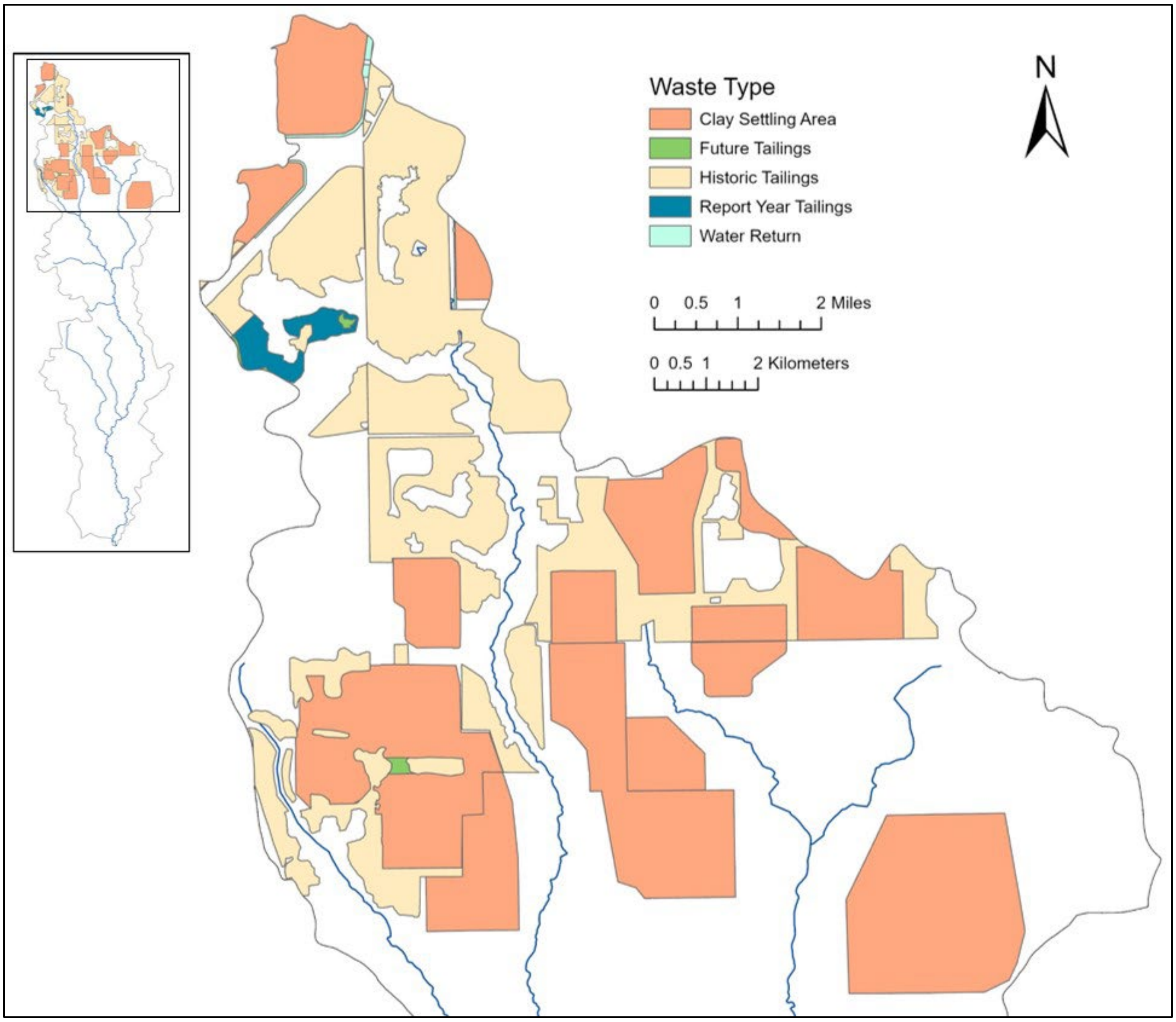

Figure 2-10. Phosphate waste disposal sites within the northern Horse Creek watershed and relative to the entire watershed (inset map; source: GIS layer maintained by the DEP (2021d)).

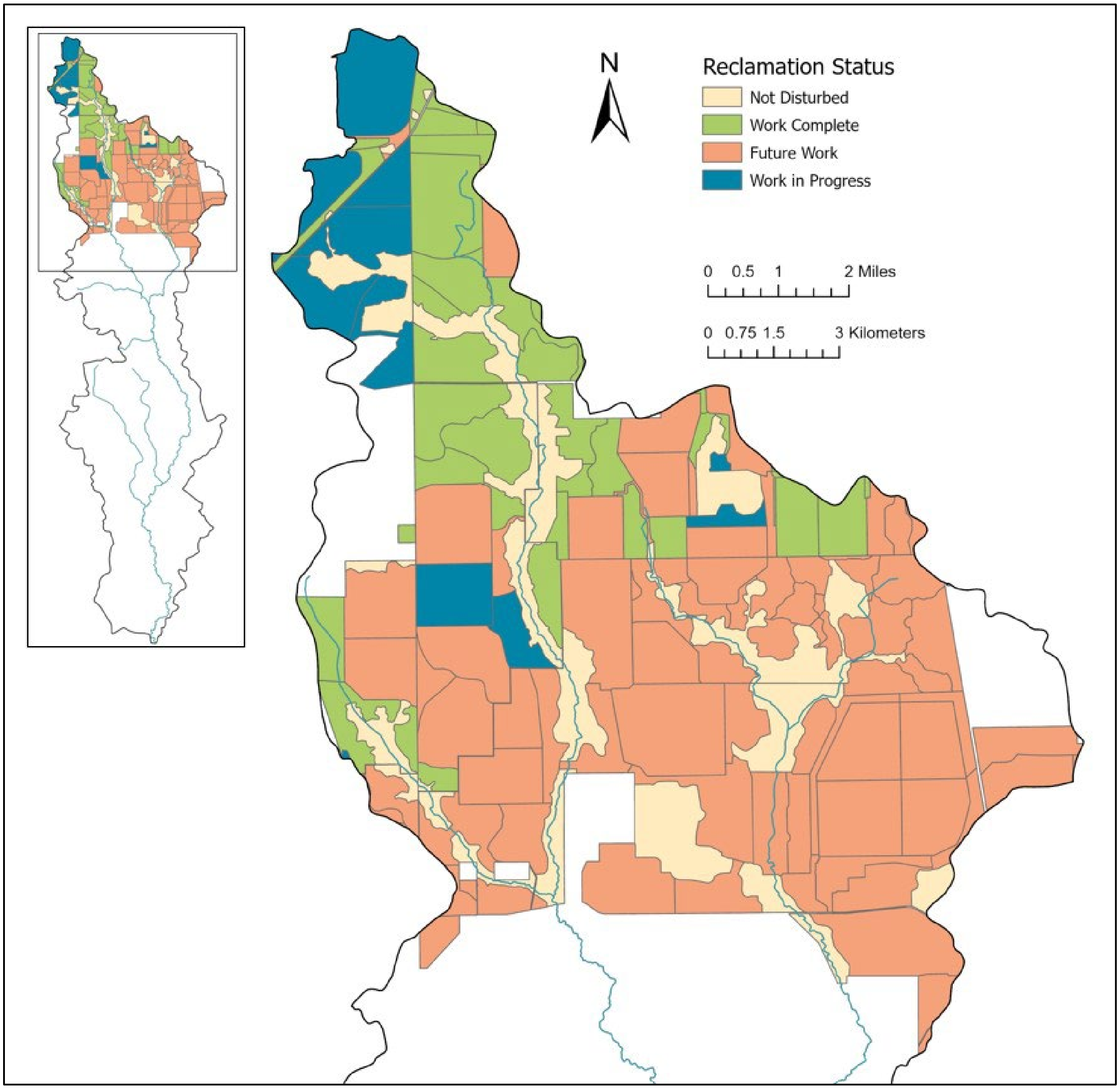

Figure 2-11. The reclamation status of mandatory phosphate lands as of 2019 in the northern Horse Creek watershed and relative to the entirse watershed (inset map; source: GIS layer files maintained by the DEP (2021c)).

2.2.2. Landscape Development Index

The LDI of the DEP Bioassessment Program (see information available at https://floridadep.gov/program-content/DEAR/Bioassessment) is a method to quantify levels of anthropogenic disturbance on ecological systems within a watershed and can be applied at many scales. Generally, the more intensive the human activity, the greater the negative impact on ecological processes. Many landscapes are patchy, with a mixture of developed and natural lands. In such cases, natural lands and their associated ecosystems can experience secondary impacts originating from areas with higher human disturbance, such as the runoff of nutrients through surface or groundwater. To calculate the LDI of an area, areas of a particular land use classification are multiplied by an LDI energy coefficient and the resulting values for all land use classifications are summed in the evaluated catchment. The energy coefficients consider the amount of non-renewable energy used per unit area, including the consumption of electricity, fuels, fertilizers, pesticides, public water supply, and water used for irrigation (Brown and Vivas 2005).

The LDI was calculated at two scales within the Horse Creek watershed: for the entire watershed and for the 100-meter buffer around the main channel and seven main tributaries. Land use and land cover data were obtained from 2020 Level 4 FLUCCS codes, available from the District (SWFWMD 2021d). Where FLUCCS descriptions did not exactly match those described by Brown and Vivas 2005, a best approximation was made by either averaging LDI coefficients for similarly classified areas, or by assigning the value associated with the most intensive probable use. The LDI for the buffered main stem and tributaries of Horse Creek was calculated as 1.63, indicative of a minimally disturbed watershed (Brown and Vivas 2005). This is largely due to natural land classifications, such as stream bottomlands, hardwoods, and marshes accounting for 85% of the area within the 100-meter buffer surrounding the creek channel. When LDI was instead calculated for the entire watershed, the LDI score was 3.28, indicative of a basin primarily dominated by agricultural use (Brown and Vivas 2005).

2.2.3. Conservation Land

In 2023, the DEP completed a purchase of an 11,958-acre conservation easement within the Horse Creek Ranch Florida Forever project (DEP 2022b). The District purchased development rights to the remaining acreage of the 16,316-acre parcel that surrounds a 5.3-mile stretch of the middle of Horse Creek (DEP 2022b; Figure 2-12). The goal of this land acquisition was to enhance natural communities and provide habitat protection for rare species, while providing a buffer for Horse Creek. Approximately 10 miles of the southernmost portion of the Horse Creek runs through or adjacent to the Peace River State Forest. Other Florida-managed conservation lands, conservation easements, and Florida Forever Board of Trustees projects exist throughout the watershed and along the mainstem of the creek (Figure 2-12).

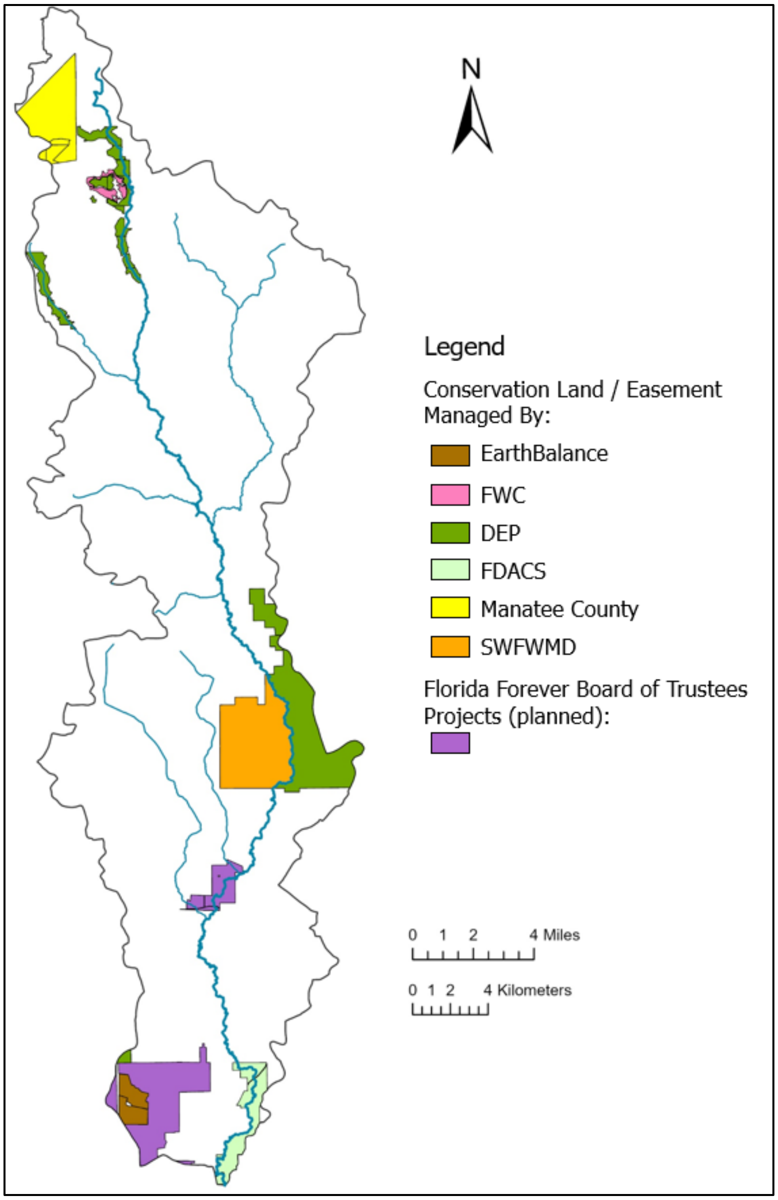

Figure 2-12: Conservation land, conservation easements, and planned Florida Forever Board of Trustees Projects within the Horse Creek Watershed, with their managing agency including: EarthBalance mitigation banks, the Florida Fish and Wildlife Conservation Commission (FWC), the Florida Department of Environmental Protection (DEP), the Florida Department of Agirculture and Consumer Services (FDACS), and the District (SWFWMD). Sources include GIS layers from the Florida Natural Areas Inventory (FNAI) including Florida Conservation Lands (2022a), Florida Forever Board of Trustees Projects (2022b), and Florida Managed Areas (2022c) and layers from the DEP including FL-SOLARIS/CLEAR Conservation Easements (2018a) and FL-SOLARIS/CLEAR Conservation Owned Lands (2018b)).

2.3. Soils

Soils in the United States can be assigned to one of four main hydrologic groups (A, B, C, and D) based upon estimated runoff potential. Group A soils have a low runoff potential when thoroughly saturated and have a high infiltration rate. This includes well-drained sands or gravelly sands. Group B soils have a moderate infiltration rate when thoroughly wet and include moderately well-drained soils with a moderately fine to coarse texture. Group C soils have a slow infiltration rate and higher runoff potential when thoroughly wet and include soils with an underlying layer that hinders water transmission. Group D soils have very high runoff potential when thoroughly wet and low infiltration. This group includes clays, soils with a high water table, and shallow soils overlying impervious materials. Soils can also be classified into one of three dual classes (A/D, B/D, or C/D) based on their saturated hydraulic conductivity and the water table depth when drained. In such instances, the first letter indicates the properties of drained areas and the second describes undrained areas (USDA 2016).

The Horse Creek watershed is primarily composed soils classified as A/D (53.19%) and B/D (30.17%; Figure 2-13). The majority of these soils (89%) were described as “sand” to “fine sand,” 4% were described as “frequently flooded” complexes, and 3% were described as “muck.” Soil saturation is common and infiltration to the surficial aquifer is low throughout much of the watershed (SWFWMD 2000). Mining and reclamation activities may impact the runoff potential of affected lands.

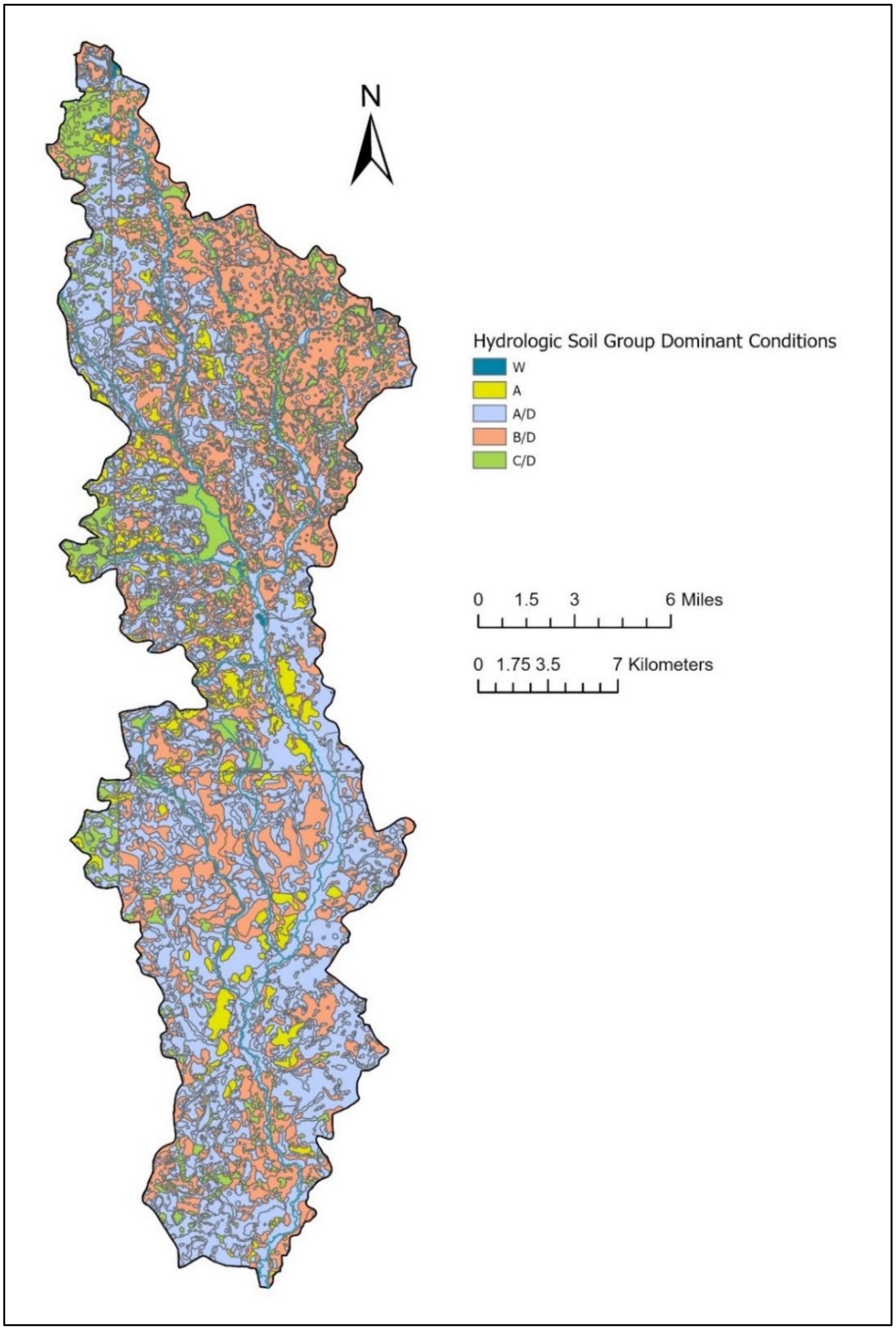

Figure 2-13. Hydrologic soil groups in the Horse Creek watershed. Soil groups are defined as A = high infiltration rate/low runoff, B = moderate infiltration rate, C = slow infiltration rate, D = very slow infiltration rate/high runoff potential. If soil is assigned to a dual hydrologic group, the first letter describes conditions in drained areas and the second describes undrained areas. A classification of "W" is indicative of water (source: GIS layer files maintained by SWFWMD (2019c)).

2.4. Climate

The climate of central Florida is classified as humid subtropical and is characterized by warm, relatively wet summers and mild dry winters. The mean annual temperature in the region ranges from 91°F in July and August to a low of 49° F in January. The average annual rainfall based on the Arcadia National Weather Service site (District Station No. 24570) is approximately 49 inches and more than 60% of the annual rainfall occurs during the months of June, July, August, and September (Figure 2-14). Rainfall is unevenly distributed during the summer months because most of the summer rainfall is derived from local showers or thunderstorms. The passing of tropical storms and hurricanes can sometimes result in higher rainfall, usually in late summer months. A dry season extends from mid-October through mid-June, with lowest average rainfall in November. Winter rainfall increases slightly from January through March due to passing of cold fronts that bring rain in advance of high pressure by dry air (Kelly et al. 2004; Hood et al. 2011). Winter rainfall tends to be more evenly distributed than summer rainfall, since it generally results from large frontal systems as cold air masses from the north move south through the area (Kelly and Gore 2008). The rainfall to runoff conversion on average ranges from 4% in May to 38% in October.

The Arcadia National Weather Service site has a rainfall record that extends back to 1900 (Figure 2-15). Annual rainfall totals of less than the long term average (49 inches) were recorded for 55 years during the period of record from 1900 through 2021. The highest three yearly rainfall totals occurred in 1947, 1982, and 1959 with 80, 78, and 74 inches respectively (Figure 2-15). These high rainfalls are attributable to tropical depressions and hurricanes that can move through the area in the late summer and early fall. A smoothed trend line using locally estimated scatterplot smoothing (LOESS) shows an overall increasing trend from 1900 through 1949 and a decreasing trend from 1950 through 1969, while the period 1970 through 2021 has exhibited a slightly positive trend (Figure 2-15). A detailed trend analysis for rainfall is provided in Section 2.5.4.

Within this general seasonal cycle, rainfall intensities and frequencies are controlled by the effects of larger scale oscillations, notably the Atlantic Multidecadal Osccillation (AMO) and El Niño-Southern Oscillation (ENSO) (Kelly 2004; Kelly and Gore 2008). These oscillations are often thought to be driven by natural variability in the climate system, although some recent studies (e.g., Mann et al. 2021, Qu et al. 2021) claim oscillations are driven by episodes of high amplitude volcanic activities that happened in past centuries. The AMO is an index of Sea Surface Temperature (SST) anomalies averaged over the North Atlantic from 0–70°N and has a strong influence on summer rainfall over the conterminous United States. (McCabe et al. 2004). The ENSO, a naturally occurring phenomenon associated with an irregular cycle of warming and cooling of SSTs in the tropical Pacific Ocean (5°N to 5°S, 150° to 90°W), is also known as a dominant force, causing climate variations over the United States and much of the globe (Hansen et al. 1997; Schmidt and Luther 2002).

To better understand how these climate indices are related to the temporal variability of streamflow in Horse Creek, the mean annual SST patterns tracked by these two indices and USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gaged flows were normalized. Plots of 5- and 10-year moving averages of the normalized values of AMO, and Horse Creek flows are shown in Figure 2-16. A similar pattern is evident in the two data sets, with higher flows occurring during warmer AMO phases and lower flows occurring during cooler AMO phases. The Pearson's coefficient between 5-year running means of AMO and Horse Creek flows is 0.65, while the Pearson's coefficient between 10-year running means of AMO and Horse Creek flows is 0.87. This is consistent with Kelly's (2004) previous findings in the region.

Superimposed within the AMO cycle, the ENSO anomalies were also related to the year-to-year streamflow variability in Horse Creek as shown in Figure 2-17. El Niño years are wetter than La Niña years in the region. However, El Niño effects during the summer wet season are somewhat attenuated by the seasonal occurrence of thunderstorms (Kelly and Gore 2008).

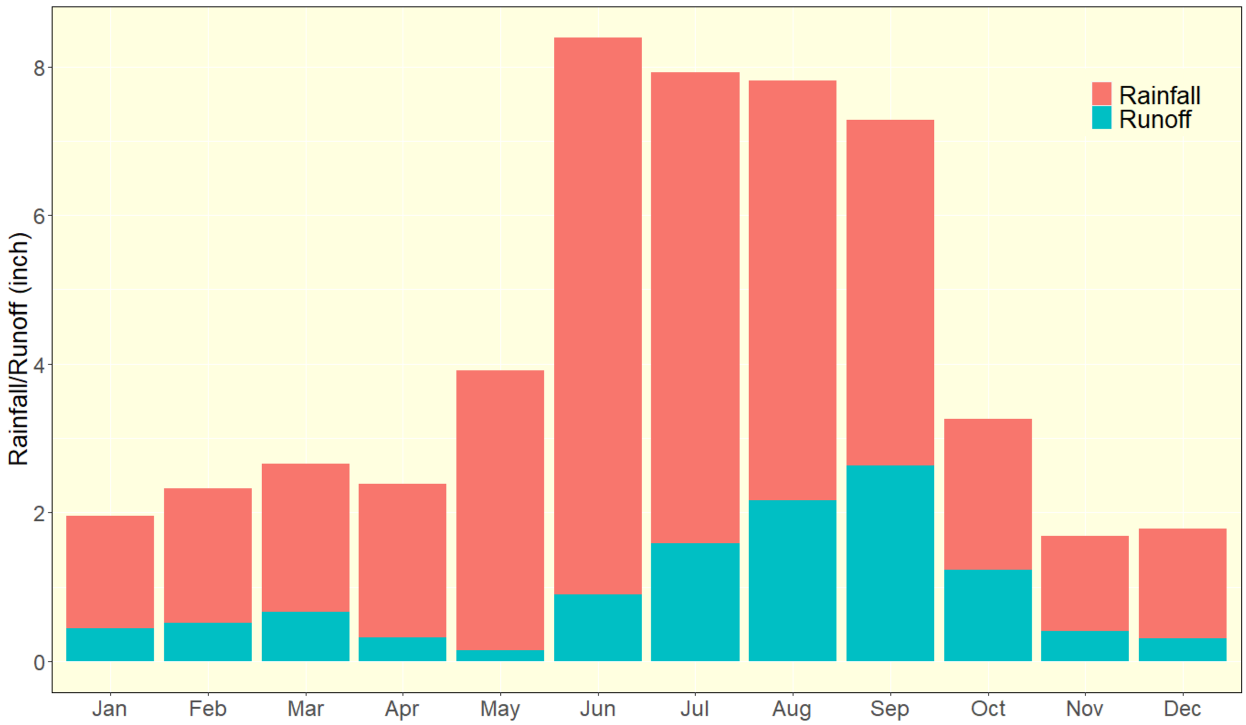

Figure 2-14. Average total monthly rainfall at the Arcadia National Weather Service site (District Station No. 24570) for the period of record from 1900 through 2021, and average monthly runoff at the USGS Horse Creek SR 72 near Arcadia, FL (No. 022973100) gage for the period of record from 1950 through 2021.

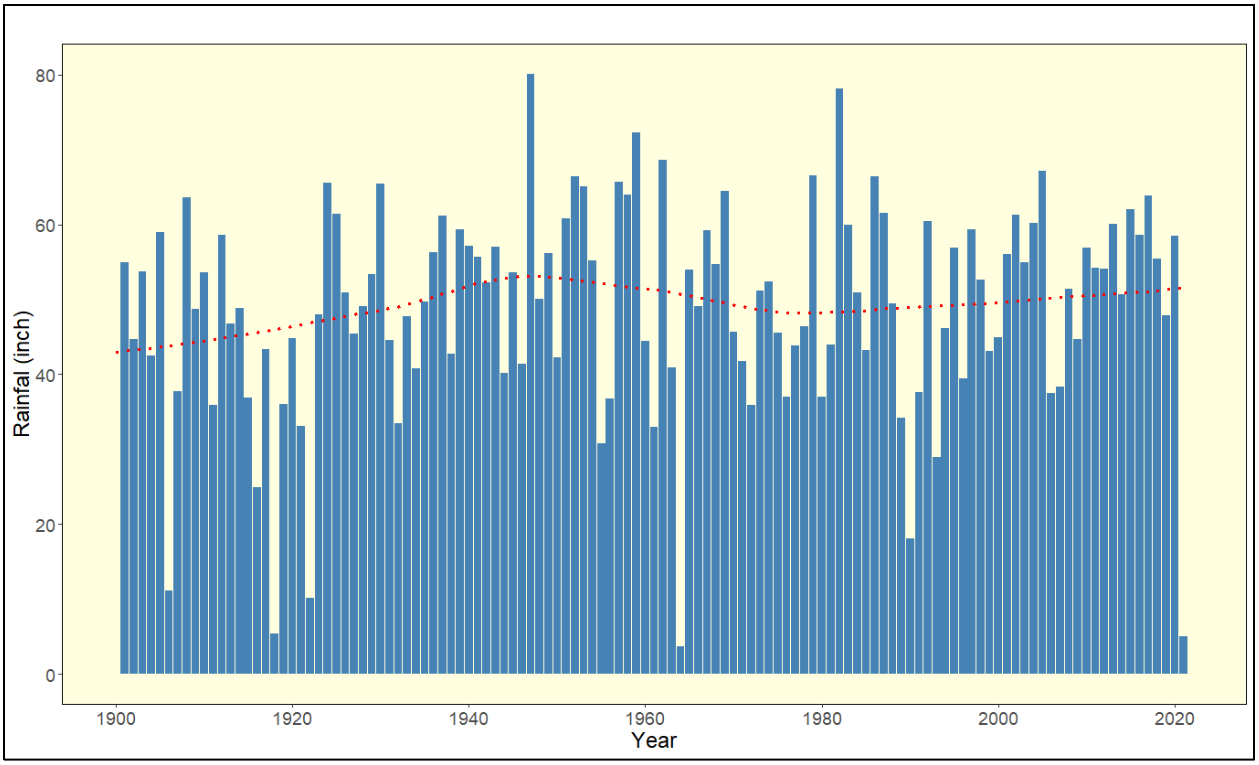

Figure 2-15. Annual rainfall totals (inches) at the Arcadia National Weather Service site (District Station No. 24570) from 1900 through 2021. The dashed line indicates the overall trend derived using locally estimated scatterplot smoothing (LOESS).

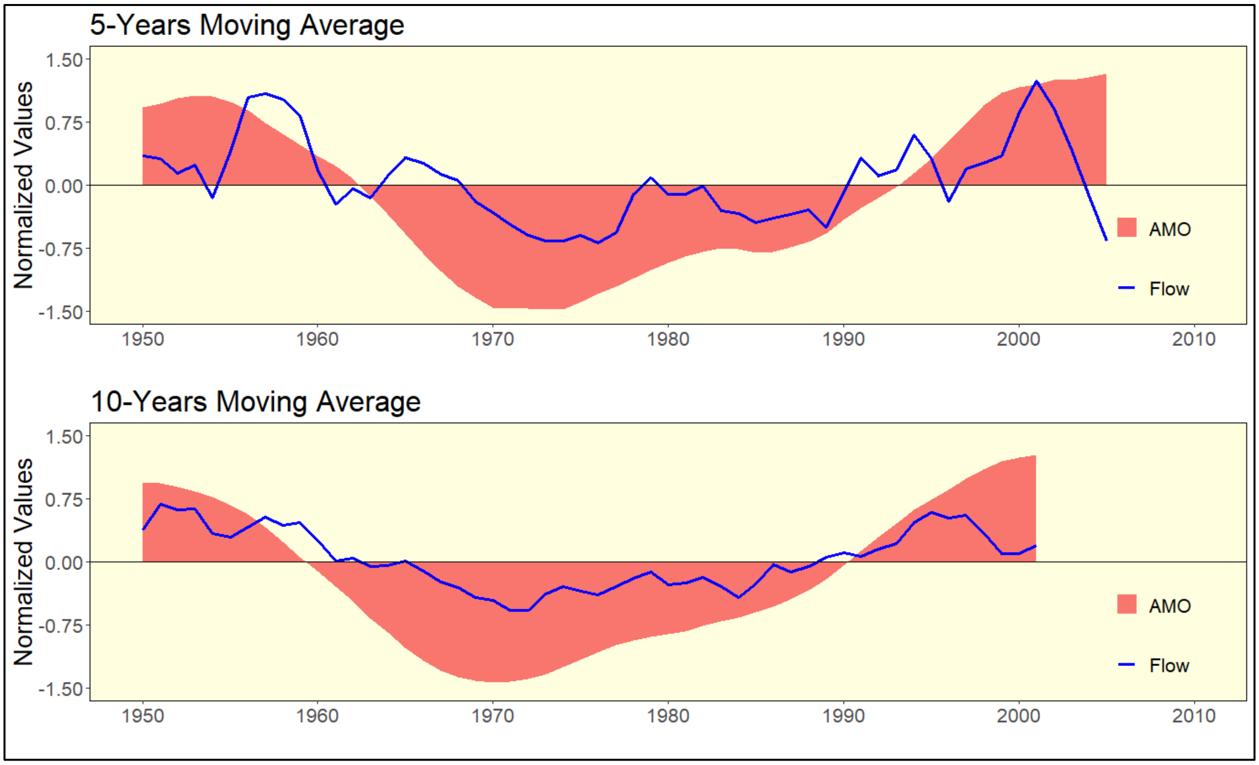

Figure 2-16. Normalized values of 5- and 10-year moving averages of annual AMO anomalies and flows at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 022973100) gage for the period from 1951 through 2008.

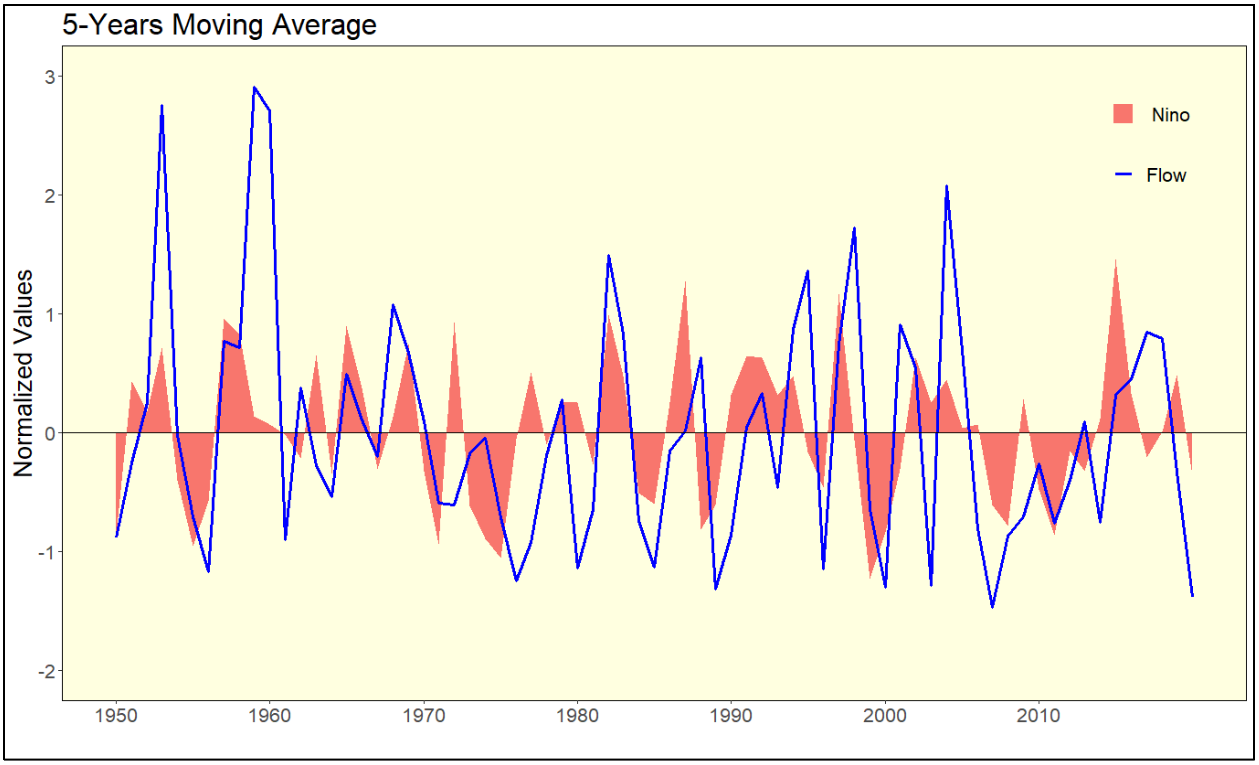

Figure 2-17. Normalized values of annual ENSO anomalies (°C) and flows at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 022973100) gage for the period from 1951 through 2020.

2.5. Streamflow

Streamflow represents the sum of contributions from groundwater, runoff, direct rainfall, and anthropogenic discharges (e.g., wastewater), minus the volume of water that is lost due to evapotranspiration, losses to groundwater, and withdrawals. The physical, chemical, and biological properties of aquatic ecosystems can be affected by the hydrologic regime (Poff and Ward 1989, 1990), so substantial ecological changes can be associated with long-term changes in flows.

Streamflow is measured by the USGS at three locations within the Horse Creek watershed (Figure 2-2). The two gages with the longest period of record, the USGS Horse Creek near Myakka Head, FL (No. 02297155) and the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310), were used for the analyses described in this report. Discharge data collection at the third location, USGS Horse Creek near Limestone, FL (No. 02297251), began October 23, 2019, and contained a short period of record. It was not included in analyses described in this report. The USGS Horse Creek near Myakka Head, FL (No. 02297155) gage is located in Hardee County at latitude 27°29'13" and longitude 82°01'25" NAD27 and has a drainage area of 42 square miles. The USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage is located in Desoto County at latitude 27°11'57" and longitude 81°59'19" NAD27 and has a drainage area of 218 square miles. There are no notable tributaries or dams that could cause backwater in the immediate vicinity of the two gauges.

2.5.1. Mean Annual Flows

Horse Creek flows have been measured at the USGS Horse Creek near Myakka Head, FL (No. 02297155) gage since October 1977. From 1977 to 2021, mean daily flows at this gage ranged from a minimum of 0 cfs to a maximum of 2,240 cfs in 1988, with a long-term average of 32 cfs. Measured flows for the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage are available for the period 1950 to the present. From 1950 to 2021, mean daily flow ranges from 0 cfs to a maximum of 10,700 cfs in 1960. The long-term mean (1950-2021) annual flow at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage is 185 cfs (Figure 2-18). The downtrend from 1950s through late 1980s is associated with reduced rainfalls during the cooler AMO phases in North Atlantic ocean, as described in section 2.4.

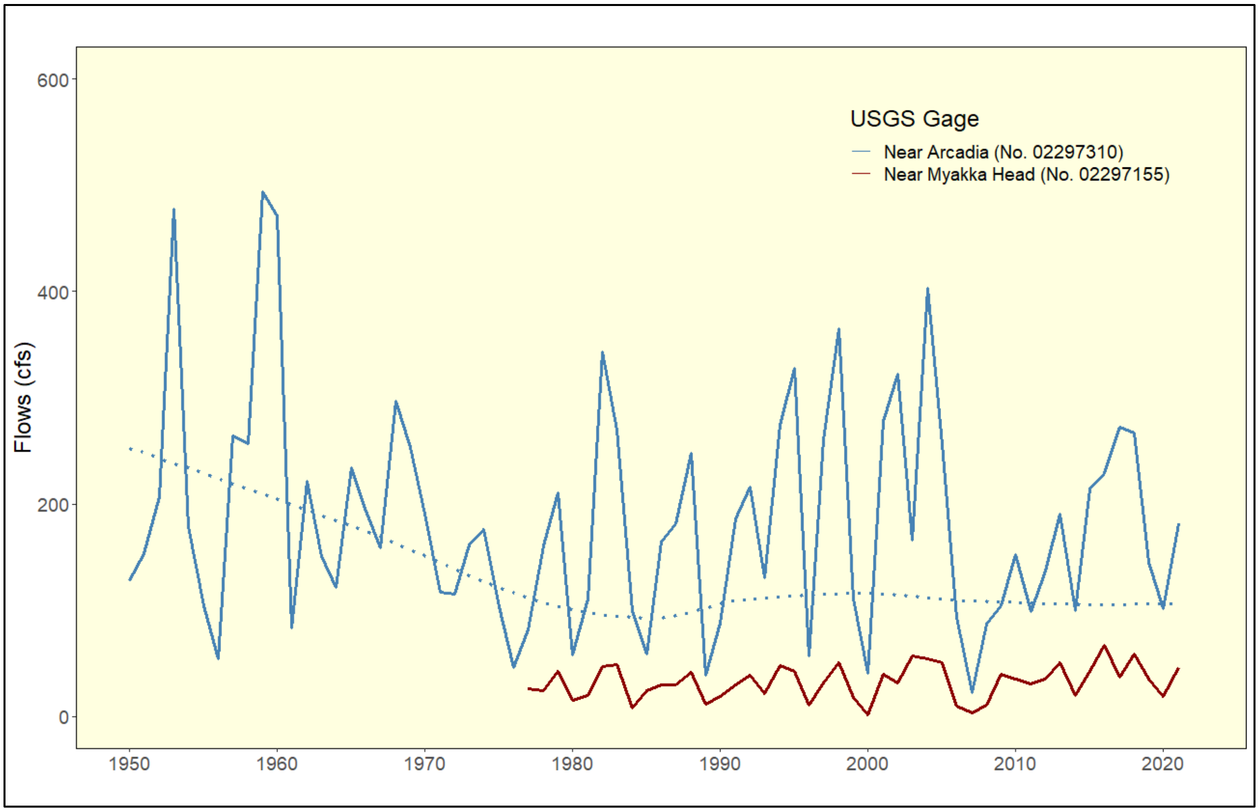

Figure 2-18. Time series of Horse Creek mean annual flows (cfs) at the USGS Horse Creek near Myakka Head, FL (No. 02297155) gage for the period 1977 through 2021 and the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage for the period 1950 through 2021, with the dashed blue line showing trend over time.

2.5.2. Seasonal Flows

Box and whisker plots of the daily flows at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage are presented in Figure 2-19. The typical seasonal distribution of flows in Horse Creek follows the seasonal pattern of rainfall in west-central Florida, with high flows occurring during a four-month wet season (mid-June to mid-October) followed by medium and low flow periods associated with the dry season that extends from mid-October to mid-June. Streamflow reaches its lowest values in May and June, when potential evapotranspiration rates are high, groundwater levels are low, and surface water storages available in sinks, depressions, soils, and wetlands are high. In the late summer and fall, surface and ground-water levels are higher, soils are more saturated, and there is much greater streamflow production per unit of rainfall, with peak flows typically occurring in August and September.

Flows in Horse Creek have been affected by mining and agricultural activities. Phosphate mining and domestic waste discharges to the river have gradually declined since the mid-1980s, while agricultural runoff originating from groundwater withdrawals has contributed to increased baseflow in Horse Creek (SWFWMD 2000). A recent study conducted by HydroGeoLogic, Inc. (2023; Appendix A) indicates that groundwater withdrawals have relatively less impact on flows in the lower versus the upper portion of the Peace River basin. The lessened impact in the lower Peace River basin, which includes Horse Creek, can be attributed to the much tighter confinement of the Upper Floridan aquifer (UFA) underlying the middle and lower portions of the basin. Additional information pertaining to anthropogenic impacts on flows in the Horse Creek is provided in Section 5.1.

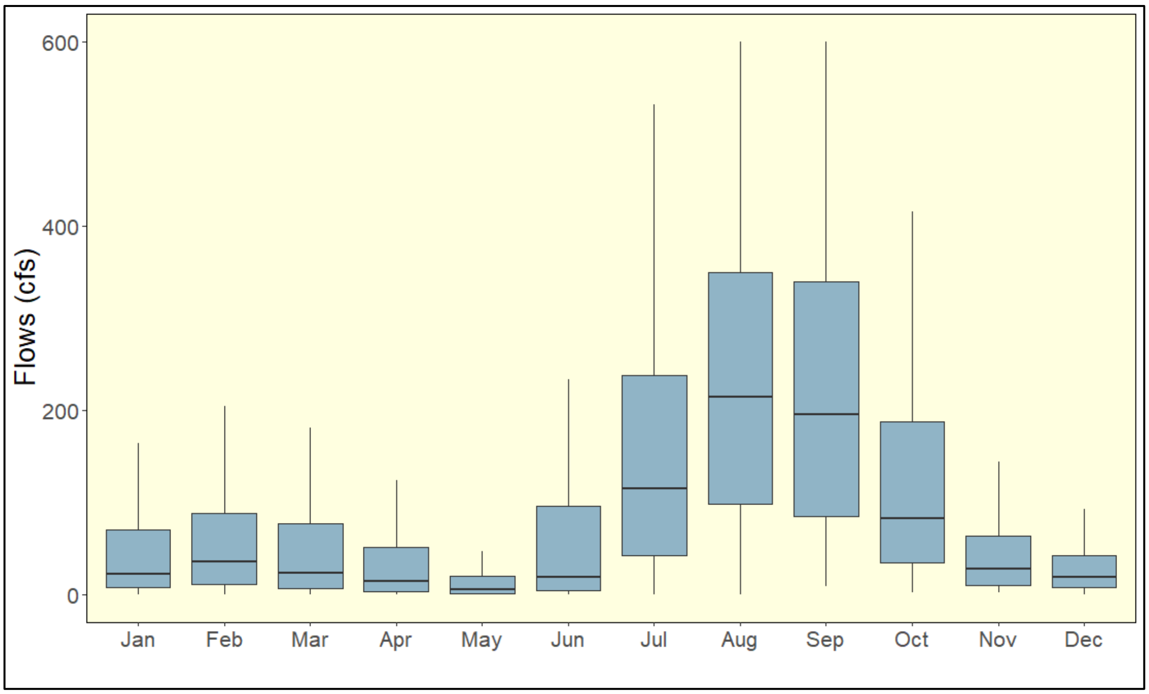

Figure 2-19. Box and whisker plots of daily flows (cfs) by calendar month for the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage. Boxes represent the interquartile range; whiskers represent lowest and highest observations.

2.5.3 NPDES Effluent Discharge

Mosaic has permitted National Pollutant Discharge Elimination System (NPDES) effluent discharges to Horse Creek at the Fort Green Mine-(outfall D-003, NPDES #FL0027600) and the Wingate Mine (outfall D-004, NPDES #FL0032522), north of SR 64 (Flatwoods 2020). According to their associated DEP-issued permits, at FTG-003, discharge to Horse Creek may include trated excess process wastewater, stormwater runoff, and groundwater inflow. At WIN-004, excess mine recirculation water and stormwater may be discharged into Horse Creek. Combined daily discharge from these sites are provided in Figure 2-20. Discharges from these sites are rainfall-dependent and are typically highest during periods of seasonal high flow, from July to September (Figure 2-21).

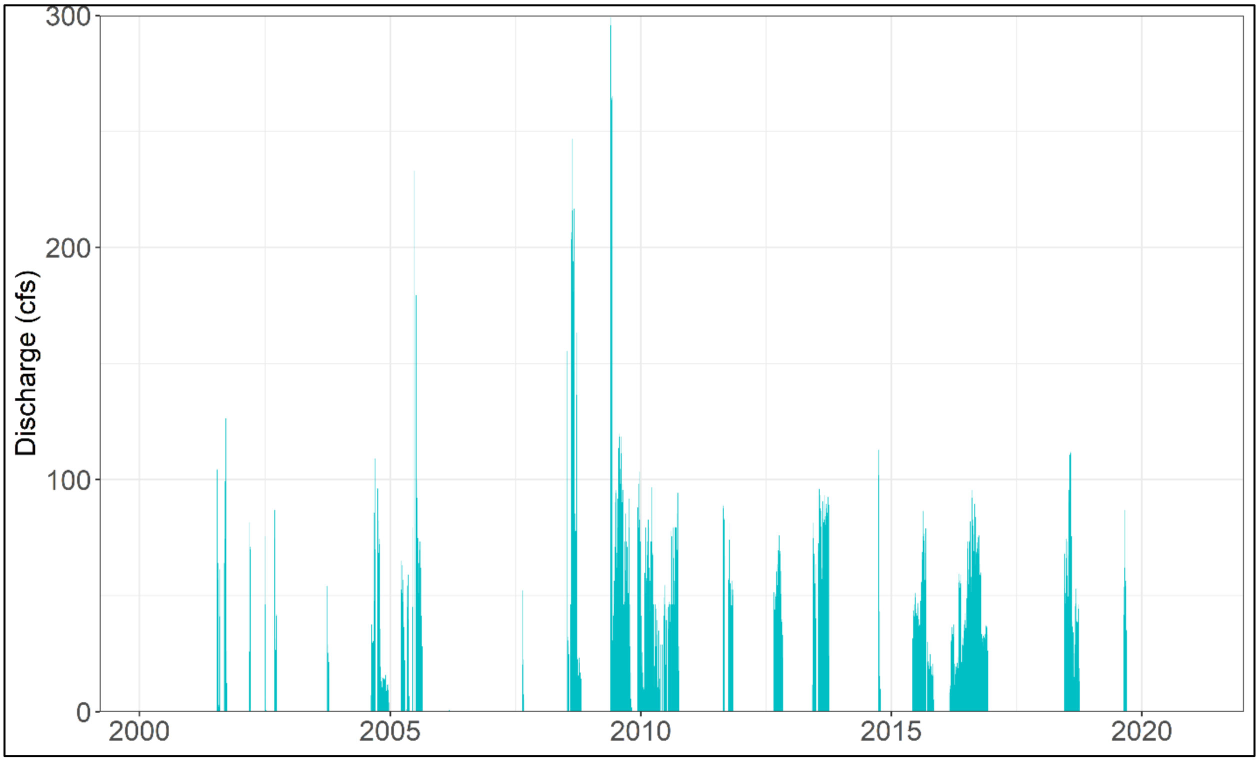

Figure 2-20. Combined daily National Pollutant Discharge Elimination System (NPDES) effluent discharges to Horse Creek from the Fort Green Mine (FTG-003) and Wingate (WIN-004) from 2000 through 2020.

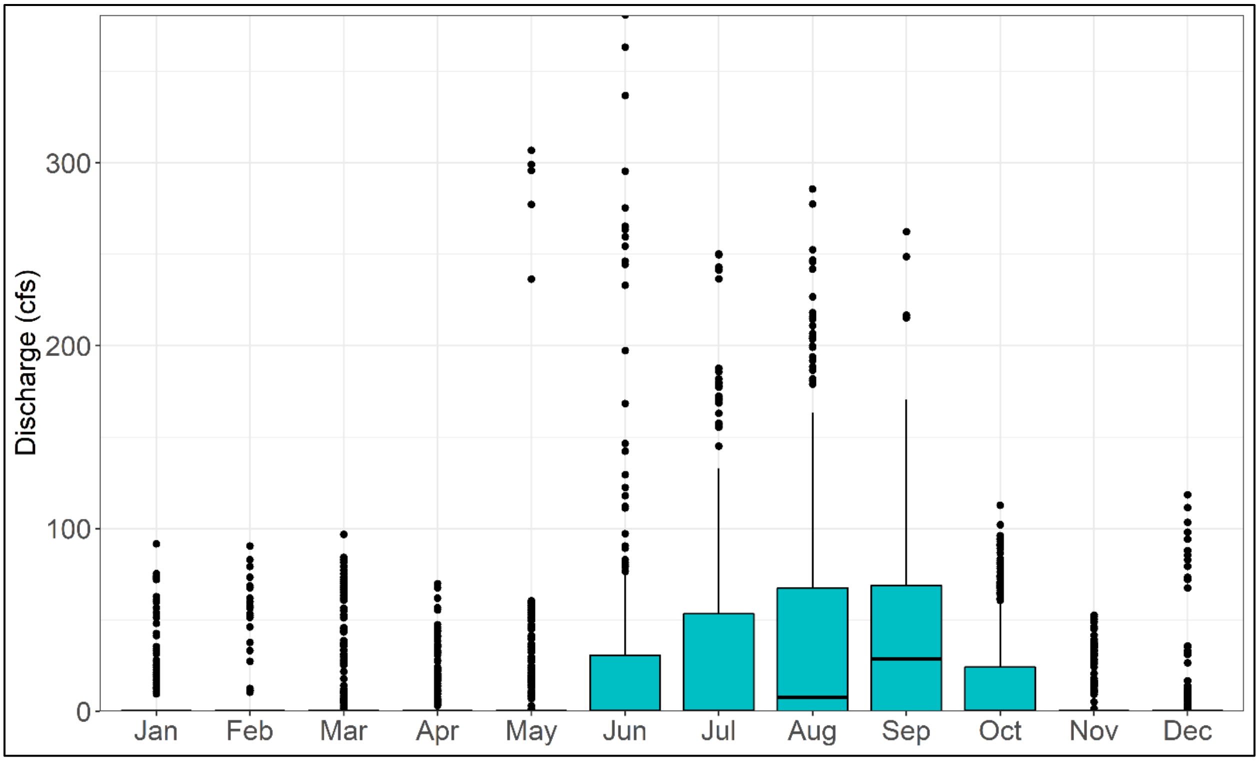

Figure 2-21. Monthly National Pollutant Discharge Elimination System (NPDES) effluent discharge from the Fort Green Mine (FTG-003) and Wingate (WIN-004) from 2000 through 2020. Boxed values indicate the 25th to 75th percentiles with the centerline reflecting the 50th percentile value. Dots represent outliers, indicative of values outside of the 1.5*interquartile range.

2.5.4 Flow Trends

Flow data collected from May 1950 through December 2018 for the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage and NWS rainfall data (District Station No. 24570) were analyzed for trend analysis. Using the nonparametric Mann-Kendall's trend test on monthly time-step, trend analysis for rainfall identified a significant decreasing trend at alpha level of 0.05 for February and October. Horse Creek flows exhibited no significant trend pattern for all months, suggesting that anthropogenic influences on flows in the creek have not significantly changed over time (Table 2-2). A study conducted by INTERA (2018) also indicated that monthly flows in Horse Creek exhibited no significant trends over the period from 1950 through 2013.

Trend analysis conducted by PBS&J (2007) indicated that the historic flows in nearby Charlie Creek are consistent with the timing of the wet and dry climate periods in southwest Florida. Based on land use change analysis for the period from 1940 to 1999, they found that, among the nine watersheds in the Peace River Basin, Charlie Creek was relatively un-impacted, with no phosphate mining at that time and limited urbanization..

Using flows from Charlie Creek as a reference, a comparison of median daily flows per unit area for three periods for Horse Creek is presented in Figure 2-22. If climate is the major controlling factor, one should expect similar flow patterns in these neighboring two watersheds. The top panel of Figure 2-22 suggests that the 1950-1969 flow patterns for Horse and Charlie Creeks were similar for most of the year with the exception that Horse Creek flows during May-June (from approximately the 121st day of the year to the 181st day) were relatively lower than the flows in Charlie Creek. During the periods of 1970-1995 and 1996-2021, however, the May through June flows in Horse Creek increased over time (see the middle and lower panels of Figure 2-22). These increases are consistent with the timing of the growing season where return flows from irrigated fields are expected to contribute to streamflow.

Table 2-2. Trend analysis for rainfall near Arcadia (District Station No. 24570) and flows at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage.

Month	Rainfall near Arcadia		Flows at USGS Horse Creek at SR 72 near Arcadia gage	
	p-value	Trend Direction	p-value	Trend Direction
Jan	0.52	No trend	0.74	No trend
Feb	0.05*	Decreasing	0.28	No trend
Mar	0.88	No trend	0.37	No trend
Apr	0.98	No trend	0.79	No trend
May	0.97	No trend	0.09	No trend
Jun	0.27	No trend	0.23	No trend
Jul	0.97	No trend	0.68	No trend
Aug	0.08	No trend	0.5	No trend
Sep	0.72	No trend	0.64	No trend
Oct	0.02*	Decreasing	0.89	No trend
Nov	0.11	No trend	0.65	No trend
Dec	0.14	No trend	0.46	No trend

* p-values significant at an alpha level of 0.05

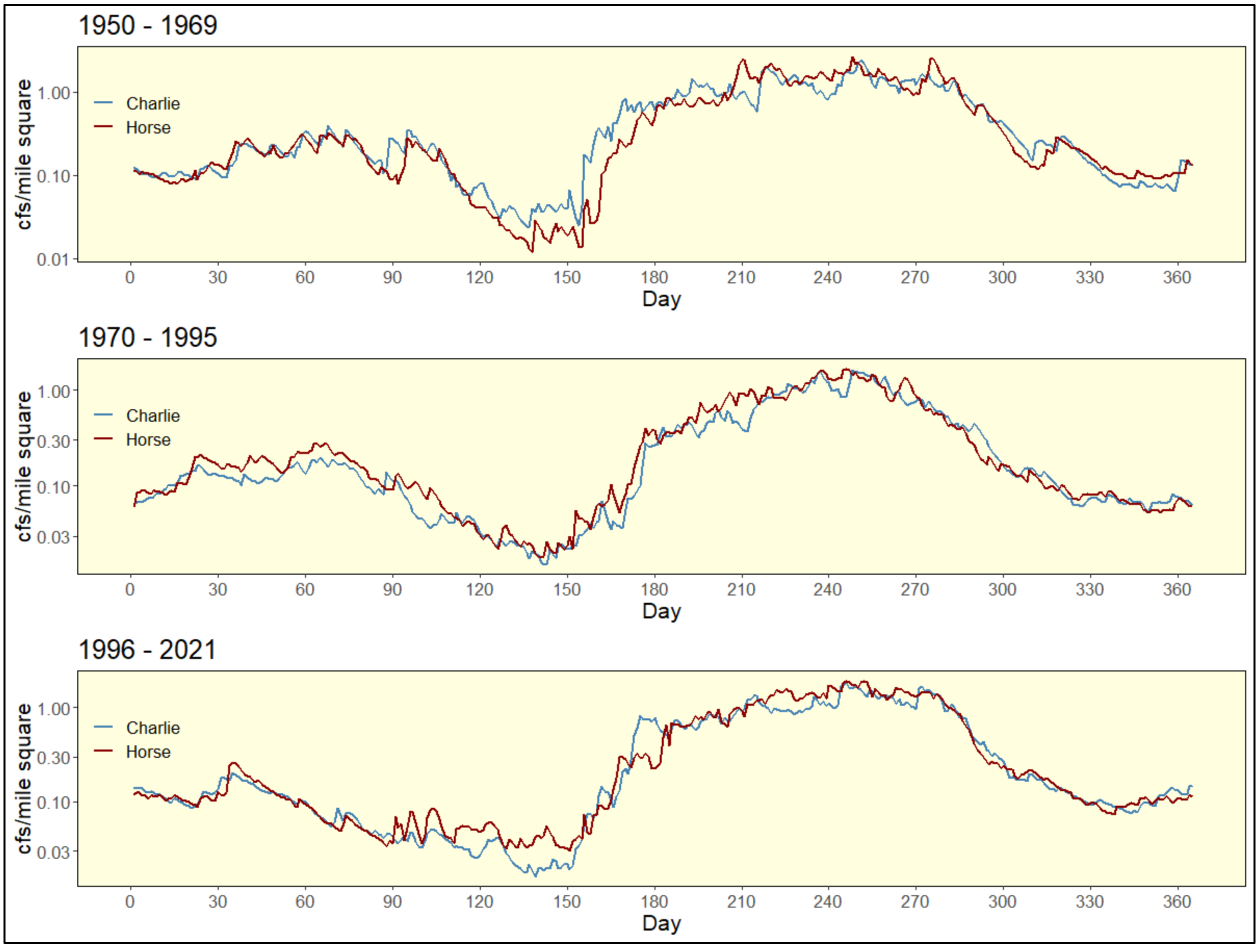

Figure 2-22. Comparison of median daily flows (logarithmic scale) for three time periods at the USGS Charlie Creek near Gardner, FL (No. 02296500) and USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gages. Data from 1950 begin on May 1st.

2.6. Hydrogeology and Aquifer Levels

The hydrogeology of the District can generally be divided into three broad regions that correspond to major groundwater basins within the UFA (Figure 2-23). Within the District, from upstream to downstream, are the Northern West-Central Florida Groundwater Basin (NWCFGWB), the Central West-Central Florida Groundwater Basin (CWCFGWB), and the Southern West-Central Florida Groundwater Basin (SWCFGWB). The UFA is mostly unconfined in the NWCFGWB, semi-confined in the CWCFGWB, and well-confined in the SWCFGWB as the intermediate confining unit (ICU) thickens from upstream to downstream (Basso 2019).

The uppermost aquifer system within the Horse Creek watershed is the unconfined surficial aquifer (SA) composed primarily of unconsolidated fine to medium sand, becoming increasingly clayey and phosphatic with depth (SWFWMD 1988, SWFWMD 2004, Gates 2009, Basso 2019). The SA thickness ranges approximately from 25 to 50 feet and is mainly recharged by rainfall and irrigation of agricultural land or landscape areas (Weber 1999, Spechler and Kroening 2007).

The average transmissivity of the SA, estimated from two aquifer tests is reported to be 502 square feet per day, with an average specific yield of 0.06 square feet per day (SWFWMD 1988). Horizontal hydraulic conductivities range from 7 feet per day in the northeastern to 20 feet per day in the northwestern portion of Horse Creek. Vertical hydraulic conductivity ranges from 0.001 to 0.014 feet per day (SDI 2010).

Underlying the SA is the Hawthorn aquifer system (HAS), primarily composed of sand, carbonate rocks, and discontinued beds of sandy clay. The HAS is confined by a clayey pebbly sand, clay, and marl confining unit that separates the HAS from SA, and a clays and dolomitic limestones confining unit that hinders the vertical movement of groundwater between the HAS and the underlying Upper Floridan aquifer (UFA; Gates 2009, HydroGeoLogic, Inc. 2009, Lewelling and Metz 2009). The HAS consists of three aquifers: the Peace River aquifer, the upper Arcadia aquifer, and the lower Arcadia aquifer (LaRoche and Horstman, 2022). The HAS is a major source of water throughout DeSoto, Hardee, Hillsborough, Manatee, and Polk counties in the Peace River basin and thickens to the south (SWFWMD 2001).

Underlying the HAS, the confined Floridan aquifer system exists as a major source of fresh groundwater for most of southwest Florida. The Floridan aquifer system is composed primarily of carbonate rocks that are generally highly permeable and hydraulically connected to each other in varying degrees (Duerr and Enos 1991, Weber 1999, Gates 2009). The Floridan aquifer system is subdivided into UFA and Lower Floridan aquifer (LFA) which are separated by a confining unit. About 85% to 90% of all groundwater is derived from the UFA. The LFA is generally brine-saturated (SWFWMD 2004). Historically, substantial amounts of the groundwater were withdrawn for irrigated agriculture in the basin and contributed to surface flow increase in Horse Creek.

As part of the Regional Observation and Monitor-Well Program (ROMP), the District has installed cluster wells, which monitor discrete vertical horizons in each aquifer system at several locations within the Horse Creek watershed (Figure 2-2). Water levels at ROMP 17 site are shown in Figure 2-24 for District Station Nos. 24039 and 24041, which are wells used to monitor water levels in the SA and the UFA, respectively. The hydrographs show larger fluctuations caused by seasonal rainfall and groundwater withdrawals. The SA water levels at the site fluctuated between 12.6 and 22.9 feet NAVD88 during the period from 1993 through August 2022, and did not exhibit a long-term temporal trend. The UFA at ROMP 17 is Artesian and tightly confined, where there is an upward vertical head gradient from the UFA to the land surface. The monitoring wells at the site are capped so they do not discharge to the land surface. Water levels estimated from the Artesian pressure indicate that the wells would have flowed freely between 8.1 and 26.4 feet NAVD88 above land surface during the period from 1993 through August 2022.

Surficial (District Station No. 24003) and UFA (District Station No. 24008) water level fluctuations for non-artesian wells at the ROMP 25 site are shown in Figure 2-24. Surficial aquifer water levels at the site have fluctuated between 77.2 and 88.8 feet NAVD88, while the UFA water levels fluctuated between -12.9 and 44.5 feet NAVD88 during the period from 1993 through August 2022. Large vertical head differences between the SA and the UFA indicate relatively low hydraulic connection and tight confinement separating the aquifer systems.

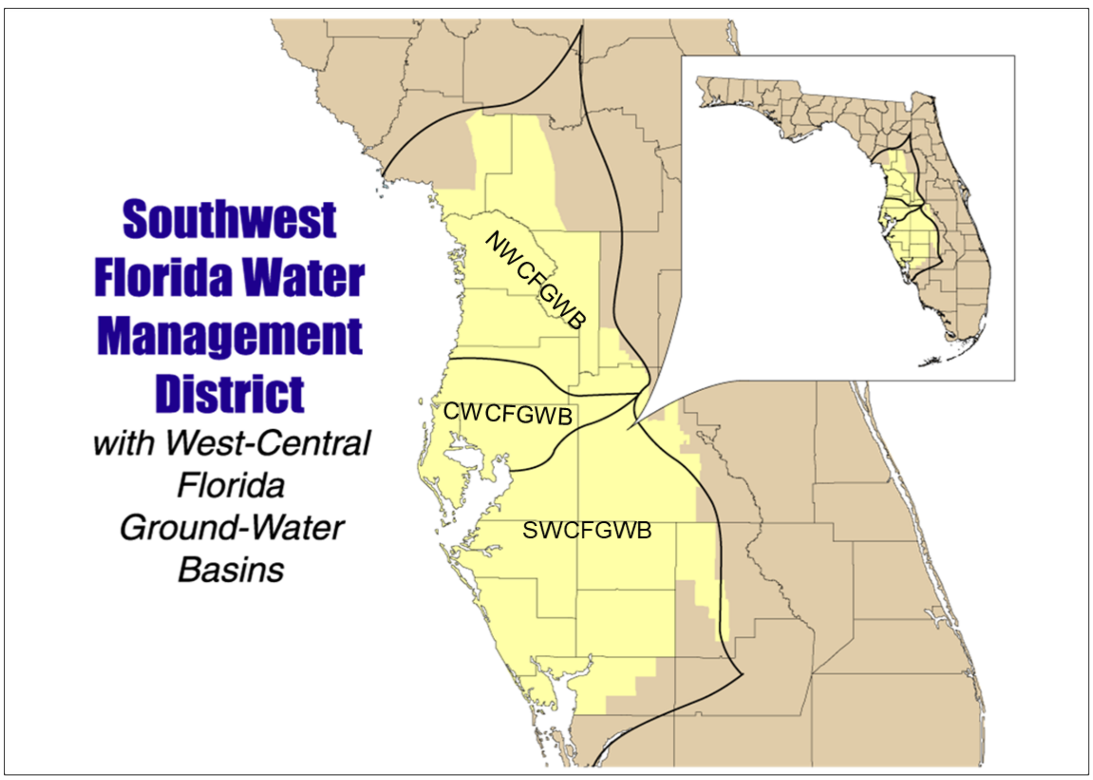

Figure 2-23. Location of regional groundwater basins within the District boundary, including the Northern West-Central Florida Groundwater Basin (NWCFGWB), the Central West-Central Florida Groundwater Basin (CWCFGWB), and the Southern West-Central Florida Groundwater Basin (SWCFGWB).

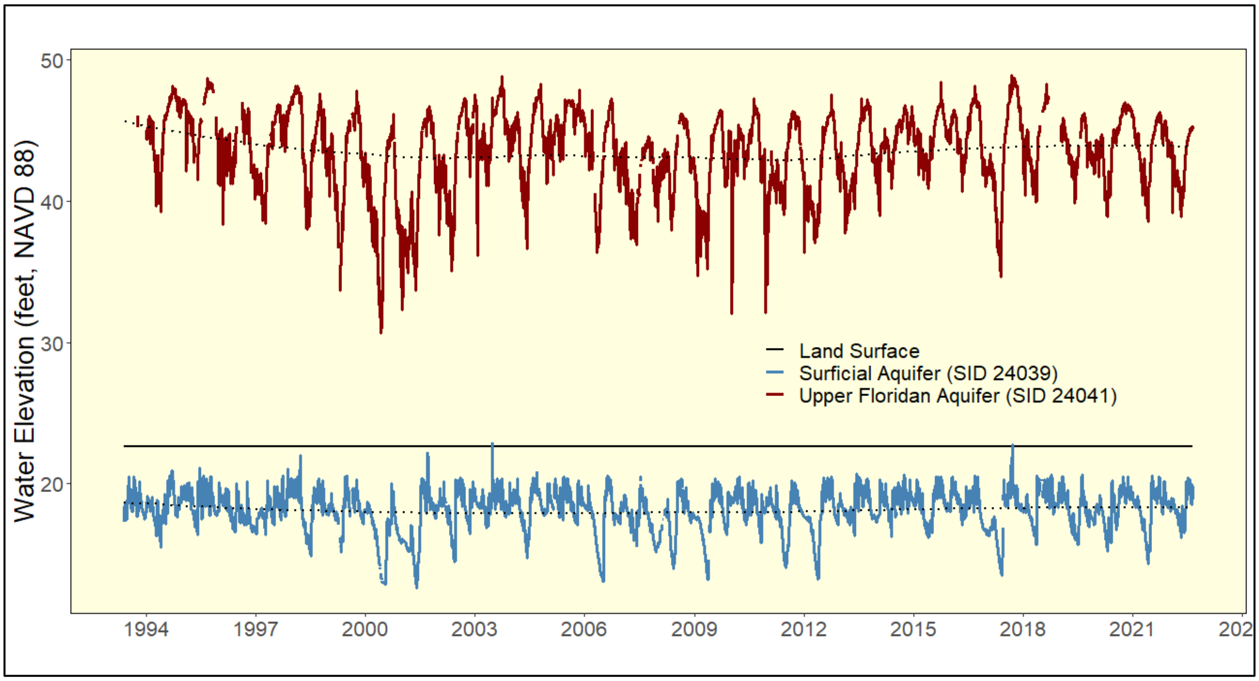

Figure 2-24. Water levels (feet) from monitor wells installed into the surficial and Upper Floridan aquifers at the District Regional Observation and Monitor-Well Program 17 site from 1993 through August 2022. The dashed lines indicate the overall trend using LOESS.

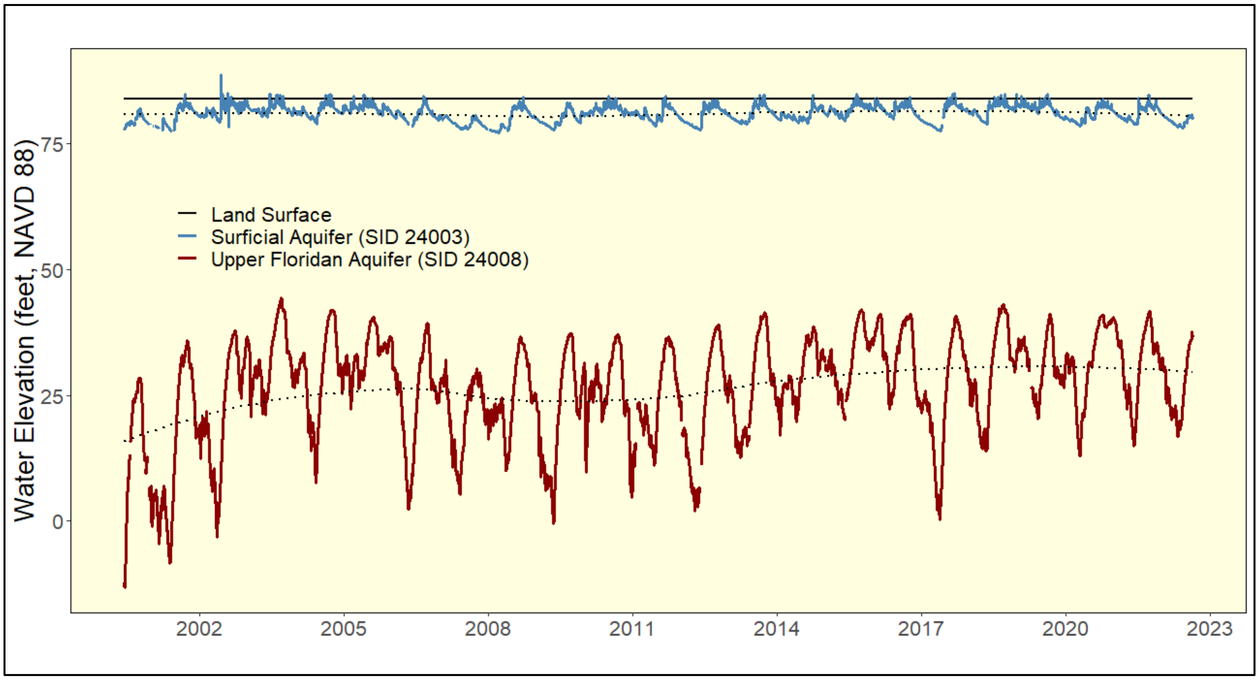

Figure 2-25. Water levels (feet) from monitor wells installed into the surficial and Upper Floridan aquifers at the District Regional Observation and Monitor-Well Program 25 site from 2000 through August 2022. The dashed lines indicate the trend using LOESS.

CHAPTER 3 - WATER QUALITY CHARACTERISTICS

Water quality is one of the ten "Environmental Values" defined in the State Water Resource Implementation Rule for consideration when establishing minimum flows. This chapter provides an overview of trends for water quality parameters measured in Horse Creek, including exploratory evaluations of water quality and flow relationships prepared for the District (ATM and JEI 2021; Appendix B). Several studies were reviewed for preparation of this chapter, including extensive work conducted for Mosaic Fertilizer, LLC through the Horse Creek Stewardship Program (HCSP; Flatwoods 2019, 2020, 2021), and studies by the DEP (2000), the USGS (Lewelling 1997) and the District (SWFWMD 2000). Finally, we note the inclusion of information pertaining to adopted water quality standards in this chapter is for informational purposes only and not intended to be a determination of impairment by the District.

3.1. Designated Use and Impaired Waters Rule

Under Rule 62-302.200, F.A.C., Florida's surface water quality standards consist of four components: 1) the designated use of classification of each water body, 2) the surface water quality criteria (numeric and narrative) for each water body, which are established to protect its designated use, 3) the anti-degradation policy, and 4) moderating provisions, such as mixing zones. Surface water bodies in Florida are classified according to their present and future most beneficial use, referred to as designated use, with class-specific water quality criteria for select physical and chemical parameters (Chapter 62-302, F.A.C.).

The DEP assigns waterbody identification numbers (WBIDs) to portions of watersheds, rivers, and other water bodies with homogenous water quality. Used as an assessment unit, each WBID is accompanied by a GIS polygon layer that delineates the drainage basin surrounding it. The Horse Creek watershed contains sixteen WBIDs. Of these, fifteen are categorized as class III, meaning their designated use is for fish consumption, recreation, propagation, and maintenance of a healthy and well-balanced population of fish and wildlife (Rule 62-302.400, F.A.C.; Figure 3-1). Approximately 5.2 square kilometers of Horse Creek (WBID 1787A2) is designated as Class I, indicating that it is suitable as a source of potable water (Rule 62-302.400, F.A.C.; Figure 3-1). This potable section occurs from the confluence of Horse Creek with Peace River to a point approximately 16.2 kilometers (10 miles) upstream (ATM and JEI 2021).

Section 303(d) of the Federal Clean Water Act requires each state to identify and list impaired waters where applicable water quality criteria are not being met. To comply with this requirement, the DEP has traditionally assessed waterbodies on a five-year cycle, although the department is changing this to a biennial schedule under the Impaired Waters Rule (IWR; Chapter 62-303, F.A.C.). During assessments, the DEP's Watershed Assessment Section utilizes the best available data to determine if WBIDs are meeting applicable water quality standards (Chapter 62-302, F.A.C.) and their designated use (Chapter 62-303, F.A.C.). If a waterbody does not meet the applicable water quality criteria, it is no longer considered to support its designated use. It is then added to the DEP's Verified List for subsequent total maximum daily load (TMDL) development and is reported to the United States Environmental Protection Agency.

The most recently adopted Verified List for Horse Creek was approved on July 15, 2022, based upon the IWR Run 60 Database which contains data through 2020. The only impaired waterbody on the Verified List in the Horse Creek watershed was Brandy Branch (WBID 1939; Figure 3-1), impaired for *Escherichia coli* (bacteria). Two waterbodies were added to the Study List for Dissolved Oxygen Percent Saturation impairment: Brush Creek (WBID 1826A) and Cypress Branch (WBID 1915). Horse Creek above Brushy Creek (WBID 1787B) was previously listed for nutrient (total phosphorus) exceedance but is now proposed to be delisted, as the annual geometric mean did not exceed the threshold more than once in a three-year period. The DEP has not established a TMDL or basin management plan (BMAP) specific to any waterbody within Horse Creek. A statewide mercury TMDL has been developed due to widespread atmospheric deposition (DEP 2013).

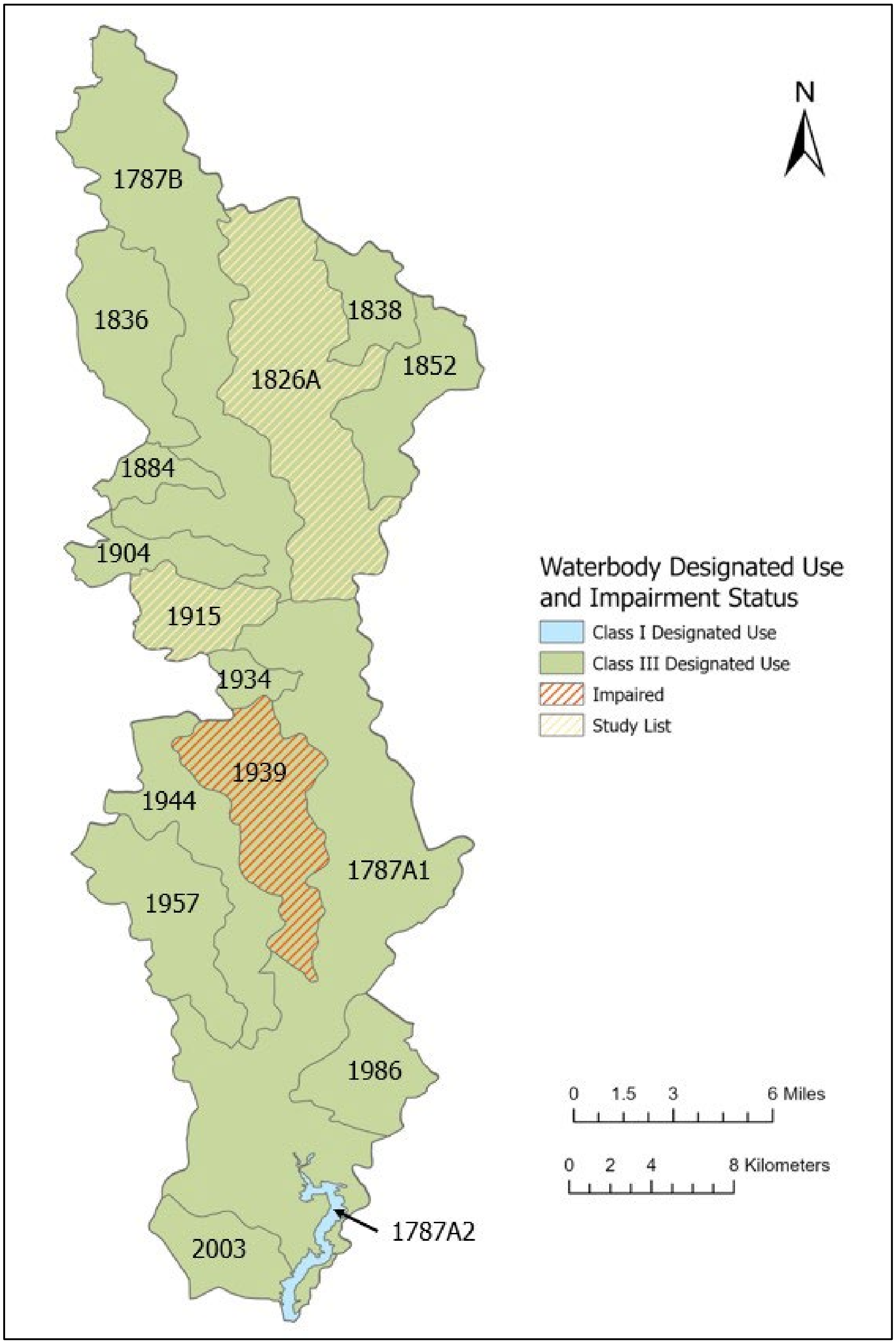

Figure 3-1. Location of waterbodies by waterbody identification numbers (WBID) within the Horse Creek watershed (DEP 2005), colored according to designated use classification, impairment status, and inclusion on the study list, according to the DEP's Impaired Waters Rule Run 60 and the Verified List adopted in 2022.

3.2. Water Quality Review

As discussed in Section 2.2, phosphate mining dominates land use north of SR 64, while significant agricultural use extends throughout the remainder of the watershed. Intermittent NPDES discharges (Figure 2-16) to the river occur at the Wingate D-004 outfall and the Fort Green D-003 outfall, both several miles north of the northernmost water quality sampling stations. Mining can change the natural flow of water and levels of water quality constituents from baseline conditions as lands are altered during active mining, throughout reclamation, and in the creation of clay settling areas. Agricultural use in the basin has also historically affected water quality in the Horse Creek, particularly due to mineralized runoff from groundwater used for irrigation during the dry season when flows in the creek are low (Lewelling 1997, SWFWMD 2000).

The water quality of Horse Creek has been examined by various entities since at least the 1990s, primarily over concern for land use changes. A report by the USGS (Lewelling 1997) describes water quality parameters in the Horse Creek basin from samples collected from 1992-1995. At that time, increases in constituents like calcium, magnesium, sulfate, and strontium in surface water were observed in the lower portion of the basin, near Buzzard Branch and Brandy Branch (Figure 2-2). This was attributed to either the upward movement of groundwater to the surficial aquifer or irrigation with highly mineralized water, as increases were observed during low flow periods. In general, concentrations were highest for major ions at Buzzard Roost Branch and were highest for nutrients (particularly total nitrogen) at Brushy Creek (Lewelling 1997).

In 2000, the District conducted a study to evaluate the success of stream reclamation in mined locations, using Horse Creek as a reference site. In this study, it was noted that total phosphorus was highest at a downstream station near SR 70 (USGS Brandy Branch at Pine Level Road, FL (No. 02297272) gage). For all sampled stations, total phosphorus was in the 80^{th} to 85^{th} percentile compared to typical Florida stream values. This was not deemed unusual, considering dominant phosphatic soil types throughout the watershed. Total nitrogen values were also examined, with the northernmost station in the study (USGS West Fork Horse Creek near Myakka Head, FL (No. 02297153) gage) ranking in the 25^{th} percentile for Florida streams and the more downstream station near SR 70 (USGS Brandy Branch at Pine Level Road, FL (No. 02297272) gage) ranking in the 85^{th} percentile. The relatively high value of inorganic nitrogen at the downstream sampled station indicated the influence of agricultural runoff in the watershed (SWFWMD 2000). Compared to other Florida streams, a segment of Horse Creek above SR 64 was also found to have elevated total Kjeldahl nitrogen and total phosphorus by the DEP (2000) in a study of reclaimed streams. In 2000, the time of this study, there was significantly less mining activity throughout the northern portion of the watershed than at present (Figure 2-5).

The HCSP was established by Mosaic in 2003 to conduct water quality and biological sampling throughout the Horse Creek watershed. The goals of the program are to ensure mining activities are not adversely affecting this system or those downstream and to protect potable use by the Peace River Manasota Regional Water Supply Authority (Flatwoods 2021). In their annual site-specific analyses, one station, HCSW-2 (Figure 3-2) frequently exceeds dissolved oxygen percent saturation, chlorophyll-a, and nutrient “trigger levels” for potable water, as defined by the HCSP. This is likely due to increased residence time at the site and substantial inputs of organic materials from nearby wetlands. Elevated ions in southern stations have been attributed to agricultural impacts. The trend of increasing specific conductivity at stations in the Horse Creek watershed has also been observed regionally, in streams both with and without mining (Flatwoods 2021).

In addition to annual reports summarizing routine data collection, the program has initiated studies specific to analytes that have exceeded HCSP trigger levels. Their analyses of total dissolved solids, calcium, and sulfate indicate that exceedances frequently occurred during low flow periods, suggesting a non-point source and groundwater influence (Flatwoods 2019). They also found differences in molar concentrations of major ions between the upper portion of the Horse Creek (stations HCSW-1 and -2) and the lower portion of the creek (HCSW-3 and -4), which implies different processes or land use contributions were impacting water chemistry along the river (Flatwoods 2019). In their 2020 analysis of total ammonia in the system, exceedances primarily occurred during the rainy season, south of station HCSW-1 and may have been linked to inputs of inorganic nitrogen including fertilizer use along the creek and its tributaries (Flatwoods 2020).

3.3. Water Quality Analysis

3.3.1. Data

To assess the relationship between water quality and flow, Janicki Environmental, Inc. (JEI) through Applied Technology & Management, Inc. (ATM), conducted regression and time series trend analysis on select water quality parameters (ATM and JEI 2021). Long-term flow data were obtained from two USGS gaging stations: Horse Creek near Myakka Head, FL (No. 02297155) and Horse Creek at SR 72 near Arcadia, FL (No. 02297310; Figure 3-2). Flow data has been measured at the upstream site near Myakka Head since 1977 and at the downstream site near Arcadia since 1950. Water quality data were obtained from the DEP (IWR Run 59), USGS, HCSP, and the District at several stations along Horse Creek with varying periods of record (Table 3-1, Figure 3-2). Station data were retained if they met minimum sample requirements of 30 observations. Outlier analysis was performed to identify and eliminate potentially erroneous data.

From the available data, water quality constituents were grouped based upon their relevance to one another and their likely impact on water quality (Table 3-2). The constituent groups included: Nitrogen, Phosphorus, Chlorophyll, Physio-Chemical, Minerals and Metals, and Indicators of Water Clarity. Further details about each constituent group and their results are provided in Section 3.3.3.

To develop relationships between water quality and flow, each water quality station was a discharge record from one of the two USGS gages identified for the water quality analyses. Stations located at or upstream of SR 70 (Figure 3-2) were associated with the USGS Horse Creek near Myakka Head, FL gage flow record. Stations downstream of SR 70 were associated with the USGS Horse Creek at SR 72 near Arcadia, FL flow record. Due to the proximity of all water quality stations to USGS gages, antecedent flow conditions were not considered in the analysis.

Table 3-1. Water quality sampling stations in Horse Creek (HC) meeting the criterion of at least 30 observations and the general period of record (POR) used for analysis in ATM and JEI (2021).

Source	Station ID	Station Name	POR Start	POR End
DEP	21FLA 25020111	HC near State Road 72	5/15/1972	4/13/1998
DEP	21FLA 25020423	HC at State Road 70	5/15/1972	8/21/1991
DEP	21FLA 25020428	HC at State Road 64	5/15/1972	7/10/1990
DEP	21FLA 25020430	HC at County Road 663A	12/12/1972	7/5/1990
DEP	21FLFTM 25020420	HC at County Road 769	10/9/2001	1/17/2018
HCSP	HCSW-1	HC at State Road 64	4/30/2003	12/12/2018
HCSP	HCSW-2	HC at County Road 663A	4/30/2003	12/12/2018
HCSP	HCSW-3	HC at State Road 70	4/30/2003	12/12/2018
HCSP	HCSW-4	HC at State Road 72	4/30/2003	12/12/2018
SWFWMD	23949	HC near Myakka Head	8/4/1997	5/6/2020
SWFWMD	24049	HC near Arcadia	8/5/1997	5/6/2020
USGS	02297155	HC near Myakka Head	10/26/1978	9/28/1999
USGS	02297310	HC near Arcadia	6/13/1962	9/19/1999

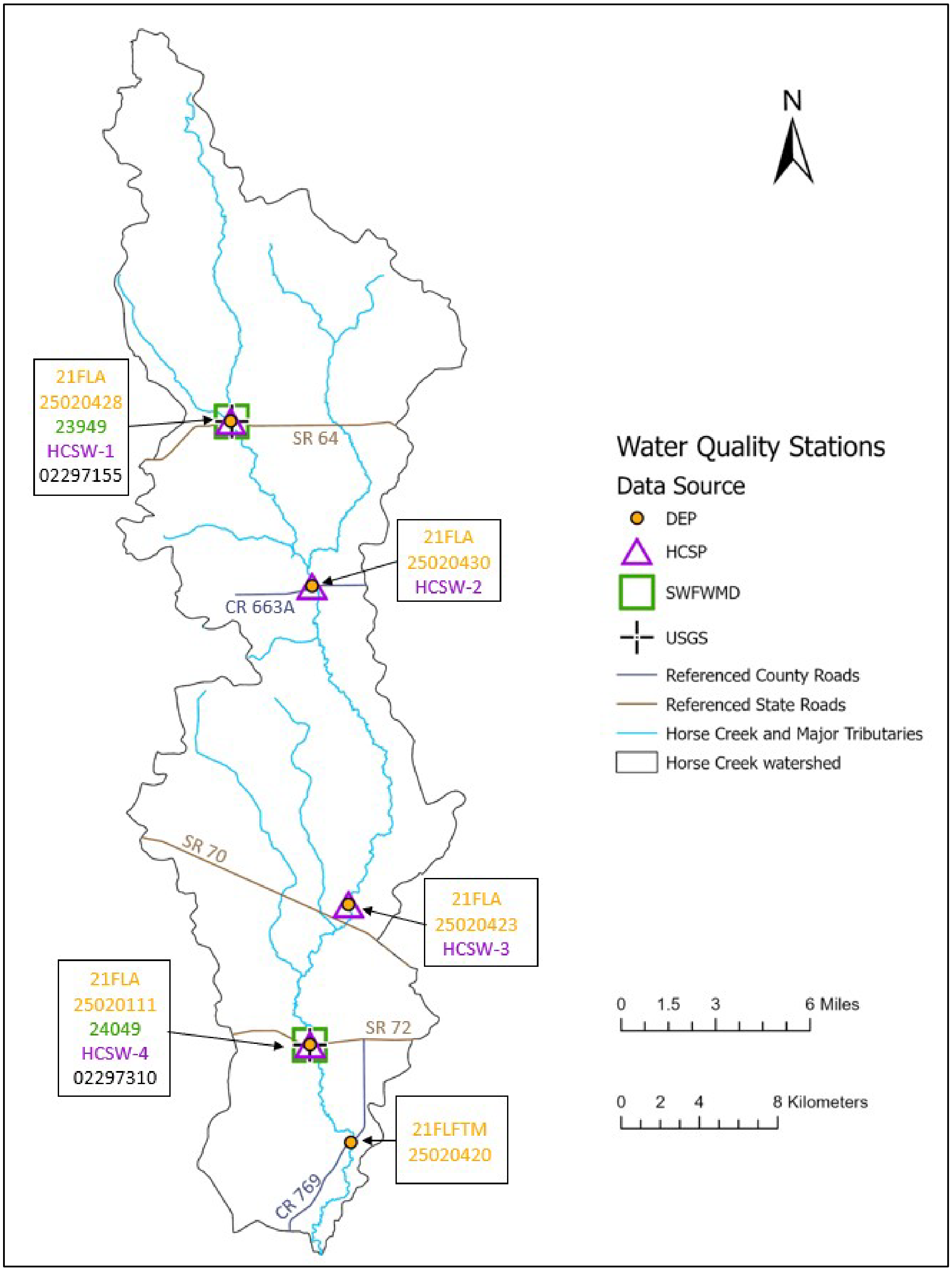

Figure 3-2. Locations of the water quality sampling sites that met criteria for inclusion in analysis by ATM and JEI (2021), with roads referenced in Table 3-1.

Table 3-2. Water quality constituent groups used for analysis by ATM and JEI (2021) with their associated constituents.

Group	Constituent
Nitrogen	Ammonia
	Ammonium
	Nitrate
	Nitrate-Nitrite
	Nitrite
	Organic Nitrogen
	Total Kjeldahl Nitrogen
	Total Nitrogen
	Unionized Ammonium
Phosphorus	Dissolved Orthophosphate
	Orthophosphate
	Phosphorus in Total Orthophosphate
	Total Phosphorus
Chlorophyll	Chlorophyll *a*
Physio-Chemical	Biological or Chemical Oxygen Demand
	Conductivity
	Dissolved Oxygen
	Hardness
	pH
	Temperature
Minerals and Metals	Calcium
	Chloride
	Fluoride
	Iron
	Magnesium
	Radium 226
	Radium 228
	Radium Total
	Sulfate
Water Clarity	Color
	Total Dissolved Solids
	Total Organic Carbon
	Total Suspended Solids
	Turbidity

3.3.2. Analytical Methods

Trend tests, linear regressions, and logistic regressions were used to characterize the relationship between water quality constituents and flow. Trend tests were used to assess whether flow and water quality data have increased or decreased over time and whether the trend in either direction was significant. For flow trend analysis, Mann Kendall tests were performed using median monthly flow values at a USGS gage. Seasonal Mann Kendall was performed for water quality trend analysis, with a correction for serial dependence (Hirsh and Stack 1984). While this method can screen for monotonic trends over time, it does not account for the effects of other explanatory factors affecting trends, and therefore does not provide inferences as to the cause of detectable change. Inclusion criteria for these tests consist of having recent data (within the past five years), and for the seasonal Mann Kendall, at least five years of data and 60 observations were required (Reckhow et al., 1993; ATM and JEI 2021). Six stations met the requirements for seasonal Mann Kendall analysis: HCSW-1, HCSW-2, HCSW-3, HCSW-4, 23949, and 24049 (Figure 3-2). A total of 129 constituent and station combinations were ultimately evaluated by ATM & JEI 2021.

To investigate relationships between water quality constituents and flow, linear regressions were performed on natural log transformed flow and water quality parameter data. Linear regression is a common statistical method for relating predictor variables to response variables under strict assumptions. A seasonal classification term was added to the model to evaluate how different months may have affected the response between flows and water quality parameters. To evaluate model fit and potential utility in assessing water quality relationships, the sign of the slope statistic, the p value indicating the statistical significance of the slope statistic, and the coefficient of determination (R^2) defining the proportion of variation explained by the model were reported. For example, an R^2 value of 0.4 would indicate that 40% of the variation in a constituent is explained by the model (flow). Only regressions with an R^2 value of 0.2 or more are included in this chapter. Importantly, even when linear regressions suggested statistically significant relationships, this did not imply causation. Results of linear regressions were reported for "primary sites," which had at least 100 observations for a constituent of interest, and "secondary sites," which had fewer observations. Analyses performed on "secondary sites" with smaller sample sizes should be interpreted with caution (ATM and JEI 2021).

Logistic regressions were used to examine the probability of exceeding ecologically relevant water quality thresholds as a function of flows. This analysis was restricted to stations and constituents with 100 or more observations, which had more than 10% of their observations exceeding thresholds. Based on these criteria, only total nitrogen and total phosphorus were considered for logistic regression analysis. Threshold values associated with DEP water quality standards (based on annual statistics) were used, including the maximum total nitrogen concentration for freshwater streams (annual geometric mean of 1.65 mg/L, per Rule 62-302.531, F.A.C.) and the maximum total phosphorus concentration for freshwater streams (annual geometric mean of 0.49 mg/L, per Rule 62-302.531, F.A.C.). The use of these threshold values is not intended to suggest that variation in flow would lead to impairment according to state standards, but rather to identify constituents for further investigation, should reductions in flow lead to an increased probability of exceeding the state-established thresholds. Evaluation of the logistic regression model fits included calculating a generalized R^2, which was rescaled to conform to the typical inference regarding R^2, in which the maximum value is 1 (ATM and JEI 2021). As with linear regression results, only those regressions with an R^2 greater than 0.2 are included in this chapter.

3.3.3. Results

3.3.3.1. Nitrogen

Nitrogen is an essential nutrient for plants; however, an overabundance can have deleterious effects on aquatic life by causing overgrowth of phytoplankton and nuisance vegetation. Several nitrogen species have been monitored throughout Horse Creek (Table 3-2). Statistically significant ($p < 0.05$) results of the seasonal Mann Kendall trend test indicated a decreasing trend for ammonia ($p = 0.007$) at HCSW-1 (Figure 3-3a), nitrate-nitrite ($p = 0.009$) at HCSW-2 (Figure 3-3b), and total nitrogen ($p = 0.017$) at station 24049 (Figure 3-3c). An increasing trend ($p = 0.04$) was observed for total nitrogen at the same location as station 24049 using the HCSW-4 dataset, which contains a more recent and shorter period of record (2003-2019) compared to station 24049 (which dates to 1997, Figure 3-3d). The increase in total nitrogen at HCSW-4 may be due to impacts of agricultural use in the lower basin (Flatwoods 2021).

When relationships with flow were considered by linear regression analysis, positive relationships with an R^2 value of 0.2 or greater were observed for several nitrogen species including: nitrite at stations 23949 ($p = 0.007$) and 24049 ($p = 0.003$); nitrate-nitrite at HCSW-1 ($p = 0.003$); organic nitrogen at station 0297155 ($p < 0.001$) and 02297310 ($p = 0.047$); total Kjeldahl nitrogen at HCSW-1 ($p < 0.001$), HCSW-4 ($p < 0.001$), station 02297310 ($p < 0.001$), station 02297155 ($p <0.001$), station 24049 ($p = 0.026$) and 21FLA 25020111 ($p < 0.001$); and total nitrogen at stations 23409 ($p = 0.038$), HCSW-1 ($p < 0.001$), station 02297155 ($p < 0.001$), and station 24049 ($p = 0.007$; Table 3-3). Some of these positive trends are only observed at one station or over one POR at a given station.

This indicates site-specific conditions may be impacting constituent results. The positive relationship between many nitrogen species and flow is comparable to findings from other Florida rivers (ATM and JEI 2020), and generally results from the flushing of decomposing organic matter and agricultural runoff that can increase nitrogen loads to the system during the wet season (ATM and JEI 2021). Most regressions for nitrogen species, with R^2 greater than 0.2 and more than 100 observations, had a statistically significant seasonal term (Table 3-3).

Logistic regression results indicated a negative association at station HCSW-2 ($p = 0.002$) with an R^2 value of 0.24, suggesting a weak association between flow and the probability of a total nitrogen exceedance (ATM and JEI 2021). The annual geometric means were calculated based upon available data at HCSP, SWFWMD, and USGS stations. Individual annual exceedances of the State water quality threshold for total nitrogen freshwater streams (annual geometric mean of 1.65 mg/L, not to be exceeded more than once in any three-calendar year period) within this dataset have occurred at stations HCSW-2 (n = 1), HCSW-4 (n=1), and 02297310 (n =5), with 71% of occurrences happening prior to 1993 (Figure 3-4). The inclusion of these data is not intended to be a designation of impairment but rather a comparison to established benchmarks. Furthermore, District stations 23949 and 24049 failed to meet requirements for calculating the annual geometric mean in years 1998, 2000, 2001, and 2020. They are still included in Figure 3-4 for comparative purposes.

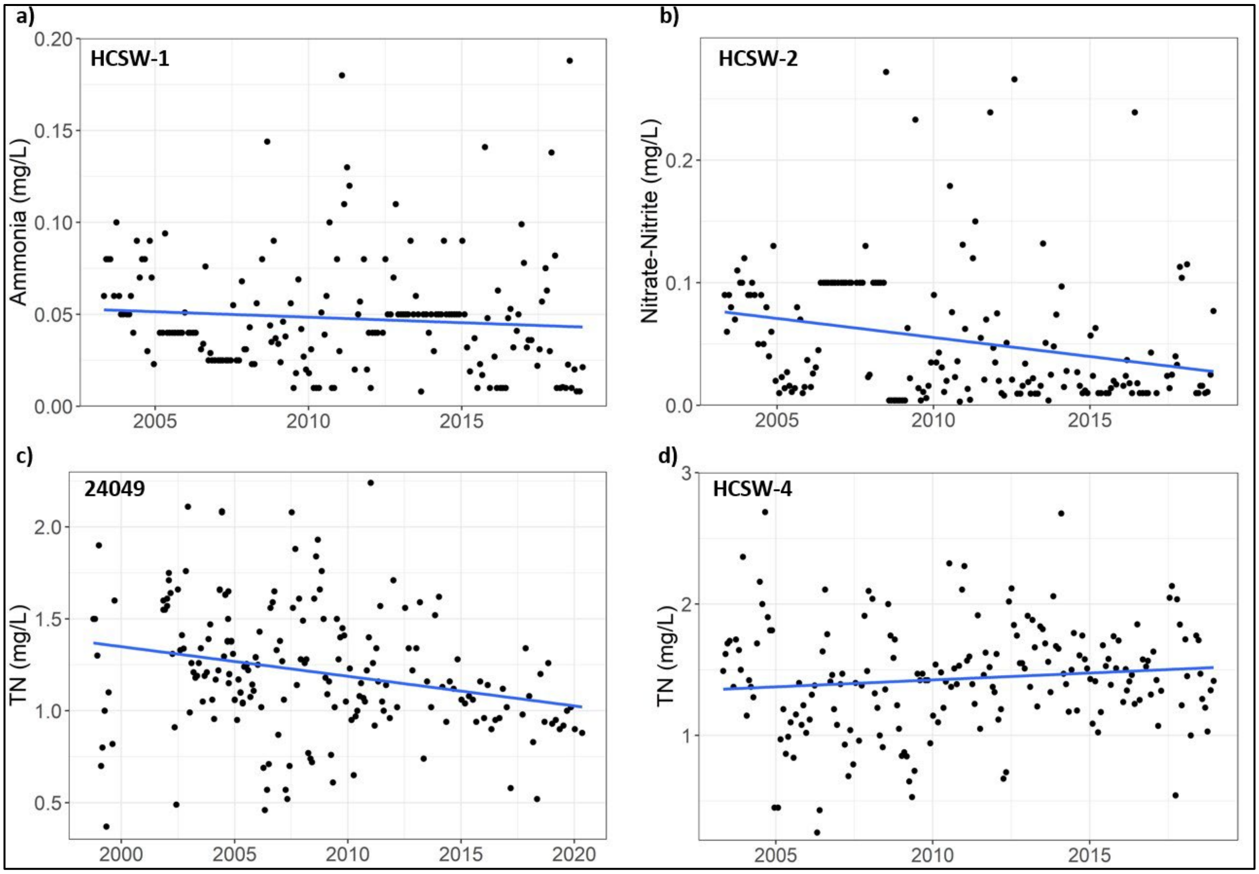

Figure 3-3. Time series of statistically significant trends over time for constituents in the nitrogen group including a) ammonia at HCSW-1, b) Nitrate-nitrite at HCSW-2, and total nitrogen (TN) at c) station 24049 and d) HCSW-4. The blue line represents the predicted trend over time.

Table 3-3. Summary of statistically significant ($p < 0.05$) linear regression relationships between nitrogen group constituents and flow, with R^2 values greater than or equal to 0.20. The positive (Pos.) or negative (Neg.) slope designation refers to the relationship between constituent and flow at the corresponding USGS gage. Non-significant monthly p-values are listed as "ns." Significant regressions are listed by constituent from upstream to downstream. Stations occurring at the same location are listed in alphabetical order of their sampling agency (modified from ATM and JEI, 2021).

Constituent	Station	Samples (n)	Period of Record	Month p-value	Flow p-value	R^2	Slope
Nitrate-Nitrite	HCSW-1	176	4/2003-12/2018	0.003	0.047	0.21	Pos.
Nitrite	23949	158	1/2002-3/2019	<0.001	0.007	0.44	Pos.
	24049	154	1/2002-3/2019	<0.001	<0.001	0.49	Pos.
Organic Nitrogen	02297155	44	8/1982-9/1999	ns	<0.001	0.50	Pos.
	02297310	116	6/1970-9/1999	<0.001	<0.001	0.56	Pos.
Total Kjeldahl Nitrogen	HCSW-1	176	4/2003-12/2018	ns	<0.001	0.20	Pos.
	02297155	44	8/1982-9/1999	ns	<0.001	0.49	Pos.
	21FLA 25020111	141	12/1977-4/1998	ns	<0.001	0.37	Pos.
	HCSW-4	179	4/2003-12/2018	ns	<0.001	0.36	Pos.
	02297310	114	7/1979-9/1999	<0.001	<0.001	0.60	Pos.
Total Nitrogen	HCSW-1	179	4/2003-12/2018	ns	<0.001	0.23	Pos.
	23949	162	2/1998-3/2019	<0.001	0.002	0.40	Pos.
	02297155	44	8/1982-9/1999	ns	<0.001	0.47	Pos.
	24049	161	3/2000-3/2019	<0.001	0.007	0.30	Pos.
Unionized Ammonium	21FLA 25020111	112	5/1972-4/1998	0.015	<0.001	0.47	Neg.

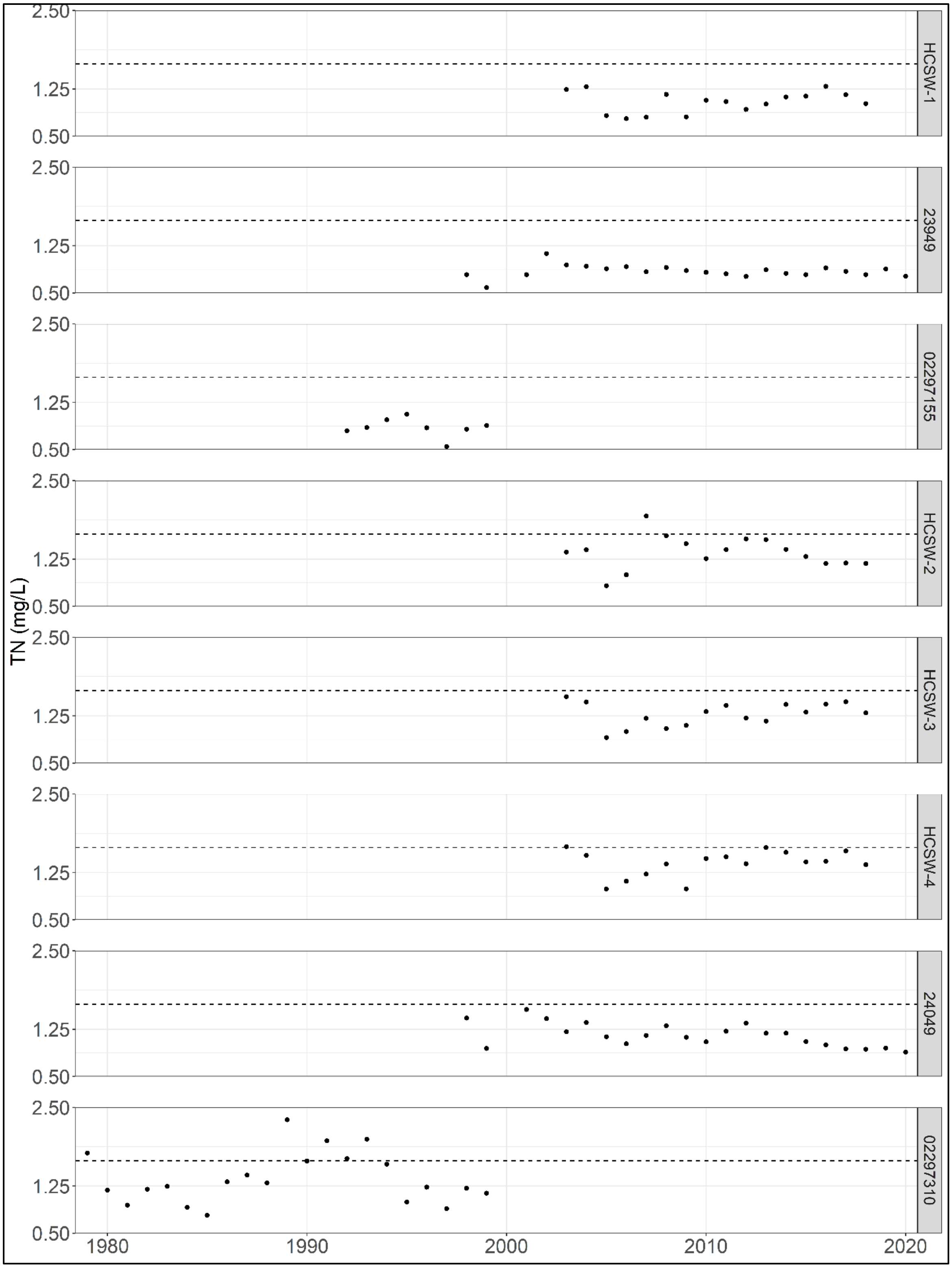

Figure 3-4. Annual geometric mean of total nitrogen (TN) at HCSP (HCSW-1, -2, -3, and -4), District (23949 and 24049) and USGS (02297155 and 02297310) stations

over the period of record for each station. Stations are listed from upstream to downstream along Horse Creek. The dashed line indicates the State water quality threshold for TN (an annual geometric mean of 1.65 mg/L).

3.3.3.2. Phosphorus

Phosphorus is another nutrient essential for plant growth that can lead to ecological degradation at high concentrations. Over time, orthophosphate has exhibited an increasing trend at stations HCSW-2 ($p = 0.035$, Figure 3-5a) and HCSW-3 ($p = 0.047$, Figure 3-5b). Compared to other HCSP stations over the period of record (2003-2018), station HCSW-2 has had the lowest mean levels of orthophosphate (Figure 3-6), with relatively similar concentrations evident at the remaining stations. Horse Creek resides in a phosphate-rich geological formation, and groundwater seepage and agricultural runoff may increase orthophosphate concentrations in the lower portion of the basin (Flatwoods 2020).

Four of the five statistically significant linear regressions between flow and phosphate group constituents, with R^2 values greater than 0.20, were negative (Table 3-4). Four stations met the criteria for total phosphorus logistic regression analysis; however, none had a significant relationship with flow (defined as a p-value < 0.05 and R^2 value greater than 0.20).

District staff calculated annual geometric means for total phosphorus over the available POR and plotted them against the State water quality threshold of 0.49 mg/L (Figure 3-7). There were 42 exceedances in the data, at SWFWMD stations 23949 (n = 7) and 24049 (n = 7), USGS stations 02297155 (n = 1) and 02297310 (n = 11), and DEP station 21FLA 25020111 (n = 16; Figure 3-6). Exceedances have occurred throughout the POR at stations in both the upper and lower portions of Horse Creek. These data are not an accurate indicator of whether the system meets state water quality criteria, rather, they represent a simple comparison using the water quality criteria as a benchmark. Total phosphorus data at SWFWMD stations 23949 (from years 2017 and 2020) and 24049 (years 2017 and 2020), USGS stations 02297155 (in 1993) and 02297210 (years 1970, 1972-1974, and 1979), and DEP station 21FLA 25020111 (years 1972-1974, 1994, and 1996-1998) were insufficient to calculate an annual geometric mean according to state guidelines but are included in Figure 3-7 for comparison purposes.

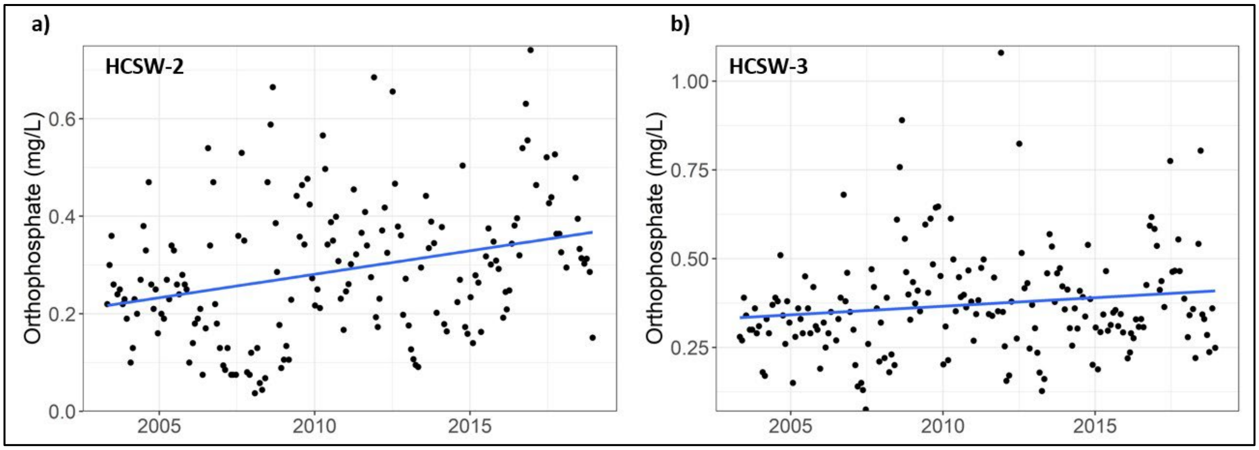

Figure 3-5. Time series of statistically significant trends over time for orthophosphate at HCSP stations a) HCSW-2 and b) HCSW-3. The blue line represents the predicted trend over time.

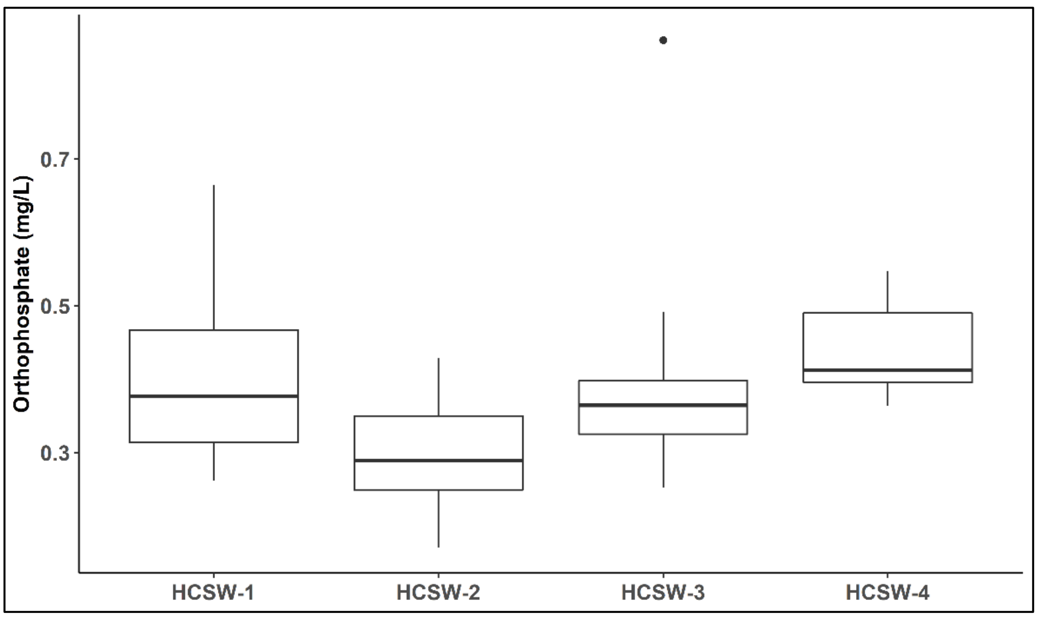

Figure 3-6. Orthophosphate at HCSP stations from 2003-2018. Boxed values indicate the 25th to 75th percentiles with centerline reflecting the 50th percentile value. Dots represent outliers, indicative of values outside of the 1.5*interquartile range.

Table 3-4. Summary of statistically significant ($p < 0.05$) linear regression relationships between phosphorus group constituents and flow, with R^2 values greater than or equal to 0.20. The positive (Pos.) or negative (Neg.) slope designation refers to the relationship between constituent and flow at the corresponding USGS gage. Significant regressions are listed by constituent from upstream to downstream. Stations occurring at the same location are listed in alphabetical order of their sampling agency (modified from ATM and JEI, 2021).

Constituent	Station	Samples (n)	Period of Record	Month p-value	Flow p-value	R^2	Slope
Ortho-phosphate	HCSW-2	170	4/2003-12/2018	<0.001	<0.001	0.43	Pos.
	HCSW-4	176	4/2003-12/2018	<0.001	0.043	0.20	Neg.
	24049	207	9/1997-3/2019	<0.001	0.004	0.26	Neg.
Total Phosphorus	24049	204	8/1997-3/2019	<0.001	0.01	0.32	Neg.
	02297310	122	5/1968-9/1999	<0.001	0.029	0.25	Neg.

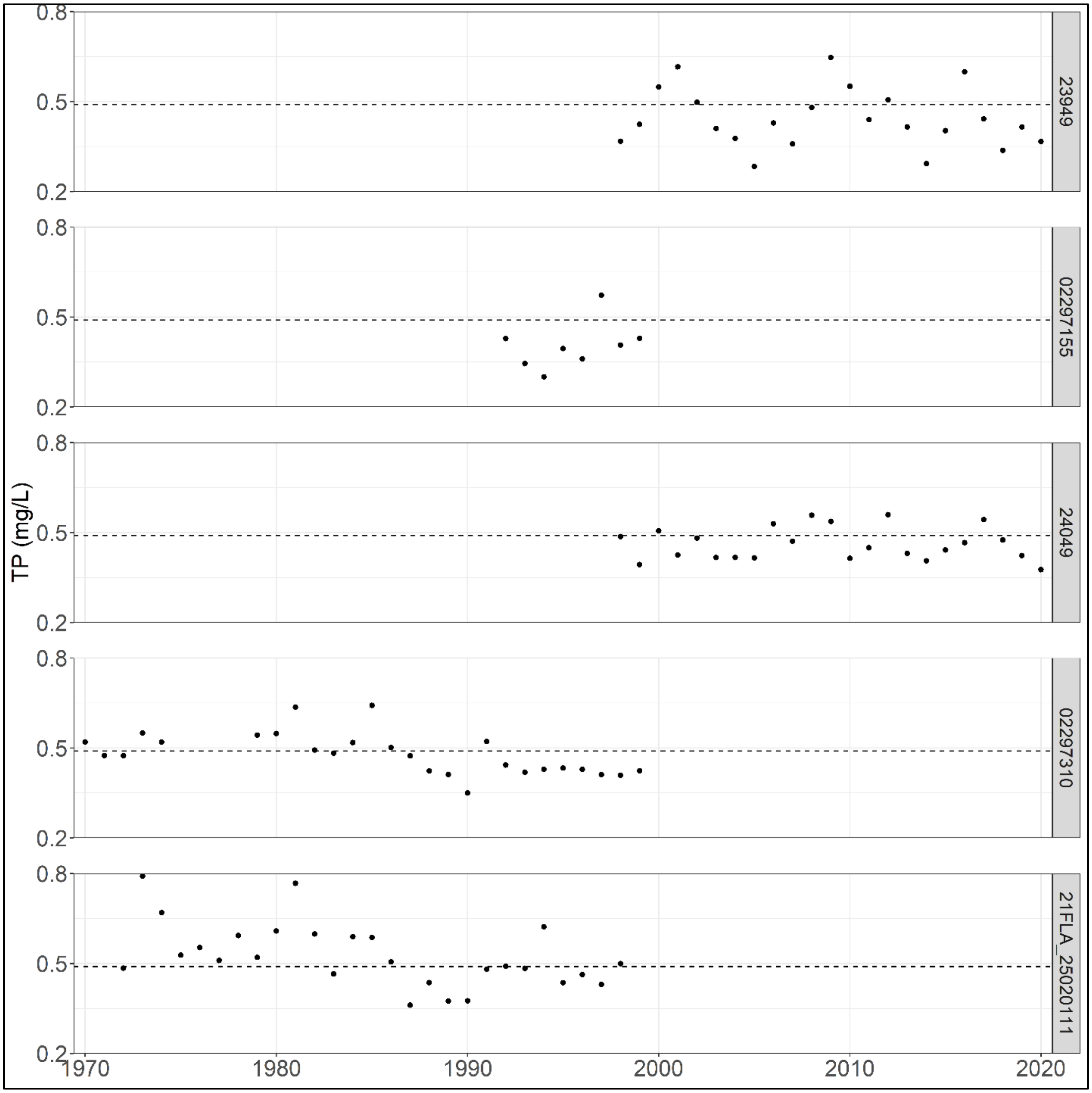

Figure 3-7. Annual geometric mean of total phosphorus (TP) at DEP (21FLA 25020111), District (23949 and 24049) and USGS (02297155 and 02297310) stations over the period of record for each station. Stations are listed from upstream to downstream along Horse Creek. The dashed line indicates the State water quality threshold for TP in Class III waters (0.49 mg/L).

3.3.3.3. Chlorophyll *a*

Excess nutrients in a system can stimulate phytoplankton growth, whose biomass can be approximated by measurement of chlorophyll concentrations. With reduced flushing and increased residence time, eutrophication can occur leading to oxygen depletion and ecological stress. Although there are many types of chlorophyll, chlorophyll *a* is commonly assessed for aquatic ecosystems studies. Station HCSW-2 frequently had elevated levels of chlorophyll *a* compared to other stations along the creek (Figure 3-8). This has been attributed to site characteristics, as it receives elevated nutrient loads from an upstream wetland prairie and has increased residence time due to upstream impoundment from above-grade culverts (Flatwoods 2020). Linear regression at this station indicated a statistically significant ($p < 0.001$, $R^2 = 0.26$) negative relationship between flow and chlorophyll *a* and a significant ($p = 0.003$) seasonal term (ATM and JEI 2021). Over the period of record, chlorophyll *a* levels tended to be higher during the typically dry months of April and May (Figure 3-9).

Chlorophyll *a* concentration had a statistically significant decreasing trend over time at stations HCSW-1 ($p < 0.001$, Figure 3-10a) and HCSW-4 ($p =0.001$, Figure 3-10b). A statistically significant ($p < 0.001$) negative relationship with flow was observed at station HCSW-2.

Logistic regression analysis was not performed on chlorophyll *a* data either due to stations failing to meet sample size requirements or threshold exceedance rates of less than 10%. Annual geometric means were calculated by the District over the POR for all stations where chlorophyll *a* was measured, however, there were no exceedances of the 20 µg/L threshold for freshwater streams (per Rule 62-303.651, F.A.C). The highest values occurred at station HCSW-2, with a maximum chlorophyll *a* annual geometric mean of 9.2 µg/L in 2007.

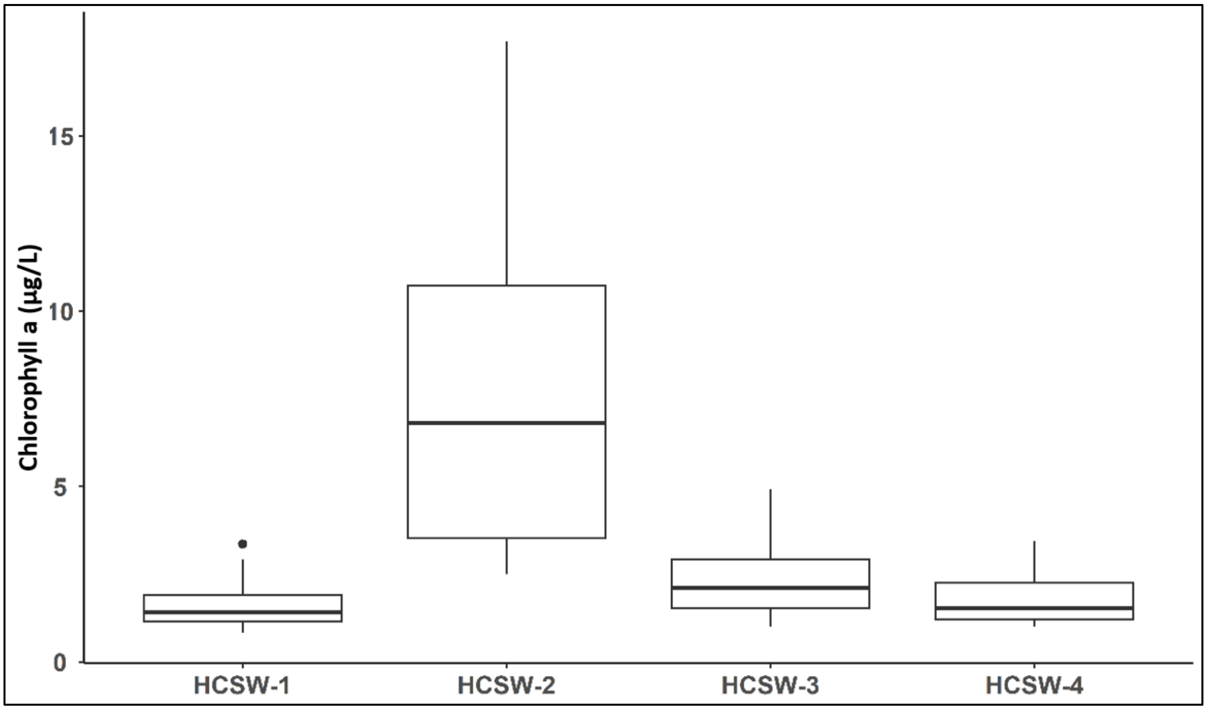

Figure 3-8. Chlorophyll *a* concentration at HCSP stations from 2003 through 2018. Boxed values indicate the 25th to 75th percentiles with centerline reflecting the 50th percentile value. Dots represent outliers, indicative of values outside of the 1.5*interquartile range.

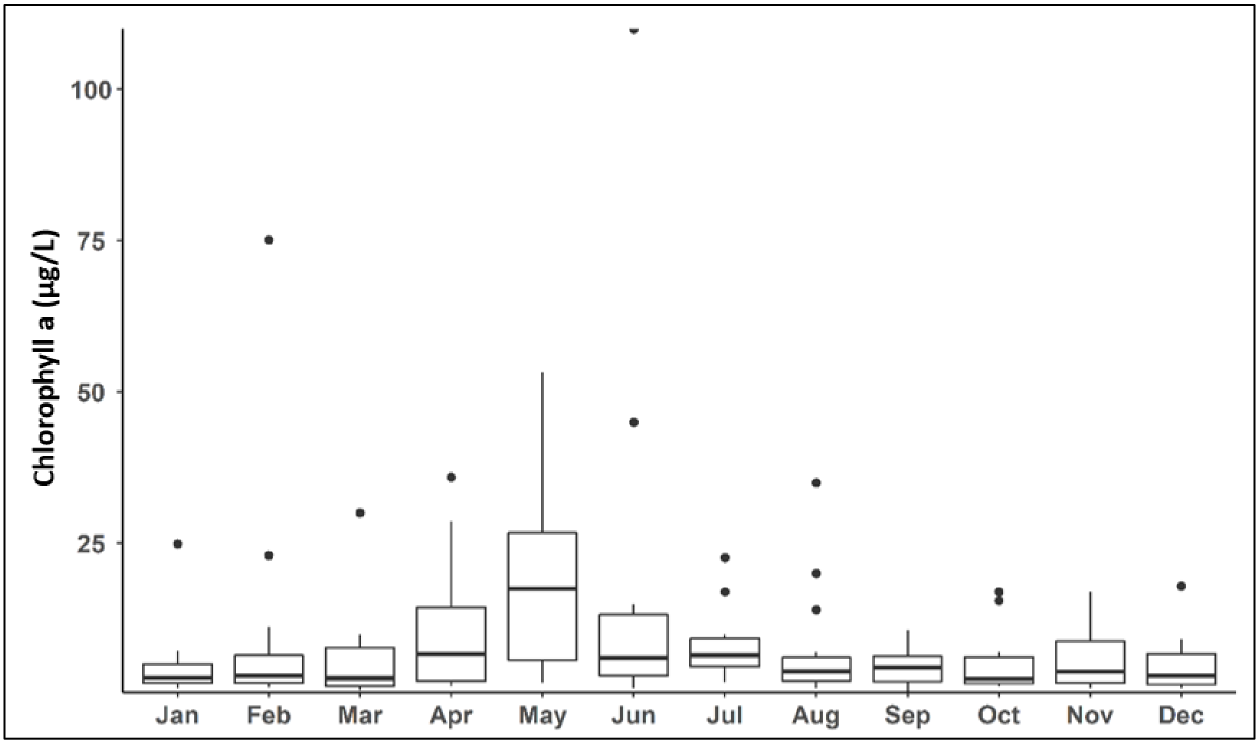

Figure 3-9. Monthly chlorophyll *a* concentration at HCSW-2 from 2003 through 2018. Boxed values indicate the 25th to 75th percentiles with centerline reflecting the 50th percentile value. Dots represent outliers, indicative of values outside of the 1.5*interquartile range.

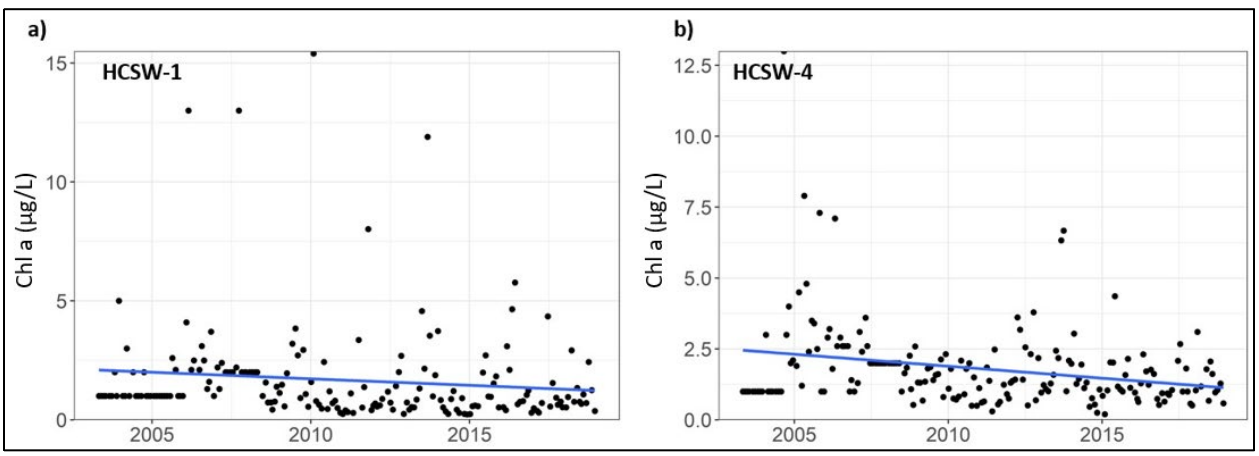

Figure 3-10. Time series of statistically significant trends over time for chlorophyll *a* (Chl a) at HCSP stations a) HCSW-1 and b) HCSW-4. The blue line represents the predicted trend over time.

3.3.3.4. Physio-Chemical Constituents

Physio-chemical parameters analyzed in Horse Creek included: dissolved oxygen, pH, alkalinity, conductivity, and temperature. Dissolved oxygen levels have been reported in this system as both concentration and percent saturation, the latter of which approximates the amount of oxygen the water can hold as a function of temperature. Dissolved oxygen can increase through physical processes, atmospheric interaction, and photosynthesis and decrease as it is used by organisms or through the decomposition of organic materials. The pH of a waterbody is important since different chemical species become soluble and bioavailable at different pH levels and as such many aquatic organisms have evolved to survive within certain pH ranges. The alkalinity of a system refers to the buffering capacity of the water against rapid fluctuations in pH. Limestone-dominated systems tend to have higher alkalinity overall. Conductivity refers to the ability of water to pass an electrical current and can increase with increasing levels of dissolved salts and other inorganic chemicals or rising temperature. In addition to previously mentioned roles, temperature is critical both for the types and life stages of biological organisms a river can support and the rate of chemical and biological reactions that happen within a liquid medium.

When statistically significant ($p < 0.05$), pH, alkalinity, and conductivity were increasing over time in Horse Creek (Figures 3-11 through 3-13). This suggests increasing loads of dissolved salts or inorganic chemicals, which may be attributed to the natural flow through the geological formations within Horse Creek, the influence of climatic conditions including rainfall, and the impact of changing land use throughout the watershed including the increase of mined and reclaimed land and runoff from irrigated agriculture (Flatwoods 2021). Mean pH and mean alkalinity over the POR were slightly higher at the most upstream stations (HCSP station HCSW-1 and SWFWMD station 23949) compared to other stations (Figures 3-14, 3-15). Mean specific conductance was higher at downstream sites (Figure 3-16), indicating different factors may influence these parameters.

In Appendix I of the 2017 Annual Report for the HCSP, Cardno, Inc. describes the regional increase in specific conductance in waters within and around the Horse Creek basin and used change-point analysis to observe increasing trends in specific conductance (and by proxy, total dissolved solids, and other ions) during periods of drought and decreasing trends during wetter periods (Cardno 2019). Their analysis considered the influence of NPDES discharge and found no conclusive impact of discharge on elevated conductance.

Statistically significant relationships were observed between the physio-chemical constituents and flow, with R^2 values ranging from 0.21 to 0.75 (Table 3-5). All physio-chemical constituents have negative relationships with flow except the chemical oxygen demand at DEP station 21FLA 25020111. Because only 39 samples were used for the chemical oxygen demand regression analysis, the regression should be cautiously interpreted (ATM and JEI 2021). Seasonal effect was significant for alkalinity, conductivity, dissolved oxygen, and temperature relationships with flow with more than 100 observations (Table 3-5). Typically, low levels occur during the wet season from July through October. An example for seasonal trends using specific conductivity is provided in Figure 3-17.

Hypoxic conditions can occur in waters with dissolved oxygen concentrations below 3 mg/L. Over the POR at HCSP and District stations (which had the most recently collected data), hypoxic conditions were most frequent at station HCSW-2 (Figure 3-18). At this station, dissolved oxygen concentrations were below 3 mg/L for 58% of samples over the POR. Hypoxic conditions occurred for less than 3% of samples at the remaining stations.

Dissolved oxygen percent saturation did not meet the requirements for logistic regression analysis. The most recent data for this constituent were taken at HCSP stations and DEP station 21FLA 25020420 (Figure 3-19). Frequent exceedances of the State water quality threshold for dissolved oxygen percent saturation (10% of daily samples less than 38%, per Rule 62-302.533, F.A.C.) occurred at HCSP station HCSW-2 and occasional samples below 38% were recorded at DEP station 21FLA 25020420.

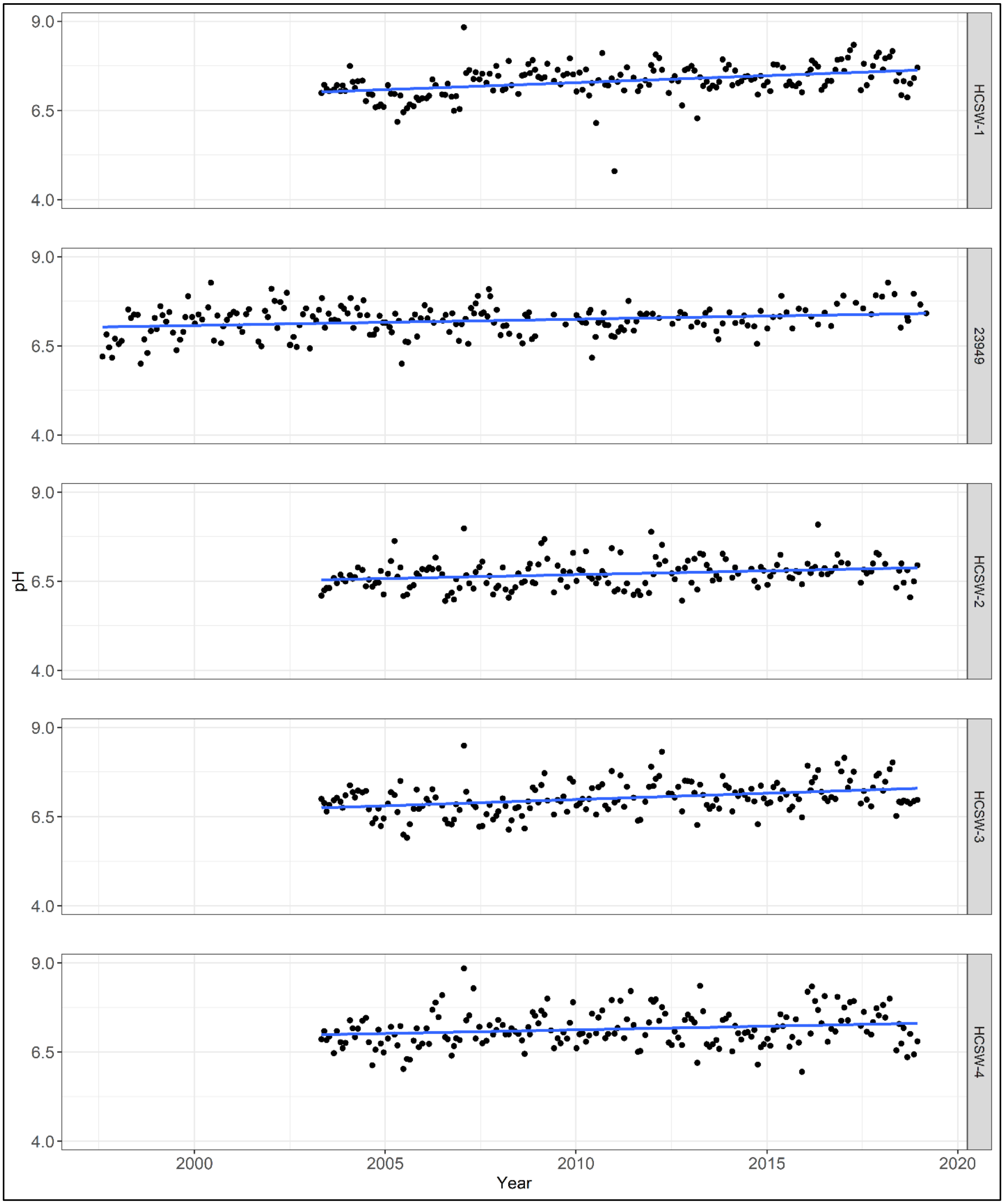

Figure 3-11. Time series of pH data over the period of record for stations with a statistically significant increasing trend, including District station 23949 and HCSP stations HCSW-1, -2, -3, and -4. Stations are listed from upstream to downstream in the watershed. The blue line indicates the predicted trend.

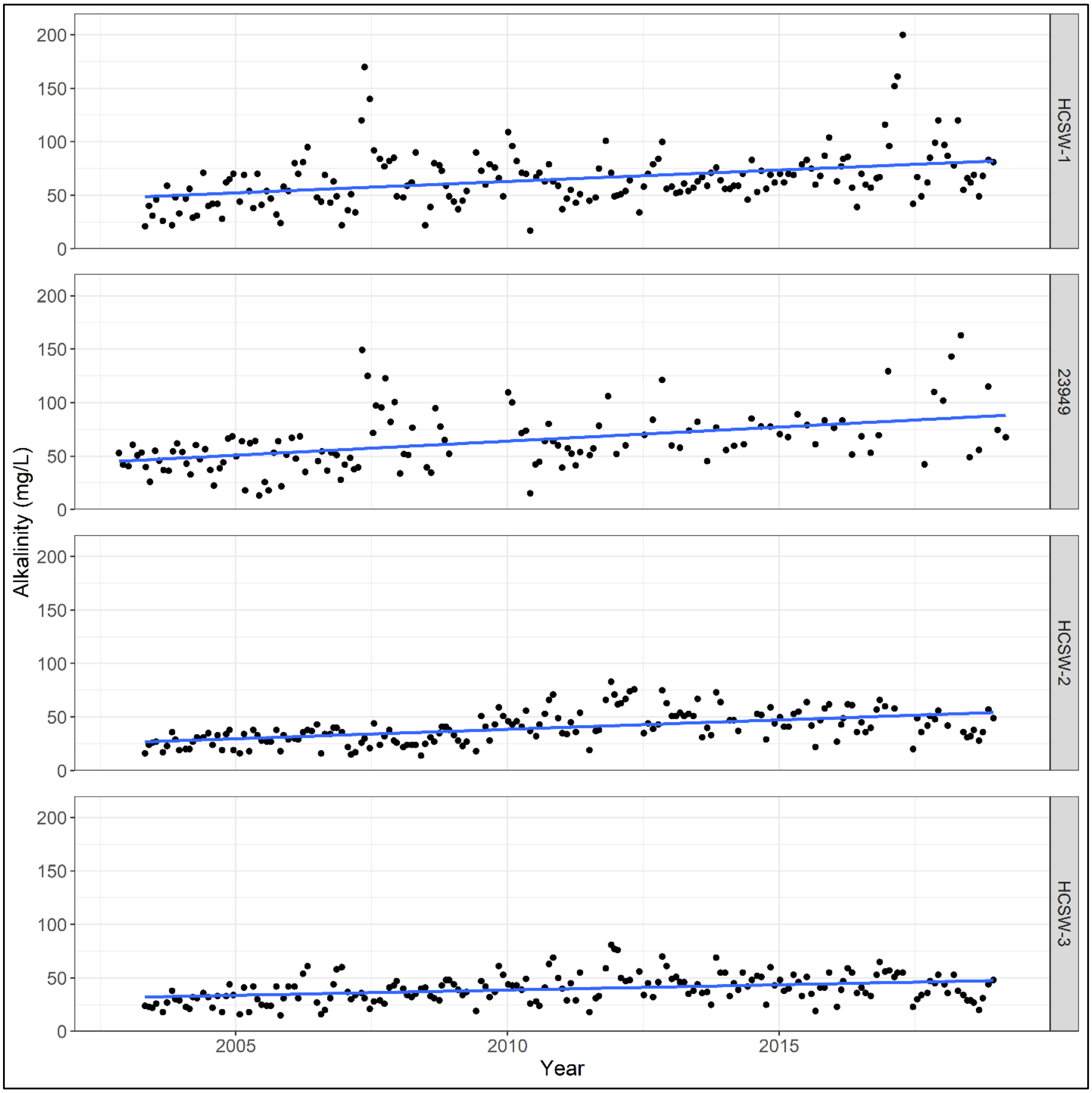

Figure 3-12. Time series of alkalinity data over the period of record for stations with a statistically significant increasing trend, including District station 23949 and HCSP stations HCSW-1, -2, and -3. Stations are listed from upstream to downstream in the watershed. The blue line indicates the predicted trend.

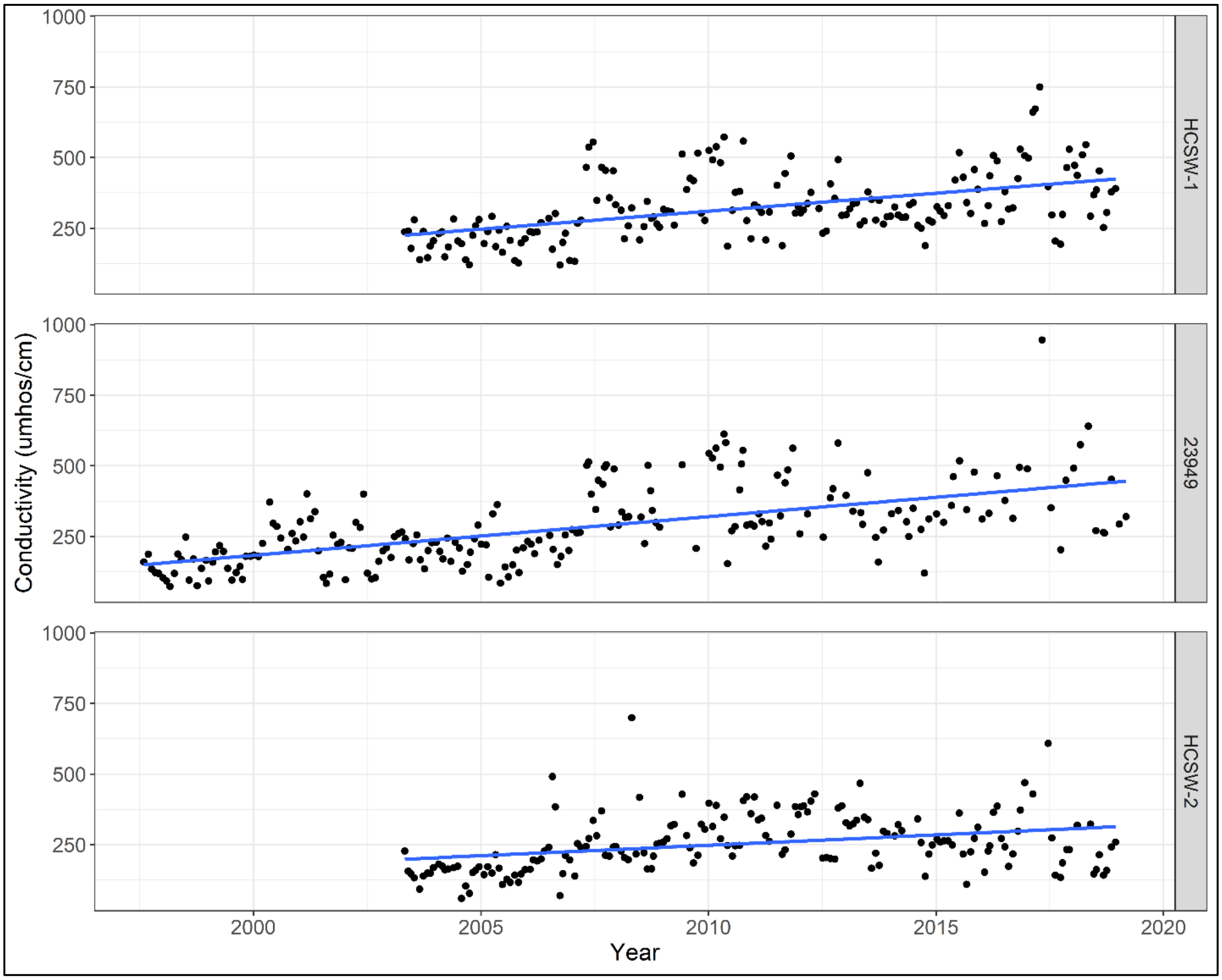

Figure 3-13. Time series of conductivity data over the period of record for stations with a statistically significant increasing trend, including District station 23949 and HCSP stations HCSW-1 and -2. Stations are listed from upstream to downstream in the watershed. The blue line indicates the predicted trend.

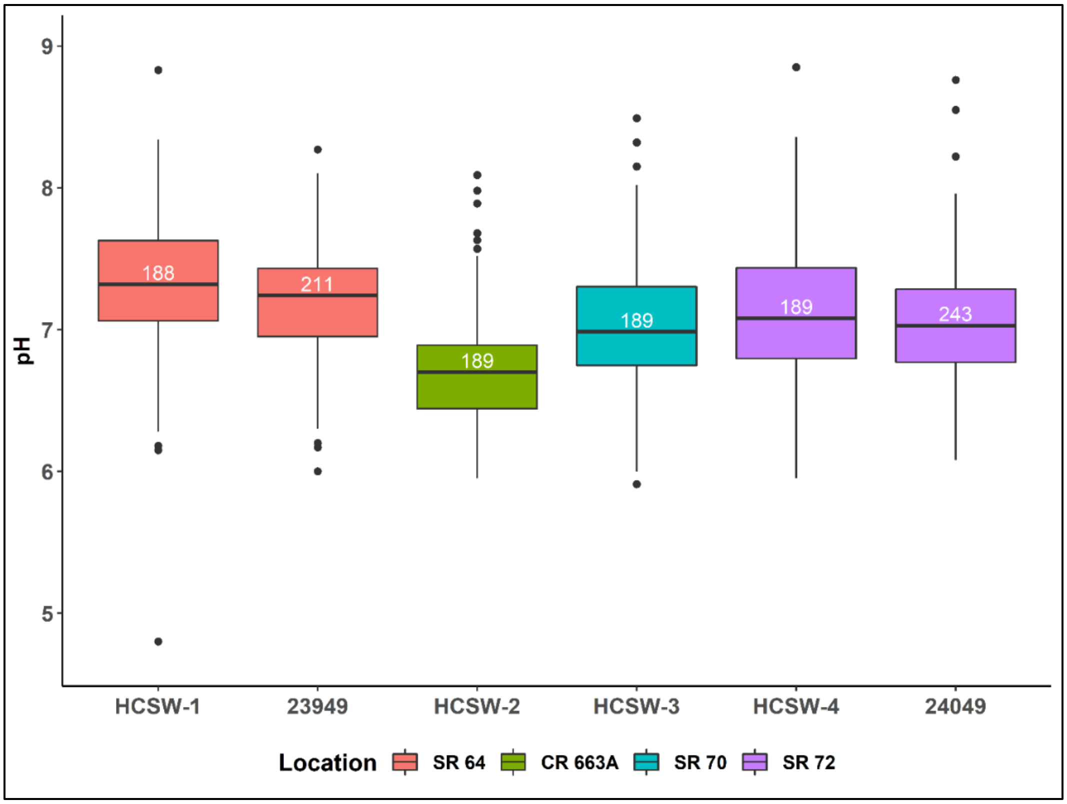

Figure 3-14. Measured pH at stations with a similar period of record (POR). The HCSP stations (HCSW-1, -2, -3, and -4) have a POR from April 2003 through December 2018 and the District stations (23949 and 24049) have a POR from August 1997 through July 2019. The number of samples measured at each station is noted above the mean line. Stations are color-coded by their relative location since some stations are sampled at nearly the same coordinates. Boxed values indicate the 25th to 75th percentiles with centerline reflecting the 50th percentile value. Dots represent outliers, indicative of values outside of the 1.5*interquartile range.

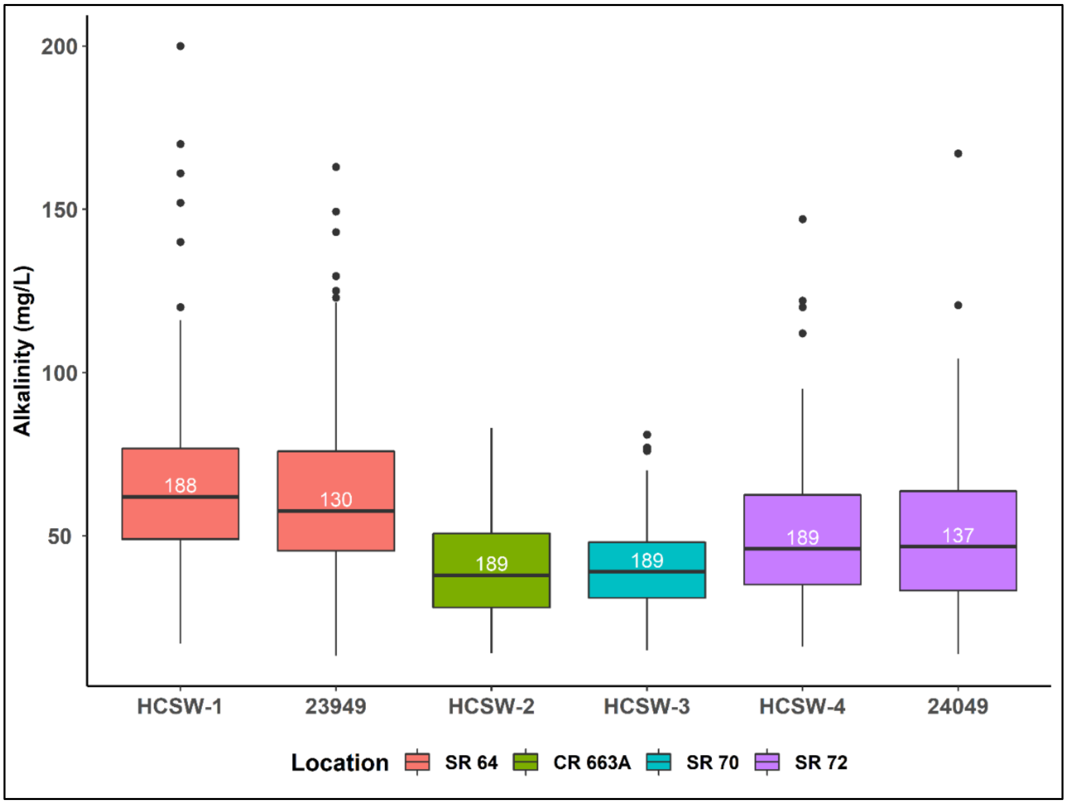

Figure 3-15. Alkalinity at stations with a similar period of record (POR). The HCSP stations (HCSW-1, -2, -3, and -4) have a POR from April 2003 through December 2018 and the District stations (23949 and 24049) have a POR from January 2000 through May 2020. The number of samples measured at each station is noted above the mean line. Stations are color-coded by their relative location since some stations are sampled at nearly the same coordinates. Boxed values indicate the 25th to 75th percentiles with centerline reflecting the 50th percentile value. Dots represent outliers, indicative of values outside of the 1.5*interquartile range.

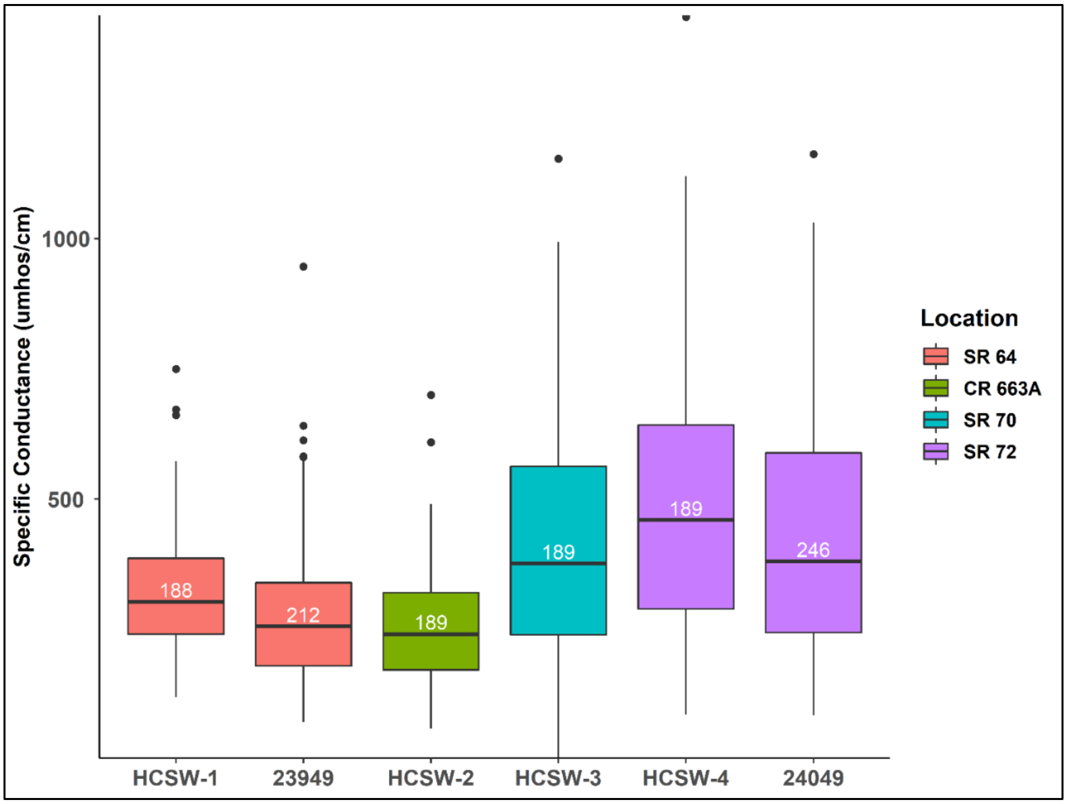

Figure 3-16. Specific conductance at stations with a similar period of record (POR). The HCSP stations (HCSW-1, -2, -3, and -4) have a POR of April 2003 through December 2018 and the District stations (23949 and 24049) have a POR from August 1997 through July 2019. The number of samples measured at each station is noted above the mean line. Stations are color-coded by their relative location since some stations are sampled at nearly the same coordinates. Boxed values indicate the 25th to 75th percentiles with centerline reflecting the 50th percentile value. Dots represent outliers, indicative of values outside of the 1.5*interquartile range.

Table 3-5. Summary of statistically significant ($p < 0.05$) linear regression relationships between physio-chemical group constituents and flow with R^2 values greater than or equal to 0.20. The positive (Pos.) or negative (Neg.) slope designation refers to the relationship between constituent and flow at the corresponding USGS gage. Non-significant monthly p-values are listed as "ns." Significant regressions are listed by constituent from upstream to downstream. Stations occurring at the same location are listed in alphabetical order of their sampling agency (modified from ATM and JEI, 2021).

Constituent	Station	Samples (n)	Period of Record	Month p-value	Flow p-value	R^2	Slope
Alkalinity	23949	179	1/2000-5/2020	0.012	<0.001	0.23	Neg.
	HCSW-3	180	4/2003-12/2018	<0.001	0.047	0.28	Neg.
	HCSW-4	180	4/2003-12/2018	0.016	<0.001	0.70	Neg.
	24049	175	1/2000-5/2020	0.002	<0.001	0.75	Neg.
Chemical Oxygen Demand	21FLA 25020111	39	3/1978-9/1983	ns	<0.001	0.57	Pos.
Conductivity	21FLA 25020428	29	5/1972-7/1990	ns	<0.001	0.66	Neg.
	02297155	76	10/1978-9/1999	0.018	<0.001	0.67	Neg.
	HCSW-3	182	4/2003-12/2018	<0.001	<0.001	0.47	Neg.
	21FLA 25020111	208	8/1974-4/1998	0.002	<0.001	0.68	Neg.
	HCSW-4	181	4/2003-12/2018	<0.001	<0.001	0.71	Neg.
	24049	213	8/1997-7/2019	<0.001	<0.001	0.69	Neg.
	02297310	261	6/1962-9/1999	ns	<0.001	0.59	Neg.
	21FLFTM 25020420	227	10/2001-1/2018	<0.001	<0.001	0.67	Neg.
Dissolved Oxygen	23949	217	8/1997-6/2019	<0.001	0.021	0.56	Neg.
	HCSW-2	164	4/2003-12/2017	<0.001	0.01	0.33	Neg.
	21FLA 25020423	39	5/1972-8/1991	ns	<0.001	0.27	Neg.
	21FLA 25020111	289	5/1982-4/1998	<0.001	<0.001	0.50	Neg.

Constituent	Station	Samples (n)	Period of Record	Month p-value	Flow p-value	R^2	Slope
Dissolved Oxygen (Cont.)	HCSW-4	171	4/2003-1/2018	<0.001	<0.001	0.62	Neg.
	24049	213	8/1997-5/2020	<0.001	<0.001	0.6	Neg.
	02297310	183	5/1968-9/1999	<0.001	0.002	0.37	Neg.
Dissolved Oxygen (Percent Saturation)	HCSW-1	64	5/2013-12/2018	ns	<0.001	0.48	Neg.
	HCSW-2	55	5/2013-12/2018	ns	<0.001	0.33	Neg.
	21FLA 25020423	39	5/1972-8/1991	ns	<0.001	0.26	Neg.
	HCSW-3	65	5/2013-12/2018	ns	<0.001	0.39	Neg.
	21FLA 25020111	282	5/1972-4/1998	<0.001	<0.001	0.36	Neg.
	HCSW-4	66	5/2013-12/2018	ns	<0.001	0.56	Neg.
pH	21FLA 25020428	42	5/1972-7/1990	ns	<0.001	0.64	Neg.
	02297310	209	6/1962-9/1999	ns	<0.001	0.21	Neg.
	HCSW-4	181	4/2003-12/2018	ns	<0.001	0.22	Neg.
	24049	212	8/1997-7/2019	<0.001	<0.001	0.53	Neg.
	21FLA 25020111	281	5/1982-4/1998	ns	<0.001	0.53	Neg.
Temperature	21FLA 25020111	287	5/1972-4/1998	<0.001	0.014	0.54	Neg.

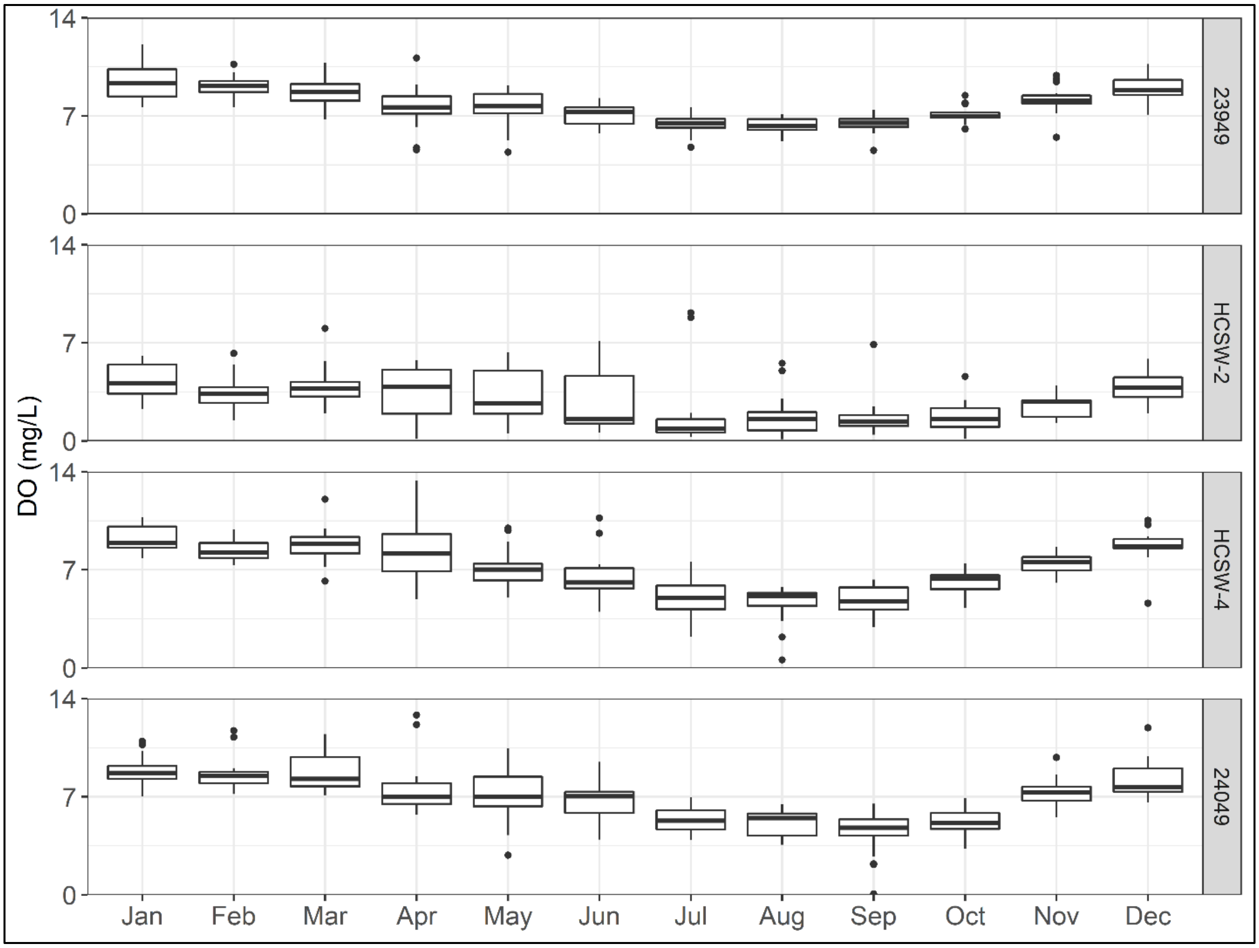

Figure 3-17. Mean monthly dissolved oxygen (DO) concentration over the period of record at stations with statistically significant seasonal trends, including HCSP stations HCSW-2 and HCSW-4 and District stations 23949 and 24049. Stations are listed from upstream to downstream in the watershed. Boxed values include the 25th to the 75th percentiles with the centerline reflecting the 50th percentile value. Outliers are indicated by dots, representing values outside of the 1.5*Interquartile Range.

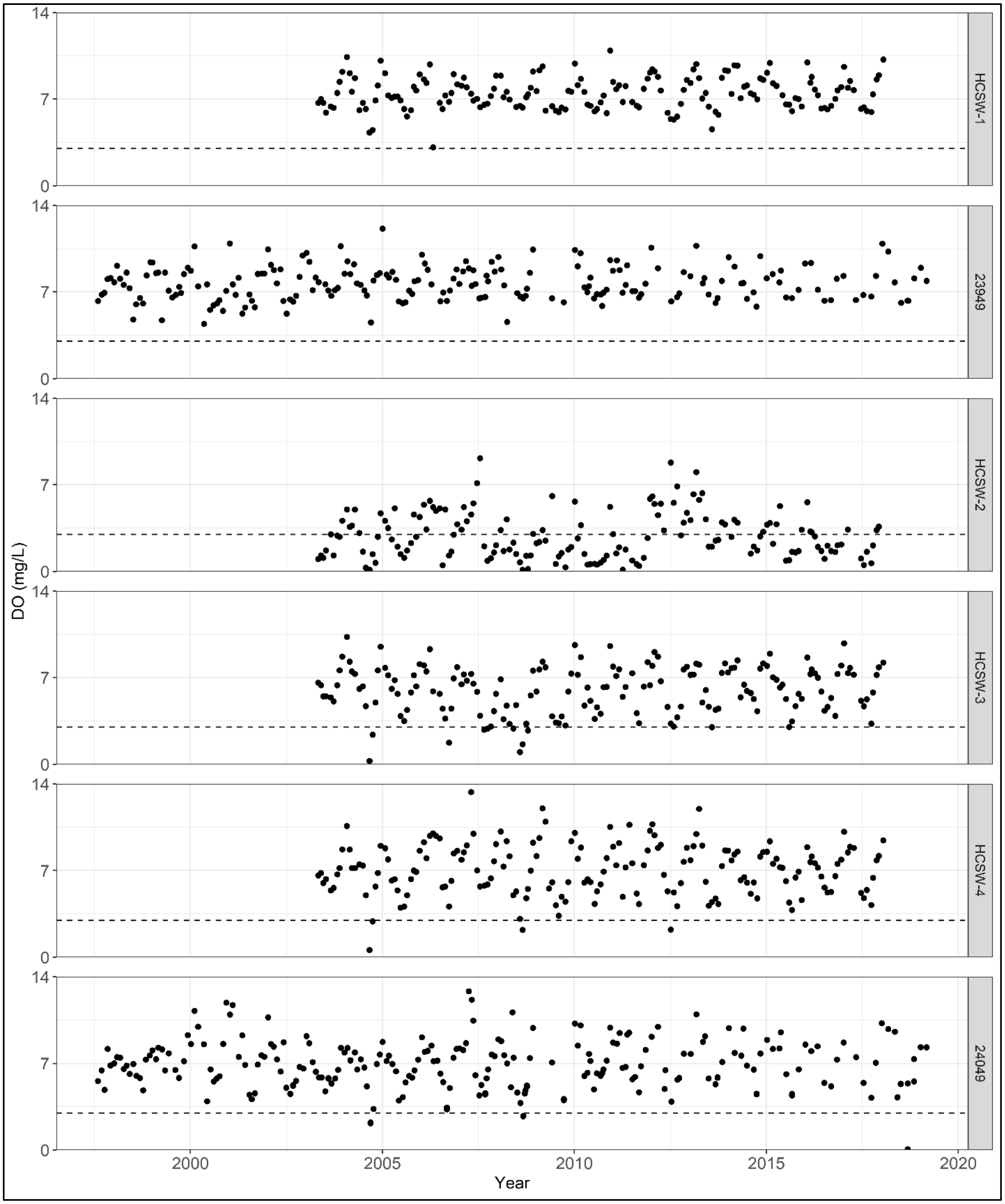

Figure 3-18. Sample distribution for dissolved oxygen (DO) concentration (mg/L) over the period of record at HCSP stations (HCSW-1, -2, -3, and -4) and District stations (23949 and 24049). Stations are listed from upstream to downstream in the watershed. The dashed line indicates a generally accepted dissolved oxygen threshold for hypoxic conditions (3 mg/L).

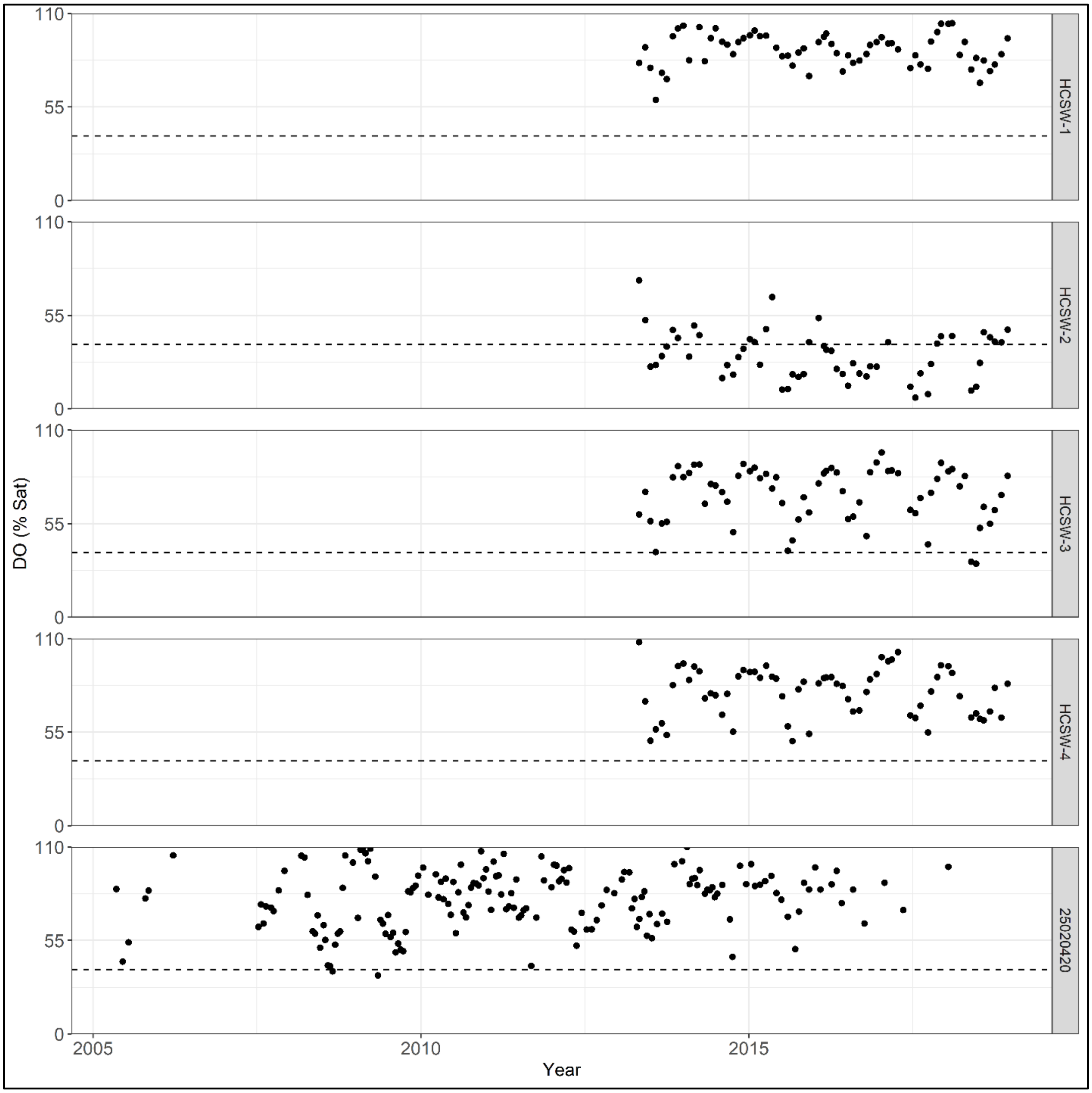

Figure 3-19. Annual distribution of dissolved oxygen percent saturation (DO (% Sat)) values at HCSP stations (HCSW-1, -2, -3, and -4) and DEP station (21FLA) 25020420 over the period of record. Stations are listed from upstream to downstream in the watershed. The State water quality threshold for DO (% Sat; 38%) is indicated by the dashed line.

3.3.3.5. Minerals and Metals

The presence of minerals and metals in waterways is typically indicative of the geology of an area through which they or groundwater flows. Charged particles like calcium, chloride, fluoride, iron, magnesium, and sulfate can affect the conductivity of water. Hardness is the concentration of dissolved minerals in water, particularly calcium and magnesium. Radium is naturally occurring, particularly in the presence of phosphate rock. Increased levels of these minerals could have negative implications for humans and environmental health.

Statistically significant ($p < 0.05$) seasonal Mann Kendall tests indicated that both calcium and sulfate were increasing over time in the northern portion of the watershed (Figures 3-20 and 3-21; note that total sulfate is shown for station 23949, rather than dissolved sulfate, in order to facilitate comparison with HCSP stations). Total radium (radium 228 plus radium 226) and radium 228 decreased over time at all HCSP stations (Figure 3-22). Other statistically significant trends were station-specific, including increasing fluoride and magnesium trends at station 23949 and decreasing dissolved iron trends at HCSW-2 (ATM and JEI 2021).

A 2019 report by Flatwoods Consulting, Inc. examined the increasing trend in calcium and sulfate throughout the Horse Creek watershed. In this report, higher levels of calcium (Figure 3-23) and sulfate (Figure 3-24) in the lower basin of the watershed were attributed to fertilizers and pesticides applied on agricultural lands. Previous studies have concluded elevated sulfate levels throughout the aquifer system in the Peace River Valley were due to the dissolution of calcium-sulfate minerals within the Avon Park Formation (Metz and Brendle 1996). Irrigation wells in the watershed may pull from this mineralized water and redistribute it to crops, ultimately running off into Horse Creek. Except for iron, relationships between minerals or metals and flow were negative (Table 3-6) and R^2 values were generally above 0.5 for this group.

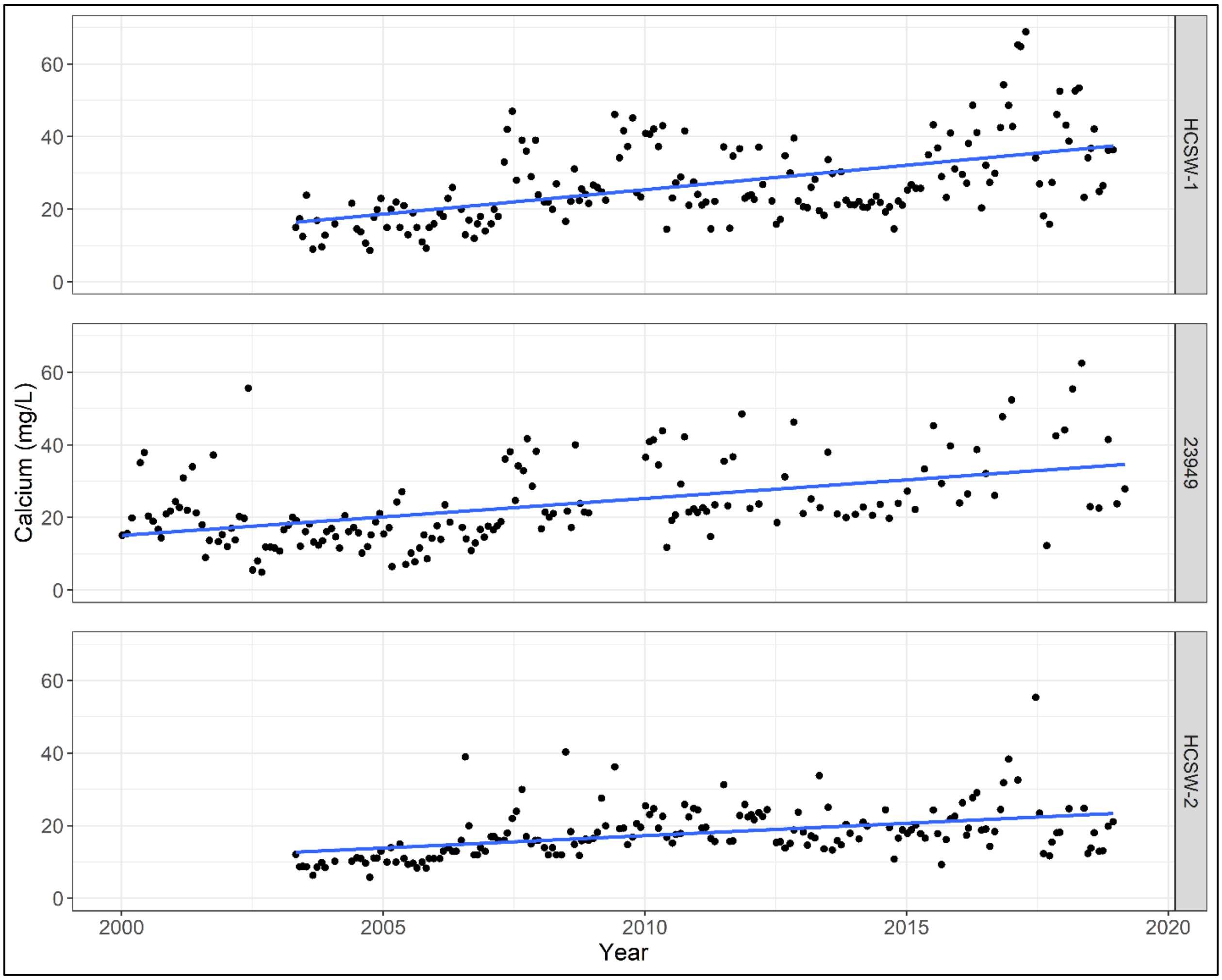

Figure 3-20. Time series of dissolved calcium data over the period of record for stations with a statistically significant increasing trend, including HCSP stations HCSW-1 and -2 and District station 23949. Stations are listed from upstream to downstream in the watershed. The blue line indicates the predicted trend over time.

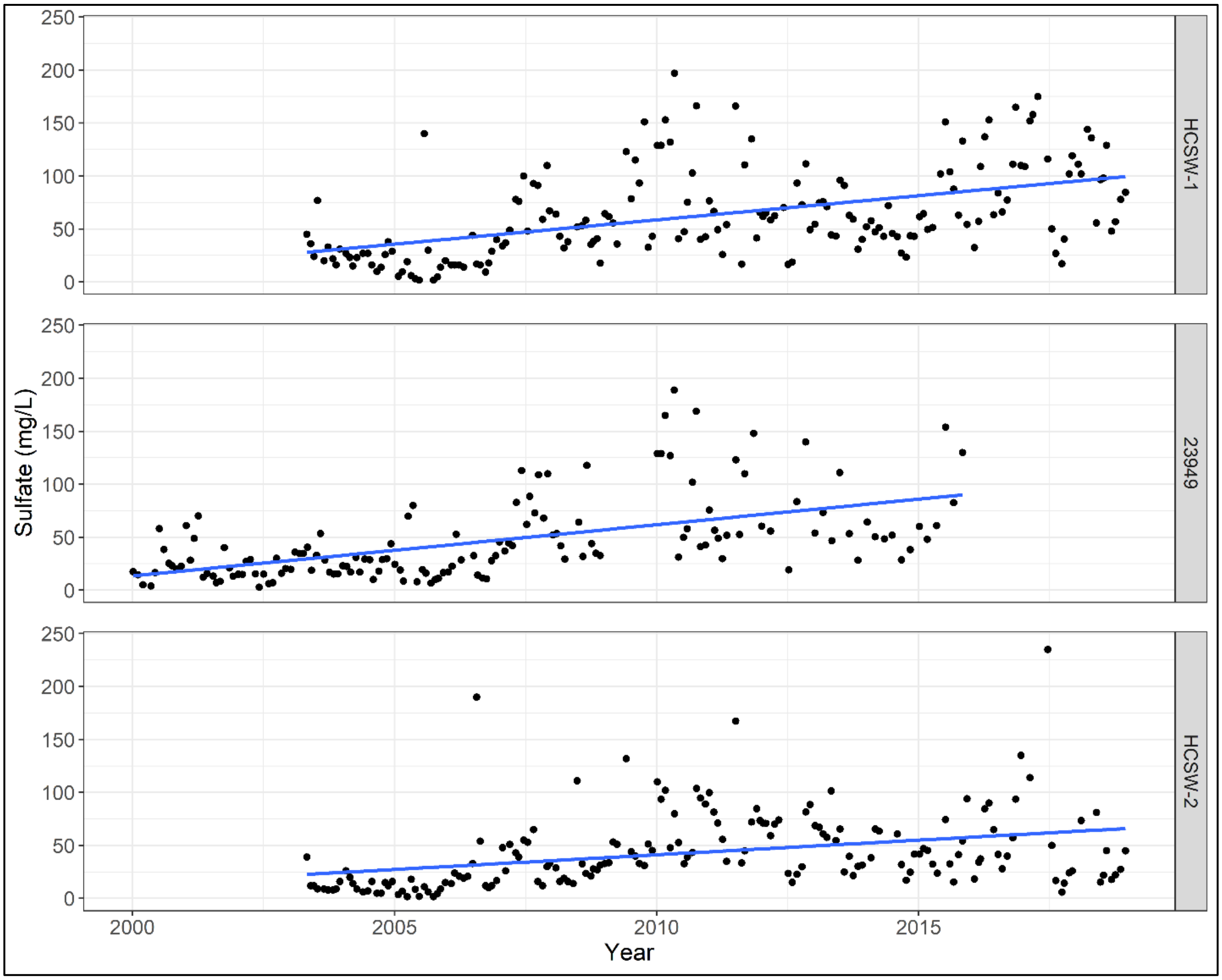

Figure 3-21. Time series of total sulfate data over the period of record for stations with a statistically significant increasing trend, including HCSP stations HCSW-1 and -2 and District station 23949. Stations are listed from upstream to downstream in the watershed. The blue line indicates the predicted trend over time.

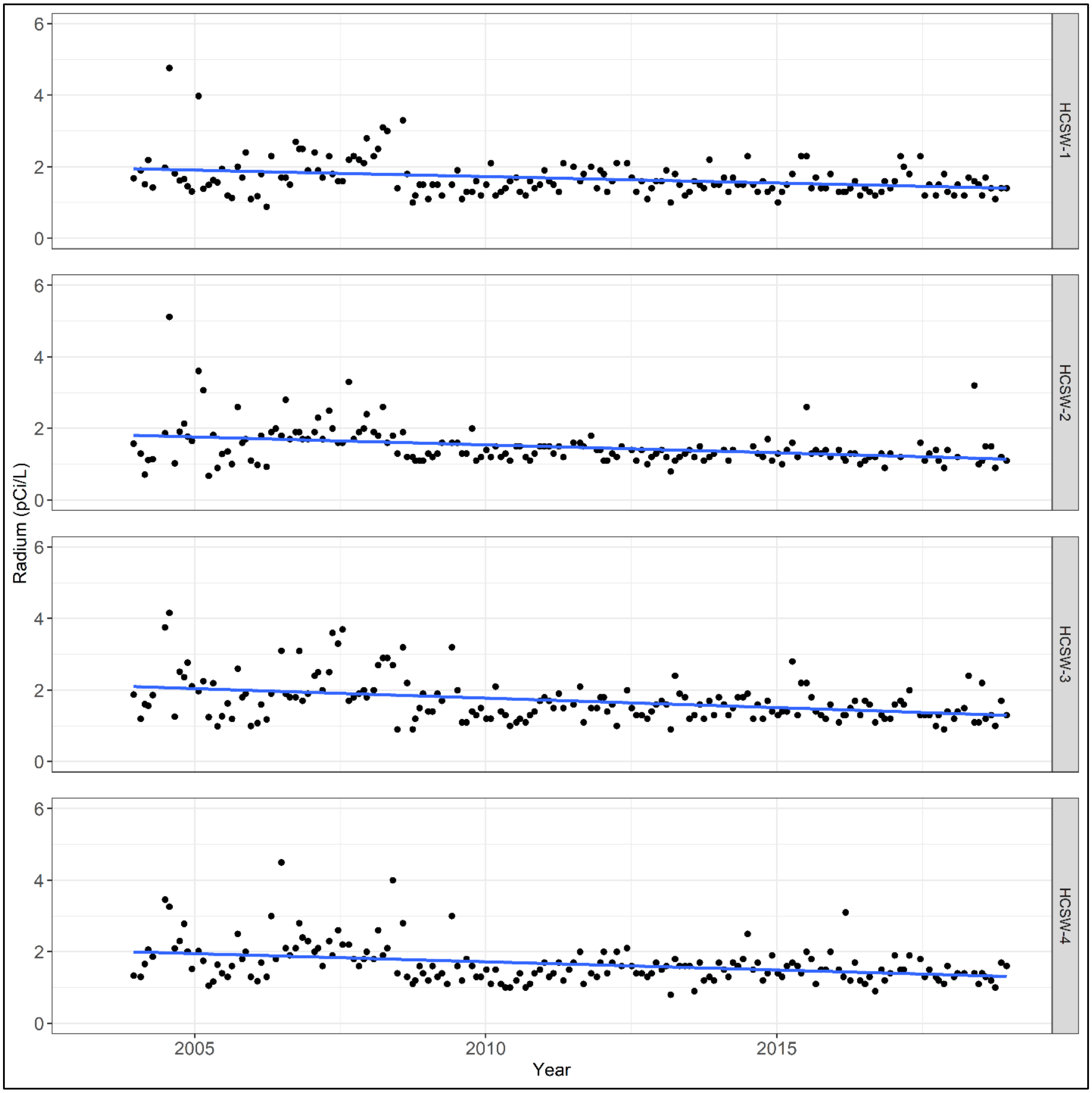

Figure 3-22. Time series of total radium data over the period of record for stations with a statistically significant decreasing trend, including HCSP stations HCSW-1, -2, -3, and -4. Stations are listed from upstream to downstream in the watershed. The blue line indicates the predicted trend over time.

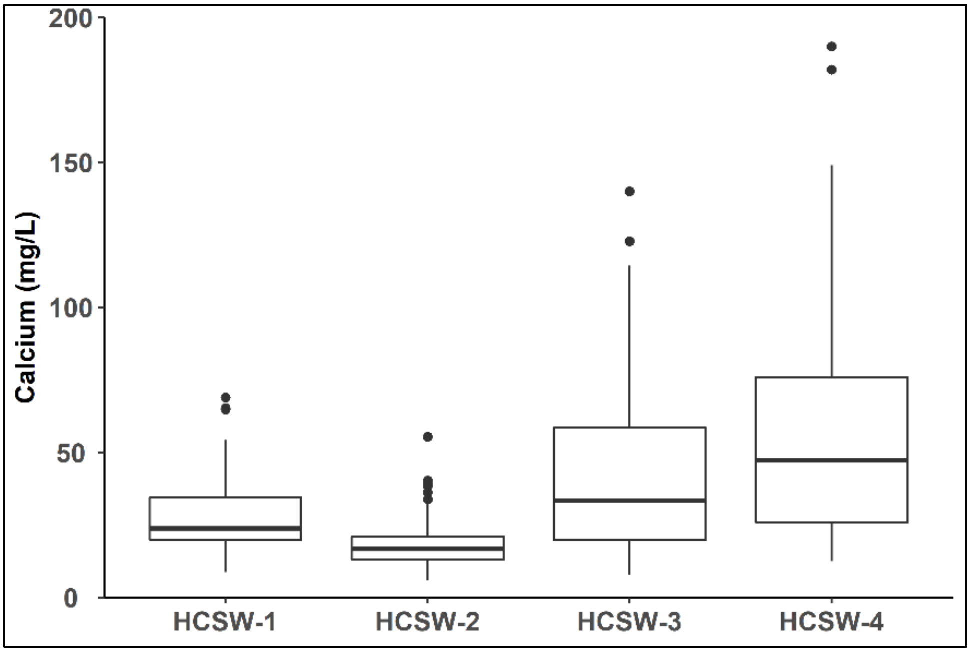

Figure 3-23. Dissolved calcium at HCSP stations from 2003-2018. Boxed values indicate the 25th to 75th percentiles with centerline reflecting the 50th percentile value. Dots represent outliers, indicative of values outside of the 1.5*interquartile range.

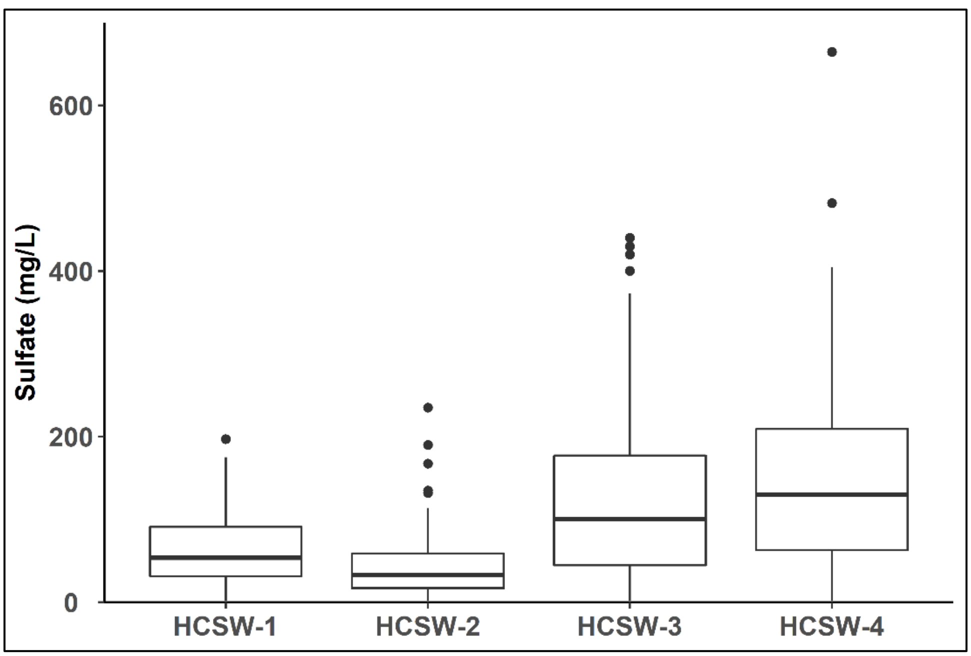

Figure 3-24. Total sulfate at HCSP stations from 2003-2018. Boxed values indicate the 25th to 75th percentiles with centerline reflecting the 50th percentile value. Dots represent outliers, indicative of values outside of the 1.5*interquartile range.

Table 3-6. Summary of statistically significant ($p < 0.05$) linear regression relationships between mineral and metals group constituents and flow with R^2 values greater than or equal to 0.20. The positive (Pos.) or negative (Neg.) slope designation refers to the relationship between constituent and flow at the corresponding USGS gage. Non-significant monthly p-values are listed as "ns." Significant regressions are listed by constituent from upstream to downstream. Stations occurring at the same location are listed in alphabetical order of their sampling agency (modified from ATM and JEI, 2021).

Constituent	Station	Samples (n)	Period of Record	Month p-value	Flow p-value	R^2	Slope
Calcium (Dissolved)	HCSW-3	178	4/2003-12/2018	<0.001	<0.001	0.62	Neg.
	HCSW-4	177	4/2003-12/2018	<0.001	<0.001	0.69	Neg.
	24049	160	1/2000-5/2020	<0.001	<0.001	0.79	Neg.
Calcium (Total)	23949	30	2/2000-10/2002	ns	<0.001	0.54	Neg.
	21FLA 25020111	64	8/1974-4/1998	ns	<0.001	0.62	Neg.
	24049	29	2/2000-10/2002	ns	<0.001	0.64	Neg.
	02297310	62	6/1962-9/1999	ns	<0.001	0.71	Neg.
Chloride	HCSW-1	179	4/2003-12/2018	<0.001	<0.001	0.63	Neg.
	HCSW-2	172	4/2003-12/2018	<0.001	<0.001	0.6	Neg.
	HCSW-3	181	4/2003-12/2018	<0.001	<0.001	0.7	Neg.
	21FLA 25020111	147	5/1972-4/1998	0.004	<0.001	0.53	Neg.
	HCSW-4	180	4/2003-12/2018	<0.001	<0.001	0.77	Neg.
	02297310	75	6/1962-9/1999	ns	<0.001	0.5	Neg.
	21FLFTM 25020420	233	10/2001-1/2018	<0.001	<0.001	0.69	Neg.
Fluoride	HCSW-3	181	4/2003-12/2018	ns	<0.001	0.25	Neg.
	21FLA 25020111	87	2/1976-4/1998	ns	<0.001	0.74	Neg.

Constituent	Station	Samples (n)	Period of Record	Month p-value	Flow p-value	R^2	Slope
Flouride (Cont.)	HCSW-4	180	4/2003-12/2018	ns	<0.001	0.33	Neg.
	02297310	73	6/1962-9/1999	ns	<0.001	0.32	Neg.
Hardness	21FLA 25020111	53	11/1975-4/1998	ns	<0.001	0.61	Neg.
Iron	HCSW-1	176	4/2003-12/2018	0.003	<0.001	0.38	Pos.
	HCSW-3	178	4/2003-12/2018	<0.001	<0.001	0.5	Pos.
	21FLA 25020111	51	8/1974-1/1991	ns	<0.001	0.53	Pos.
	HCSW-4	177	4/2003-12/2018	<0.001	<0.001	0.67	Pos.
Magnesium	23949	32	2/200-10/2002	ns	<0.001	0.7	Neg.
	24049	31	2/2000-11/2002	ns	<0.001	0.48	Neg.
Magnesium (Dissolved)	23949	153	1/2000-5/2020	0.041	0.007	0.2	Neg.
	24049	151	1/2000-5/2020	0.001	<0.001	0.7	Neg.
Sulfate (Dissolved)	24049	160	1/2000-5/2020	<0.001	<0.001	0.7	Neg.
Sulfate (Total)	HCSW-3	182	4/2003-12/2018	0.024	<0.001	0.38	Neg.
	HCSW-4	181	4/2003-12/2018	0.007	<0.001	0.58	Neg.
	21FLA 25020111	91	1/1975-4/1998	ns	<0.001	0.58	Neg.
	24049	31	2/2000-9/2002	ns	<0.001	0.39	Neg.
	02297310	63	6/1962-9/1999	ns	<0.001	0.45	Neg.

3.3.3.6. Indicators of Water Clarity

Water clarity is a measure of light penetration in the water column, which impacts the diversity of aquatic life within a system. Water clarity can naturally be affected by the presence of tannins, resulting from the decomposition of organic materials, sediment loads, influxes of organic and inorganic matter and increased algae or plankton biomass. Higher flows are generally related to increases in turbidity and decreases in water clarity, as water carries soil off into a system and increasing suspended materials. Total organic carbon (TOC) is included in this section as it can represent the contribution of both anthropogenic and natural sources of carbon into a river (ATM and JEI 2021).

Seasonal Mann Kendall tests indicated statistically significant ($p < 0.05$) increasing trends over time for several water clarity indicators (color (Figure 3-25a), total dissolved solids (Figure 3-25b), turbidity (Figure 3-25c), and total organic carbon (Figure 3-25d)) at the northernmost stations on Horse Creek (HCSW-1 and 23949). Turbidity has also increased at HCSW-3 and HCSW-4, stations located in the lower portion of the watershed (Figure 3-26).

When statistically significant ($p < 0.05$), color, total organic carbon, and turbidity had increasing relationships with increasing flow (Table 3-7). This correlates with the seasonal flow patterns in southwest Florida, as tannins from surrounding wetlands and nutrients from agricultural runoff enter the system during periods of high flow (JEI 2019). The relationship is particularly strong for color, with R^2 values generally above 0.5 and statistically significant seasonal effects, with higher color levels during periods of high flow (Figure 3-27a). Total dissolved solids at stations HCSW-3 and HCSW-4 had a negative relationship with flow. This constituent can be an indicator of declining groundwater inputs when flows increase (ATM and JEI 2021). Elevated levels of total dissolved solids have been documented in the aquifer within the Peace River valley (Metz and Brendel 1996). Irrigation wells pulling from this groundwater may then cause increases in total dissolved solids to the Horse Creek when excess runoff drains from agricultural fields. As opposed to the seasonal trend observed with color, TDS levels are higher in the dry season, when flows are reduced, and irrigation of agricultural lands is necessarily elevated (see example data from HCSW-4 in Figure 3-27b).

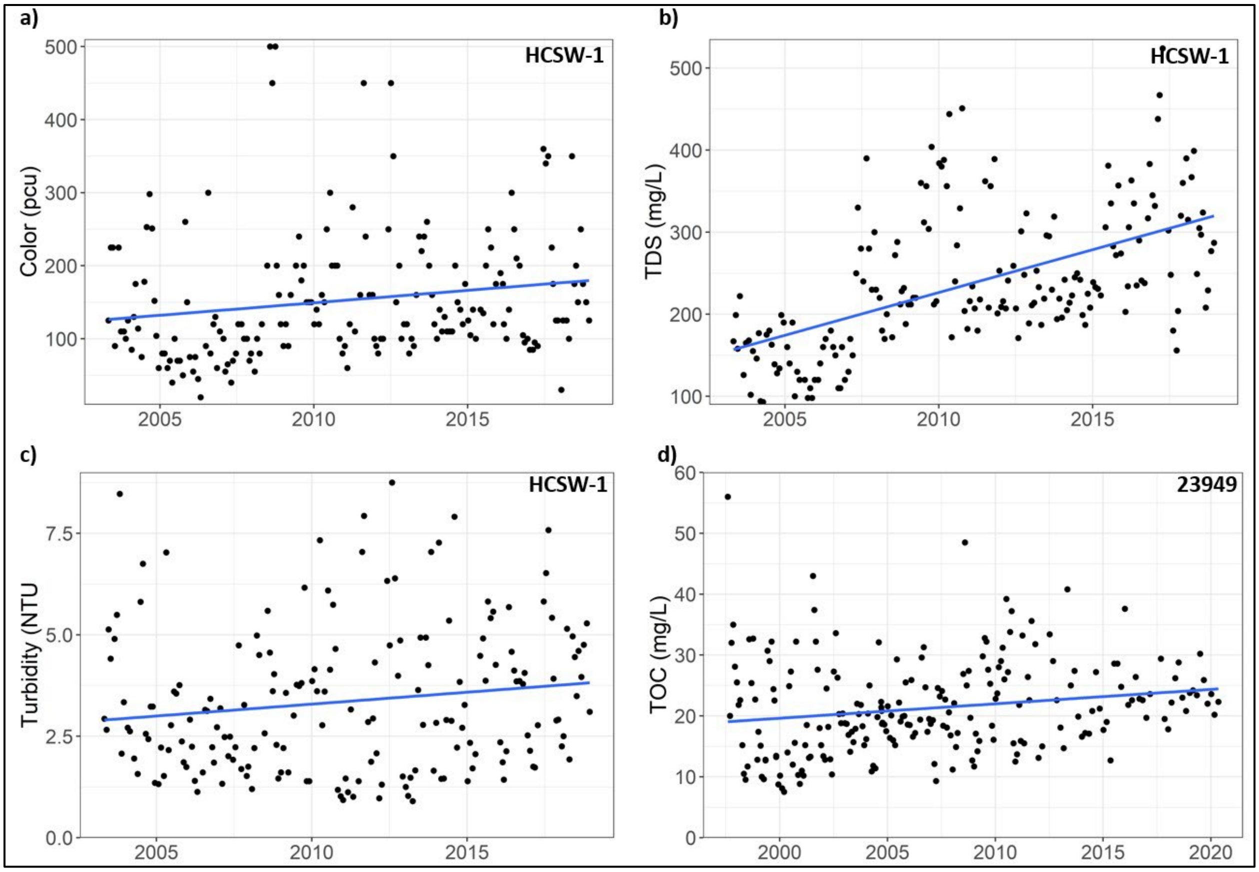

Figure 3-25: Statistically significant increasing trends by seasonal Mann Kendall tests for water clarity constituents in the northernmost sampling locations in Horse Creek, where HCSP station HCSW-1 and District station 23949 co-occur. This includes a) color at HCSW-1, b) total dissolved solids (TDS) at HCSW-1, c) turbidity at HCSW-1, and d) total organic carbon (TOC) at 23949. The blue line represents the predicted trend over time.

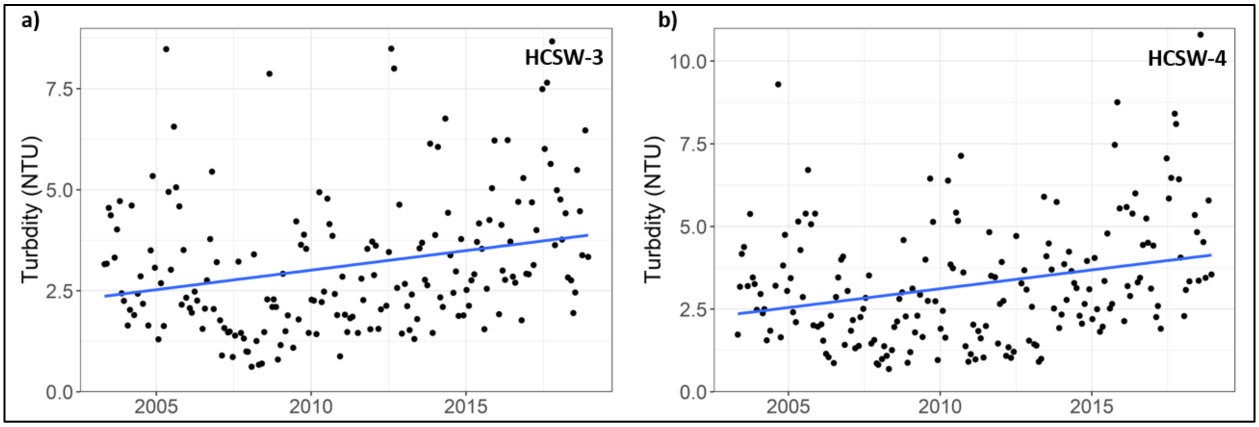

Figure 3-26: Statistically significant increasing trends by seasonal Mann Kendall tests in turbidity at HCSP stations a) HCSW-3 and b) HCSW-4. The blue line represents the predicted trend over time.

Table 3-7. Summary of statistically significant ($p < 0.05$) linear regression relationships between water clarity constituents and flow with R^2 values greater than or equal to 0.20. The positive (Pos.) or negative (Neg.) slope designation refers to the relationship between constituent and flow at the corresponding USGS gage. Non-significant monthly p-values are listed as "ns." Significant regressions are listed by constituent from upstream to downstream. Stations occurring at the same location are listed in alphabetical order of their sampling agency (modified from ATM and JEI, 2021).

Constituent	Station	Samples (n)	Period of Record	Month p-value	Flow p-value	R^2	Slope
Color	21FLA 25020428	42	5/1972-7/1990	ns	<0.001	0.38	Pos.
	HCSW-1	179	4/2003-12/2018	0.011	<0.001	0.45	Pos.
	23949	213	8/1997-5/2020	<0.001	<0.001	0.57	Pos.
	21FLA 25020423	37	12/1972-8/1991	0.004	0.01	0.75	Pos.
	HCSW-3	181	4/2003-12/2018	<0.001	<0.001	0.49	Pos.
	21FLA 25020111	279	5/1972-4/1998	<0.001	<0.001	0.69	Pos.
	HCSW-4	180	4/2003-12/2018	<0.001	<0.001	0.69	Pos.
	24049	206	9/1997-5/2020	<0.001	<0.001	0.76	Pos.
	02297310	62	6/1962-9/1999	0.004	<0.001	0.64	Pos.
Total Dissolved Solids	HCSW-3	178	4/2003-12/2018	<0.001	<0.001	0.47	Neg.
	HCSW-4	177	4/2003-12/2018	<0.001	<0.001	0.56	Neg.
Total Organic Carbon	23949	208	8/1997-5/2020	<0.001	<0.001	0.54	Pos.
	21FLA 25020111	82	8/1974-4/1998	ns	<0.001	0.53	Pos.
	24049	202	8/1997-5/2020	<0.001	<0.001	0.66	Pos.
	02297310	39	4/1972-6/1991	ns	<0.001	0.33	Pos.
Turbidity	HCSW-1	180	4/2003-12/2018	ns	<0.001	0.35	Pos.
	23949	212	8/1997-5/2020	0.002	<0.001	0.23	Pos.
	HCSW-4	181	4/2003-12/2018	ns	<0.001	0.31	Pos.
	24049	206	8/1997-5/2020	0.001	<0.001	0.32	Pos.

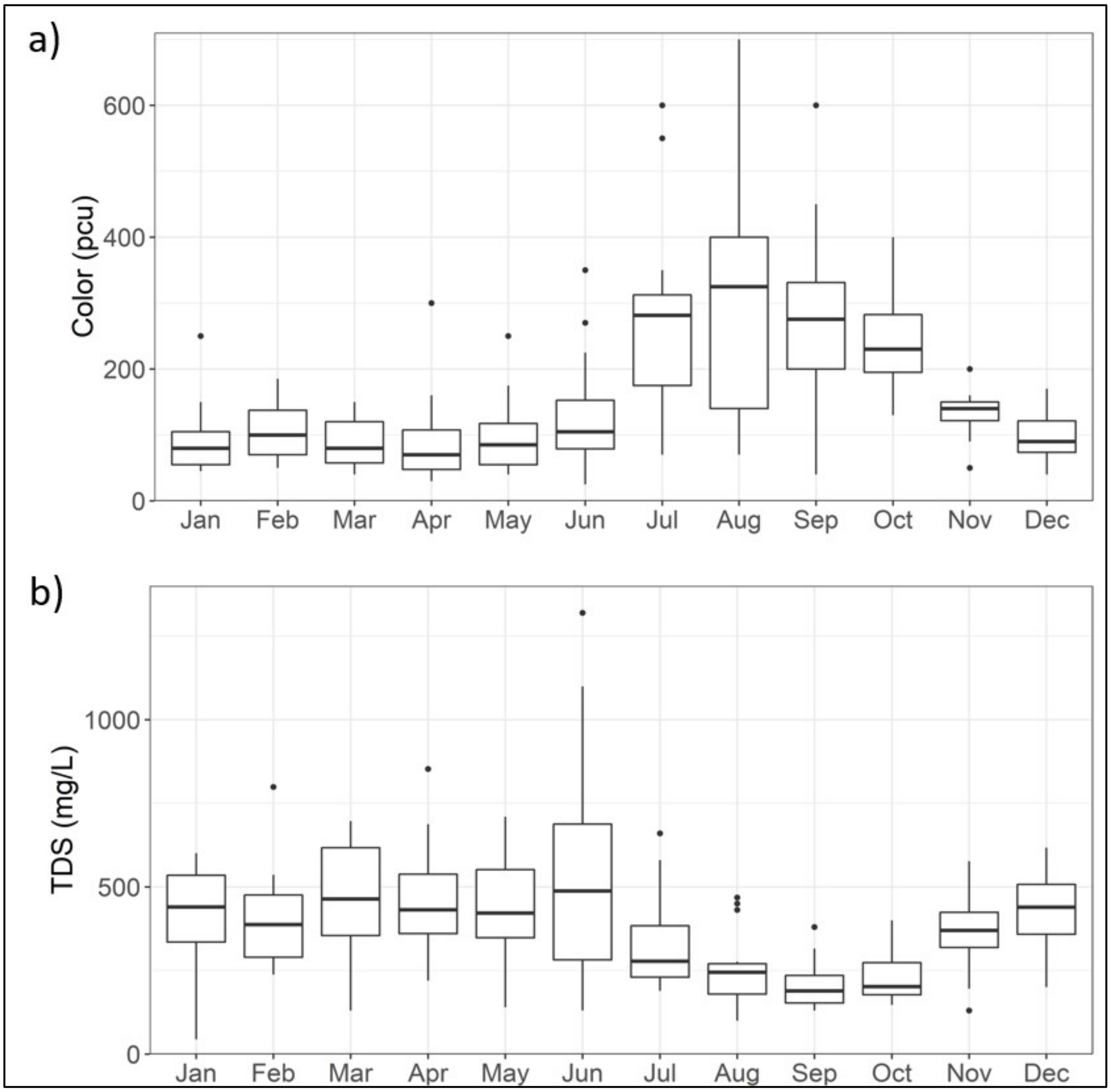

Figure 3-27. Monthly distribution of a) color and b) total dissolved solids (TDS) at HCSP station HCSW-4 from 2003-2018. Boxed values indicate the 25th to 75th percentiles with centerline reflecting the 50th percentile value. Dots represent outliers, indicative of values outside of the 1.5*interquartile range.

3.4. Summary

Temporal trends in water quality parameters and their relationships with flow in Horse Creek generally met the expectations for Florida streams and rivers under the influence of mining and agricultural use. An exception is negative relationships observed between flow and phosphorus species (total phosphorus and orthophosphate), however, these relationships had low R^2 values, indicating majority of variation in phosphorus constituents were unexplained by linear regression (ATM and JEI 2021).

CHAPTER 4 – ECOLOGICAL RESOURCES

Although extensive mining and agricultural use is evident in the Horse Creek watershed, important palustrine and riverine habitats remain that serve as valuable resources for natural communities. The description of existing flora and fauna and consideration of their habitat requirements is essential when establishing minimum flows. This chapter summarizes data collection efforts and studies performed by the Florida Fish and Wildlife Conservation Commission (FWC), DEP, University of Florida (UF), HCSP, and consultants hired by the District, that best describe the ecological resources within the watershed. The focus is on taxa diversity and distribution within the river corridor and surrounding floodplain.

4.1 Macroinvertebrates

Since 2003, the HCSP has collected macroinvertebrate data at four stations along Horse Creek (Figure 4-1) up to three times a year, depending upon flow conditions. Sampling occurs within the following sampling windows: from March to April, from July to September, and from October to December. Samples are collected following the DEP protocols for Stream Condition Index (SCI), and habitat is characterized using DEP methods for Habitat Assessment (HA), Rapid Periphyton Survey, Linear Vegetative Survey, and Physical/Chemical Characterization (Flatwoods 2021).

The HA method quantifies the overall habitat quality by considering eight attributes known to impact stream biota, including: substrate diversity, substrate availability, water velocity, habitat smothering, artificial channelization, bank stability, riparian buffer zone width, and riparian zone vegetation quality. The values assigned for each parameter are then averaged and a rating is developed for the habitat on a scale from poor to optimal.

The SCI captures the capacity for flowing freshwater systems to support a balanced community, by classifying and quantifying benthic macroinvertebrates and identifying impairment relative to what may be expected with minimally disturbed conditions. Dipnet sweeps are used to sample a 100-meter stretch of stream and collected macroinvertebrates are used to calculate ten biological metrics: total number of taxa, number of long-lived taxa, number of Mayfly (Ephemeroptera) taxa, number of Caddisfly (Trichoptera) taxa, number of sensitive taxa, number of clinger taxa, percent dominant taxon, percent Tanytarsini, percent very tolerant taxa, and percent filterer individuals. These metrics predominantly respond negatively to anthropogenic disturbance, though two are expected to increase with human influence (percent dominant taxon and percent very tolerant taxon). Scores for each metric are aggregated into an overall score of ecosystem health.

As of 2020, the HCSP had collected nearly 48,000 macroinvertebrates from Horse Creek, and categorized the individuals into more than 320 taxa. The twenty most abundant taxa groups, by HCSP taxa identification number, are provided in Table 4-1. Of the 181 samples receiving SCI scores over the period of record, 35 were considered “impaired,” with an SCI score of 34 or below (Figure 4-2). The majority (66%) of “impaired” samples were collected at station HCSW-2. The natural conditions of this station include low dissolved oxygen and low pH due to frequent low flow, an increased residence time compared to other stations in the creek, and the impact of runoff from a large upstream wetland. At other stations with “impaired” samples, bank erosion and habitat smothering may contribute to a reduction in habitat availability and diversity. This effect can be exacerbated at stations HCSW-3 and HCSW-4, which have larger drainage areas and higher flows compared to station HCSW-1. Despite these potential impacts, the majority (61%) of samples throughout the watershed were considered “healthy,” with an SCI score of 35-67 and 20% of samples were considered “exceptional,” indicating good biointegrity for supporting a healthy benthic macroinvertebrate community in this system (Flatwoods 2021).

The DEP has conducted sporadic macroinvertebrate sampling throughout Horse Creek (Figure 4-1) from 1993 to 2006. They have collected 5,682 individuals from 308 taxa in their exploration of 16 stations over 25 sampling dates (Table 4-2).

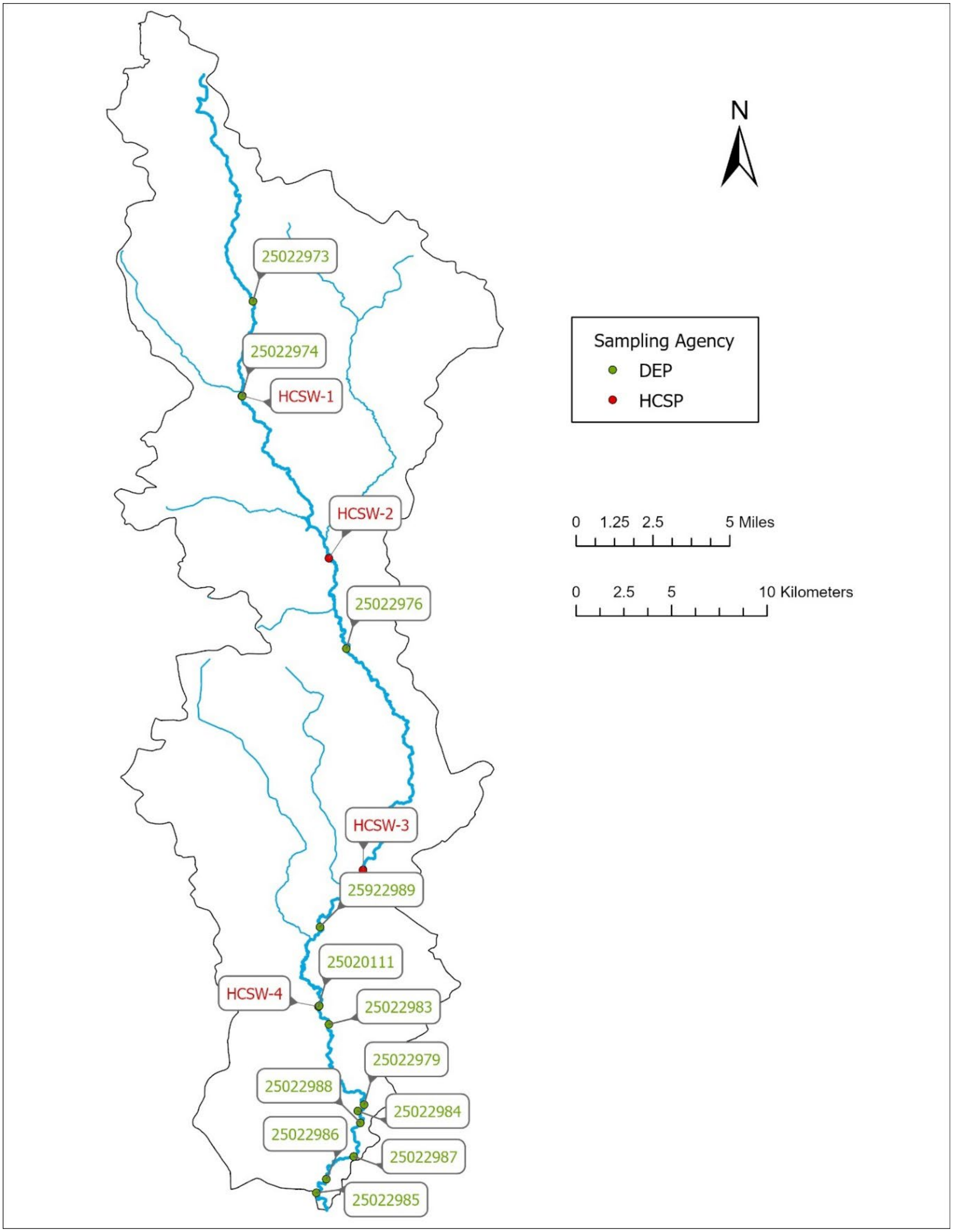

Figure 4-1. Stations where benthic macroinvertebrate data have been collected by the DEP and HCSP along Horse Creek.

Table 4-1. The twenty most abundant macroinvertebrates collected by the HCSP from 2003-2020, grouped by HCSP Taxa Identification Number (ID).

Rank	Taxa ID	Common Name	Scientific Name	Count (n)
1	250	Non-biting midge	*Polypedilum beckae*	93
			Polypedilum fallax	9
			Polypedilum flavum	5024
			Polypedilum halterale sp.	130
			Polypedilum illinoense sp.	827
			Polypedilum scalaenum sp.	948
			Polypedilum sp.	1
			Polypedilum trigonus	47
			Polypedilum tritum	88
2	185	Riffle beetle	*Microcylloepus pusillus*	3993
			Microcylloepus sp.	464
3	140	Amphipod	*Hyalella azteca*	3488
4	264	Serrate Crownsnail	*Pyrgophorus platyrachis*	2838
5	289	Beetle	*Stenelmis fuscata*	31
			Stenelmis hungerfordi	1135
			Stenelmis lignicola	35
			Stenelmis sp.	1420
6	49	Net-spinning Caddisfly	*Cheumatopsyche sp.*	1834
7	96	Riffle beetle	*Dubiraphia sp.*	456
			Dubiraphia vittata	889
8	188	Snail	*Mieniplotia scabra*	1199
9	270	Non-biting midge	*Rheotanytarsus exiguus sp.*	738
			Rheotanytarsus pellucidus	360
			Rheotanytarsus sp.	12
10	122	Midge	*Goeldichironomus amazonicus*	30
			Goeldichironomus carus	3
			Goeldichironomus cf. natans	401
			Goeldichironomus fluctuans	109
			Goeldichironomus holoprasinus	474
			Goeldichironomus sp.	49

Rank	Taxa ID	Common Name	Scientific Name	Count (n)
11	181	Snail	*Melanoides tuberculata*	829
12	69	Asian Clam	*Corbicula fluminea*	676
			Corbicula sp.	127
13	53	Non-biting midge	*Chironomus decorus*	23
			Chironomus sp.	681
			Chironomus stigmaterus	2
14	178	Cruiser Dragonfly	*Macromia illinoiensis*	9
			Macromia illinoiensis georgina	31
			Macromia sp.	37
			Macromia taeniolata	3
15	201	Caddisfly	*Neotrichia sp.*	542
16	133	Leech	*Helobdella elongata*	76
			Helobdella fusca	1
			Helobdella papillata	16
			Helobdella sp.	74
			Helobdella stagnalis	286
			Helobdella triserialis	4
17	314	Mayfly	*Tricorythodes albilineatus*	451
18	277	Black Fly	*Simulium*	3
			Simulium lakei	33
			Simulium sp.	400
19	1	Midge	*Ablabesmyia mallochi*	235
			Ablabesmyia peleensis	6
			Ablabesmyia rhamphe	130
			Ablabesmyia sp.	37
20	235	Non-biting midge	*Pentaneura inconspicua*	392

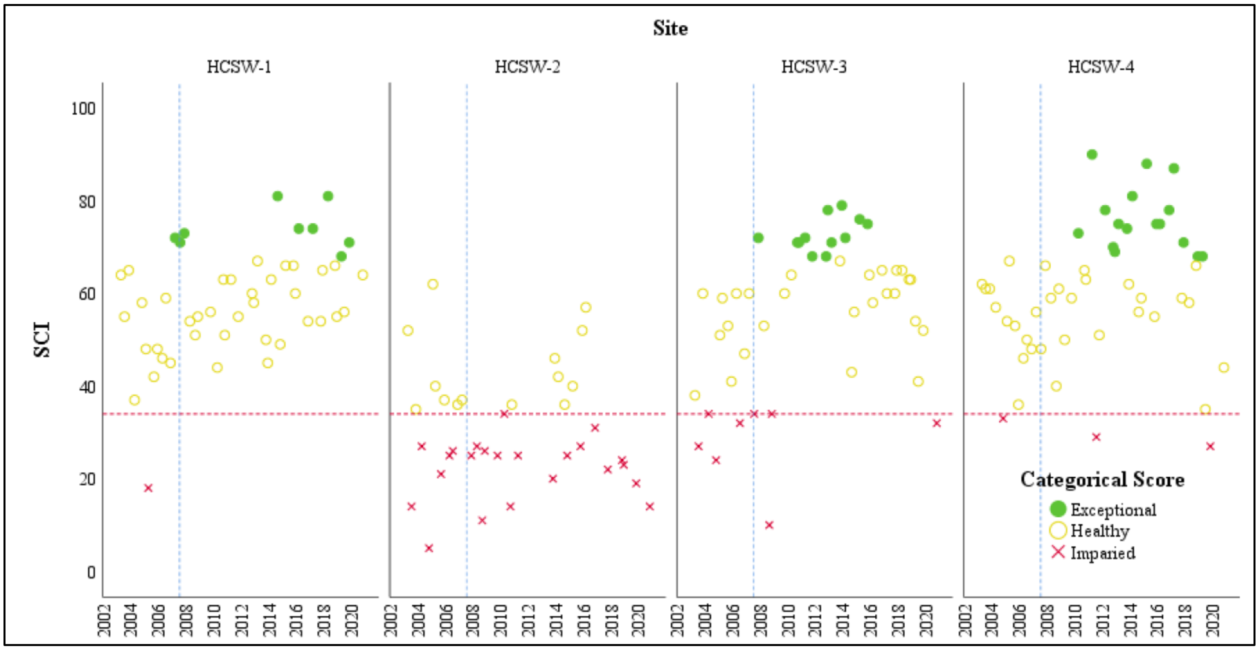

Figure 4-2. Stream Condition Index (SCI) scores for HCSP stations HCSW-1 through HCSW-4 over the period of record. The dashed vertical line designates a methods revision that occurred in 2007. Scores prior to 2007 are not compatible with those occurring later (Figure from Flatwoods 2021).

Table 4-2. The twenty most abundant macroinvertebrates from available DEP data from 1993 through 2006.

Rank	Common Name	Scientific Name	Count (n)
1	Serrate Crownsnail	*Pyrgophorus platyrachis*	671
2	Non-biting midge	*Polypedilum flavum*	293
3	Net-spinning Caddisfly	*Cheumatopsyche*	282
4	Non-biting midge	*Polypedilum convictum grp.*	273
5	Asian Clam	*Corbicula fluminea*	267
6	Amphipod	*Hyalella azteca*	211
7	Beetle	*Stenelmis*	160
8	Riffle Beetle	*Microcylloepus pusillus*	152
9	Riffle Beetle	*Dubiraphia vittata*	146
10	Non-biting midge	*Cladotanytarsus cf. daviesi*	120
11	Black Fly	*Simulium*	108
12	Non-biting midge	*Tanytarsus sp. c epler*	104
13	Non-biting midge	*Polypedilum scalaenum grp.*	102
14	Mayfly	*Tricorythodes albilineatus*	96
15	Amphipod	*Gammarus*	86
16	Mayfly	*Pseudocloeon*	81
17	Mayfly	*Caenis*	74
18	Mud Snail	Hydrobiidae	72
19	Netspinning Caddisfly	*Hydropsyche*	71
20	Biting Midge	Ceratopogonidae	68

4.2. Fish

Both the FWC and the HCSP have conducted fish sampling throughout Horse Creek. The first FWC study consisted of 100-m electrofishing transects sampled from July to August 2008 (n = 21), during August 2009 (n = 17) and during March 2010 (n = 10) between the Country Road 769 bridge and Horse Creek's confluence with the Peace River (Call et al., 2011, Figure 4-3). A total of 876 individuals were caught, representing 27 species common to streams in southwestern Florida. The most frequently encountered species in this study were Shiners (*Notropis sp.,* 19.84% of catch), Spotted Sunfish (*Lepomis punctatus,* 15.3%), Largemouth Bass (*Micropterus salmoides*, 12.64%), and Bluegill (*Lepomis macrochirus*, 11.86%). The popular sportfish Common Snook (*Centropomus undecimalis*) accounted for 2.1% of the catch. This study was confined to a relatively short (8-km long), southern stretch of the Horse Creek (Figure 4-3).

The lower portion of Horse Creek was also fished by the FWC during seven electrofishing sampling events that took place from Summer 2010 through Spring 2012, as part of an effort to understand four tributaries to the Peace River (Schworm et al. 2013). A total of 252 transects were sampled, during which 3,406 fish were collected from 49 taxa.

Information provided in appendices to Schworm et al. (2013) was compiled to identify the ten most abundant taxa by number (Table 4-3) and biomass (Table 4-4). While this FWC study has a shorter period of record than HCSP data, it provides insight into the use of the system by larger, recreationally important species. For example, Largemouth Bass accounted for 5.43% of the total catch and 17.24% of total biomass. Thirty-five adult Common Snook (maturation categorized by reported mean total length) dominated the biomass of the samples (22.65%), and they were caught at five of the seven sampling events.

Schworm et al. (2013) notes a similarity in species composition between Horse and Charlie Creek, with potential separation (i.e., distinction) from the fish assemblages in the impounded Prairie and Shell Creeks, based on a two-dimensional non-metric scaling ordination analysis. Other salient findings for Horse Creek includes the high densities of species that prefer shallow areas with elevated current velocities (identified by principal component analysis) and those that are known to thrive under a variety of stream flow conditions, important for a system with variable hydrology. As an example of the latter, Coastal Shiner (*Notropis petersoni*), which experience ontogenetic shifts in depth and velocity requirements, were common in the creek. Spotted Sunfish were more common in Horse Creek than in Prairie and Shell (contributing 12% to dissimilarity by similarity percentages (SIMPER) analysis), which was attributed to their preference for the complex woody habitat available in Horse Creek (Schworm et al., 2013).

The HCSP has conducted triannual seining and electrofishing surveys at four locations on Horse Creek (HCSW-1 through -4; Figure 4-1) since 2003. As of November 2020, over 67,500 fish have been documented by the HCSP in Horse Creek from 44 taxa, including 11 non-native species. The HCSP has suggested the proliferation of invasive species has contributed to the negative monotonic trend in taxa richness they have observed (-0.25

units/year both by seasonally adjusted and non-adjusted analyses with all sites combined and analyzed by sampling event (seasonal Kendall-tau and Kendall-tau analysis ($p < 0.05$); Flatwoods 2021).

Raw fish catch data provided by the HCSP were used to calculate descriptive statistics. When all sampling events were combined, Shannon-Wiener diversity (H) was highest at station HCSW-1 (H = 2.46; 47 sampling events) and lowest at station HCSW-2 (H = 1.03; 35 sampling events). A similar trend was apparent when species diversity was compared during different seasons; the highest species diversity occurred at stations HCSW-1 and HCSW-4 and the lowest diversity was observed at station HCSW-2 (Figure 4-4). When catch was averaged by sampling event, it was evident that total abundance was generally lower (Figure 4-5), but representative of more species (Figure 4-4) at HCSW-1. Small species like Eastern Mosquitofish (*Gombusia holbrooki*) and Least Killifish (*Heterandria formosa*) dominated catch at station HCSW-2 (Table 4-5). Note the number of stations sampled by event is variable, with more sampling events occurring in the Fall and Spring compared to the Summer, and fewer successful sampling events at HCSW-2 due to frequent low flow conditions.

Overall, taxa richness was highest at station HCSW-4 (41 species) and lowest at station HCSW-1 (31 species). The ten most abundant taxa, by station, are provided in Table 4-5 and the ten largest contributors to total biomass, by station, are listed in Table 4-6. At least one non-native (invasive) species was found at each station by either total count or biomass, apart from abundance counts at HCSW-3. Use of Horse Creek by Largemouth Bass, a recreationally important species, is documented at stations HCSW-1, -3, and -4 (Table 4-6).

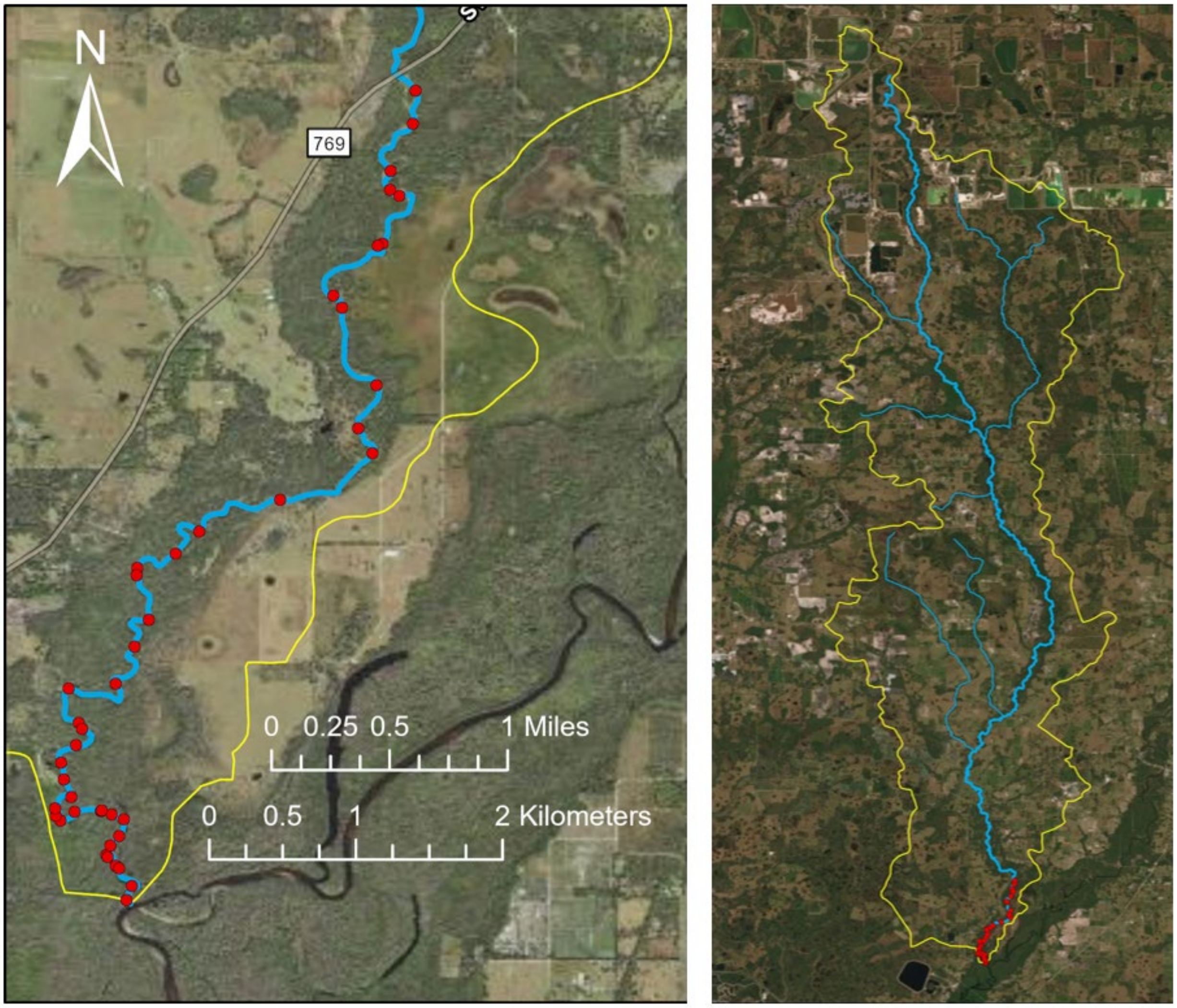

Figure 4-3. Electrofishing sample locations by the FWC (Call et al. 2011; left) with their location relative to the entire Horse Creek watershed (yellow outline; right).

Table 4-3. The ten most abundant species collected by the FWC (Schworm et al. 2013) in Horse Creek from 2010 to 2012.

Common Name	Scientific Name	Total Count (n)	Percent Composition (%)
Bluegill	*Lepomis macrochirus*	524	15.38
Coastal Shiner	*Notropis petersoni*	504	14.80
Spotted Sunfish	*Lepomis punctatus*	451	13.24
Eastern Mosquitofish	*Gombusia holbrooki*	427	12.54
Seminole Killifish	*Fundulus seminolis*	327	9.6
Largemouth Bass	*Micropterus salmoides*	185	5.43
Taillight Shiner	*Notropis maculatus*	139	4.08
Hogchoker	*Trinectes maculatus*	131	3.85
Redear Sunfish	*Lepomis microlophus*	124	3.64
Florida Gar	*Lepisosteus platyrhincus*	84	2.47

Table 4-4. The ten largest contributors to total biomass collected by the FWC in Horse Creek from 2010 to 2012.

Common Name	Scientific Name	Total weight (g)	Percent Composition (%)
Common Snook	*Centropomus undecimalis*	60596	22.65
Florida Gar	*Lepisosteus platyrhincus*	47504	17.76
Largemouth Bass	*Micropterus salmoides*	46138	17.24
Longnose Gar	*Lepisosteus osseus*	28892	10.80
Bluegill	*Lepomis macrochirus*	28077	10.49
White Catfish	*Ameiurus catus*	9338	3.49
Striped Mullet	*Mugil cephalus*	8225	3.09
Spotted Sunfish	*Lepomis punctatus*	7033	2.63
Bowfin	*Amia calva*	6252	2.34
Sailfin Armored Catfish sp.	*Pterygoplichthys sp.*	5105	1.91

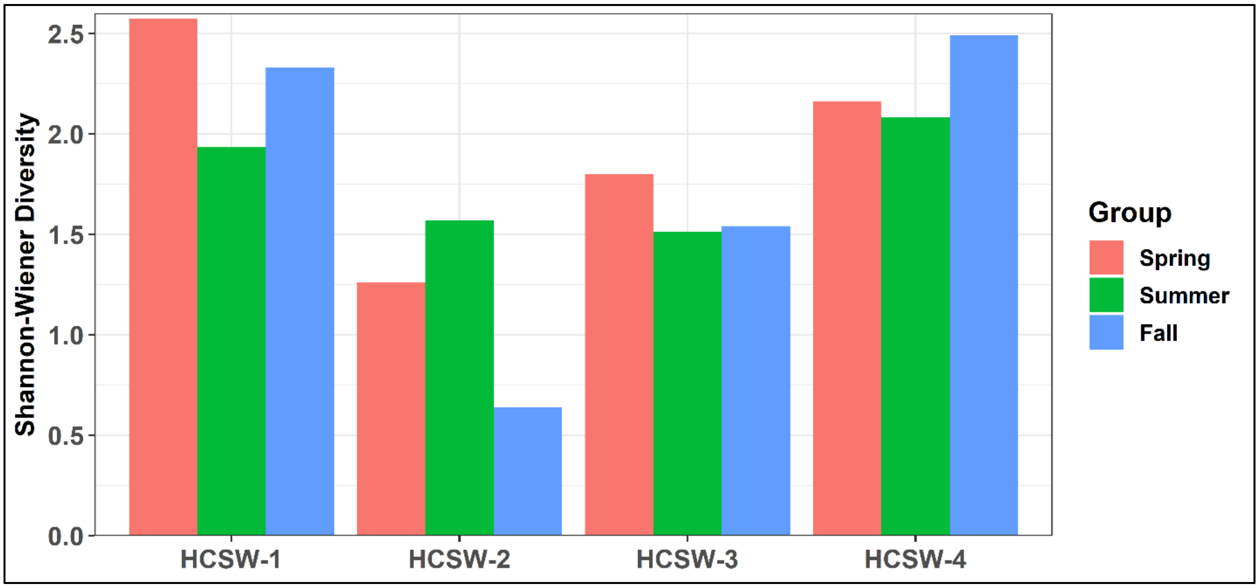

Figure 4-4. Shannon-Wiener Diversity for fish collected by the HCSP from 2003 through 2020 during the Spring (February, March, and April), Summer (July, August, and September) and Fall (October, November, and December).

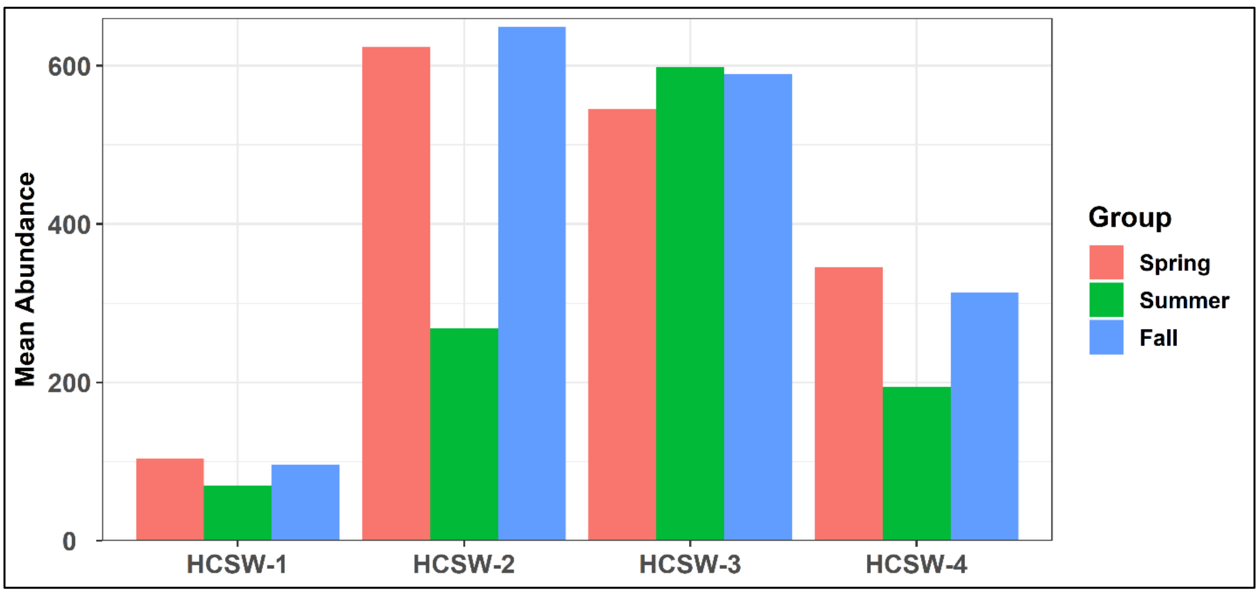

Figure 4-5. Mean fish abundance per sampling event for samples collected by the HCSP from 2003 through 2020 during the Spring (February, March, and April), Summer (July, August, and September) and Fall (October, November, and December).

Table 4-5. The ten most abundant fish species, by station, collected by the HCSP from 2003 through 2020. Non-native (exotic) species are indicated with an 'X'.

Station	Common Name	Scientific Name	Count (n)	Percent Composition (%)	Non-Native
HCSW-1	Eastern Mosquitofish	*Gombusia holbrooki*	2102	47.34	
	Coastal Shiner	*Notropis petersoni*	1198	26.98	
	Golden Silverside	*Labidesthes vanhyningi*	246	5.54	
	Spotted Sunfish	*Lepomis punctatus*	177	3.99	
	Ironcolor Shiner	*Notropis chalybaeus*	170	3.83	
	Least Killifish	*Heterandria formosa*	132	2.97	
	Bluegill	*Lepomis macrochirus*	81	1.82	
	Warmouth	*Lepomis gulosus*	48	1.08	
	African Jewelfish	*Hemichromis bimaculatus*	37	0.83	X
	Walking Catfish	*Clarias batrachus*	31	0.70	X
HCSW-2	Eastern Mosquitofish	*Gombusia holbrooki*	16955	81.15	
	Least Killifish	*Heterandria formosa*	2689	12.87	
	Sailfin Molly	*Poecilia latipinna*	655	3.13	
	Bluefin Killifish	*Lucania goodei*	139	0.67	
	African Jewelfish	*Hemichromis bimaculatus*	82	0.39	X
	Warmouth	*Lepomis gulosis*	64	0.31	
	Flagfish	*Jordanella floridae*	52	0.25	
	Swamp Darter	*Etheostoma fusiforme*	51	0.24	
	Sailfin Catfish	*Pterygoplichthys gibbiceps*	35	0.17	X
	Oriental Weatherfish	*Misgurnus anguillicaudatus*	28	0.13	X
HCSW-3	Yellow Bullhead	*Ameiurus natalis*	20042	74.01	
	Channel Catfish	*Ictalurus punctatus*	2495	9.21	
	Redear Sunfish	*Lepomis microlophus*	1038	3.83	
	Everglades Pygmy Sunfish	*Elassoma everglade*	960	3.55	
	Hogchoker	*Trinectes maculatus*	330	1.22	

Station	Common Name	Scientific Name	Count (n)	Percent Composition (%)	Non-Native
HCSW-3 (Cont.)	Florida Gar	*Lepisosteus platryhincus*	503	1.86	
	Eastern Mosquitofish	*Gombusia holbrooki*	338	1.25	
	Flagfish	*Jordanella floridae*	224	0.83	
	Dollar Sunfish	*Lepomis marginatus*	198	0.73	
	Bluefin Killifish	*Lucania goodei*	163	0.60	
HCSW-4	Eastern Mosquitofish	*Gombusia holbrooki*	9057	59.68	
	Coastal Shiner	*Notropis petersoni*	1752	11.54	
	Sailfin Molly	*Poecilia latipinna*	893	5.88	
	Least Killifish	*Heterandria formosa*	631	4.16	
	Spotted Sunfish	*Lepomis punctatus*	600	3.95	
	Golden Silverside	*Labidesthes vanhyningi*	498	3.28	
	Seminole Killifish	*Fundulus seminolis*	312	2.06	
	African Jewelfish	*Hemichromis bimaculatus*	290	1.91	X
	Hogchoker	*Trinectes maculatus*	210	1.38	
	Bluefin Killifish	*Lucania goodei*	191	1.26	

Table 4-6. The ten largest contributors to total biomass by station collected by the HCSP from 2003 through 2020. Non-native (exotic) species are indicated with an 'X'.

Station	Common Name	Scientific Name	Total Weight (g)	Percent Composition (%)	Non-Native
HCSW-1	Florida Gar	*Lepisosteus platyrhincus*	7904	33.33	
	Vermiculated Sailfin Catfish	*Pterygoplichthys disjunctivus*	2765	11.66	
	Spotted Sunfish	*Lepomis punctatus*	2521	10.63	
	Bluegill	*Lepomis macrochirus*	2482	10.47	
	Largemouth Bass	*Micropterus salmoides*	1805	7.61	
	Asian Swamp Eel	*Monopterus albus*	1230	5.19	X
	Eastern Mosquitofish	*Gambusia holbrooki*	933	3.94	
	Walking Catfish	*Clarias batrachus*	870	3.67	X
	Coastal Shiner	*Notropis petersoni*	784	3.30	
	Warmouth	*Lepomis gulosus*	629	2.65	
HCSW-2	Florida Gar	*Lepisosteus platyrhincus*	5139	38.76	
	Eastern Mosquitofish	*Gambusia holbrooki*	3226	24.33	
	Bowfin	*Amia calva*	1823	13.75	
	Warmouth	*Lepomis gulosus*	858	6.47	
	Sailfin Molly	*Poecilia latipinna*	476	3.59	
	Spotted Sunfish	*Lepomis punctatus*	330	2.49	
	Least Killifish	*Heterandria formosa*	267	2.01	
	African Jewelfish	*Hemichromis bimaculatus*	232	1.75	X
	Bluegill	*Lepomis macrochirus*	210	1.59	
	Asian Swamp Eel	*Monopterus albus*	170	1.28	X

Station	Common Name	Scientific Name	Total Weight (g)	Percent Composition (%)	Non-Native
HCSW-3	Largemouth Bass	*Micropterus salmoides*	6979	18.69	
	Florida Gar	*Lepisosteus platyrhincus*	6037	16.16	
	Eastern Mosquitofish	*Gambusia holbrooki*	4552	12.19	
	Spotted Sunfish	*Lepomis punctatus*	4405	11.79	
	Bluegill	*Lepomis macrochirus*	2642	7.07	
	Sailfin Molly	*Poecilia latipinna*	2412	6.46	
	Vermiculated Sailfin Catfish	*Pterygoplichthys disjunctivus*	1882	5.04	X
	Redear Sunfish	*Lepomis microlophus*	1381	3.70	
	Blue Tilapia	*Oreochromis aureus*	1092	2.92	X
	Seminole Killifish	*Fundulus seminolis*	826	2.21	
HCSW-4	Spotted Sunfish	*Lepomis punctatus*	7723	22.81	
	Florida Gar	*Lepisosteus platyrhincus*	6571	19.41	
	Bluegill	*Lepomis macrochirus*	2720	8.03	
	Largemouth Bass	*Micropterus salmoides*	2428	7.17	
	Eastern Mosquitofish	*Gambusia holbrooki*	2402	7.09	
	Seminole Killifish	*Fundulus seminolis*	1775	5.24	
	Longnose Gar	*Lepisosteus osseus*	1400	4.13	
	Coastal Shiner	*Notropis petersoni*	1112	3.29	
	Sailfin Molly	*Poecilia latipinna*	1047	3.09	
	Walking Catfish	*Clarias batrachus*	1041	3.07	X

4.3. Avian Wildlife

The Peninsular Florida Landscape Conservation Cooperative identified approximately 31.94% of the Horse Creek watershed as potential Florida Sandhill Crane (*Antigone canadensis pratensis*) habitat (PFLCC 2021; Figure 4-6). Florida Sandhill Cranes are a non-migratory species designated as threatened by the state, with a current population estimate of 4,000 to 5,000 birds (FWC 2020). Their preferred locales include freshwater marshes and wetlands for nesting, particularly those associated with nearby pastures, prairies, or other grasslands (Downs et al. 2020). Approximately 25,000 migratory Greater Sandhill Cranes (*Antigone canadensis tabida*) travel through Florida each year, which also rely upon well-connected and shallowly inundated riparian and palustrine lands for foraging and roosting (FWC 2020, Donnelly et al. 2021). According to 2017 National Wetland Inventory (NWI) data, compiled by the District in 2019, the Horse Creek watershed contains 58.56 square miles (151.68 square kilometers) of palustrine habitat, much of which occurs around the Horse Creek and its tributaries. A map of NWI data is included in Figure 4-8, accompanying a description of vegetation sampling.

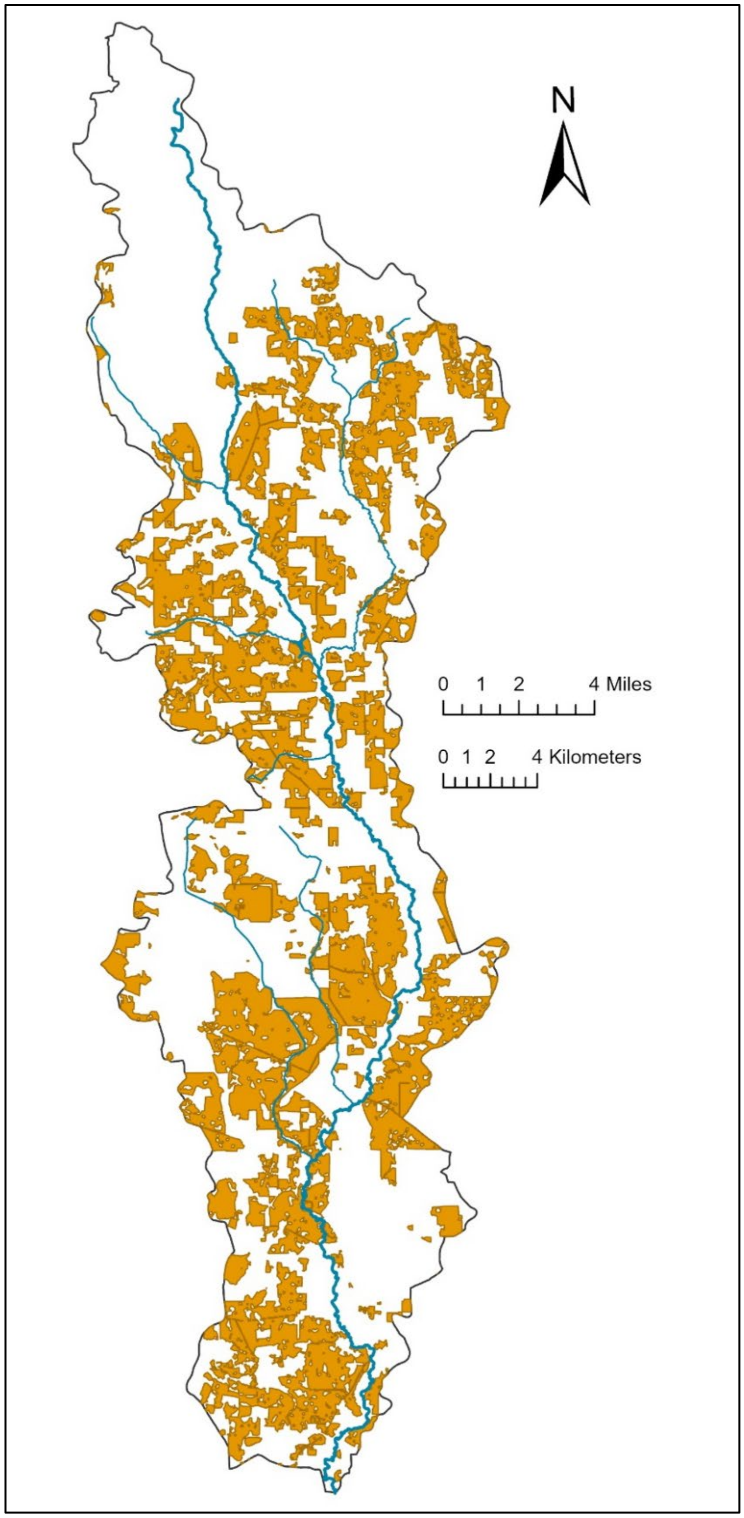

Figure 4-6. Golden areas reflect the potential distribution of Florida Sandhill Cranes throughout the Horse Creek watershed (source: GIS layer maintained by the Peninsular Florida Landscape Conservation Cooperative (2021)).

4.4. Watershed and Floodplain Vegetation

Approximately 40.8% of the Horse Creek watershed is classified as vegetated, according to 2020 land use and cover data (SWFWMD 2021d; Table 4-7, Figure 4-7). Of this, swamps (14.11%), shrub and brushland (7.96%), and freshwater marshes (6.88%) are the dominant vegetation types (Table 4-7).

HSW Engineering, Inc. conducted a study of the Horse Creek riparian corridor in 2012 (Appendix C), to better describe the composition and distribution of plant communities and hydrologic indicators across six floodplain transects (Figure 4-8). Elevated lichen lines and water stains were the predominant hydrologic indicator in Horse Creek, representing the approximate high-water elevation. Along the sampled transect, all hydrologic indicators occurred 5 to 10 feet above channel bottom and their vegetative communities were classified as either floodplain swamp or bottomland forest, according to the FNAI ecological community classification system (HSW 2012).

Vegetation sampling of trees, shrubs, and ground cover along floodplain transects was performed using a modified point-centered quarter methodology. Within quadrats, the data recorded included: species presence, distance to the nearest tree or shrub, the diameter of the nearest tree at breast height, and the dominant types of shrub vegetation and ground cover. The basal area and frequency of trees were then used to calculate the relative importance value of trees (HSW 2012).

Four wetland communities were identified along sampled transects: floodplain swamp, bottomland forest, hydric hammock, and a drier upland hammock community. Within these areas, sixteen tree species were identified and assigned importance values (Table 4-8).

The dominant trees in floodplain swamps at the lowest surveyed elevations were buttressed hydrophytic species like Bald Cypress (*Taxodium distichum*) and Sweet Tupelo (*Nyssa sylvatica var. biflora*). Species with the highest importance values in this zone included Pop Aash (*Fraxinus caroliniana*; 42.78), Bald Cypress (36.71) and Water Locust (*Gleditsia aquatica*; 27.95), which are all either obligate or facultative wetland indicators. Live Oak (*Quercus virginiana*) was the most important species in the bottomland forest and hydric hammock communities, with importance values of 100.71 and 153.39, respectively. The upland hammock was comprised of mixed hardwoods, dominated by Laurel Oak (*Quercus lauriflora*, importance value of 129.65). Where palustrine NWI categories existed along the Horse Creek and its tributaries, most habitats were classified as broad-leaved deciduous or evergreens with seasonal flooding.

Table 4-7. Summary of vegetation within the Horse Creek watershed according to recent District Level 4 Florida Land Use and Cover Classification System (FLUCCS) codes (SWFWMD 2021d).

FLUCCS Level 4 Description	Area (mi^2)	Area (Acres)	Percent of Watershed (%)
Stream and lake swamps (bottomland)	34.22	21899.98	14.11
Shrub and brushland	19.31	12358.33	7.96
Freshwater marshes	16.70	10688.55	6.88
Pine flatwoods	10.59	6779.19	4.37
Upland hardwood - coniferous mix	6.93	4437.67	2.86
Wet prairies	5.49	3511.46	2.26
Mixed rangeland	2.31	1480.71	0.95
Cypress	0.79	504.15	0.32
Herbaceous	0.71	454.11	0.29
Wetland hardwood forests	0.42	267.47	0.17
Upland hardwood forests - Part 1	0.36	229.41	0.15
Wetland forested mixed	0.31	199.98	0.13
Wetland coniferous forests	0.28	178.81	0.12
Emergent aquatic vegetation	0.24	154.94	0.10
Vegetated non-forested wetlands	0.21	133.33	0.09
Upland coniferous forest	0.17	110.64	0.07
Bay swamps	0.08	48.84	0.03
Upland hardwood forests - Part 2	0.05	32.01	0.02

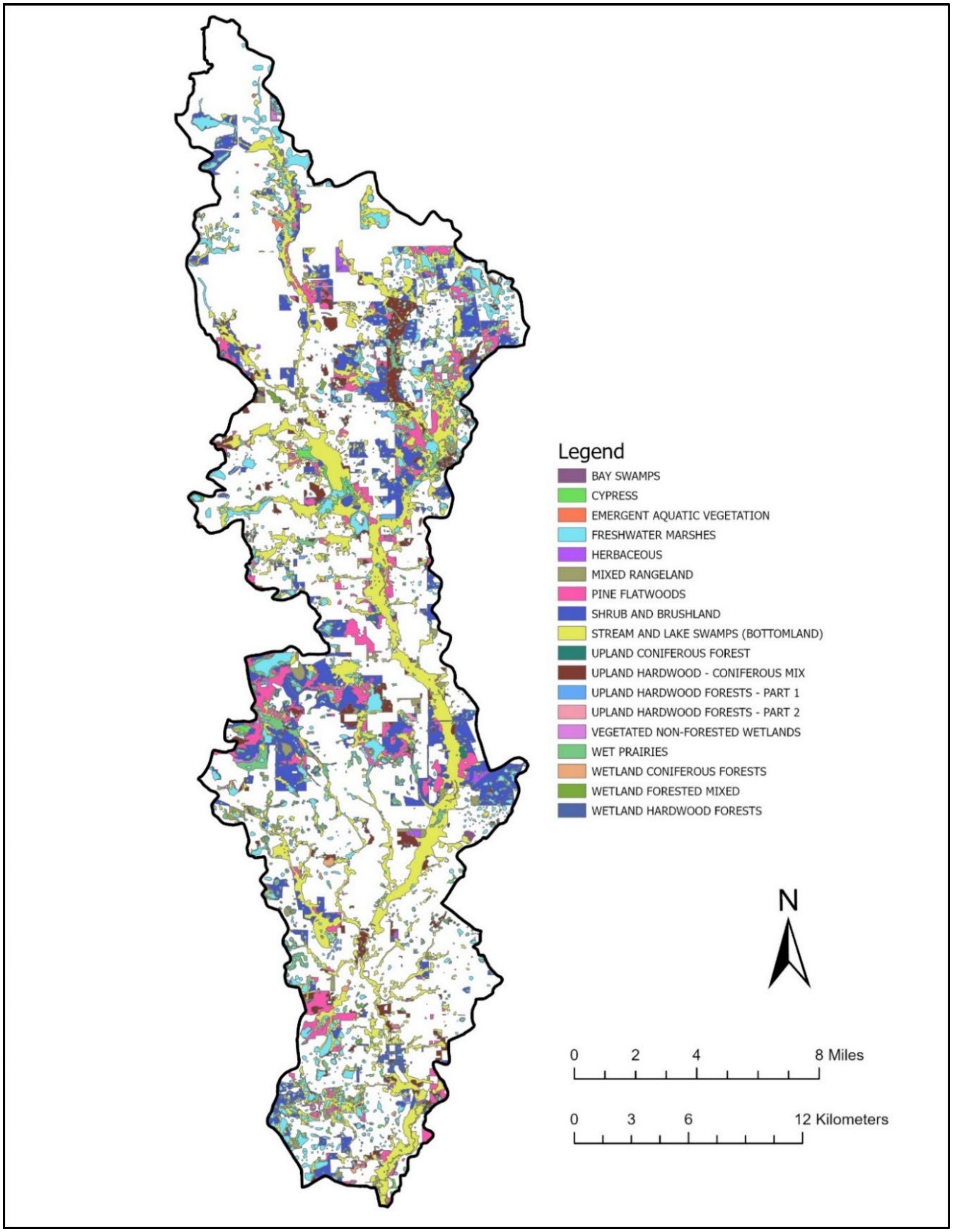

Figure 4-7. Vegetation groups within the Horse Creek watershed according to recent Level 4 Florida Land Use and Cover Classification System (FLUCCS) designations (source: GIS layer maintained by SWFWMD (2021d)).

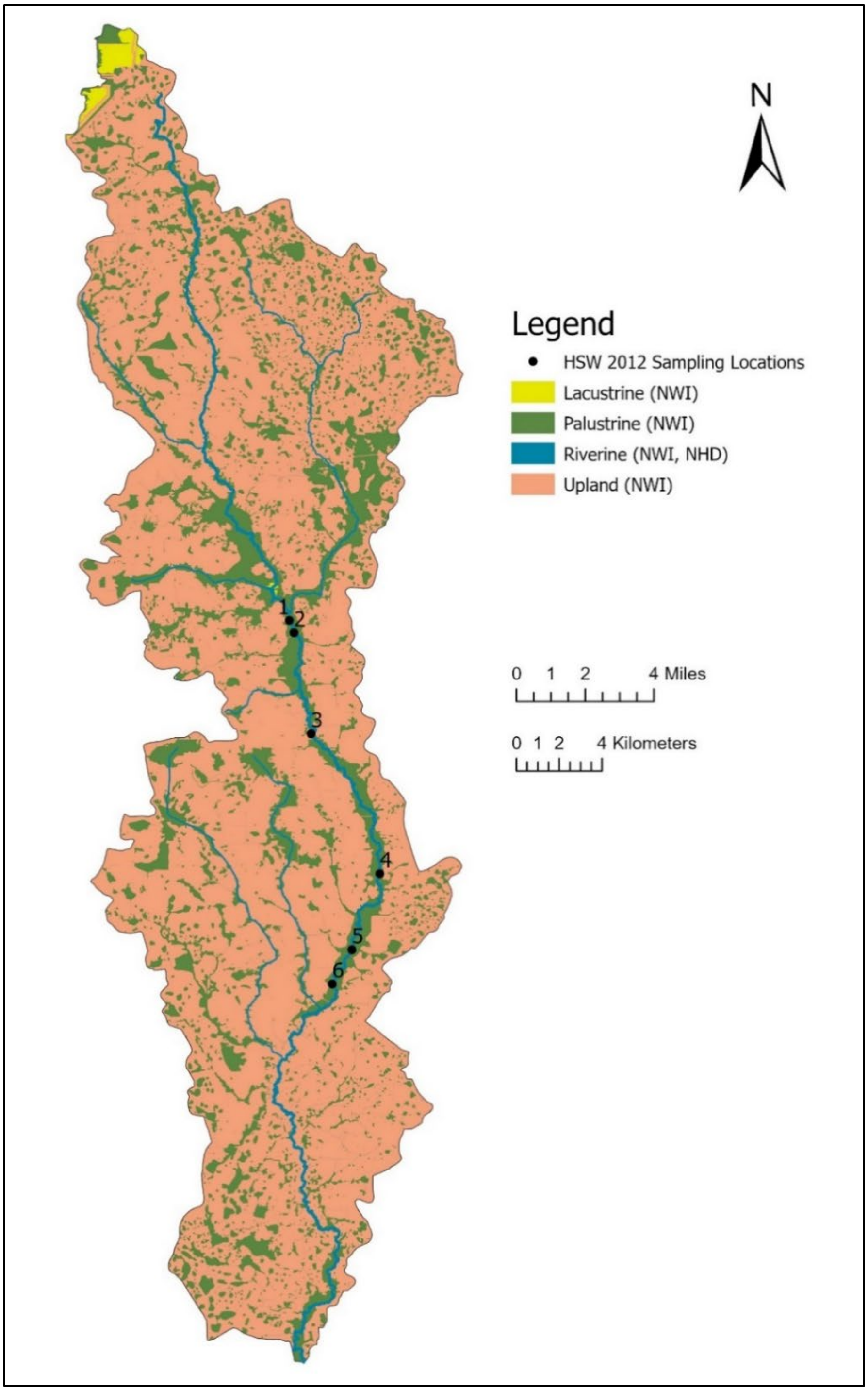

Figure 4-8. Floodplain transect locations sampled by HSW Engineering, Inc. along Horse Creek in 2012, in relation to National Wetland Inventory (NWI) and National Hydrography Dataset (NHD) habitat designations (source: GIS layer files maintained by SWFWMD (2019a, 2019b)).

Table 4-8. Tree species with their importance value within each vegetative community: Floodplain swamp (FS), bottomland forest (BF), hydric hammock (HH), and upland hammock (UH). Cells labeled "NA" indicate species were not present within the community (adapted from HSW 2012).

Common Name	Scientific Name	Importance Value			
		FS	BF	HH	UH
American Elm	*Ulmus americana*	6.46	15.42	NA	25.50
Bald Cypress	*Taxodium distichum*	36.71	14.03	NA	NA
Buttonbush	*Cephalanthus occidentalis*	6.00	2.76	NA	19.24
Cabbage Palm	*Sabal palmetto*	27.30	78.57	39.79	NA
Laurel Oak	*Quercus lauriflolia*	14.29	21.33	83.26	129.65
Live Oak	*Quercus virginiana*	40.16	100.71	153.39	73.09
Persimmon	*Diospyros virginiana*	NA	NA	5.85	NA
Pop Ash	*Fraxinus caroliniana*	116.68	19.63	11.97	NA
Swamp Tupelo	*Nyssa sylvatica var. biflora*	10.30	NA	NA	NA
Sweetgum	*Liquidambar styraciflua*	NA	8.71	NA	52.52
Water Locust	*Gleditsia aquatica*	27.95	22.06	NA	NA
Water Oak	*Quercus nigra*	NA	NA	5.75	NA
Honey Locust	*Gleditsia triacanthos*	14.15	3.70	NA	NA
Groundsel Tree	*Baccharis halimifolia*	NA	2.68	NA	NA
Viburnum	*Viburnum nudum*	NA	5.60	NA	NA
Swamp Dogwood	*Cornus foemina*	NA	4.80	NA	NA

4.5. Ecological Integrity of Lands

The Florida Ecological Greenways Network (FEGN) is a database maintained by the University of Florida (UF) Center for Landscape Conservation Planning that identifies and ranks connected public and private lands in terms of ecological benefit on a scale from 1 (highest priority) to 5 (lowest priority). It is intended to inform land acquisition programs about the most important ecological corridors within a given region, to best preserve wildlife and ecosystem services and promote resiliency. As of the 2021 update, 69% of the Horse Creek watershed was classified as Priority 3 lands and 1.1% was classified as Priority 5 (Figure 4-9). Lands currently protected by the state were shown in Figure 2-10.

The UF Center for Landscape Conservation Planning also developed a Critical Lands and Waters Identification Project (CLIP). This effort compiled natural resource data from the Florida Natural Areas Inventory (FNAI), the UF GeoPlan center, and the FWC, and worked with a variety of advisors to develop models to better prioritize areas for conservation (Oetting et al. 2016). One of the resource categories considered is biodiversity, which is calculated by the combination of the following data layers: Strategic habitat conservation areas (provided by the FWC), potential habitat richness (provided by the FWC), rare species habitat conservation priorities (provided by FNAI), and priority natural communities (provided by FNAI). The most recent CLIP analysis (version 4.0, 2016) indicates that most of the land (47.14%) within the Horse Creek watershed is considered Priority 4 in terms of Biodiversity Resources, on a scale of 1 (highest) to 5 (lowest). Approximately 3.86% of the watershed is considered Priority 1, 12.46% is Priority 2, and 11.27% is considered Priority 3 (Figure 4-10).

The CLIP also produces a landscape integrity index, based on data from the UF Geoplan Center and Center for Landscape Conservation Planning. Within this index, areas with large expanses of remote, intact, predominantly natural lands are considered to have high ecological integrity. Using data from 2010-2015, approximately 35.79% of land within the Horse Creek watershed is classified as having high ecological integrity (Figure 4-11). Lower values are given to fragmented landscapes and those with intensive land use including agriculture and urban development. Approximately 33.39% of the Horse Creek watershed is classified as having moderate ecological integrity and 30.83% is considered to have no ecological integrity. The main stem and tributaries to Horse Creek wind through lands of all classifications (Figure 4-11).

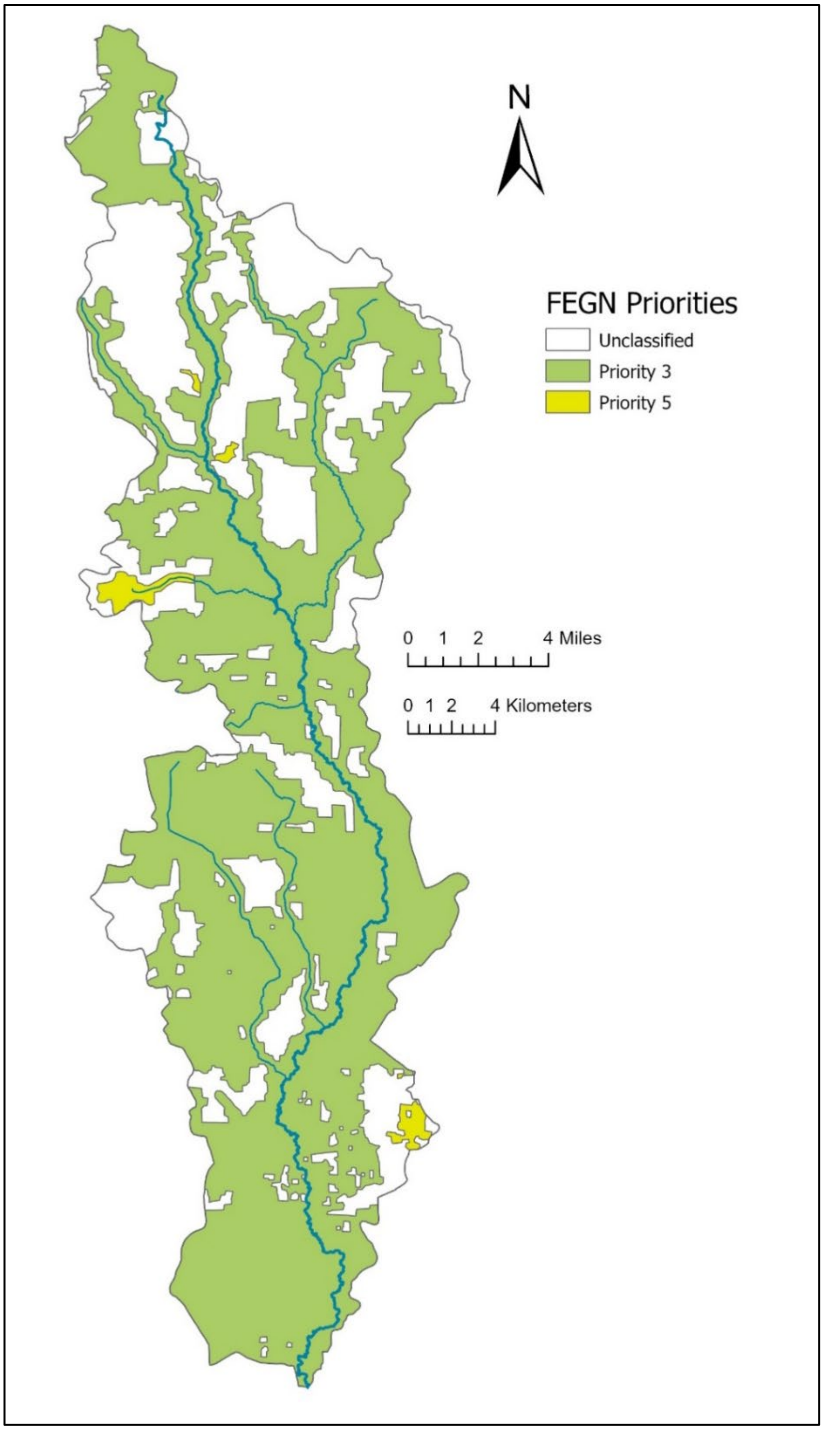

Figure 4-9. Florida Ecological Greenways Network (FEGN) 2021 priorities within the Horse Creek watershed (source: GIS layer maintained by the University of Florida Center for Landscape Conservation Planning (2021)).

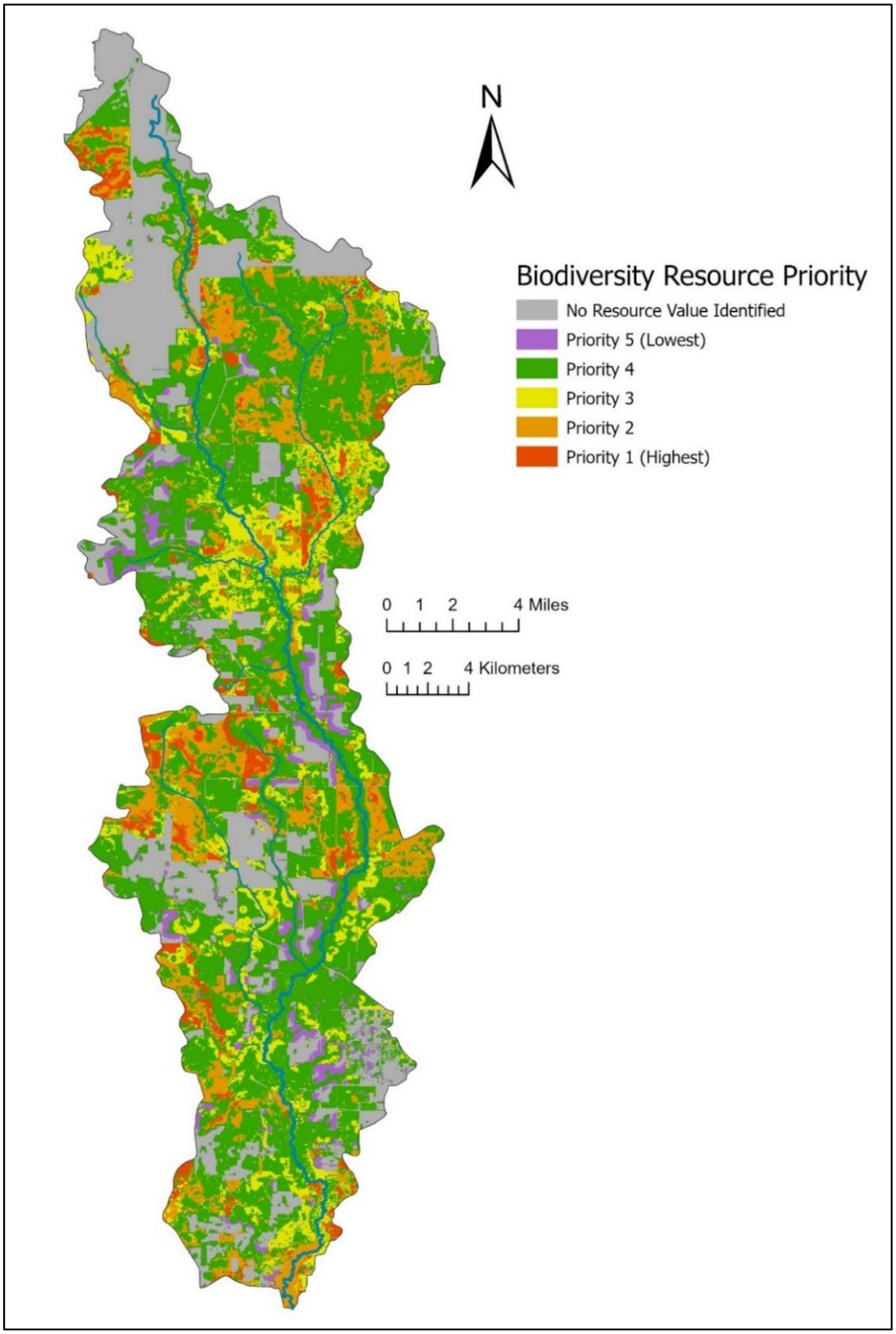

Figure 4-10. Biodiversity resource priority areas within the Horse Creek Watershed, as designated by the Critical Lands and Waters Identification Project, version 4.0 (source: GIS layer maintained by the University of Florida Center for Landscape Conservation Planning (2016a)).

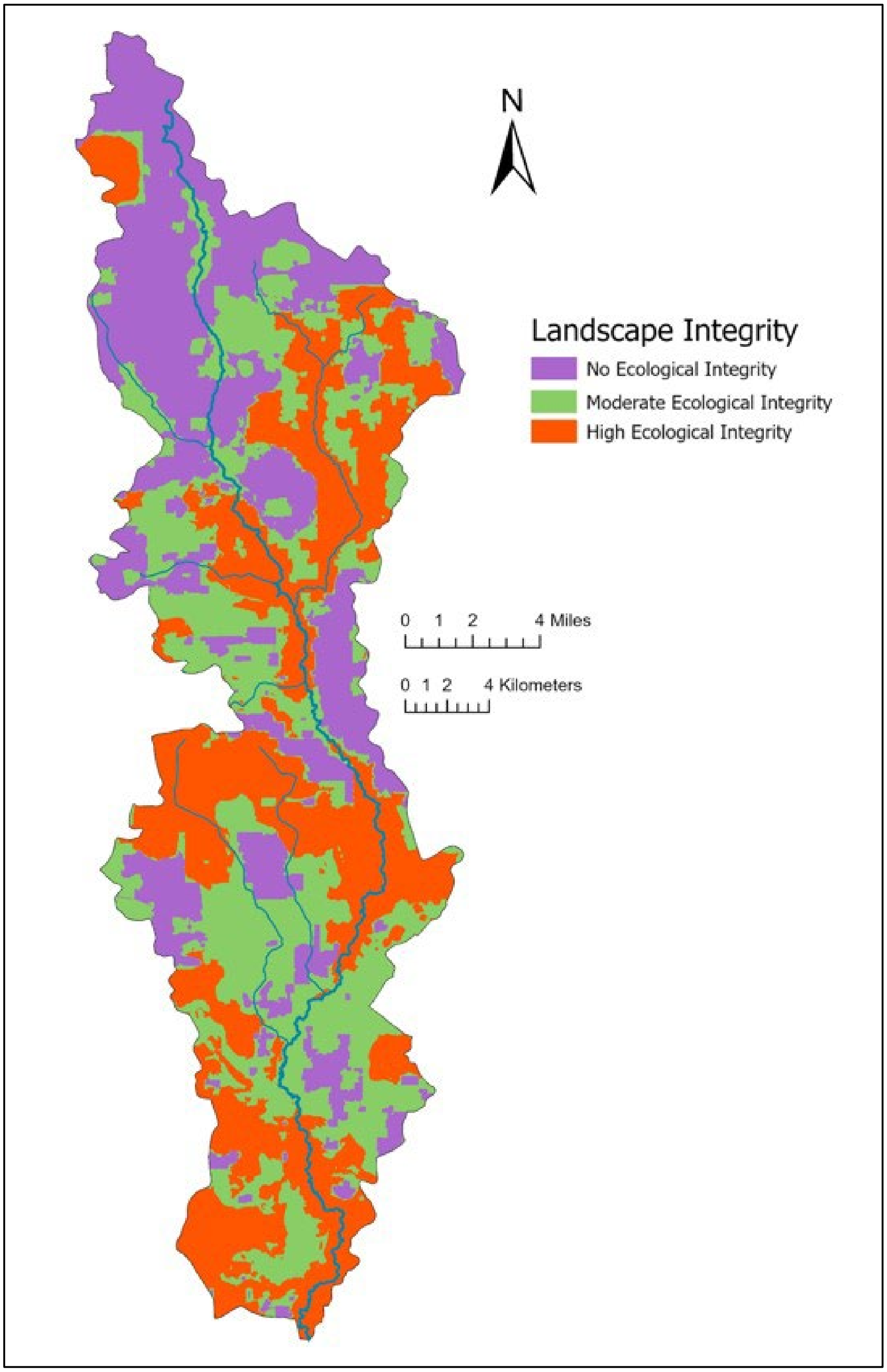

Figure 4-11. Landscape integrity values within the Horse Creek Watershed, as designated by the Critical Lands and Waters Identification Project, version 4.0 (source: GIS layer maintained by the University of Florida Center for Landscape Conservation Planning (2016b).

CHAPTER 5 – TECHNICAL APPROACHES FOR ESTABLISHING MINIMUM FLOWS

This chapter describes the methods used to determine minimum flow requirements for Horse Creek. A variety of hydrologic and ecological analyses and modeling approaches were used to develop baseline flows and flow-based blocks, identifiy low flow threshold, and develop allowable flow reductions for low (Block 1), medium (Block 2), and high (Block 3) flow ranges. The low flow threshold is used to identify a minimum flow condition and is expected to be applicable to flows throughout the year. The allowable flow reductions are based on limiting potential changes in aquatic and wetland habitat availability that may be associated with changes in river flow during each flow-based block.

5.1. Baseline Flow Development

Assessment of anthropogenic impacts on Horse Creek flow records, in particular those associated with water use, was considered essential for the determination of minimum flows. To assist in this effort and other water management activities, the District developed and subsequently updated the Peace River Integrated Model (PRIM2) to investigate the effects of climate variability, groundwater pumping, land use changes, and other factors on flows in the Peace River and its tributaries. Detailed information on model components, required inputs, calibration and validation results, and results of simulated scenarios are documented in HydroGeoLogic, Inc. (2023).

The PRIM2 was used with measured groundwater withdrawals to simulate flows for a 15-year period, from 2003 through 2018. The daily flows produced by PRIM2 agreed reasonably well with the observed streamflow in the Peace River and some tributaries. Correlations were strong for streamflow measured at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage (R^2 = 0.82), the USGS Peace River at SR 70 at Arcadia, FL (No. 02296750) gage (R^2 = 0.77), the USGS Peace River at US 17 at Zolfo Springs, FL (No. 02295637) gage (R^2 = 0.82), the USGS Peace River at Fort Meade, FL (No. 02294898) gage (R^2 = 0.80), the USGS Peace River at SR 60 at Bartow, FL (No. 02294650) gage (R^2 = 0.76), and the USGS Peace Creek Drainage Canal near Wahneta, FL (No. 02293987) gage (R^2 = 0.72). Correlation results for streamflow at the USGS Charlie Creek near Gardner, FL (No. 02296500) gage (R^2 = 0.57) and the USGS Joshua Creek at Nocatee, FL (No. 02297100) gage (R^2 = 0.52) were slightly less than the goal of 0.6 or greater. Groundwater head calibration statistics indicated that predicted water levels at individual wells in the SA, HAS, and UFA met the calibration target. Coefficients of determination (R^2) values for 24 wells (57%) in the SA, 21 wells (75%) in the HAS, and 34 wells (94%) in the UFA were greater than or equal to 0.6. The accurate simulations of seasonal and pumping-induced head changes in the HAS and UFA indicated the model performed reasonably well in quantifying impacts of groundwater pumping on streamflow in the Peace River and its tributaries.

After calibration with measured flows that integrate withdrawal-related effects, PRIM2 was run for 25% and 50% reductions in groundwater pumping to assess the effects of reducing pumping on streamflow in the Peace River and its tributaries. Results from the PRIM2 simulations indicated a strong linear response for the 25% and 50% reductions in groundwater pumping scenarios. Impacts for zero groundwater withdrawals were therefore simply estimated by doubling the impacts estimated under the 50% puping reduction scenario.

Given that PRIM2 was designed to simulate long-term groundwater pumping or rainfall impacts on regional hydrology, daily flows generated using PRIM2 were not used. Rather, the simulation results were aggregated into monthly average values to establish a reasonable cause-and-effect relationship between baseline and impacted flows.

The specific steps undertaken to develop Horse Creek's daily baseline flows were as follows:

(1) The daily simulated flows for both the actual and 50% pumping reduction scenarios were each averaged into monthly flows and differences in flows between the two scenarios were calculated for each month.
(2) The monthly average percentage differences in flows calculated in step 1 were multiplied by two to estimate the effects of no, i.e., zero, groundwater -pumping on flows.
(3) The daily gaged flows measured at the USGS Horse Creek near Arcadia, FL (No. 02297310) gage for the period from May 1,1950, through December 31, 2021, were corrected for the effects of groundwater withdrawals calculated for each month in step 2. Because the effects of groundwater withdrawals were found to increase flows in the creek, the corrections involved subtracting excess groundwater flow from the gaged flow to yield the baseline flow record.

Changes expected in the absence of groundwater withdrawals for flows at the USGS Horse Creek near Arcadia, FL (No. 02297310) gage are presented in Table 5-1. The effects of reduced groundwater withdrawals were positive, with 0.5 to 3.5 cfs decreases in flows associated with the 50% groundwater withdrawal reductions. This result is due primarily to reduction of groundwater runoff associated with agriculture.

Median daily baseline and gaged flows for the period May 1, 1950, through December 31, 2021, for the USGS Horse Creek near Arcadia, FL (No. 02297310) gage are shown in Figure 5-1. The contribution from excess irrigation flow ranged from 0 cfs in October to 7 cfs in August (see Table 5-1).

There are uncertainties associated with inputs and simplified assumptions and approximations of complex hydrologic interactions in the PRIM2 model that may induce errors in the baseline flow development. Some of the sources of uncertainty include:

- The quality of meteorological forcing datasets, particularly rainfall and evapotranspiration are a large source of uncertainty.
- Uncertainty associated with interpolation of gridded input data could affect the accuracy of the model.
- The PRIM2 model solves groundwater water levels and flows at the center of a grid cell but is calibrated against observed data measured at locations not the center of grid cells.
- The effects of groundwater withdrawals were assumed the same over the period of record from May 1, 1950, through December 31, 2021.

Given these uncertainties, the daily flows generated using PRIM2 were not considered appropriate for use. Rather, the simulation results were aggregated into a longer timescale (e.g. monthly) and the relative difference between baseline and impacted flows were used for establishing a reasonable cause-and-effect relationship.

Table 5-1. Estimated changes in flows at the USGS Horse Creek at SR 72 near Arcadia (No. 02297310) gage in the absence of groundwater withdrawals (and associated runoff).

Month	Average Gaged Flows (cfs)	Average Simulated Flows under 50% Pumping Reduction (cfs)	Difference (cfs)	Groundwater Withdrawal Impact (cfs)*	Average Ajusted Flows (cfs)
Jan	86.5	85.1	-1.3	-2.6	83.9
Feb	94.3	92.1	-2.2	-4.4	89.9
Mar	98.1	96.5	-1.6	-3.1	95.0
Apr	30.5	29.6	-0.9	-1.8	28.7
May	25.5	24.0	-1.5	-3.0	22.5
Jun	197.3	194.4	-2.9	-5.8	191.5
Jul	202.1	198.7	-3.4	-6.8	195.3
Aug	500.8	497.3	-3.5	-7.0	493.8
Sep	652.7	652.0	-0.6	-1.2	651.5
Oct	283.6	283.7	0.2	-0.3	283.9
Nov	54.4	53.9	-0.5	-0.9	53.5
Dec	69.8	68.8	-1.0	-1.9	67.9

* Groundwater withdrawal impacts estimated by doubling the difference between the average gaged flows and average simulated flows under the 50% pumping reduction scenario.

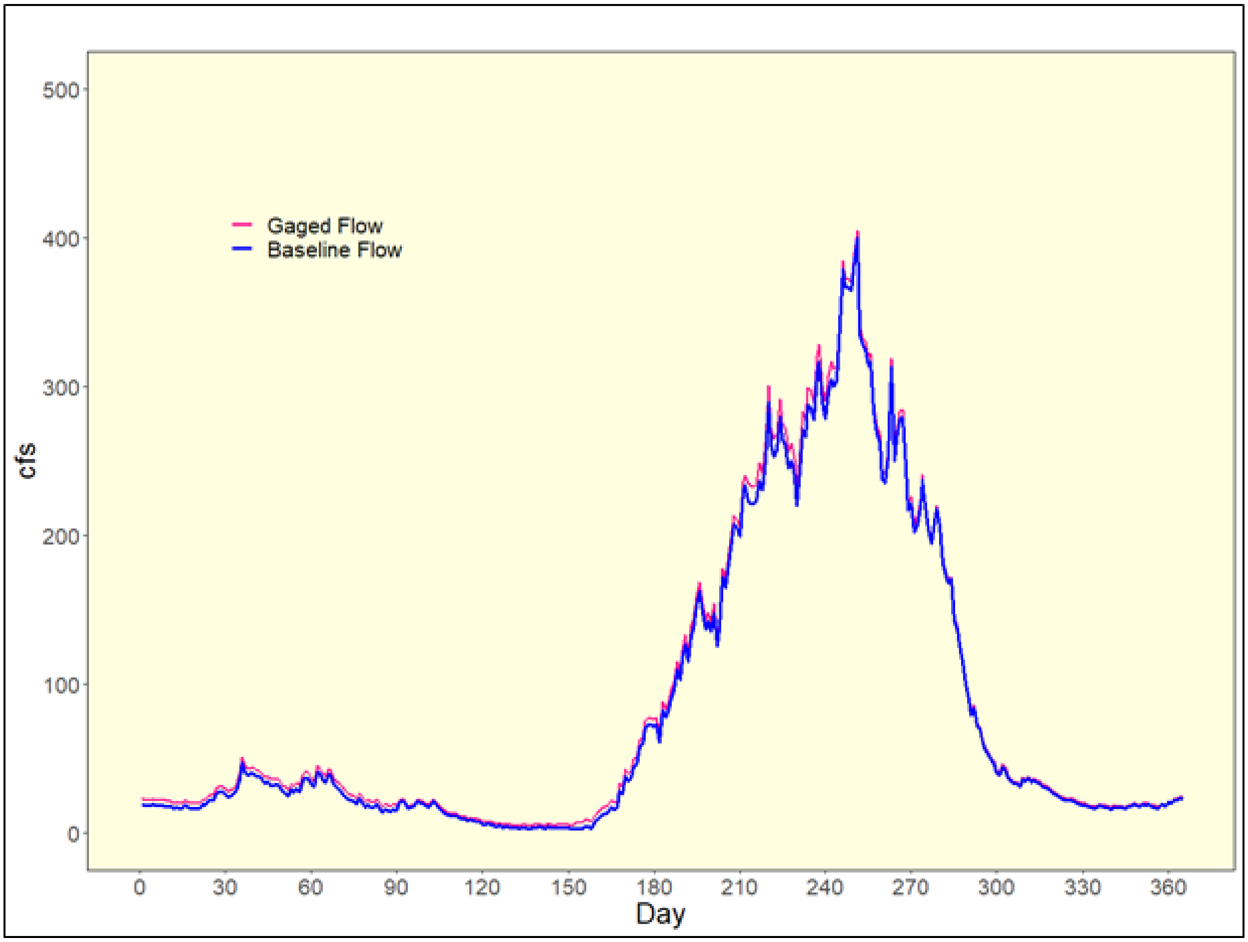

Figure 5-1. Median daily baseline and gaged flows at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage for the period from 1950 through 2021.

5.2. Development of Flow Blocks

For most rivers in the District, there is an average annual flow regime that can be divided into three periods. These three periods are characterized by low, medium, and high flows and for the purpose of developing minimum flows, are termed Block 1, Block 2, and Block 3, respectively (Kelly et al. 2005a). This approach was originally proposed during the independent peer review of the recommended minimum flows for the Upper Peace River with the intent of appropriately representing hydrologic and hydroperiodic conditions in the river (Gore et al. 2002). The identification of flow blocks accounts for flow requirements associated with ecosystem functions, biological populations, and communities, and the assembly of flow blocks form a minimum flow prescription (Postel and Richter 2003). As noted by the Upper Peace River minimum flows peer review panel, the assumptions behind block techniques are based upon basic ecological theory–

organisms and communities occurring in a river have evolved and adapted their life cycles to flow conditions over a long period of pre-development history (Stanford et al. 1996). Since the development of the Upper Peace River minimum flows, the District has typically used calendar-based blocks developed by analyzing flow records for long-term USGS gage sites (Kelly et al. 2005a, b, c, 2007, Leeper et al. 2018, Munson et al. 2007). The calendar-based block approach uses the median flow for days of the year to identify dates when flows typically are above or below the 25th and 50th percentiles. Calendar-based Block 1 begins when median flows fall below and stay below the 25th percentile, calendar-based Block 3 begins on the day of year when median flows exceed and stay above the 50th percentile, and calendar-based Block 2 extends from the end of Block 3 to the beginning of Block 1.

To help reduce unintended negative impacts on biological communities in years where flows are not well-matched to the fixed start and end dates of the calendar-based blocks, flow-based blocks were recently introduced by the District to re-evaluate the minimum flows for the Lower Peace River and develop recommended minimum flows for Lower Shell Creek (Ghile et al. 2021) and Little Manatee River (Holzwart et al. 2023).

For Horse Creek, flow-based blocks (Figure 5-2) were developed from analysis of fish passage and floodplain inundation criteria that are discussed in greater detail in Sections 6.1 and 6.2, respectively. The threshold for fish passage was determined to be 15 cfs and was used to define the threshold or transition between the low-flow Block 1 and medium-flow Block 2. The threshold for floodplain inundation was determined to be 78 cfs, and this flow was identified as the threshold or transition differentiating the medium flow Block 2 and high flow Block 3. Based on the sensitivity of the floodplain inundation, the high flow Block 3 was divided into three subblocks (Block 3a, Block 3b and Block 3c) at flow thresholds of 172 cfs and 644 cfs. For reference, 15 cfs is the 23rd non-exceedance percentile, 78 cfs is the 57th non-exceedance percentile, 172 cfs is the 72nd non-exceedance percentile, and 644 cfs is the 93rd non-exceedance percentile. These blocks are defined using the flow record from May 1, 1950, through December 31, 2021, at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage. Days are assigned to the following blocks based on daily average flow, regardless of calendar date:

- Block 1 – Flows less than or equal to 15 cfs
- Block 2 – Flows greater than 15 cfs and less than or equal to 78 cfs
- Block 3a – Flows greater than 78 cfs and less than or equal to 172 cfs
- Block 3b – Flows greater than 172 cfs and less than or equal to 644 cfs
- Block 3c – Flows greater than 644 cfs

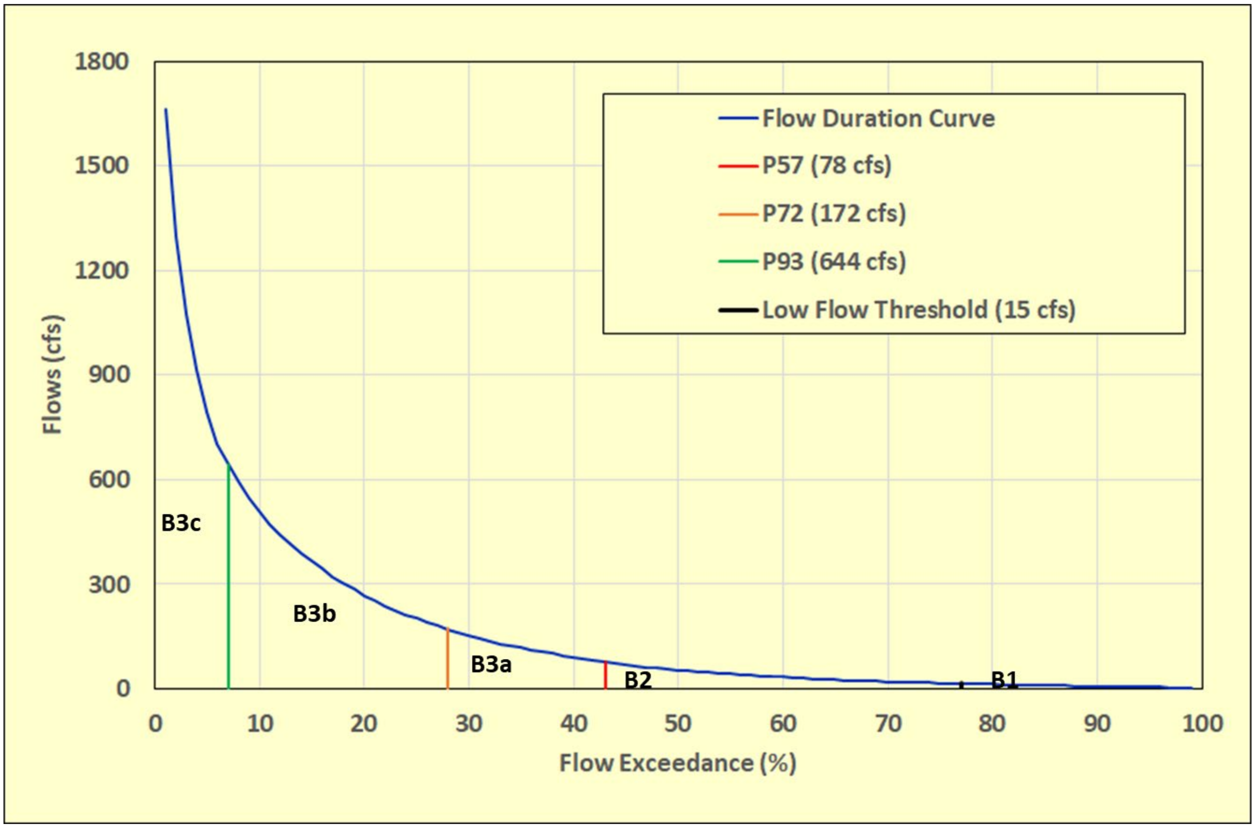

Figure 5-2. Flow blocks superimposed on a flow duration curve (solid blue line) at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage. The high flow Block 3 is divided into three sub-blocks as shown by green and orange vertical lines. The boundary between the high-flow Block 3 and medium-flow Block 2 is shown as a red vertical line. The boundary between medium-flow Block 2 and low-flow Block 1 is shown as a black vertical line. The flow duration curve is shown here for reference; blocks were determined based on fish passage and floodplain inundation criteria, not on the median flows.

5.3. Resources of Concern

The District's approach for developing minimum flows is habitat-based. Because river systems include aquatic and wetland habitats that support diverse biological communities, it is necessary to identify key ecological resources for consideration, and when possible, determine hydrologic requirements for specific habitats associated with the resources. It is assumed that protecting the resources of concern will also provide protection for other ecological aspects or functions of the river system that are more difficult to quantify, such as transfer of detrital material and the maintenance of river channel geomorphology.

Resource management goals that were the focus of the technical analyses for the development of minimum flows for Horse Creek and the relevant environmental values associated with each of these goals are listed below.

- Determination of a low flow threshold to provide protection for ecological resources and human uses of Horse Creek by prohibiting withdrawal impacts during critical low-flow periods. This supports maintenance of a minimum depth for fish passage, which also promotes natural flow continuity, and maintains water depths above inflection points in the wetted perimeter of the river channel to maximize aquatic habitat with the last amount of flow. Relevant environmental values include:
    - Recreation in and on the water
    - Fish and wildlife habitats and the passage of fish
    - Transfer of detrital material
    - Maintenance of freshwater storage and supply
    - Aesthetic and scenic attributes
    - Filtration and absorption of nutrients and other pollutants
    - Water quality
    - Navigation
- Maintenance of the inundation of instream woody habitat, including snags and exposed roots in the river channel. Relevant environmental values include:
    - Fish and wildlife habitats and the passage of fish
    - Transfer of detrital material
    - Sediment loads
- Maintenance of seasonal hydrologic connections between Horse Creek and floodplain to ensure the persistence of floodplain structure and function. Relevant environmental values include:
    - Recreation in and on the water
    - Fish and wildlife habitats and the passage of fish
    - Transfer of detrital material
    - Aesthetic and scenic attributes
    - Filtration and absorption of nutrients and other pollutants
    - Sediment loads
    - Water quality
    - Navigation
- Maintenance of available instream habitat for fish and macroinvertebrate taxa throughout Horse Creek. Relevant environmental values include:
    - Recreation in and on the water
    - Fish and wildlife habitats and the passage of fish

- Transfer of detrital materials
- Aesthetic and scenic attributes
- Filtration and absorption of nutrients and other pollutants
- Sediment loads
- Water quality

The primary approach used for minimum flows development in Horse Creek focused on the maintenance of 85% of the most sensitive criterion associated with the resource management goals. In addition, a low flow threshold was identified to ensure flow continuity for environmental and human use values.

5.3.1. Low Flow Threshold

Development of minimum flows for Horse Creek included identification of a low flow threshold. This is a flow rate below which no surface withdrawals would be permissible, and it is developed for some rivers because environmental values may exhibit high sensitivity to impacts at very low rates of flow. A low flow threshold has been included in minimum flows established for many District rivers, including portions of the Alafia, Anclote, Braden, Hillsborough, Myakka, Pithlachascotee rivers, the middle and lower sections of the Peace river, and Gum Slough Spring Run, and is currently proposed for the Little Manatee River.

Two metrics are typically associated with the development of a low flow threshold. One is based on maintaining fish passage along the river corridor. The other is based upon the lowest wetted perimeter inflection point, a measure of gain in available habitat per unit of flow. The low flow threshold is then established at the higher of the two metrics, if comparison of that criterion with historical flow records indicates that it is reasonable. Although flows less than the low flow threshold may occur during anytime of the year, they typically occur during the dry season, when Block 1 flows are most common.

5.3.1.1. Fish Passage

Ensuring sufficient flows to support the longitudinal connectivity for the natural passage or movement of fishes along a river is an important component of the development of minimum flows. Maintenance of these “fish passage” flows is assumed to promote natural patterns of continuous flow within the channel or river segment, allow for recreational navigation (e.g., canoeing and kayaking), enhance aesthetics, and avoid or lessen potential negative effects associated with pool isolation (e.g., high water temperatures, low dissolved oxygen concentrations, localized phytoplankton blooms, and increased predatory pressure resulting from loss of habitat/cover).

To protect benefits associated with longitudinal flow continuity and channel connectivity, a 0.6-ft (0.18-m) fish passage criterion was used to develop a low flow threshold for Horse Creek. This fish passage criterion is routinely used by the District for minimum flows development and has been considered acceptable, reasonable, and representing the best available information by numerous peer review panels convened to review minimum flows developed by the District.

Output from multiple runs of a Horse Creek HEC-RAS model created to support minimum flow development was used to assess flow-related water depths at each of the 93 HEC-RAS cross-sections included in the model for the mainstem of the river (see Section 6.1.1). Flows at the USGS Horse Creek at SR 72 near Arcadia, FL gage (No. 02297310) were associated with flows at each cross-section that resulted in at least 0.6-ft (0.18-m) of water in the deepest part of the channel were identified. The highest flow at the USGS gage required to maintain this depth at the most sensitive cross-section was calculated for use as a fish passage metric to be considered for development of the low flow threshold.

5.3.1.2. Lowest Wetted Perimeter

Wetted perimeter is defined as the distance along the stream bed and banks at a cross-section where there is contact with water. Evaluation of the "wetted perimeter" of the stream bottom is useful for assessing relationships between flow and the quantity of stream bottom habitat. Wetted perimeter methods for evaluating streamflow requirements assume that there is a direct relationship between wetted perimeter and fish habitat (Annear and Conder 1984), and with aquatic habitat in general. Studies on streams in the Southeast United States have demonstrated that the greatest amount of macroinvertebrate biomass per unit reach of stream occurs on the stream bottom (Benke et al. 1985). Although production on a unit area basis may be greater on snag and root habitats, the greater the area of stream bottom along a reach makes it the most productive habitat under low flow conditions (Heinz and Woodard 2013).

By plotting the response of wetted perimeter to incremental changes in discharge, an inflection or inflections can be identified in the resulting curve where small decreases in flow result in increasingly greater decreases in wetted perimeter. This inflection point or points represent flows at which the water surface recedes from stream banks and habitat (particularly for benthic macroinvertebrates and other bottom-dwelling organisms) is lost at an accelerated rate. Stalnaker et al. (1995) describe the wetted perimeter approach as a technique for using the “break” or inflection point in the stream’s wetted perimeter versus discharge relation as a surrogate for minimally acceptable habitat. They note that when this approach is applied to riffle (shoal) areas, “the assumption is that minimum flow satisfies the needs for food production, fish passage, and spawning.” The District refers to the lowest breakpoint on the wetted perimeter-discharge curve as the LWPIP. Identification of this point permits evaluation of flows that provide the greatest amount of inundated bottom habitat in the river channel on a per-unit flow basis.

Output from multiple runs of the HEC-RAS model was used to generate a wetted perimeter versus discharge plot for each of the 93 HEC-RAS cross-sections included in the model for Horse Creek. Plots were visually examined for the LWPIP at each cross-section and used along with calculated changes in wetted perimeter on a per unit of flow basis to identify flows at the USGS Horse Creek SR 72 near Arcadia (No. 02297310) gage that were associated with relatively large changes in wetted perimeter within the river channel. For cross-sections that displayed no distinct inflection point, or where the majority of in-channel wetted perimeter was inundated at the lowest modeled flow, the LWPIP was established at the lowest modeled flow. The LWPIP flows at each HEC-RAS cross-section were used as a metric for consideration when developing the low flow threshold.

5.3.2. Floodplain Inundation

Floodplains are valuable ecosystems that support high levels of biodiversity, enhance habitat heterogeneity, and serve as hotspots for primary production, while providing important ecosystem services like the filtration of surface water and groundwater recharge (Opperman et al. 2010). Their periodic inundation strongly influences overall biological productivity of riverine systems (Junk et al. 1989). Flooding can result in areas of shallow water that are less turbid than that of the main river channel, and thus can stimulate high rates of primary production from aquatic plants and algae (Ahearn et al. 2006). Furthermore, during inundation, different prey items and habitats become available to instream organisms, which can have positive impacts on the condition and abundance of large, predatory fish (Blewett et al. 2017). High velocity flood events can disperse organic materials throughout the river and affect the geomorphology of the river channel.

The duration and depth of floodplain inundation, along with the frequency of floods, are primary drivers of plant community composition and distribution in these ecosystems (Light et al., 2002, Whitlow and Harris 1979). In areas with longer hydroperiods, the decomposition of organic materials can be slow, with the development of anaerobic mucky or peaty soils (Tate 1980, Brown et al. 1990). Plants growing in flooded areas are tolerant to these anoxic conditions and the physical structure of saturated soils (Hook and Brown 1973, McKevlin et al. 1998). Spatial gradients in vegetative communities are frequently observed in floodplains with increasing distance from the river channel, as changes in the depth and frequency of inundation impact soil saturation and anoxia (Capon 2005, Junk et al., 1989). Changes to floodplain inundation can therefore affect the distribution of these soils and the plants that grow within them (Light et al., 2002).

Floodplain vegetation, soil, and hydrologic indicator data collection and analysis for Horse Creek were completed by HSW Engineering, Inc. (2012), included as Appendix B to this report, for six representative cross-sections perpendicular to the river channel (Figure 4-8. Floodplain cross-sections were selected based upon review of the District's available soils and vegetation mapping data and inspection of previously established physical habitat simulation sites along the creek. Representative wetland communities that best represented the floodplain of the targeted corridor were selected.

To characterize forested vegetation communities along each cross-section, changes in dominant vegetation communities were located and used to delineate boundaries between vegetation zones. Trees, rather than shrubs and herbaceous species, were used to define vegetation communities, because relatively long-lived tree species are better integrators of long-term hydrologic conditions. Trees with obligate or facultative wetland indicator status dominated the floodplain swamp and bottomland forest communities, with facultative species in the hydric hammock community.

Soils along the floodplain cross-sections were evaluated for the presence of hydric or flooding indicators, as well as saturation and inundation condition. Key physical indicators of historical inundation were identified, including lichen or moss lines, trunk buttresses, and water marks, with lichen and moss lines being the most prevalent. Elevations were surveyed along transects to characterize conspicuous changes and heights of hydrologic indicators were recorded. As expected, hydric soils occurred at lower elevations and non-hydric soils occurred at the ends of transects or higher than the boundary of transition bottomland hardwood to hydric hammock or upland hammock community with a significant difference in median elevation between hydric and non-hydric soils. Based on the occurrence of wetlands throughout Horse Creek, a floodplain inundation criterion was developed.

The HEC-RAS model was used to evaluate the extent of floodplain inundation as a function of flows at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02293710) gage. Then HEC-GeoRAS, a geo-processing accessory to HEC-RAS that incorporates a digital elevation layer, was used to import the HEC-RAS model water surface profile simulation data into ArcGIS for spatial mapping of the extent of the floodplain inundation for the baseline flow scenario. A prescriptive standard allowing up to 15% change in floodplain inundation from the baseline condition was adopted to define the limit beyond which further withdrawals would result in significant harm. Inundation of the floodplain by river flows occurs predominantly during Block 3, which has a wide range of flows. To protect the various floodplain habitats, three percent-of-flow reductions were identified: Block 3a for out-of-bank floodplain inundation (swamps), Block 3b for inundation of lowland floodplains and Block 3c for infrequent and extreme high pulse flooding events (leading to inundation of upland floodplains). Both total area of inundation and duration of inundation were considered.

5.3.3. Instream Habitat

Maintaining instream habitat is critical for proper ecosystem function. Geomorphically distinct substrate patches (sand, mud, or woody debris) can benefit different microbial, macroinvertebrate, and fish assemblages. Changes in community composition and function occurring along the river continuum are in part a consequence of the relative abundance of different habitat patches, which are under the control of channel geomorphology and flow. The District quantified instream habitat on Horse Creek using System for Environmental Flow Analysis (SEFA) modeling to predict habitat suitability for aquatic biota and by modeling flows required for woody habitat inundation.

5.3.3.1 Habitat Suitability for Aquatic Biota

One of ten environmental values in the water resource implementation rule is “fish and wildlife habitats and the passage of fish.” Fish, including game fish, non-game fish, and the invertebrates that support the ecosystem have specific requirements for water depth, velocity, substrate, and cover. Instream habitat modeling combines field measurements of channel geometry, water depth and velocity with substrate and cover characteristics.

Aquatic biota, including fish and benthic macroinvertebrates, need sufficient habitat to obtain resources, avoid predation, and reproduce in a flowing water environment. This habitat can be quantified in terms of depth and velocity which vary with the quantity of discharge. In addition, qualitative habitat variables include substrate types, presence of organic detritus, nearby structural elements such as overhanging banks or logs, and other characteristics. As the total quantity of discharge varies in a stream, these habitat elements will vary as well, affecting the amount and quality of habitat available.

Predicting changes to depth and velocity with changing flow requires hydraulic modeling. The SEFA software package offers a flexible modeling framework for quantifying changes to the habitat of aquatic biota in response to changing flow regimes (Jowett et al. 2020, Aquatic Habitat Analysts, Inc. 2021). The SEFA software is capable of analysis identical to PHABSIM, which was commonly used in past minimum flows analysis by the District and offers options for analysis in addition to PHABSIM methods.

The SEFA modeling software (Jowett et al. 2020) was used to quantify changes in available instream habitat with flow in Horse Creek. HSW Engineering, Inc. collected habitat, stage, and flow data at five locations along Horse Creek (HSW 2021, included as Appendix D to this report). To support use of the best available information for minimum flow development, the District conducted an analysis of instream habitat using SEFA based on data collected by HSW and an updated baseline flow record (Herrick 2022, included as Appendix E to this report). For the analysis, taxa were evaluated for a 15% change in their area weighted suitability under flow reduction scenarios.

5.3.3.2 Woody Habitat Inundation

Woody habitats are important instream features that can be influenced by flow conditions (Benke and Wallace 1990). Wood provides a relatively stable, structurally complex medium that serves as cover for a variety of invertebrates, fish, and other organisms. As physical impediments to flow, woody structures enhance the formation of leaf packs and debris dams that further improve instream habitat diversity and complexity. With sustained inundation, microbial conditioning and periphyton growth can occur on woody materials, leading to successful macroinvertebrate colonization and subsequent support for aquatic food webs.

Mean elevation of exposed root and snag woody habitats were obtained at six locations in Horse Creek, corresponding to the floodplain vegetation work performed by HSW Engineering, Inc. (2012; included as Appendix C to this document). The Horse Creek HEC-RAS model was run to identify flow-stage relationships at these instream habitat sites. Based on these relationships, corresponding flows at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage necessary to inundate mean elevations of exposed roots and snags were determined. The maximum percent-of-flow reduction that would result in 15% fewer days of 1-day, 7-days, and 30-day periods of inundation of the mean woody habitat elevation was then calculated, relative to baseline conditions.

5.4. Modeling Tools and Technical Approaches for Addressing Resources of Concern

This section describes the modeling tools and technical approaches used to determine the minimum flow requirements for Horse Creek between the USGS Horse Creek near Myakka Head (No. 02297155) gage and the USGS Horse Creek at SR 72 near Arcadia (No. 02297310). A HEC-RAS model was developed to characterize river stages as a function of flow, and their relationships with ecological criteria, including wetted perimeter, fish passage, navigation, sediment loads, transfer of detrital material, floodplain inundation, and woody habitat. The HEC-GeoRAS software was used to process geospatial data and support hydraulic model development, and to import the HEC-RAS model water surface profile simulation data into ArcGIS for spatial mapping of the extent of floodplain inundation. The SEFA modeling software was used to characterize potential changes in the availability of fish habitat and macroinvertebrate habitat.

5.4.1. HEC-RAS Modeling

The HEC-RAS model allows users to perform a one-dimensional steady flow and unsteady flow calculations, as well as two-dimensional unsteady flow calculations. It has been used by the District as one of the major modeling tools in support of minimum flows development for flowing systems.

A one-dimension HEC-RAS model was initially developed for Horse Creek in 2016 by INTERA to analyze and characterize water levels and flows throughout the Horse Creek. After initial model construction, the District identified the need for improved model accuracy, improved flow apportionment by reach along the Creek, and inclusion of overbank bathymetry/topography for floodplain inundation analysis. With these goals in mind, the District contracted with INTERA to incorporate additional cross-sections into the model, collect additional flow and stage data, re-calibrate the model, and perform predictive simulations, including floodplain inundation mapping (INTERA 2018, Appendix F).

The updated HEC-RAS model was constructed for approximately 30 miles of the creek from the USGS Horse Creek near Myakka Head, FL (No. 02297155) gage to the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage, flowing southeasterly to its confluence with Peace River (Figure 5-3). Geometric data used for the analyses consisted of surveyed transects and bathymetric/topographic data (point data) collected by the District. A field survey was conducted by District professional land surveyors at thirteen locations (Figure 5-3). Additionally, Digital Elevation Model (DEM) data (5-foot by

5-foot cells) from the District's GIS and Mapping Department was used to develop new HEC-RAS cross-sections. The District DEM is based on aerial LiDAR data collected in 2005 by 3001 Northrop Grumman (Appendix G). Both the surveyed and DEM-based cross-sections were extended to the outer boundary of the river-corridor wetlands to incorporate the range floodplain elevations. A total of 93 cross-sections are defined in the updated HEC-RAS model, including 13 surveyed cross-sections and 80 digitized cross-sections from the DEM (Figure 5-3).

Hydraulic data input required by the model includes flow data and stage data for the boundary conditions. Daily flow and stage data for the USGS Horse Creek near Myakka Head, FL (No. 02297155) gage and the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage were obtained from the USGS. However, additional flow and stage data were required to develop and run the HEC-RAS model for Horse Creek. Field engineers from INTERA collected additional flow data at six locations during three discrete events in October 2017 and May and June 2018 that represented medium, low and high flow conditions respectively. To improve model calibration, additional stage data was collected at three locations (Goose Pond, County Road 665, and SR 70) continuously from November 14, 2017, through August 19, 2018. Locations of the additional flow data collection sites, which were evenly distributed along the creek, are shown in Figure 5-3.

Required steady-flow data included the USGS gage records and the flow measurements collected by INTERA at six locations. Based on these data, 11 cross-sections (out of 93 cross-sections) were assigned with a flow relationship between the cross-section and the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage, located at the SR 72 bridge, and a linear interpolation approach was used to generate flow values at each cross-section (Table 5-2).

A known water surface elevation was used as the downstream boundary condition at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage, where a USGS stage-flow rating curve was available. To ensure the model accurately simulated low, medium and high flows, five flow and stage profiles were developed using the flow data collected at six locations, stage data collected continuously at three locations from November 14, 2017, through August 19, 2018, as well as the stage and flows measured at the USGS Horse Creek near Myakka Head (No. 02297155) gage and the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage. All these data were used for model calibration or validation purposes.

The HEC-RAS model was run for steady flow analysis and was considered well-calibrated when calculated water surface elevations were within plus or minus 0.5 foot of observed stage value, in keeping with standard USGS practices where this range of error is based on the potential error associated with using data collected to a 1-foot contour interval aerial mapping standard for model development (Lewelling 2004). The model was able to capture the hydrologic response to all flow conditions at the calibration sites, with stage residuals of less than 0.5 feet (Table 5-3). Model validation was conducted at two sites where the observed stage data was not utilized for model calibration. Review of the model validation results for eight flow profiles indicated that all stage residuals fell within a range of plus or minus 0.5 feet, except for one flow profile at T3 where stage residual was 0.52 feet (Table 5-4).

The HEC-RAS model was then run for fifteen flow rate profile scenarios to establish flow versus stage rating curves for each cross-section. Each profile represents a non-exceedance percentile ranging from 5 to 99 percent at USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage for the period from May 1, 1950, to December 31, 2021.

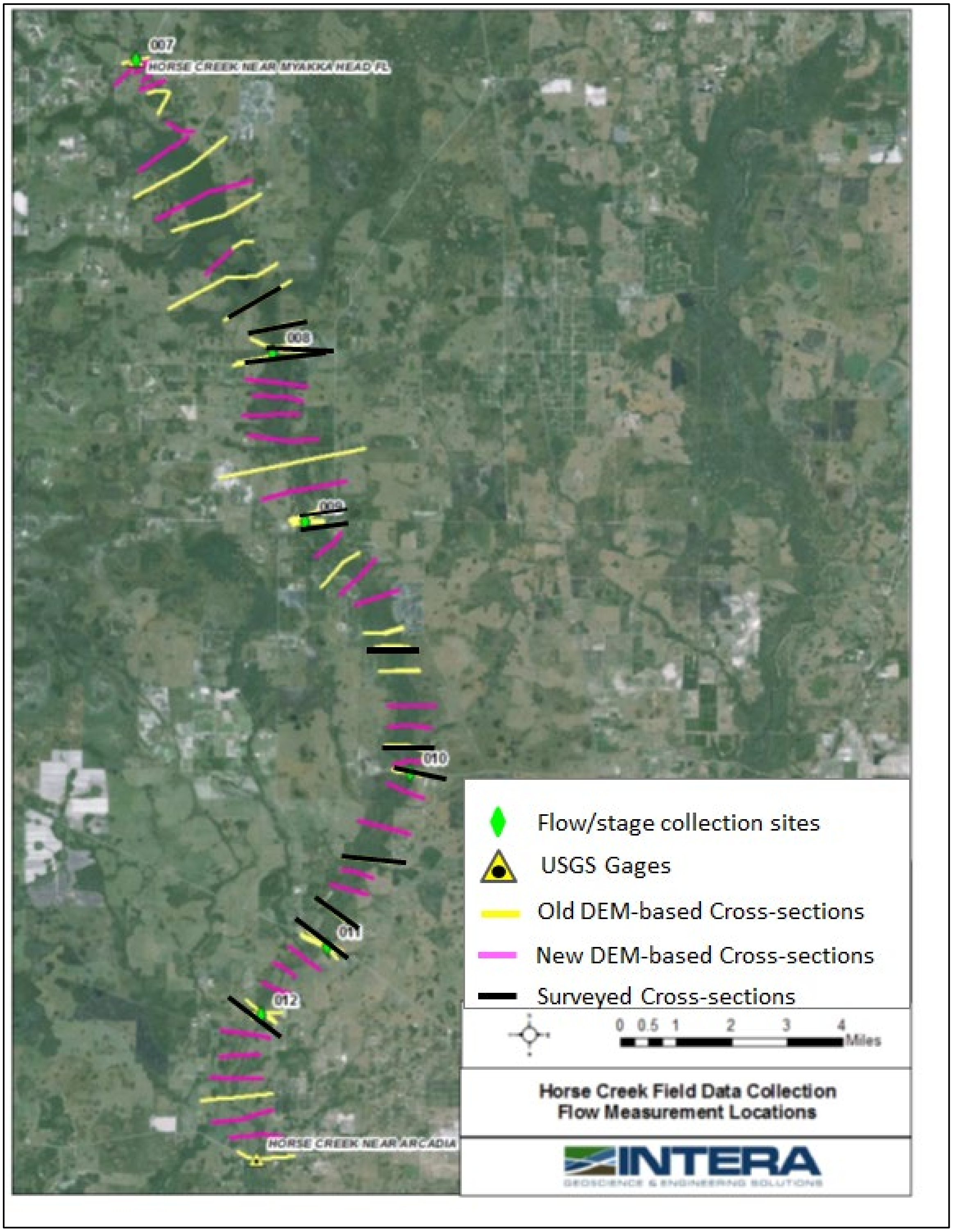

Figure 5-3. Locations of the USGS gages, data collection sites, and surveyed and DEM-based cross-sections of Horse Creek used for development of the HEC-RAS model.

Table 5-2. Summary of the channel flow apportionment percentage for 11 cross-sections used for the Horse Creek HEC-RAS model.

Reach Name	Station Name	HEC-RAS River Station	Flow Apportionment Percentage (%)
Upper Reach	State Road 64	171902.2	22
Upper Reach	Transect 150443.2	150443.2	36
Upper Reach	Goose Pond Bridge	129660.5	51
Upper Reach	Highway 665 Bridge	104926.9	57
Horse Creek East	Powerline Bridge East	86606.43	31
West Trib.	Powerline Bridge West	5260.038	31
Lower Reach	Juncture	79453.61	63
Lower Reach	Brownville Bridge	66049.37	66
Lower Reach	State Road 70	37235.93	86
Lower Reach	NW Pine Level Bridge	23380.24	94
Lower Reach	State Road 72	29.54714	100

Table 5-3. Summary of Horse Creek HEC-RAS model calibration results; all stages in feet NAVD88 (Table 27 from INTERA 2018).

Calibration Site		Flow Profiles				
		PF1	PF2	PF3	PF4	PF5
USGS Myakka Head	Observed	68.23	68.61	68.21	68.67	70.74
	Simulated	68.06	68.24	68.27	68.84	70.34
	Residual	-0.16	-0.37	0.06	0.18	-0.39
Goose Pond Road	Observed	56.17	56.68	57.31	57.56	58.16
	Simulated	56.26	56.55	57.26	57.95	58.40
	Residual	0.09	-0.14	-0.05	0.39	0.24
Country Road 665	Observed	52.8	52.15	53.32	54.01	54.58
	Simulated	52.31	52.60	53.39	54.26	54.81
	Residual	-0.49	0.45	0.07	0.25	0.23
State Road 70	Observed	32.12	32.40	32.98	34.39	34.45
	Simulated	32.17	32.37	33.01	33.92	34.54
	Residual	0.04	-0.03	0.03	-0.47	0.09

Table 5-4. Summary of Horse Creek HEC-RAS model validation results; all stages in feet NAVD88 (Table 29 from INTERA 2018).

Flow Profile	USGS Myakka Head			Transect T3		
	Observed	Simulated	Residual	Observed	Simulated	Residual
PF1	66.32	66.57	0.25	48.77	48.79	0.02
PF2	66.51	66.77	0.26	49.47	49.68	0.21
PF3	66.65	66.77	0.12	49.99	50.31	0.32
PF4	66.71	66.82	0.11	50.05	50.57	0.52
PF5	67.21	67.44	0.23	50.69	51.11	0.42
PF6	68.24	68.55	0.31	52.77	52.5	-0.27
PF7	68.46	68.73	0.27	53.82	53.34	-0.48
PF8	68.71	68.95	0.24	54.46	54.2	-0.26

5.4.2. Low Flow Threshold Evaluation

The protection of aquatic resources associated with low flows is an important goal for minimum flow establishment and implementation. To support this goal, the District develops a low flow threshold, through use of two criteria. One is based on maintaining fish passage along the river corridor; the other involves evaluating the relationship between the quantity of stream habitat and the rate of flow for maximizing wetted perimeter for the least amount of flow. The low flow threshold is established at the higher of the two low-flow criteria, if comparison of that criterion with historic flow records indicates that the criterion is reasonable.

5.4.2.1. Evaluation of Fish Passage

For development of minimum flows, it is desirable to maintain longitudinal connectivity along a river corridor, to the extent that this connectivity has historically occurred. The HEC-RAS model output was used to assess flows necessary for fish passage at each of the HEC-RAS cross-sections by adding a 0.6-ft (0.18-m) fish-passage depth to the elevation of the lowest spot in the channel cross-section. This fish-passage depth is routinely used by the District for minimum flow and level development and was found to be acceptable by review panels that evaluated proposed minimum flows for more than 20 flowing systems.

Flows at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage were associated with flows at each cross-section that resulted in at least 0.6-ft (0.18-m) of water in the deepest part of the channel. These cross-section specific, flows were then evaluated to identify the most sensitive cross-sections to support development of a minimum low flow threshold for Horse Creek.

5.4.2.2. Evaluation of Wetted Perimeter

A useful technique for evaluating the relation between the quantity of stream habitat and the rate of flow is an evaluation of the "wetted perimeter." Wetted perimeter is defined as the distance along the stream bed and banks at a cross-section where there is contact with water. Output from the 12 flow profile scenarios of the HEC-RAS model were used to generate a wetted perimeter versus flow plot for each modeled cross-section of Horse Creek. Plots were visually examined for inflection points, which identify flow ranges that are associated with relatively large changes in wetted perimeter. The LWPIP for flows up to 30 cfs was identified for each cross-section.

Many cross-section plots displayed no apparent inflection points between the lowest modeled flow and 30 cfs. Inflection points for flows higher than 30 cfs were disregarded since the goal was to identify the LWPIP for flows contained within the stream channel. For cross-sections that displayed no distinct inflection point or where most of the wetted perimeter is inundated below the lowest modeled flow, the LWPIP was established at the lowest modeled flow. Flows associated with the LWPIP at each cross-section were converted to flows at the USGS Horse Creek at SR 72 near Arcadia (No. 02297310) gage using relationships from the HEC-RAS model output. These cross-sections specific, LWPIPs were then evaluated to identify the most sensitive cross-sections to support development of a minimum low flow threshold for Horse Creek.

5.4.3. Evaluation of Floodplain Inundation

Floodplain inundation criteria were developed to protect intermittent high flows that supply requirements for wetland vegetation and the biogeochemical processes and habitat values associated with the floodplain in Horse Creek. A prescriptive standard allowing up to a 15% change in floodplain inundation from the baseline condition was adopted to define the limit beyond which further withdrawals would result in significant harm. Horse Creek is relatively flat with the extensive low lying floodplain areas and evaluation of floodplain inundation is an appropriate criterion for establishing minimum high flows for the creek.

The updated HEC-RAS model was used to evaluate the extent of floodplain inundation as a function of flows at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage. The HEC-GeoRAS, a geo-processing accessory to HEC-RAS that incorporates a digital elevation layer, was used to import water surface profile simulation data from the HEC-RAS model into ArcGIS for spatial mapping of the extent of floodplain inundation. The steps involved in the floodplain inundation modeling were as follows:

1. Water elevations for the 5th, 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, 90th, 95th, and 99th percentile flows were converted to triangulated irregular networks (TINs) using HEC-GeoRAS in ArcGIS for the representation of water surfaces.
2. The water-elevation TINs were rasterized in ArcGIS 10.6 at the spatial resolution of the DEM.
3. The rasterized water surface profiles and DEM data were overlain to determine the extent and depths of inundation. Inundated area was defined as the area encompassed by the intersection of the water surface and land surface.
4. The inundated areas for each percentile were then intersected with the 2021 Cooperative Land Cover Map Version 3.5 (FWC 2021), which was used to characterize the extent of floodplain wetland vegetation within the floodplain of the model domain.
5. To quantify the daily inundated wetland area, a flow-inundated area rating curve was developed using flows at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage.
6. Using the rating curve, a daily time series of inundated floodplain wetland area for the baseline condition was generated for the period from May 1, 1950, through December 31, 2021, using the baseline flow record described in Section 5.1 and an interpolation function in an Excel spreadsheet.
7. A total available inundated floodplain area was calculated for the baseline condition by summing the daily time-series area values.
8. Steps 6 and 7 were repeated for 30 scenarios associated with 1% to 30% reductions in the daily baseline flows.
9. Decreases in the inundated floodplain wetland habitat availability for each reduced flow scenario were calculated to identify the flow reduction scenario that resulted in no more than a 15% reduction in available habitat relative to the baseline condition.

Multiple sources of uncertainty can be associated with our floodplain inundation modeling for Horse Creek. These sources can be ascribed to cross-section data and data-processing errors associated with DEM development, wetland mapping in the available land cover dataset that was used, and estimation of inundation from rating curves.

The model domain and the existing wetland vegetation within the model domain are shown in Figure 5-4 along with floodplain wetland vegetations within the model domain.

Additional information on the methods used for assessment of floodplain inundation in the river is provided in INTERA (2018, Appendix F).

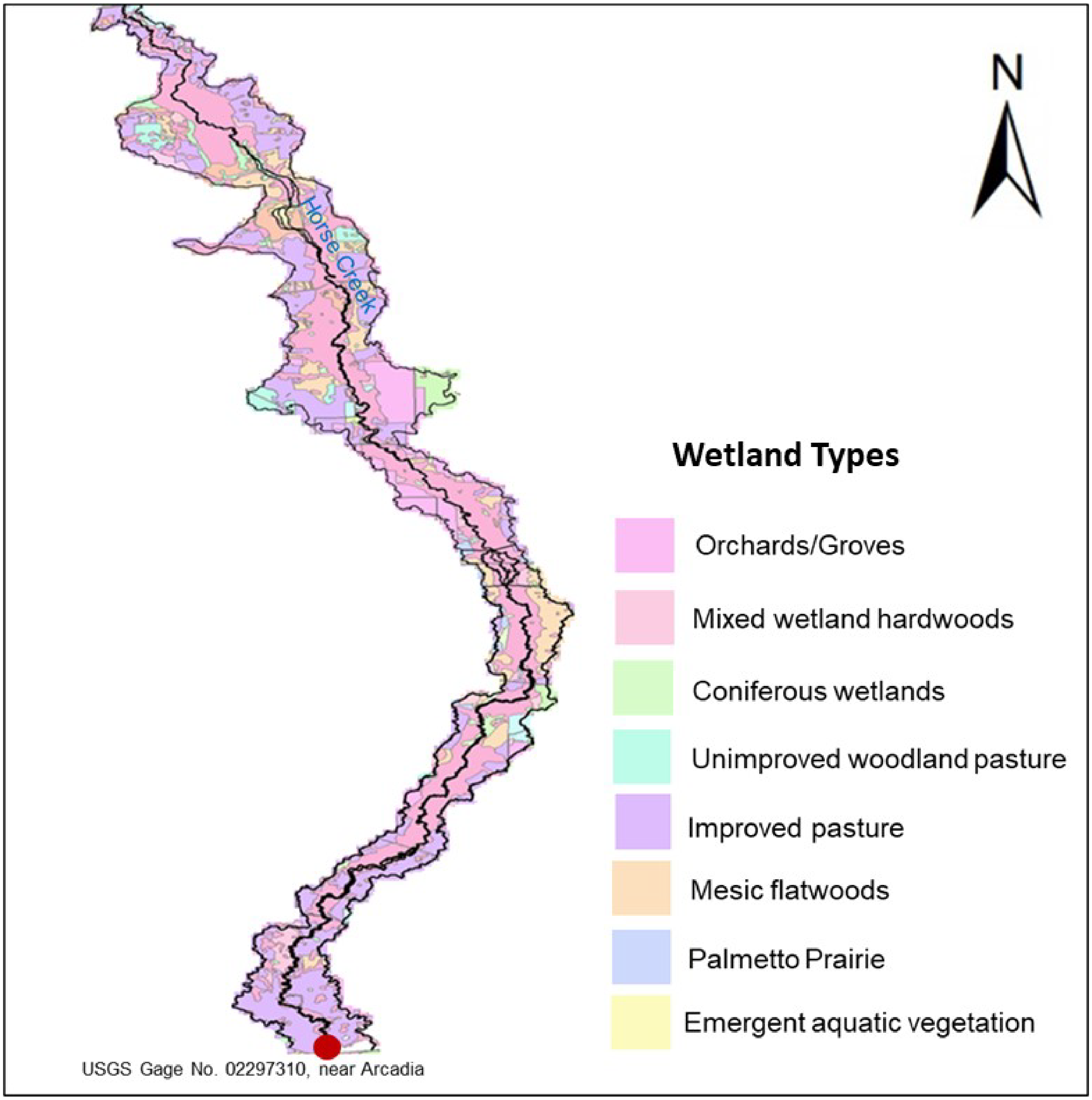

Figure 5-4. The HEC-RAS model boundary and channel for Horse Creek and floodplain wetland vegetation within the model domain (source: GIS layer maintained by the FWC (2021)).

5.4.4. Evaluation of Instream Habitat

The District evaluated the effects of flow reductions on instream habitat by using SEFA modeling to quantify impacts to fish and macroinvertebrate taxa and HEC-RAS to predict changes in the woody habitat inundation.

5.4.4.1. Habitat Suitability Modeling Methods

The SEFA habitat modeling software uses cross-sectional elevation profiles, water surface elevation, velocity, and qualitative habitat characteristics at specific locations across the channel to characterize habitat (Figure 5-5). In addition to these environmental cross-section data, SEFA uses habitat suitability curves which relate water depth, water velocity, and an index of qualitative habitat characteristics including substrate and cover to habitat suitability for fish and aquatic macroinvertebrates (Figure 5-6). These habitat suitability curves can represent species, life history stages such as juveniles and adults, and habitat guilds, which include all organisms with similar habitat requirements such as deep, fast-moving water. Suitability is scaled on an index from zero (unsuitable) to one (maximally suitable), with intermediate values between zero and one. The history and development of the habitat suitability curves used by the District is described in Nagid (2022).

For a given flow, SEFA calculates the depth and velocity at each point along a cross-section and uses the depth and velocity habitat suitability curves to quantify the suitability of each of these physical variables. In addition, field observations of qualitative habitat characteristics are converted to suitability using their habitat suitability curves. These three suitability values are averaged and weighted by the total quantity of the cross-section represented to create a dimensionless index called the area weighted suitability (AWS).

The AWS is a combined index of habitat quality and quantity. The AWS can be modeled for an individual cross-section, or in aggregate for any number of cross-sections. The SEFA model output for AWS is a curve relating flow to AWS, with each value of flow having a single corresponding AWS value. Therefore, a time series of daily flow values can be converted into a daily time series of AWS values for each habitat suitability group. Alternative scenarios, for example, time series of flows under baseline (unimpacted) conditions, can be compared to flow reduction scenarios to determine loss of habitat associated with decreases in flows. As a result, the patterns of flow variation across time scales can be modeled under differing flow scenarios.

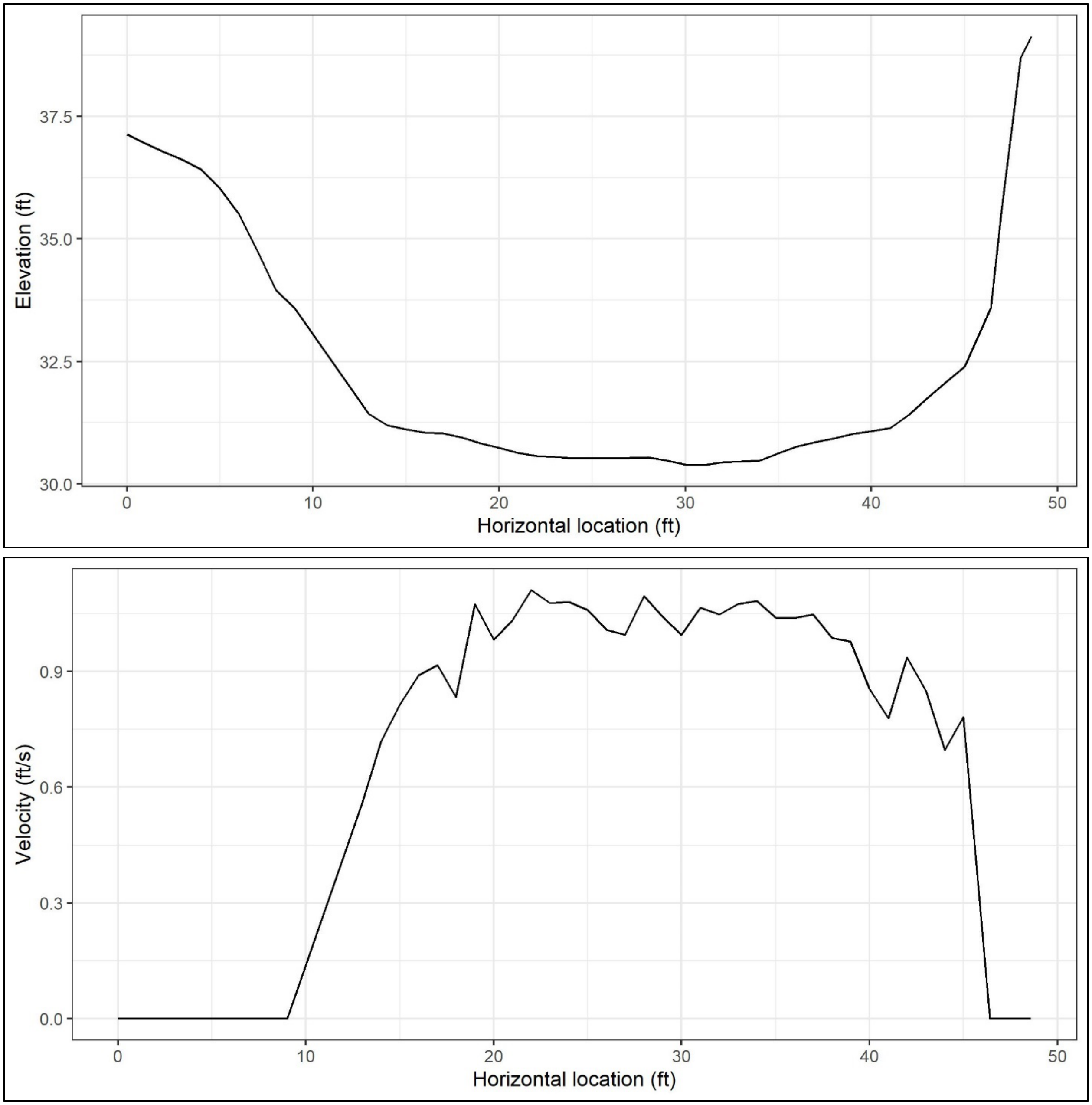

Figure 5-5. Example cross-section profile of water surface elevation (ft) and velocity (ft/s) from field observations.

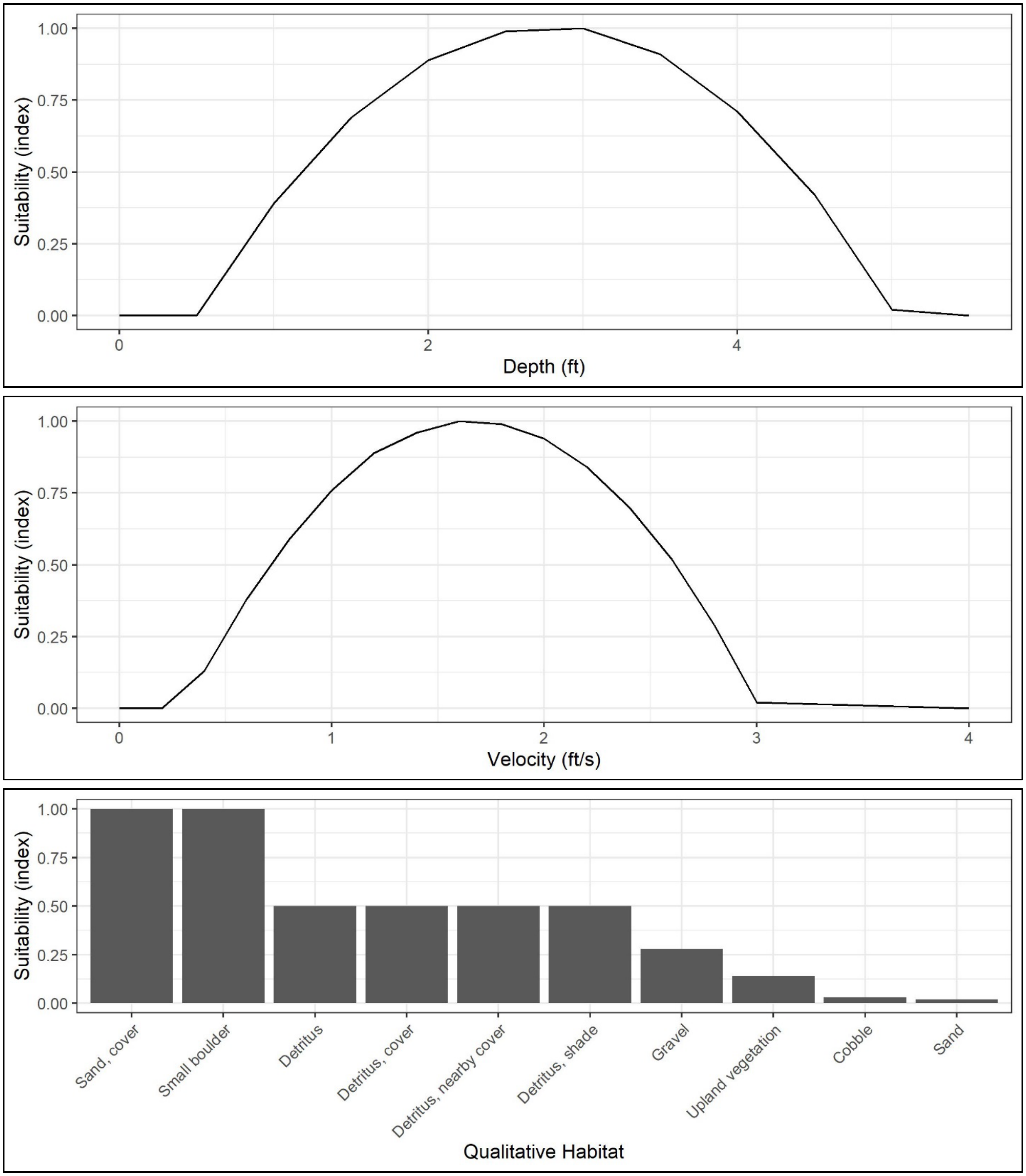

Figure 5-6. Example habitat suitability curves for net-spinning caddisflies (Hydropsychidae).

5.4.4.2. SEFA Site Descriptions

Elevation profiles, depth, velocity, substrate, and cover data were collected at five sites with three transects each, yielding a total of 15 sampled cross-sections (Figure 5-7; Table 5-5; HSW 2021). From upstream to downstream, these sites are State Route 64 (SR 64), State Route 70 (SR 70), Pine Level Road (PLR), State Route 72 North (SR 72N), and State Route 72 South (SR 72S). These sites lie between the USGS Horse Creek near Myakka Head, FL (No. 02297155; upstream) and USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310; downstream) gages. Detailed descriptions of site characteristics can be found in HSW (2021) and its Appendix A.

This sampling design follows the habitat mapping approach which is a type of stratified sampling (Jowett et al. 2008). The first step is to identify different mesohabitat types with different hydraulic characteristics (depth and velocity). We identified pools as deeper areas, shoals as shallower areas, and runs as intermediate in depth between pools and shoals. The second step is to divide the river into these mesohabitat types. We clustered these mesohabitats into sites, and spread sites throughout the study reach of the river as much as access would allow. Sites are located first by the presence of a shallow shoal. Next, a nearby pool is identified as the deepest area within approximately 150 ft of the shoal. Last, a run is identified as an area intermediate in depth between the pool and the shoal. These three habitats may occur in any upstream-downstream order within a site. In this way, each site is a representative subsample of the available habitat heterogeneity that exists within a reach of the river.

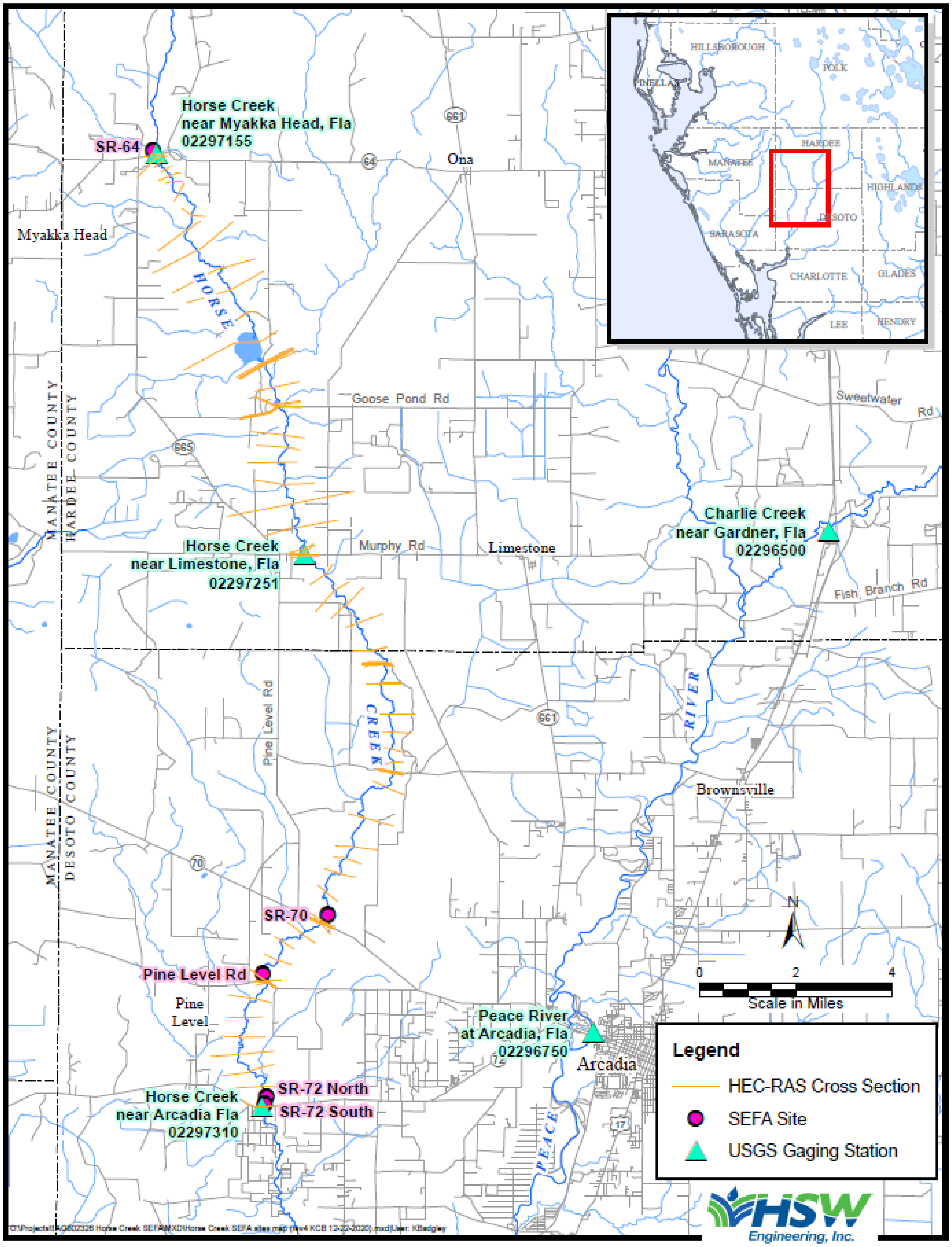

Figure 5-7. Locations of the five SEFA sites evaluated in Horse Creek (HSW 2021).

Table 5-5. Stage and flow at low, medium, and high data collection events at five sites. Reproduced from HSW (2021). Both sites and the transects at each site are presented from upstream to downstream.

Site ID (Latitude Longitude)	Transect Type	Low Flow		Medium Flow		High Flow	
		Flow (cfs)	Stage (NAVD88 ft)	Flow (cfs)	Stage (NAVD88 ft)	Flow (cfs)	Stage (NAVD88 ft)
SR 64 (27.48818, -82.02445)	Pool	1.12	66.17	7.79	66.64	77.1	69.08
	Run	1.37	66.16	8.63	66.62	79.3	69.16
	Shoal	1.32	66.15	8.45	66.60	82.5	69.13
SR 70 (27.25700, -81.96550)	Pool	1.45	28.40	28.1	29.42	127.8	31.62
	Run	1.83	28.39	29.8	29.42	131.3	31.62
	Shoal	2.11	28.39	28.1	29.42	134	31.62
Pine Level Road (PLR) (27.24000, -81.98750)	Pool	3.22	21.90	43.4	23.10	156.8	25.41
	Run	3.66	21.89	47.5	23.06	162.2	25.39
	Shoal	3.99	21.86	48.3	23.06	160.8	25.38
SR 72N (27.20260, -81.98620)	Pool	4.25	12.20	106.6	14.75	284.7	17.56
	Run	5.66	12.21	97.5	14.74	273.3	17.53
	Shoal	6.04	12.18	103.1	14.73	277.7	17.45
SR 72S (27.20069, -81.98680)	Pool	4.95	5.66	77.5	7.39	225.6	10.19
	Run	5.01	5.62	78	7.35	228.5	10.16
	Shoal	6.01	5.54	76.3	7.33	234.1	10.11

5.4.4.3. Updates to SEFA Model

HSW (2021, included as Appendix D to this report) collected SEFA data and performed a preliminary modeling analysis. Subsequently, District staff performed a separate modeling analysis of the data collected by HSW, which used different methods and produced different results from the original HSW analysis (see Appendix D). Consequently, different conclusions were reached, reflecting the differences in methods and results which are described below.

The HSW (2021) methods have the following characteristics:

- Use of median flow as the survey flow.
- SEFA default rating curves that force the curve through the survey flow (see section 12.2.1 of Jowett et al. 2020).

- Beta for velocity distribution value of -0.3, as specified in section 14.3 of Jowett et al. (2020).
- No adjustment to velocity distribution factors at elevations above the survey flow.
- Use of older habitat suitability curves developed by James Gore (Nagid 2022).
- The SR 64 site was apportioned flows equal to the upstream USGS Horse Creek near Myakka Head, FL (No. 02297155) gage, while the four downstream sites were apportioned flows equal to the downstream USGS Horse Creek near Arcadia, FL (No. 02297310) gage.
- Flows are divided into blocks based on 75th and 50th exceedance, where Block 1 is less than 17cfs and Block 2 is between 17 cfs and 54 cfs at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage.

These methods were modified in the following manner:

- Adjustment to velocity distribution factors at points above survey flow water surface to near 1 as specified in section 14.5 of Jowett et al. (2020).
- Flows were apportioned based on regression with USGS gaging sites as described in sub-section 5.4.4.5.
- Flows were analyzed in a single block from zero to 78 cfs at the gage, corresponding to the boundary between instream and overbank flows. This was determined by HEC-RAS analysis described below section 6.2.

5.4.4.4. SEFA Rating Curves

Rating curves were developed for each site. Stage at zero flow was iteratively calculated by SEFA and modified in input files to get the best fit to observed data. This is appropriate when there is no known nearby hydraulic control point. Rating curves demonstrate a good fit to data based on correlation coefficients (R^2) and Mean Error of Q (Discharge; Table 5-6).

Table 5-6. Rating curve equations from log-log regression. Transects are listed from upstream to downstream.

Site ID	Transect type	Rating Curve
SR 64	Pool	Flow = 14.851 * (Stage - 66.000) ^1.461 Mean error of Q = 0.255%
	Run	Flow = 16.812 * (Stage - 66.000) ^1.360 Mean error of Q = 0.968%
	Shoal	Flow = 16.732 * (Stage - 65.990) ^1.390 Mean error of Q = 0.407%
SR 70	Pool	Flow = 19.381 * (Stage - 28.202) ^1.581 Mean error of Q = 3.044%
	Run	Flow = 22.695 * (Stage - 28.229) ^1.394 Mean error of Q = 2.649%
	Shoal	Flow = 20.881 * (Stage - 28.191) ^1.447 Mean error of Q = 3.872%
Pine Level Road (PLR)	Pool	Flow = 30.886 * (Stage - 21.762) ^1.168 Mean error of Q = 5.267%
	Run	Flow = 32.959 * (Stage - 21.718) ^1.242 Mean error of Q = 1.122%
	Shoal	Flow = 32.625 * (Stage - 21.681) ^1.221 Mean error of Q = 0.095%
SR 72N	Pool	Flow = 21.530 * (Stage - 11.862) ^1.492 Mean error of Q = 0.612%
	Run	Flow = 22.438 * (Stage - 11.825) ^1.440 Mean error of Q = 0.358%
	Shoal	Flow = 19.855 * (Stage - 11.725) ^1.512 Mean error of Q = 0.030%
SR 72S	Pool	Flow = 33.784 * (Stage - 5.443) ^1.246 Mean error of Q = 1.995%
	Run	Flow = 36.388 * (Stage - 5.436) ^1.174 Mean error of Q = 0.633%
	Shoal	Flow = 29.230 * (Stage - 5.244) ^1.305 Mean error of Q = 0.749%

5.4.4.5. SEFA Flow Apportionment

Sites were combined to develop a single set of reach habitat curves that combines the area weighted suitability at all 15 transects. Modeling reach habitat curves requires specification of the range and increment of flows to be modeled. This is to ensure that upstream sites are modeled as receiving appropriately lower flows than downstream sites, simulating the natural accumulation of increasing flows with downstream distance. Flow apportionment for the SEFA analyses was based on linear regression of flows at each site with the gaged flow on same date (Table 5-7). Linear modeling was done with a fixed intercept at zero to avoid negative flows that may be predicted if the intercept is allowed to vary at low gaged flows. The SR 72N site was selected as the reference reach and other reaches were assigned the maxima and incremental values shown in Table 5-7.

Instream flow habitat was calculated for flows from zero to 78 cfs in the baseline flow record at the gage, which includes all instream habitat value below the point at which floodplain inundation metrics apply.

Table 5-7. Linear model results including flow maximum and increment for apportioning flows based on comparison of flows measured at individual sites with flows at the USGS Horse Creek near Arcadia, FL (No. 02297310) gage.

Site	Residual Standard Error	Adj. R^2	Slope	p-value	Max	Increment
SR 64	11.52	0.94	0.30	0.02	34	0.34
SR 70	35.58	0.79	0.38	0.07	43	0.43
Pine Level Road (PLR)	32.02	0.89	0.46	0.04	52	0.52
SR 72N	4.03	1.00	0.89	0.00	100	1
SR 72S	7.29	1.00	0.86	0.00	97	0.97

5.4.4.6. Reach Habitat Curves

Habitat suitability curves relate physical features of the environment to suitability for occupation, feeding, reproduction, refuge, and other uses to meet habitat needs. A suite of habitat suitability curves representing a range of species, life history stages, and habitat guilds appropriate for lotic Florida waterbodies (Nagid 2022) was used for our Horse Creek analyses. Plots of these habitat suitability curves are provided in HSW (2021, included as Appendix D to this report). For results presented in this report, names for each assessed group were abbreviated into four-letter codes (Table 5-9).

Reach habitat curves are the key modeling result of a SEFA analysis and relate flow to AWS as a measure of habitat availability. The reach habitat curves for flows at the USGS Horse Creek at SR72 near Arcadia, FL (No. 02297310) gage exhibit a variety of patterns or responses (Figure 5-8). Some, such as the curve for Black Banded Darter adults (BBDA), exhibit high sensitivity over very low flow ranges, with subsequent tapering or leveling-off of AWS at higher flows. These types of responses are frequently relatively insensitive to modeled flow reductions because of the relatively flat response or change in AWS at higher flows. Others, such as the juvenile Bluegill (BLUJ) curve, rise to a peak then decrease with higher flows (Figure 5-8). These peaked responses are also often relatively insensitive to flow reductions because losses in habitat at low flows are offset by increases in habitat at high flows.

Other reach habitat curves are J-shaped, such as those for the shallow fast habitat guild (SHFA) and *Tvetenia vitracies* larvae (TVET), where habitat suitability is insensitive to increases in flow at low flows but rises with higher flows (Figure 5-8). These types of curves can be among the most sensitive to modeled flow reductions because losses in flow near the median flow value tend to reduce habitat to zero. Others, such as the curves for Hydropsychidae (HYDR), the deep fast habitat guild (DPFA), total invertebrates (TINV), and spring Channel Catfish (CCSP) exhibited nearly linear responses across the entire range of flows (Figure 5-8). These linear responses are among the most sensitive to flow reductions because they directly result in a loss in habitat with a reduction in flows.

Table 1-9. Habitat suitability curves used in this analysis withtheir four-letter abbreviations (Code).

Code	Species	Stage
REDA	Redbreast Sunfish	Adult
REDJ	Redbreast Sunfish	Juvenile
REDS	Redbreast Sunfish	Spawning
REDF	Redbreast Sunfish	Fry
SHSL	Shallow	Slow
SHFA	Shallow	Fast
DPSL	Deep	Slow
DPFA	Deep	Fast
DART	Darters	Adult
PHEM	Ephemeroptera	Larvae
TRIC	Tricoptera	Larvae
TINV	Total Invertebrates	Larvae
PSEU	Pseudocloeon ephippiatum	Larvae
HYDR	Hydropsychidae	Total
TVET	Tvetenia vitracies	Larvae
LMBA	Largemouth Bass	Adult
LMBJ	Largemouth Bass	Juvenile
LMBS	Largemouth Bass	Spawning
LMBF	Largemouth Bass	Fry
BBDA	Black Banded Darter	Adult
BLUA	Bluegill	Adult
BLUJ	Bluegill	Juvenile
BLUS	Bluegill	Spawning
BLUF	Bluegill	Fry
SPOA	Spotted Sunfish	Adult
SPOJ	Spotted Sunfish	Juvenile
SPOS	Spotted Sunfish	Spawning
SPOF	Spotted Sunfish	Fry
CYPA	Cyprinidae	Adult
CCAD	Channel Catfish	Adult
CCJU	Channel Catfish	Juvenile
CCSP	Channel Catfish	Spawning
CCFR	Channel Catfish	Fry
CCJP	Channel Catfish	Juvenile (Spring)
CCJS	Channel Catfish	Juvenile (Summer)
CCJF	Channel Catfish	Juvenile (Fall)

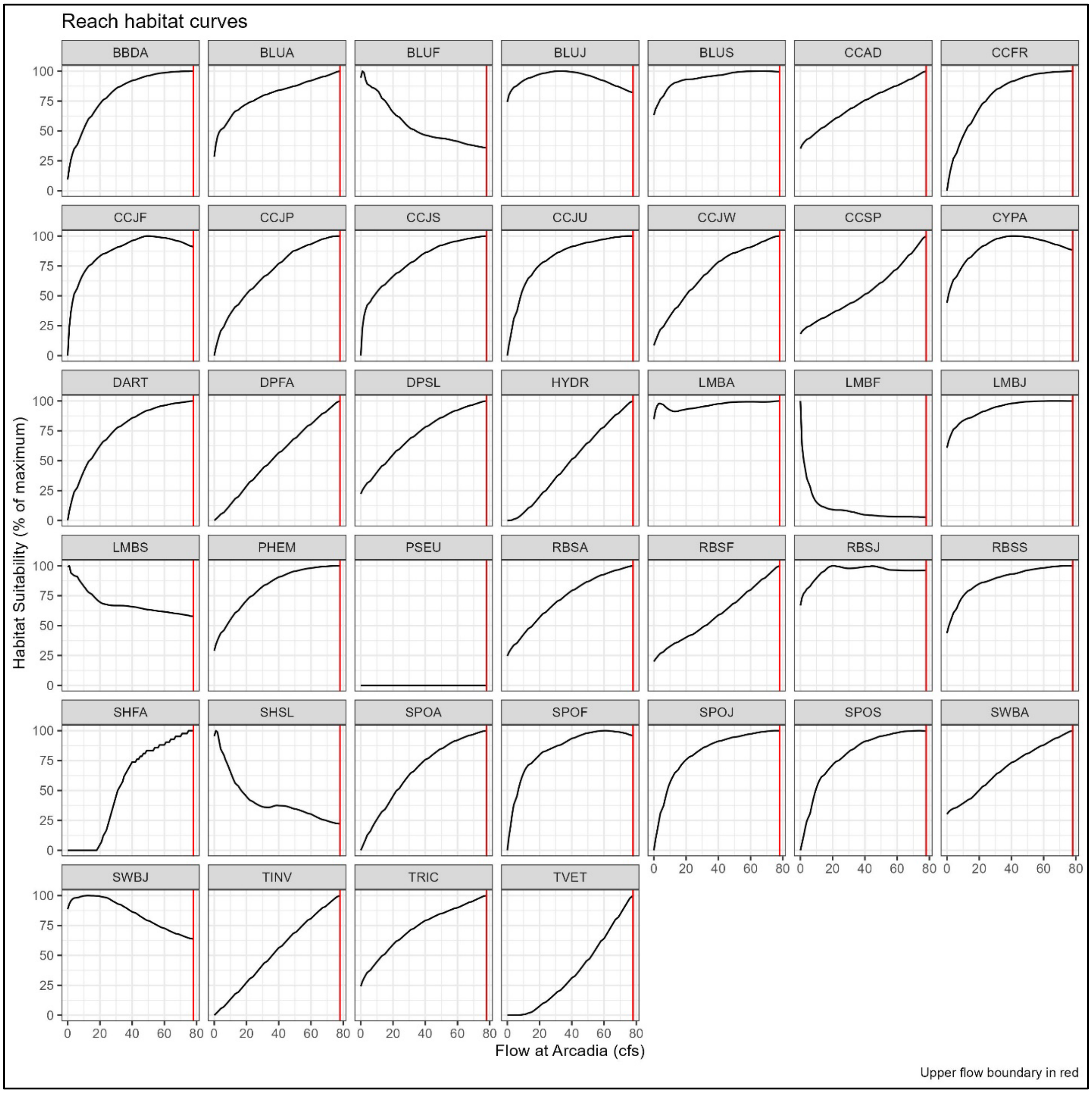

Figure 5-8. Reach habitat curves in Horse Creek for species/life history stages/niche guilds. The red vertical line is 78 cfs at the USGS Horse Creek near Arcadia, FL (No. 02297310) gage, a flow which corresponds with the initial inundation of floodplain areas and the upper limit of assessed instream habitat flows.

5.4.4.7. Filtering of Species Based on AWS-Flow Relationships

The percent-of-flow method for determining minimum flows assumes a consistent relationship between habitat and flow within a flow "block". For a percent-of-flow loss to result in the same percent of habitat loss across a range of flows, the slope of the line relating flow on the x-axis to habitat on the y-axis must be invariant. This means that the habitat-flow relationship must be linear to meet the implicit assumption in the percent-of-flow approach. J-shaped curves violate this assumption, and result in a situation where at flows corresponding to the initial insensitive part of the curve, further losses in flow do not result in losses of habitat. We do not think it is necessary that the linearity pass a formal statistical test, but it is possible to screen out relationships between AWS and flow that are not consistent across the flow range of interest.

For Horse Creek, the flow range from 0 cfs to 78 cfs at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage is of interest based on the flows that are retained within the creek banks. To eliminate species with curves that are overly concave or J-shaped, we included only those with at least 10% of their maximum AWS by at the fish passage flow of 15 cfs. This resulted in the exclusion of PSEU, SHFA, and TVET reach habitat curves from further analysis.

5.4.4.8. Flow Reduction Scenarios

Using the reach habitat curves and the daily flow record of baseline flows, a daily habitat suitability is generated for each species. The average habitat suitability over this flow record is taken as a summary of the overall habitat provided by the flow record. Reduced flow scenarios are created by reducing each daily flow by a percentage, and recalculating habitat suitability based on each new reduced flow scenario. Reduced flow scenarios are then compared to the baseline flow scenario to calculate the percentage loss in habitat associated with percentage loss in flows (Figure 5-9). The most sensitive responses show a downward trend where habitat decreases with decreasing percent-of-flow.

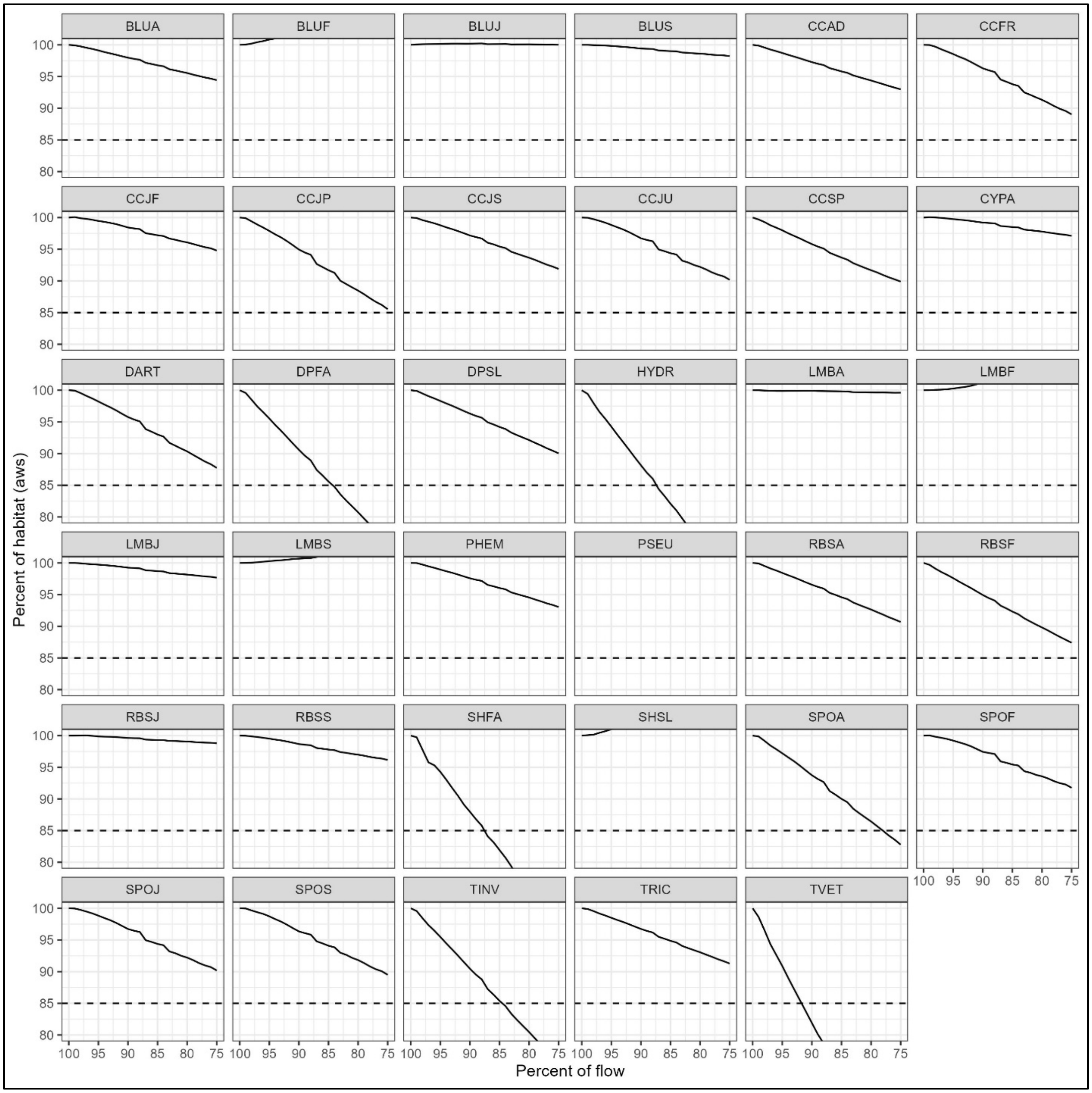

Figure 5-9. Loss of habitat associated with reduced flow scenarios from baseline conditions in Horse Creek. Note the x-axis is reversed such that 100% of the baseline flow is on the left. The dashed line shows an 85% of habitat threshold.

5.4.4.9. Evaluation of Woody Habitat Inundation

Live (exposed roots) and dead (snags) instream woody habitats were assessed at five sites on Horse Creek (Figure 5-10). At each site, cross-sections from the top of bank on one side of the channel through the river and up to the top of bank on the opposite channel, were established. Minimum and maximum (e.g., top and bottom elevations relative to NAVD88) of up to 15 samples of exposed root and snag habitats in the vicinity of each cross-section were measured along each bank and averaged for for each cross-section site. Flows at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage that would result in inundation of the mean exposed root and snag habitat elevations at each cross-section were determined using the HEC-RAS model (Table 5-10).

Because flow requirement for snags at sites T2, T4, T5 and T6 were less than the low flow threshold (15 cfs), flow reductions that would result in significant harm associated with snag habitat were not calculated. Similarly, exposed roots at T1, T2 and T4 were not considered in the woody habitat analysis since their flow requirement for inundation exceeded the 78 cfs flow associated with floodplain inundation. Of the five sampling sites, one site for snags (T1) and two sites for exposed roots (T5 and T6) that were inundated at flows between 15 and 78 cfs were considered appropriate for the woody habitat analysis.

The three site-specific flow requirements and eight additional within-bank flows between 15 and 78 cfs were then used along with the baseline flow record and sequentially reduced flow records to identify the number of days during the historic period of record that the specified flows were equaled or exceeded.

Because sustained inundation prior to colonization by invertebrates is essential for microbial conditioning and periphyton development that enhances the woody habitat utility for many invertebrate species, we assessed 1-day, 7-day and 30-day durations of flows associated with the specified flows. Several days of inundation were evaluated because the rate of biofilm accumulation on instream woody habitat can vary widely in different streams and seasonally within a stream (Findlay 2010, Gulis et al. 2008).

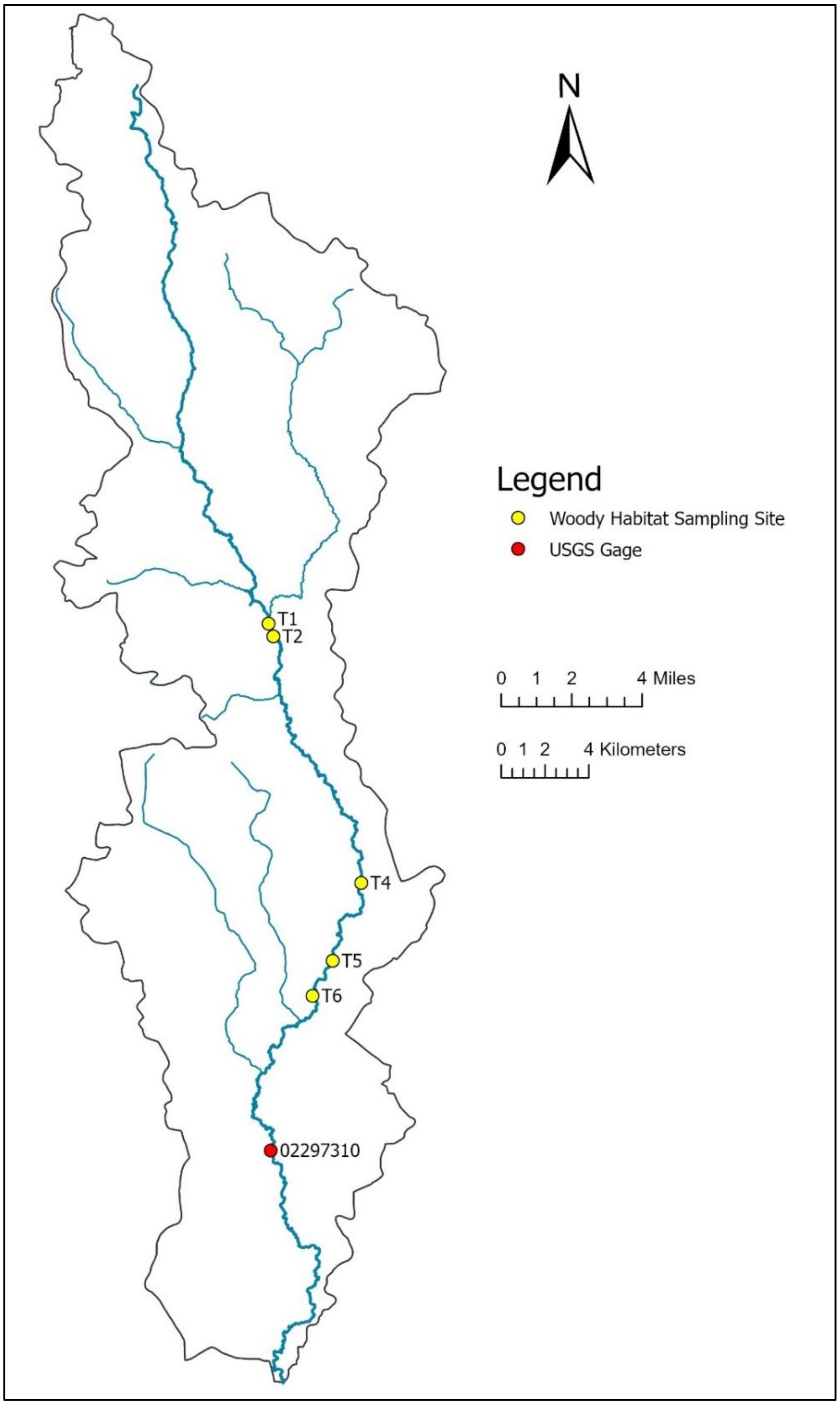

Figure 5-10. Locations of the woody habitat data collection sites and the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage used for analysis.

Table 5-10. Flows at the USGS Horse Creek at SR71 near Arcadia, FL (No. 02297310) gage required to inundate elevations of instream woody habitats (snags and exposed roots) at five sites in Horse Creek.

Site	Elevation (ft, NAVD88)		Horse Creek Flows (cfs) near Arcadia Gage	
	Snags	Exposed Roots	Snags	Exposed Roots
T1	53.3	54.6	28.5	79.4
T2	51.7	56.5	1.1	320.5
T4	38.4	39.5	8.6	107.4
T5	34.8	36.4	7.8	58.3
T6	29.8	31.8	10.4	48.8

CHAPTER 6 – RESULTS OF THE MINIMUM FLOW ANALYSES

The District approach for setting minimum flows is generally habitat-based and involves assessment of sensitive ecological resources that provide protection to all relevant environmental values identified in the Water Resource Implementation Rule for consideration when establishing minimum flows or levels. Results from modeling and field data for Horse Creek were assessed to develop minimum flows and to ensure the ecological characteristics and functions associated with various flows and levels are protected from significant harm. A low flow threshold based on fish passage depth and wetted perimeter inflection points is recommended. Based on low flow threshold and 15% change in habitat criteria minimum flows are also identified for flow-based blocks corresponding with low (Block 1), medium (Block 2) and high (Block 3) flow ranges.

6.1. Low flow threshold

The low flow threshold defines flows that are to be protected in their entirety (i.e., flows that are not available for consumptive-use) throughout the year. The low flow threshold is established at the higher of two flow standards, which are based on maintaining fish passage and maximizing wetted perimeter for the least amount of flow in the river channel. Results of fish passage and wetted perimeter were used to develop a recommended low flow threshold for Horse Creek.

6.1.1. Fish Passage Results

Flows necessary to reach a maximum water depth of 0.6-ft (0.18-m) to allow for fish passage at each of the 93 cross-sections in the HEC-RAS model of Horse Creek between the USGS Horse Creek at Myakka Head, FL (No. 02297155) gage and the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage were identified (Figure 6-1).

At most cross-sections, the minimum water surface elevation that would allow for fish passage was lower than the elevation associated with the lowest modeled flow. These cross-sections were located in pool or run areas, where fish passage would be possible during low flow periods. The analysis also indicated that to maintain fish passage depth at the most restrictive cross-section, a flow of 15 cfs is required at the USGS Horse Creek near Arcadia, FL (No. 02297310) gage. A flow of 15 cfs was therefore used to define the fish passage criterion for this gage site on Horse Creek. The standard flow is sufficient to maintain constant flow in the river and would minimize problems such as low dissolved oxygen levels that may be associated with low flow or stagnant conditions.

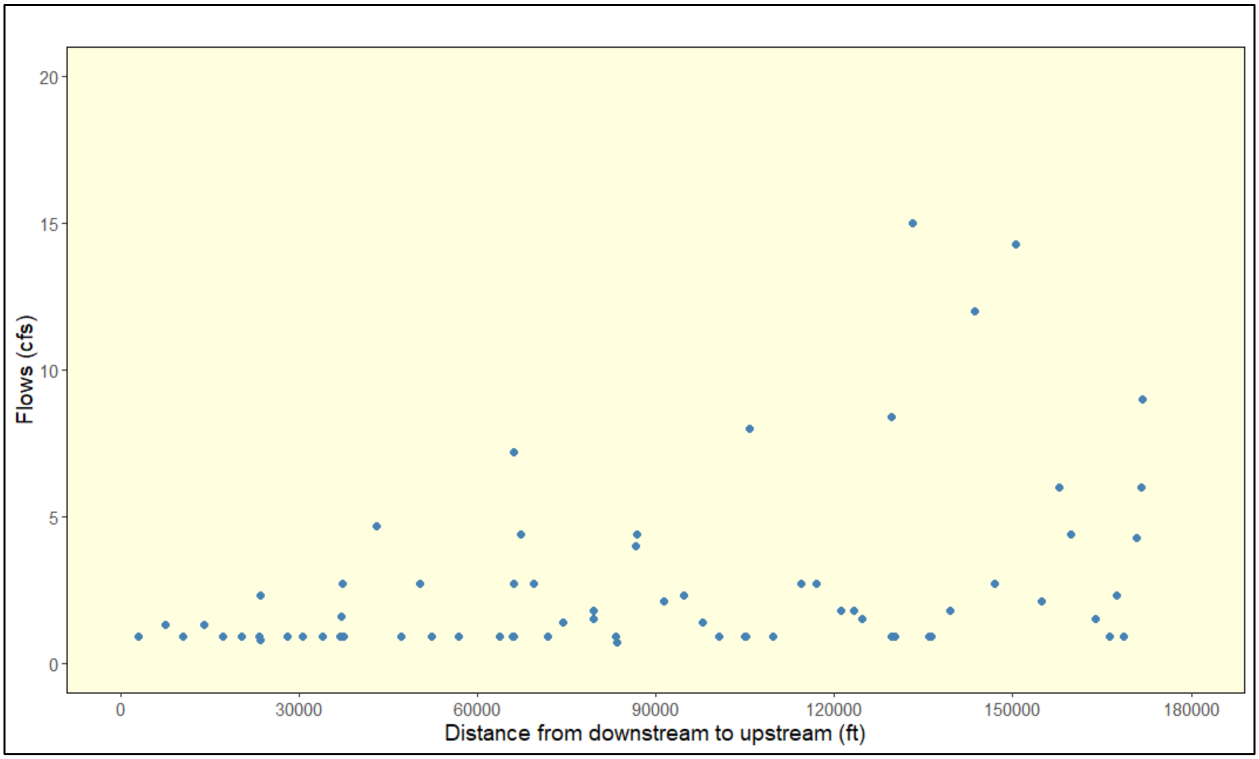

Figure 6-1. Flow required at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage to inundate the deepest part of the channel to a depth of 0.6 ft in the Horse Creek HEC-RAS model, arrayed by distance upstream of the gage.

6.1.2. Evaluation of Wetted Perimeter Results

Wetted perimeter plots (wetted perimeter versus local flow) were developed for each HEC-RAS cross-section of Horse Creek to identify the LWPIP as potential low flow threshold protective of benthic macroinvetebrates and other benthic organisms and processes. Most cross-sections exhibited either no LWPIP or LWPIPs associated with flows above 30 cfs at the USGS Horse Creek near Arcadia, FL (No. 02297310) gage and for these cross-sections, the LWPIP was established at the lowest modeled flow, 3.2 cfs. The nine cross-sections that exhibited an LWPIP for flows of less than 30 cfs at the USGS Horse Creek near Arcadia gage are shown in Figure 6-2.

The LWPIP at cross-sections 1, 2 and 6 corresponds to local flows of 7.9, 4.2 and 7.9 cfs respectively (Table 6-1). These flows correspond to a flow of 12 cfs at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage. A flow of 12 cfs at this gage would, therefore, be sufficient to meet the local LWPIP flows at all assessed cross-sections in Horse Creek.

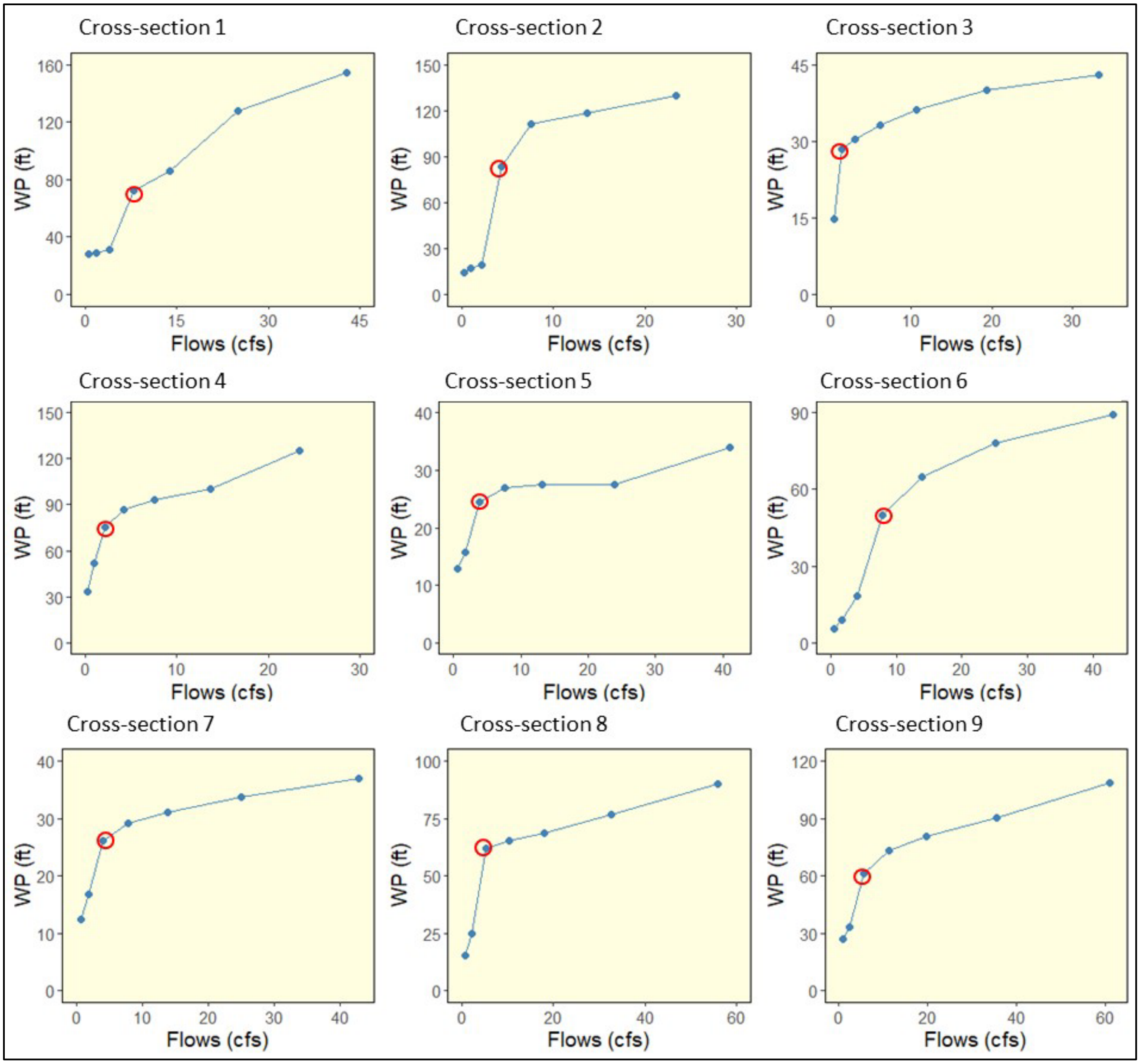

Figure 6-2. Plot of local flows versus wetted perimeter (WP) in Horse Creek at 9 HEC-RAS model cross-sections that exhibited a lowest wetted perimeter inflection point (highlighted with red circles) at flows associated with less than a 30 cfs flow at the USGS Horse Creek near Arcadia, FL (No. 02297310) gage.

Table 6-1. Summary of lowest wetter perimeter inflection point (LWPIP) results for nine HEC-RAS model cross-sections in Horse Creek.

Transect	Wetted Perimeter at LWPIP (ft)	Flow (cfs) at Cross-sections for LWPIP	Flow (cfs) at USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage for LWPIP
1	72.5	7.9	12.0
2	83.5	4.3	12.0
3	28.5	1.4	2.7
4	75.4	2.2	6.0
5	24.4	3.8	6.0
6	49.9	7.9	12.0
7	26.2	4.0	6.0
8	61.9	5.2	6.0
9	61.4	5.6	6.0

6.1.3. Recommended Low Flow Threshold

A low flow threshold of 15 cfs was identified for Horse Creek at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage. The low flow threshold was established at the higher of the fish passage and wetted perimeter criteria and is therefore expected to provide protection for environmental values associated with both criteria. Although flows in the creek at the gage site may be expected to drop below the low flow threshold naturally, the threshold is defined to be a flow that serves as a limit to surface withdrawals throughout the year, with no withdrawals permitted from the river unless the threshold flow is exceeded.

6.2. Floodplain Inundation Results

Floodplain inundation analysis was conducted based on the flow-inundated area relationship at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage (Figure 6-3). Using the baseline flow record (May 1, 1950, through December 31, 2021), flow reductions that would result in a 15% reduction of inundated floodplain wetland area were identified.

Based on historic flow records, inundation of floodplain habitats in Horse Creek is largely expected during Block 3 when flow exceeds the capacity of the creek channel and water spills over the creek banks into adjacent, low lying floodplain areas. However, some floodplain areas may also be inundated when flow is low and remains in the channel. This can occur when rainfall pools in low lying floodplain areas during low flow periods when there are no direct surface water connections between low areas and the creek channel. These depressional areas can be characterized as "ineffective" inundated areas when the creek flow is low. During high flow conditions, however, the depressional areas may be inundated when water overtops the creekbank.

For floodplain habitat assessments associated with minimum flows, inundated areas that have no direct connection to creek flows should be excluded. Manually checking for ineffective inundation areas through each cross-section is difficult and fraught with uncertainty regarding possible floodplain-channel connections between model cross-sections. A simpler approach for addressing this issue involves the use of sensitivity analysis to distinguish floodplain inundation associated with overbank flooding from inundation associated with ineffective flow areas.

Percent-of-flow reductions that would result in a 15% decrease in the amount of total inundated wetlands adjacent to Horse Creek were assessed for flows at and above 1st percentile, 2nd percentile, and so on, up to 99th percentile. When plotted against flow percentiles, the percent-of-flow reductions exhibited three general sensitivity patterns (Figure 6-4). For low flow percentiles, percent-of flow reduction changes were relatively flat with no appreciable gradient. For mid to high flow percentile, the percent-of-flow reductions exhibited greater sensitivity, with sensitivity increasing with flows.

We numerically approximated changes in sensitivity, i.e., the slope of the flow percentiles and percent-of-flow reduction curve, by fitting four straight lines to the data (Figure 6.4) and finding a maximum combined coefficient of determination (R^2) for the four lines. The maximum combined R^2 was obtained at 57th, 72nd and 93rd flow percentiles. It should be noted that the combined R^2 does not have a true statistical meaning–we simply used it as a quantitative indicator of best fit to divide the sensitivity curve into three parts based on slope changes. For flows between the 1st to 57th percentile, the 15% decrease in the total inundated wetlands exhibited minimal sensitivity to flow reductions. This lack of sensitivity to flow reductions for the lower flow percentiles suggests that overbank flooding does not occur until the flow is above the 57th percentile, which is approximately 78 cfs. This 78 cfs flow was, therefore, used to define the threshold between the medium-flow, Block 2, and the higher flow, Block 3.

In addition and to ensure protection of relatively infrequent higher flow pulses that are important for physical and ecological processes in the creek, Block 3 was split into three sub-blocks at the 72nd flow percentile (approximately 172 cfs) and at the 93rd flow percentile (approximately 644 cfs) based on the sensitivity of total inundated wetland area to river flow reductions.

For flows between 78 and 172 cfs, percent-of-flow reductions between 14.3% and 13.5% would result in 15% or less reduction in the total inundated wetland area in Horse Creek (Table 6-2). For flows between 172 cfs and 644 cfs, percent-of-flow reductions between 13.3% and 8.8% would result in 15% or less reduction in the total inundated wetlands (Table 6-3). For flows above 644 cfs, percent-of-flow reductions between 8.5% and 6.2% would result in 15% or less reduction in the total inundated wetlands (Table 6-4). Based on average allowable flow reductions for preventing significant harm to floodplain wetlands (see Tables 6-2, 6-3 and 6-4), 86% of the baseline flow for flows between 78 and 172 cfs, 88% of the baseline flow for flows between 172 and 644 cfs and 92% of the baseline flows for flows greater than 644 cfs at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage are recommended

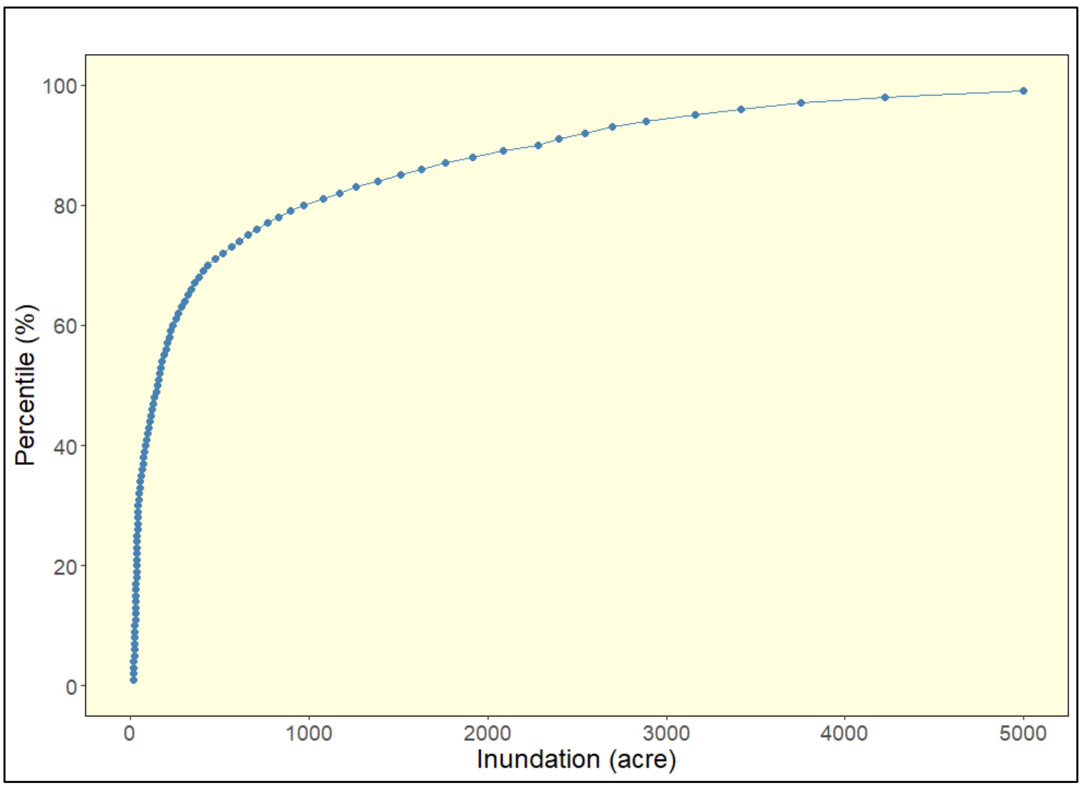

Figure 6-3. A flow percentile versus area of total inundated floodplains at the Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage.

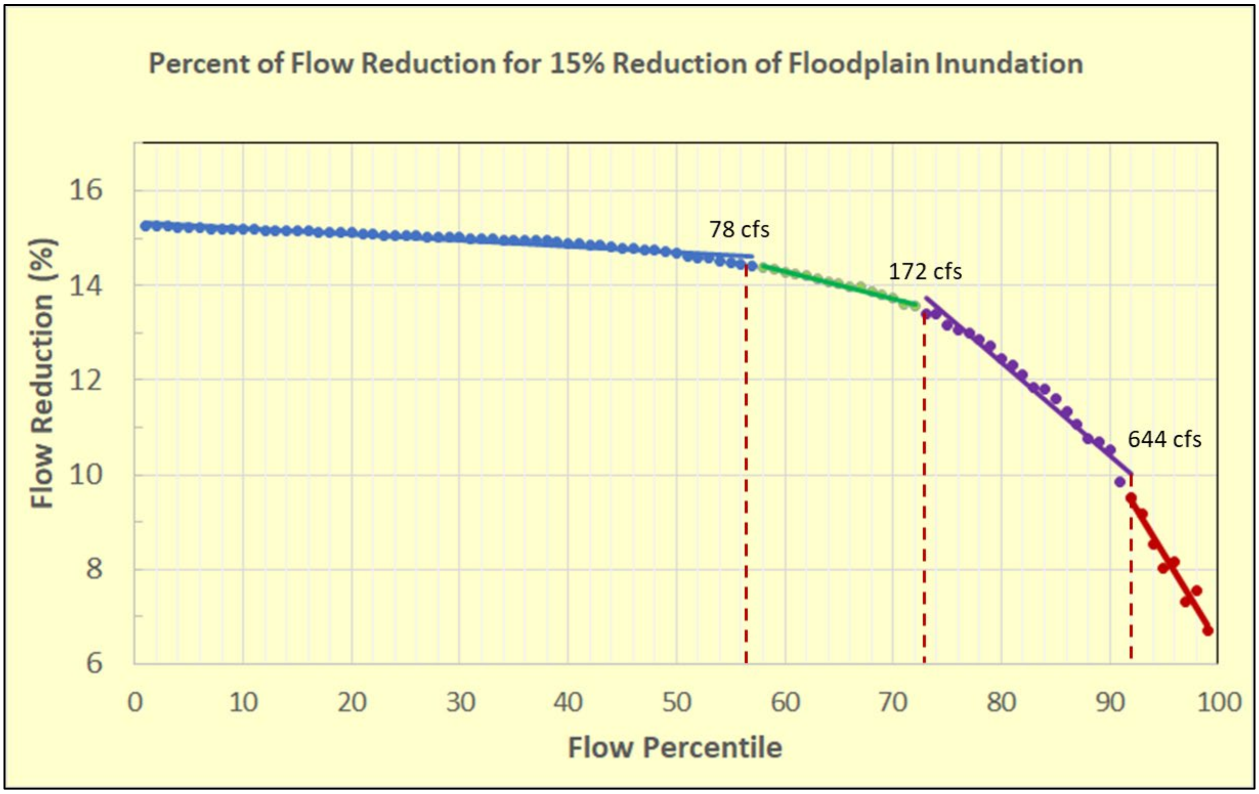

Figure 6-4. The sensitivity between the percent-of-flow reductions that would result in a 15% decrease in the amount of total inundated wetlands and river flow percentiles in Horse Creek. Note the fitting of four lines for low, mid and high flow percentile portions of the sensitivity curve.

Table 6-2. Key results of Horse Creek floodplain analysis for Block 3a, demonstrating percent-of-flow reductions at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage that result in a 15% decrease in the total inundated wetland area of Horse Creek, based on baseline flow records from May 1, 1950, through December 31, 2021.

Flow Percentile (%)	Flow (cfs)	Inundation Area (acre)	Allowable Flow Reductions (%)
57	77.94	208.93	14.4
58	81.85	218.10	14.3
59	86.02	227.89	14.3
60	90.78	239.07	14.2
61	95.69	254.18	14.1
62	100.79	269.89	14.1
63	106.09	286.22	14.1
64	111.65	303.33	14.0
65	117.85	322.44	13.9
66	124.08	341.61	13.9
67	129.77	359.14	13.8
68	137.23	382.13	13.8
69	145.22	406.73	13.7
70	153.21	431.35	13.6
71	162.77	476.16	13.5
72	171.70	518.03	13.5
Allowable average withdrawal (%)			**14**

Table 6-3. Key results of Horse Creek floodplain analysis for Block 3b, demonstrating percent-of-flow reductions at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage that result in a 15% decrease in the total inundated wetland area of Horse Creek, based on baseline flow records from May 1, 1950, through December 31, 2021.

Flow Percentile (%)	Flow (cfs)	Inundation Area (acre)	Allowable flow reductions (%)
73	181.74	565.11	13.3
74	191.29	609.90	13.2
75	201.72	658.76	13.1
76	212.60	709.79	13.0
77	224.86	767.27	12.9
78	237.86	828.19	12.6
79	252.79	898.19	12.4
80	268.32	971.01	12.3
81	288.65	1081.74	12.2
82	305.59	1173.99	12.0
83	322.07	1263.73	11.8
84	344.23	1384.46	11.7
85	367.40	1510.62	11.3
86	389.80	1632.60	11.0
87	413.57	1762.06	11.1
88	441.73	1915.40	10.8
89	473.37	2087.75	10.4
90	508.81	2280.72	10.1
91	547.88	2401.32	9.8
92	593.65	2542.58	9.1
93	644.33	2699.00	8.8
Allowable average withdrawal (%)			**12**

Table 6-4. Key results of Horse Creek floodplain analysis for Block 3c, demonstrating percent-of-flow reductions at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage that result in a 15% decrease in the total inundated wetland area of Horse Creek, based on baseline flow records from May 1, 1950, through December 31, 2021.

Flow Percentile (%)	Flow (cfs)	Inundation Area (acre)	Allowable flow reductions (%)
94	704.23	2883.91	8.5
95	794.05	3161.12	7.9
96	915.85	3418.90	7.7
97	1074.69	3755.05	8.0
98	1296.42	4224.33	7.7
99	1662.93	5000.00	6.2
Allowable average withdrawal (%)			**8**

6.3. Instream habitat

This section describes the results from SEFA modeling to determine effects of flow reductions on habitat availability for fish and macroinvertebrates and HEC-RAS modeling to determine impacts of flow reductions in instream woody habitat inundation.

6.3.1. Habitat Suitability Modeling Results

Significant harm is defined as a loss of habitat greater than or equal to 15% of the total available under baseline flow conditions. Four species are predicted to experience instream habitat losses that occur at flow reductions less than or equal to 25% (Figure 6-6). The net-spinning caddisflies of the family Hydropsychidae (HYDR) are the most sensitive group with a 15% loss of habitat occurring at flow reductions greater than 12%, or at 88% of the baseline flows.

These results are consistent with known habitat preference information for HYDR. The average depth for all 15 assessed cross-sections increased with flow (Figure 6-7). These average depths increased from 0.76 ft at zero flow to 1.88 ft at 78 cfs. These depths correspond to the rising arm of the habitat suitability curve for HYDR (Figure 5-6). This means that over the range of flows evaluated, the relationship between flow and depth results in a positive relationship between flow and habitat suitability of HYDR. This relationship is based on the geometry and hydrology of the assessed cross-sections as well as the habitat suitability curves for HYDR (HSW 2021, included as Appendix D to this report; Nagid 2022).

The average velocity for all 15 cross-sections surveyed also increased with flow (Figure 6-8). These average velocities correspond to the rising arm of the habitat suitability curve for HYDR (Figure 5-6). This means that over the range of flows we are interested in, there is a steep increase in habitat suitability for velocity associated with an increase in flows, based on the geometry and hydrology of the assessed cross-sections.

The habitat suitability curves for HYDR (HSW 2021, included as Appendix D to this report; Nagid 2022) were based on data collected by Warren and Nagid (2008) in the northern Withlacoochee River, Florida. The curves for depth and velocity (Figure 5-6) are directly translated from the northern Withlacoochee data, converted from cm to ft (Figure 6-9). Substrate suitability was modified from the data collected on the northern Withlacoochee river (Figure 6-10) to match the categorization of other habitat suitability curves (Figure 5-6). Based on the depths, velocities, and substrate types found in the assessed portion of Horse Creek, and their corresponding habitat suitability for HYDR, it makes sense that this taxonomic group was sensitive to reduced flows.

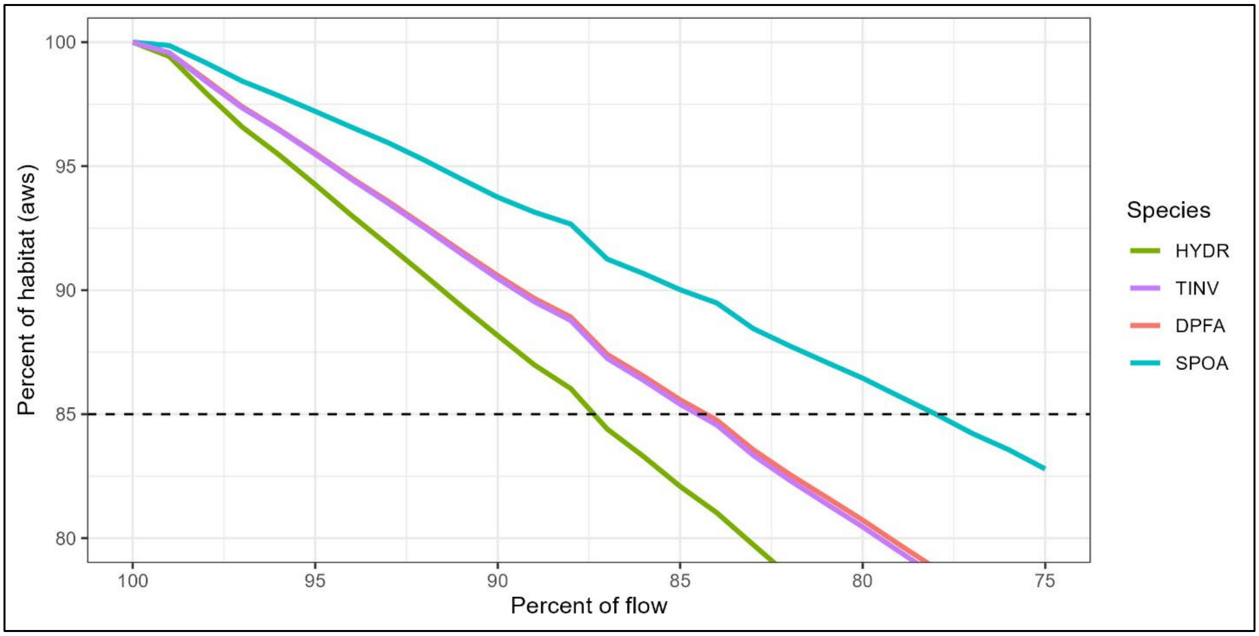

Figure 1-6. Habitat loss of the most sensitive species assessed for Horse Creek. The significant harm threshold is shown as a dashed line at 85% of habitat that would occur under the baseline condition unimpacted by withdrawals. The minimum allowable percent-of-flow occurs where the line for each species crosses the dashed threshold line. Only species, groups and species life stages that exhibit a 15% or greater loss in habitat with flow reductions of less than 25% are shown, and these include Hydropsychidae (HYDR), total invertebrates (TINV), the deep fast habitat guild (DPFA), Spotted Sunfish adults, and juvenile, spring Channel Catfish (CCJP).

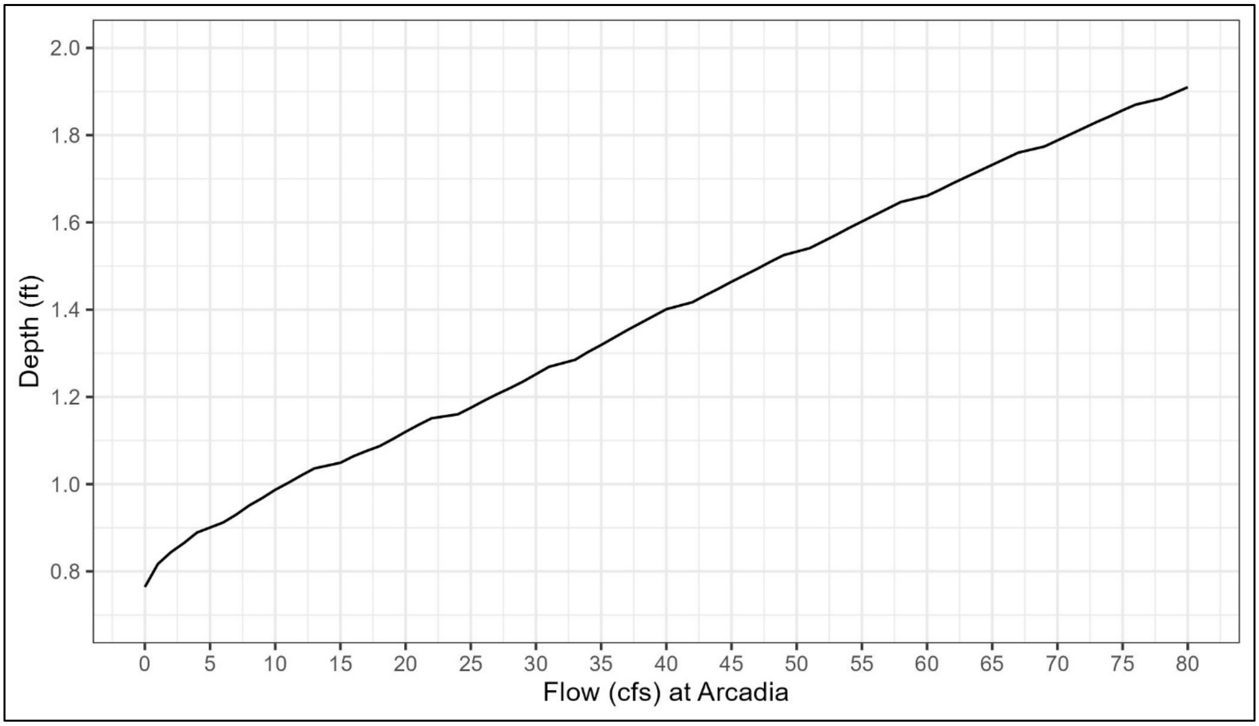

Figure 6-7. Average depth across all sites compared to flow at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage.

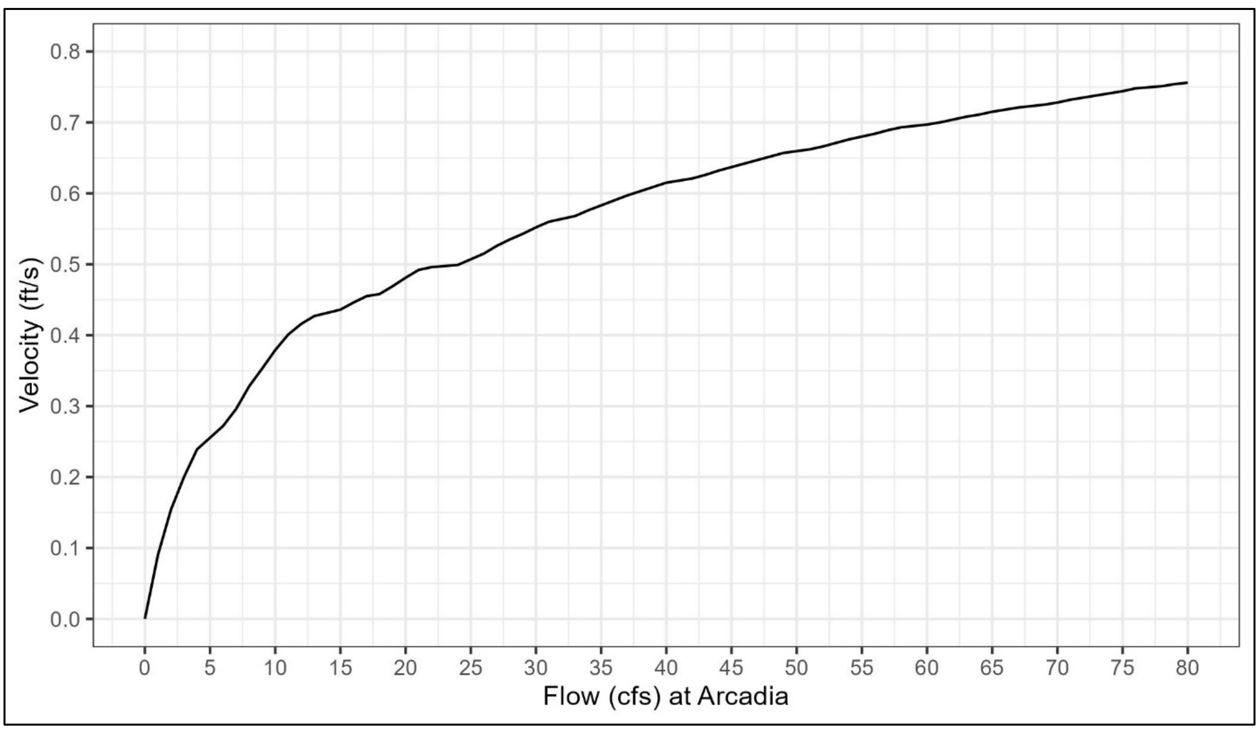

Figure 6-8. Average velocity across all sites compared to flow at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage.

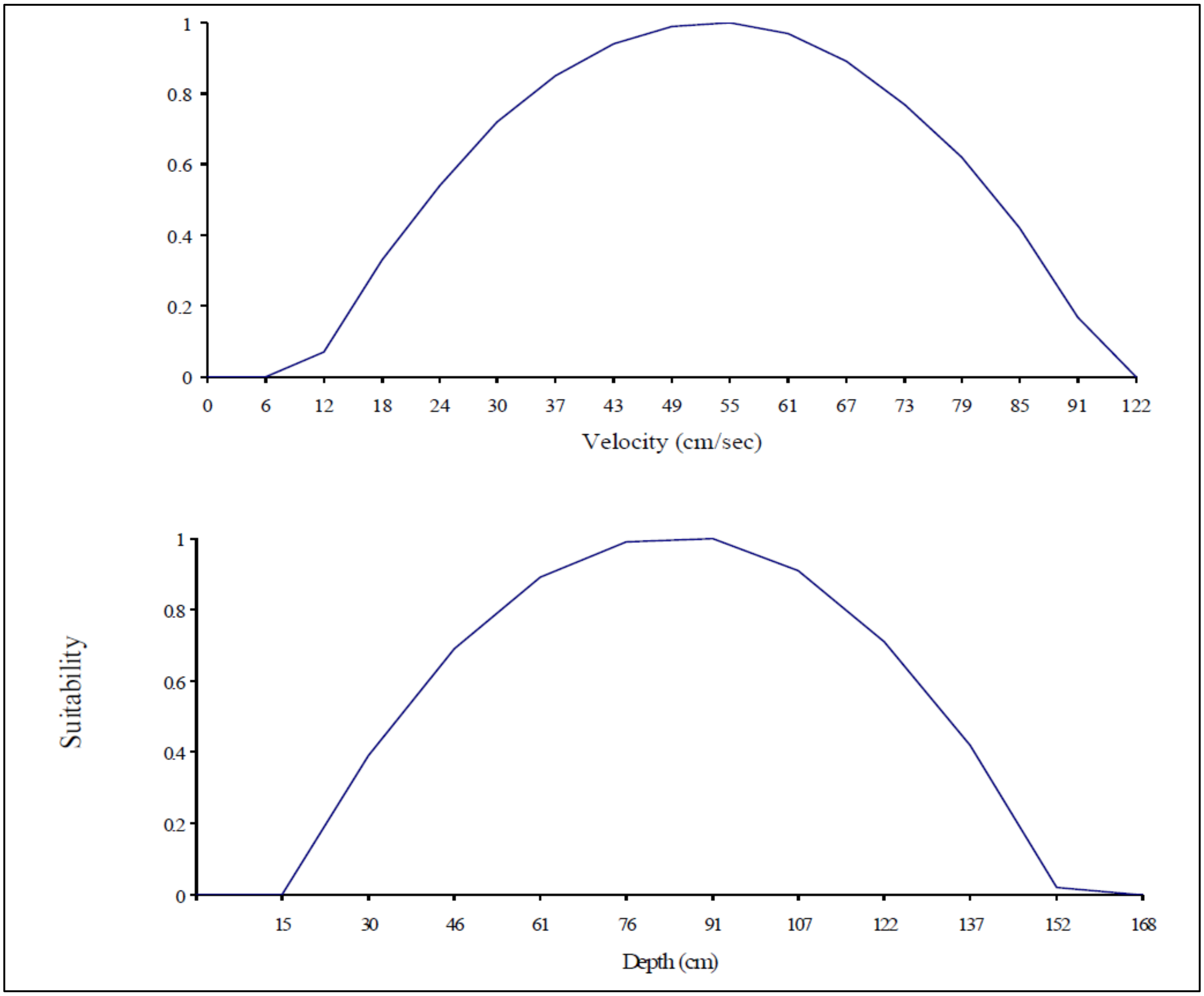

Figure 6-9. Depth and velocity habitat suitability curves for Hydropsychidae based on northern Withlacoochee River data (Warren and Nagid 2008).

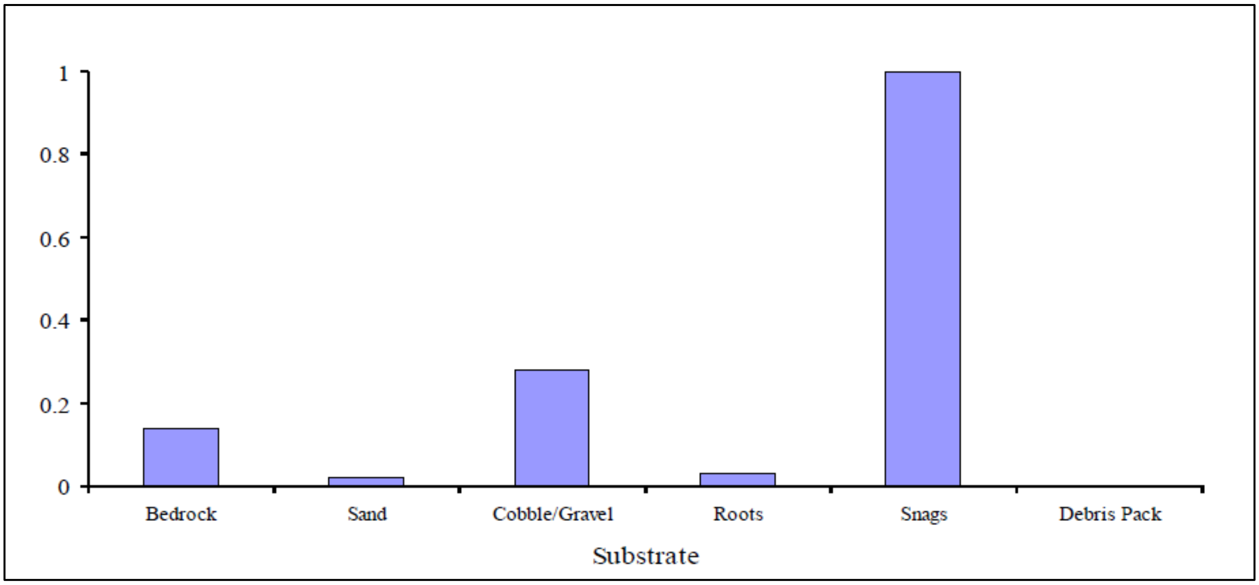

Figure 6-10. Substrate suitability for Hydropsychidae from northern Withlacoochee data from Warren and Nagid (2008).

6.3.2. Woody Habitat Inundation Results

Inundation patterns of exposed root and snag habitats were examined at three instream habitat cross-sections and eight selected flow targets between the 15 cfs low flow threshold and the 78 cfs overbank flow threshold in Horse Creek. The number of days these flow targets were equaled or exceeded for 1-day, 7-day, 30-day durations were assessed using the baseline flow record from May 1,1950 through December 31, 2021. Percent-of-flow reductions that would result in greater than a 15% reduction in the number of days the specified duration-events occurred relative to those associated with baseline conditions were also calculated (Table 6-5).

The mean allowable flow reduction associated with the 1-day duration events was 38%, with a range of 31% to 52%. The mean allowable flow reduction for inundations of 7-day duration was 31%, with a range from 27% to 43%. Inundations for 30 days were relatively sensitive to reductions in flow, with a mean allowable flow reduction of 22%, with a range from 19% to 28%. Based on these woody habitat inundation results, a 22% flow reduction from baseline conditions is considered protective of woody habitats in Horse Creek.

Table 6-5. Selected instream woody habitats flow targets and allowable flow reductions associated with a 15% reduction from baseline conditions in the number of days of flow sufficient to inundate woody habitat for 1-day, 7-day, and 30-day durations at 3 sites in Horse Creek.

Site	Target Flows at Gage near Arcadia (cfs)	Maximum Allowable Flow Reduction (%)		
		1-Days	7-Day	30-Day
T1 (Snags)*	15.0	52	43	28
	20.0	48	41	30
	25.0	43	35	23
	28.5	41	34	21
	35.0	39	31	21
	40.0	37	29	21
	45.0	34	26	19
T5 (Exposed Roots)*	48.8	33	26	18
	55.0	32	27	19
T6 (Exposed Roots)*	58.3	31	27	19
	65.0	31	27	19
Mean Allowable Reduction		**38**	**31**	**22**

*Measured elevations of woody habitat that require flows between 15 and 78 cfs

6.4. Proposed Minimum Flows

Resource management goals identified for the development of minimum flows for Horse Creek included the following:

- Determination of a low flow threshold to provide protection for ecological resources and recreational use of Horse Creek during critical low-flow periods.
- Maintenance of seasonal hydrologic connections between the Horse Creek channel and floodplain to ensure persistence of floodplain structure and function.
- Maintenance of available instream habitat for fish and benthic macroinvertebrates.
- Maintenance of the inundation of instream woody habitat, including exposed roots and snags.
- Maintenance of water quality.

A percent-of-flow approach was used with several block-specific criteria to develop minimum flows for Horse Creek that ensure maintenance of 85% of the most sensitive criterion, and by default all criteria associated with the resource management goals. A low flow threshold was also identified to ensure flow continuity for environmental and human use values. Assessments were conducted to ensure all relevant environmental values that must be considered when establishing minimum flows would be protected by the minimum flows proposed for Horse Creek.

Based on the results of the analysis described in the previous sections, the proposed minimum flows for Horse Creek are described in Tabe 6-6 and Figure 6-11. For Horse Creek, the recommended minimum flows for Block 1 are based on fish passage, for Block 2 are based on maintaining available instream habitat and for Block 3 are based on maintaining floodplain inundation. The recommended minimum flows are based on flows for the previous day at the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage that have been adjusted for withdrawal effects.

Table 6-6. Proposed minimum flows for Horse Creek based on flows at the USGS Horse Creek at SR 72 near Arcadia (No. 02297310) gage that have been adjusted for withdrawal effects.

Flow-Based Block	If Previous Day's Flow, Adjusted for Withdrawals, is:	Recommended Minimum Flow is:	Potential Allowable Flow Reduction is:
1	≤ 15 cfs	Flow on the previous day	0 cfs
2	> 15 cfs and ≤ 78 cfs	15 cfs or 88% of the flow on the previous day, whichever is greater	12% of flow on the previous day
3a	> 78 cfs and ≤ 172 cfs	69 cfs or 86% of the flow on the previous day, whichever is greater	14% of flow on the previous day
3b	> 172 cfs and ≤ 644 cfs	88% of the flow on the previous day	12% of flow on the previous day
3c	> 644 cfs	92% of the flow on the previous day	8% of flow on the previous day

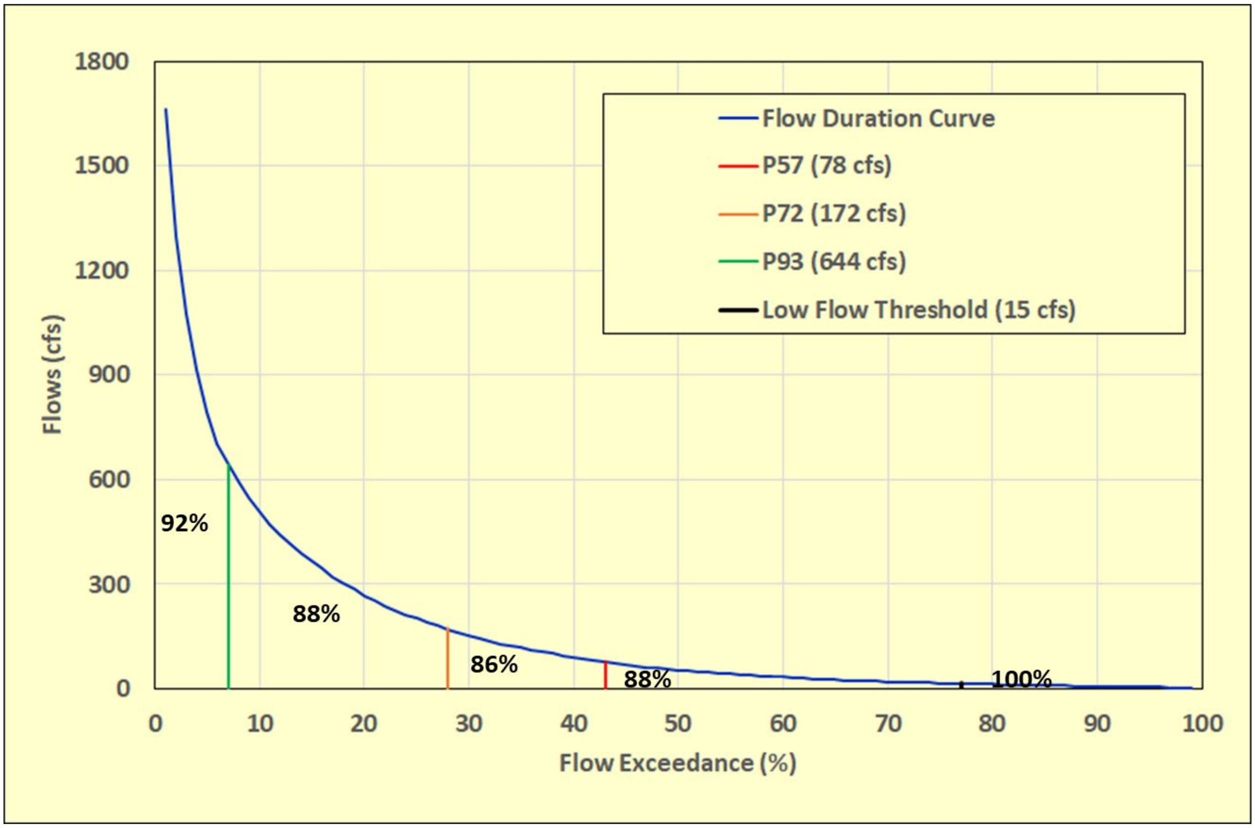

Figure 6-11. Block-based proposed minimum flows superimposed on a flow duration curve of flows at the USGS Horse Creek near Arcadia, FL (No. 02297310) gage.

6.5. Consideration of Environmental Values

Rule 62-40.473, F.A.C., within Florida's Water Resource Implementation Rule, requires that when establishing minimum flows and levels: "consideration shall be given to natural seasonal fluctuations in water flows or levels, non-consumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic and wetlands ecology, including: (a) Recreation in and on the water; (b) Fish and wildlife habitats and the passage of fish; (c) Estuarine resources; (d) Transfer of detrital material; (e) Maintenance of freshwater storage and supply; (f) Aesthetic and scenic attributes; (g) Filtration and absorption of nutrients and other pollutants; (h) Sediment loads; (i) Water quality; and (j) Navigation."

Primary factors considered for development of the recommended minimum flows for Horse Creek included potential, flow-related changes to fish passage, wetted perimeter along stream bed and banks, floodplain wetland inundation and instream habitat. Based on assessments associated with these factors, the recommended minimum flows are protective of all relevant environmental values identified for consideration in the Water Resource Implementation in Rule, as well as those included in the Water Resources Act of 1972 that pertain to the establishment of minimum flows.

6.5.1. Recreation In and On the Water

The Recreation in and on the Water Environmental Value for Horse Creek was considered through characterization of water depths, and assessment of potential changes in floodplain inundation, fish, and invertebrate habitats.

Using the bathymetric information included in the HEC-RAS model, water levels were considered to ensure that the floodplain (Sections 5.3.2, 5.4.3, and 6.2) and instream habitat (Sections 5.3.3, 5.4.4, and 6.3), including the passage of fish (Sections 5.3.3.1, 5.4.2.1, and 6.1.1), were protected under the proposed minimum flows, which also protects recreation in Horse Creek.

6.5.2. Fish and Wildlife Habitat and the Passage of Fish

To support consideration of the Fish and Wildlife Habitat and the Passage of Fish Environmental Value, information summarizing the fish, nekton, and benthic macroinvertebrate communities of Horse Creek were summarized in Chapter 4.

Using the HEC-RAS model developed for Horse Creek (Section 5.4.1), a low flow threshold of 15 cfs was developed (Sections 5.3.1, 5.4.2, and 6.1) and is proposed to protect the passage of fish in Horse Creek.

A SEFA analysis was conducted to develop minimum flows for Horse Creek that protect fish and wildlife instream habitat (Sections 5.3.3.1, 5.4.4, and 6.3.1). Flows and water levels were also evaluated during this investigation to ensure important fish and wildlife floodplain habitat was considered and protected in the creek (Sections 5.3.2, 5.4.3, and 6.2).

6.5.3. Estuarine Resources

Horse Creek flows into the Lower Peace River. While the Peace River flows into the Gulf of Mexico, through the Charlotte Habor, Horse Creek is not directly connected to estuarine resources. Therefore, this environmental value was not considered directly relevant for development of the minimum flow for Horse Creek.

6.5.4. Transfer of Detrital Material

Detrital material in rivers includes dead, particulate organic material that may originate from upland, floodplain, and in-channel areas. Detrital transfer occurs laterally and longitudinally in flowing water bodies as a function of water levels, flows, velocities, and residence times. Transport processes may be especially strong during periods of high-water levels and flows when hydrologic interactions between the floodplain and the channel are strongest and large quantities of suspended materials may be moved through the system.

The Transfer of Detrital Material Environmental Value was considered for development of recommended minimum flows for Horse Creek through use of a percent-of-flow approach intended to maintain characteristics of the baseline flow regime and patterns of Horse Creek floodplain inundation (Sections 5.3.2, 5.4.3, and 6.2). Maintenance of the floodplain habitats in Horse Creek is expected to support their structural and functional contributions to detrital transfer processes, including roles as sources or sinks for detritus generation, export, and use.

Transfer of detrital material was defined for the evaluation as the movement by water of loose organic material and debris and associated decomposing biota from the overbanks in the floodplain to the main channel. Based on the floodplain inundation analysis (Section 6.2), 78 cfs is a flow threshold in which water starts to overflow from the channel onto the adjacent floodplain. Events of 1- and 7-day duration with flows above 78 cfs were identified as primary indicators of detrital transfer in Horse Creek. These events were assumed to transfer detritus to the main channel, where it would be subsequently moved downstream. The extent to which the number of these events and their duration are expected to change as a function of the proposed minimum flows for Horse Creek was therefore summarized.

Reducing the baseline conditions by the allowable percent-of-flow reductions associated with the recommended minimum flows in each block is predicted to result in a 2% decrease in the number of 1-day and 7-day duration events with flows continuously exceeding 78 cfs (Table 6-13). Based on these results, we conclude the recommended minimum flows for Horse Creek will ensure that the transfer of detrital material is protected.

Table 6-13. Number (n) of 1- and 7-day events continuously exceeding 78 cfs in Horse Creek under the baseline and minimum flows scenarios evaluated based on flows at the USGS Horse Creek at SR 72 near Arcadia (No. 02297310) gage between May 1, 1950, and December 31, 2021.

Floodplain Inundation Threshold (cfs)	Number of 1-day Events above 78 cfs (average events per year)			Number of 7-day Events above 78 cfs (average events per year)		
	Baseline (n)	MFL (n)	Change (%)	Baseline (n)	MFL (n)	Change (%)
78	133	130	2	113	110	2

6.5.5. Maintenance of Freshwater Storage and Supply

The environmental value, maintenance of freshwater storage and supply is protected through implementation of the District's Water Use Permitting and Environmental Resource Permitting Programs in part, based on inclusion of conditions in water use and environmental resource permits which stipulate that permitted withdrawals will not lead to violation of any adopted minimum flows or levels. Additionally, the cumulative impact analysis that occurs for new water use permits or increased allocations for existing permits must demonstrate that existing legal users and established minimum flows or levels are protected, further liking minimum flows and levels with the protection of freshwater storage and supply.

The maintenance of freshwater storage and supply environmental value is specifically supportedthrough development of minimum flows, such as those proposed for Horse Creek, that include block-specific, allowable percent-of-flow reductions that can be easily used to develop permit conditions for existing and future surface water withdrawals. The low flow threshold proposed for Horse Creek can be directly linked with consideration of the maintenance of freshwater storage and supply.

The District's Environmental Resource Permitting Program also incorporates freshwater storage and minimum flow and level considerations. Design requirements for permitted stormwater treatment and management systems stipulate that where practical, these systems shall be designed to: maintain water tables, base flows, and low flows at the highest practicable level; preserve site environmental values and not waste freshwater through over drainage; not lower water tables which would adversely affect existing legal users; preserve site groundwater recharge characteristics; and retain water on-site for use and re-use for irrigation and other reasonable beneficial uses. In addition, permitted stormwater systems must not reduce or suppress flows or water levels such that an established minimum flow or level is not achieved.

6.5.6. Aesthetic and Scenic Attributes

Aesthetic and scenic attributes of Horse Creek are inextricably linked to other environmental values, such as recreation in and on the water, fish and wildlife and the passage of fish, transfer of detrital material, filtration and absorption of nutrients and other pollutants, sediment loads, water quality and navigation. As discussed in previous and subsequent sub-sections of this chapter, all environmental values have been considered and, in some cases, associated with specific criteria used in habitat-based methods to develop minimum flow recommendations for Horse Creek. As a result, the recommended minimum flows ensure that the aesthetic and scenic attributes of the system are protected.

6.5.7. Filtration and Absorption of Nutrients and Other Pollutants

The Filtration and Absorption of Nutrients and Other Pollutants Environmental Value was considered by assessing system bathymetry, floodplain inundation and instream habitats. Consideration of this environmental value is associated with other environmental values that are discussed in previous and subsequent sections of this chapter, including those associated with recreation in and on the water, fish and wildlife and the passage of fish, transfer of detrital material, sediment loads, and water quality.

6.5.8. Sediment Loads

Sediment loads typically increase during flood events, when floodplains are inundated, and large flows transport large quantities of sediment during these infrequent events. Sediment loads in rivers are also dependent on water velocities, river slope and sediment size.

Sediment transport modeling requires detailed understanding of processes involved in erosion and movement and deposition of sediments in the water column. In addition, measured bed and suspended loads are required for accurate model calibration and validation. Sediment loads were considered for development of recommended minimum flows for Horse Creek using the Engelund-Hansen method (Engelund and Hansen 1972) which evaluates changes in sediment loads associated with implementation of the recommended minimum flows. However, the simulated sediment discharges do not represent the actual sediment loads, but rather the capacity of the system to transport sediment loads. The aim is to assess if the long-term sediment transport capacity of the creek will significantly be impacted by the implementation of the recommended minimum flows.

There are several empirical methods that can be applied to calculate sediment discharge capacity.The Engelund-Hansen method was selected because it is relatively a simple approach based on a stream power approach. It is also appropriate for sandy-bed rivers, which are common in Florida. Sediment loads are predicted based on mean flow velocity, bed level shear stress, particle size, specific gravity, and channel width. The specific steps undertaken to evaluate sediment loads in Horse Creek were as follows:

1. Critical shear stress by particle size classification for sediment mobility was obtained from USGS scientific investigations report (USGS 2013**;** Table 6-14). Sediment mobility for a given particle size is assumed to occur when the bed shear stress exceeds these critical shear stress. The particle size distribution in Horse Creek is generally in the range of medium to coarse sand. Using this grain size range and, an average shear stress of 0.006 pound per square foot (lb/ft^2) was identified as a critical shear stress for sediment transport in Horse Creek.
2. The Horse Creek HEC-RAS model was run for 12 flow profiles and provided 12 flow-bed shear-velocity relationships at each of the 93 HEC-RAS cross-sections in the model. The 12 flow profiles ranged from the five percent to 99 percent exceedance and were obtained through flow-duration analysis of the flow data at USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage for the period from May 01, 1950, to December 31, 2021.
3. A flow-sediment discharge rating curve was developed at each cross-section using the Engelund-Hansen method and the 12 flow scenarios.
4. A daily sediment discharge for the baseline condition was generated at each cross-section for the period from 1951 through 2021 using the rating curves and an interpolation function in an Excel spreadsheet.
5. Mean annual sediment transport capacity (tons/year) were calculated for the creek by adding the total sediment loads generated at each cross-section in the HEC-RAS model and dividing the sum by the number of years (71 years) in the time series.
6. Steps 4 and 5 were repeated for a minimum flows scenario by reducing the baseline flow record by the allowable percent-of-flow reductions associated with the recommended minimum flows for Blocks 1, 2, 3a, and 3b.
7. Relative changes in sediment transport capacity between the baseline and minimum flow conditions were calculated to ensure that the long-term sediment loads will not be significantly impacted by the recommended minimum flows for Horse Creek.

The estimated sediment transport capacity under the baseline scenario was 1,323,413 tons/year and under the minimum flows scenario was 1,169,222 tons/year (Table 6-15). assuming unlimited sediment availability in the creek. These transport capacities are over-predicted because gravel, pebbles, and non-sand materials (e.g., shells) that retard sediment mobility are neglected in the analysis. Nevertheless, the relative change between the baseline and minimum flow conditions allows us to assess the potential effects of the recommended minimum flows on sediment loads.

Reducing the baseline flow record by the allowable percent-of-flow reductions associated with the recommended minimum flows for Blocks 1, 2, and 3 is predicted to result in a 12% decrease of the mean baseline sediment transport capacity (Table 6-15). The recommended minimum flows for Horse Creek are, therefore, not expected to negatively affect sediment loads.

Table 6-14. Critical shear stress by particle-size classification for determining approximate condition for sediment mobility at 20 degrees Celsius (Source: USGS 2013).

Particle Name	Particle Diameter (mm)	Critical Shear Stress (lb/ft^2)
Coarse cobble	128 – 256	2.24 - 4.46
Fine cobble	64 – 128	1.076 - 2.24
Very coarse gravel	32 – 64	0.518 - 1.076
Coarse gravel	16 – 32	0.244 - 0.518
Medium gravel	8 – 16	0.114 - 0.244
Fine gravel	4 – 8	0.054 - 0.114
Very fine gravel	2 – 4	0.026 - 0.054
Very coarse sand	1 – 2	0.0094 - 0.026
Coarse sand	0.5 – 1	0.0054 - 0.0094
Medium sand	0.25 – 0.5	0.00388 - 0.0054
Fine sand	0.125 – 0.25	0.0029 - 0.00388
Very fine sand	0.0625 – 0.125	0.0022 - 0.0029
Coarse silt	0.0310 – 0.0625	0.001652 - 0.0022
Medium silt	0.0156 – 0.0310	0.00126 - 0.001652
Fine silt	0.0078 – 0.0156	0.000756 - 0.00126

Table 6-15. Sediment transport capacity (tons/year) in Horse Creek under the baseline and minimum flows scenarios were evaluated using the Engelund-Hansen method.

Sediment Transport Capacity (tons/year)		Percentage Change (%)
Baseline	Minimum Flows	
1,323,413	1,169,222	12

6.5.9. Water Quality

Consideration of water quality was discussed in Chapter 3. To predict whether the proposed minimum flows would impact the probability of individual samples exceeding State water quality thresholds for Class III and Class I waters, generalized linear mixed models (GLMMs) were run (Deak 2023, Appendix H). A GLMM can be considered an extension of a linear mixed model, that allows for response variables to be from different distributions, including binary responses. Input data may be normal or non-parametric and either continuous or categorical. A GLMM allows for inclusion of fixed and random effects. Fixed effects include variables in the predictive equation for the model. Random effects allow for specific properties of a particular variable to be considered in the analysis.

A series of GLMMs were developed for total dissolved solids, sulfate, dissolved calcium, total nitrogen, total phosphorus, and dissolved oxygen percent saturation using the glmer function in the lme4 package in R programming language (Bates et al. 2015, R Core Team 2021). Models were run for each analyte, considering combinations of the continuous variables (flow) and categorical variables (season and river kilometer) and interaction terms among them. If the model failed to converge with raw flows, the log of flows was used in subsequent analyses. For each model, available analyte data was obtained from the DEP, HCSP, District, and USGS. Corresponding flow data for each sample on the day of sample collection were from the USGS Horse Creek at SR 72 near Arcadia, FL (No. 02297310) gage record. The successful model with the lowest Akaiki Information Criteria (AIC) score was selected for further analysis. The predict function in R was then applied to the selected model to predict the probability of threshold exceedance at a given flow and location. Flow reduction scenarios were run from 1-20% to determine if such reduction increased the 50% probability of State water quality threshold exceedance by more than 15% compared to baseline conditions. This 50% (or 0.5) probability threshold was selected based on its common use as a standard and its previous application during a similar analysis by Janicki Environmental, Inc. on water quality constituents in the Chassahowitzka River (JEI and WSP 2018).

Thresholds for all assessed water quality parameters, apart from dissolved oxygen percent saturation, are based upon the annual geometric mean. The threshold for dissolved oxygen percent saturation is exceeded if more than 10% of the daily average dissolved oxygen percent saturation values are below 38%. Although the statistics we calculated were based on available sample data, and therefore, reflect the probability of exceedance of the threshold on a per sample basis, we assumed that if the number of samples exceeding the threshold was not substantially increased by flow reduction, the probability of exceeding the threshold once an annual geometric mean or 10% of daily averages is calculated would also not increase.

The only water quality parameter somewhat sensitive to flow reductions of up to 20% was Total Dissolved Solids (TDS), and this parameter exhibited sensitivity at station HCSW-4 during Block 2 flows. For this station, the recommended minimum flows were predicted to cause 13.6% of samples at HCSW-4 to be above the 50% probability threshold for exceeding the State water quality threshold, as compared to 8.5% of samples under baseline conditions. This is not expected to change the overall probability of the station exceeding the state water quality standard for TDS when annual geometric means are calculated. Additional details from the analysis may be found in Appendix H.

Based on these results and trends with flow explored by ATM and JEI (2021), water quality constituents in Horse Creek are not expected to substantially change in response to flow reductions associated with implementation of the recommended minimum flows. The recommended minimum flows for Horse Creek are, therefore, not expected to negatively affect water quality or impair the water designated use of either water body.

If water quality parameters are protected, many other environmental values that can be associated with water quality are also afforded protection. As discussed in previous sub-sections of the report, this protection can be extended to recreation in and on the water (Section 6.5.1), fish and wildlife habitat and the passage of fish (Section 6.5.2), transfer of detrital material (Section 6.5.4), maintenance of freshwater storage and supply (Section 6.6.5), aesthetic and scenic attributes (Section 6.5.6), and filtration and absorption of nutrients and other pollutants (Section 6.5.7).

6.5.10. Navigation

Horse creek is too shallow for commercial and recreational boating; however, there are docks on Horse Creek that can be used for canoeing, kayaking, and fossil hunting. A navigation criterion is defined as the flow corresponding to a water depth of 0.5-ft (0.15-m) at a cross-section in the minimum flow evaluation for the Lower Santa Fe River (HSW

2021) and the Little Manatee River (Holzwart et al. 2023). Since the critical depth needed for canoe and kayak navigation is shallower than that needed for fish passage, implementation of the minimum flows is not expected to adversely affect canoe and kayak navigation in Horse Creek.

6.6. Minimum Flows Status Assessment

The current status of the flow regime of Horse Creek was assessed to determine whether flows in the river are currently and are projected over the next 20 years to remain above limits associated with the recommended minimum flows. These assessments were completed because the Florida Water Resources Act of 1972 stipulates that if the existing flow or level in a water body is below, or projected to fall within 20 years below, an applicable minimum flow or level, the DEP or the governing board as part of the regional water supply plan shall adopt or modify and implement a recovery strategy to either achieve recovery to the established minimum flow or level as soon as practical or prevent the existing flow or level from falling below the established minimum flow or level.

The minimum flow status assessment for Horse Creek required an understanding of historic and current flow conditions and evaluation of the extent to which withdrawals or other anthropogenic factors have affected flows in the creek. As noted in Section 5.1, The District developed the PRIM2 for investigating the effects of climate variability, groundwater pumping, land use changes, and other factors on flows in the Peace River and its tributaries. Results from the PRIM2 simulations indicated that the observed discharge in Horse Creek has been increased by return flow and runoff associated with groundwater withdrawals. Estimated monthly flow increases due to withdrawal-related effects generally ranged from 0 cfs in October to 7 cfs in August (see Table 5-1) for a 16-year assessment period. In addtion, the Florida Statewide Agricultural Irrigation Demand (FSAID) database (Balmorial Group 2022, FDACS 2022) indicates the volume of irrigation water in the Horse Creek watershed is projected to increase by less than 1 mgd by 2045 (refer to Section 2.2.1).

Collectively, this information indicates the recommended minimum flows for Horse Creek are currently being met and are also expected to be met over the next 20 years and beyond. Therefore, development of a specific recovery or prevention strategy for the creek is not required.

An adaptive management approach will be used by the District to monitor and assess the status of minimum flows established for Horse Creek. Because changes in the Horse Creek watershed related to numerous factors, including climate change, could potentially affect flow characteristics and additional information relevant to minimum flows development may become available, the District is committed to periodic reevaluation, and, if necessary, revision of minimum flows established for Horse Creek.

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