Recommended Minimum Flows for the Pithlachascotee River

March 2018

Southwest Florida Water Management District

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The geological evaluation and interpretation contained in the report entitled *Recommended Minimum Flows for the Pithlachascotee River* has been prepared by or approved by a Certified Professional Geologist in the State of Florida, in accordance with Chapter 492, Florida Statutes.

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ACKNOWLEDGEMENTS

We would like to thank several current and former colleagues at the Southwest Florida Water Management District for contributing to the development of the minimum flow recommendations presented in this report. Our current colleagues, Mike Hancock and Jerry Mallams provided constructive comments on earlier drafts. Our former colleagues, Richard Gant, Don Hampton and Doug Pary provided invaluable assistance with field-data collection.

We are also indebted to several individuals not directly affiliated with the District. We thank James Gore, with University of Tampa for habitat modeling using the Physical Habitat Simulation Modeling (PHABSIM) software package and for his direction and advice regarding use of model results. We thank Jiangtao Sun and Srinivas Rao for developing the Hydraulic Engineering Center's River Analysis System (HEC-RAS) model which was used for habitat inundation analyses. We thank Patricia Dooris and George Dooris, with Dooris and Associates, LLC, for their analyses of vegetation and floodplain features of the upper river. We thank Sherri Swanson of HDR Engineering, Inc., for her summarization of biological information for the lower river, and Alan Wells, also with HDR Engineering Inc., who performed hydrologic analyses and developed regressions used to predict isohaline locations in the river. Carolyn Voyles, formerly with the Florida Department of Environmental Protection, Tom Champeau with the Florida Fish and Wildlife Conservation Commission and other Department and Commission staff provided constructive comments on earlier versions of this report. We are also indebted to Warren Hogg, Christine Owen, Jeff Geurink, Nisai Wanakule, Chris Shea, Tirusew Asefa and Whitney Kiehn, all with or formerly with Tampa Bay Water, for their constructive input. Finally, we thank Bill Dunn, Sam Upchurch and Ray Walton, who provided independent, scientific peer review of a previous draft of this report.

LIST OF ABBREVIATIONS AND ACRONYMS

C	Centigrade or Celsius
cfs	Cubic Feet per Second
cm	Centimeters
DO	Dissolved Oxygen
dbh	Diameter at breast height
DEP	Department of Environmental Protection
F	Fahrenheit
F.A.C.	Florida Administrative Code
FDOT	Florida Department of Transportation
ft	Foot or feet
FLUCCS	Florida Land Use Land Cover Classification System
F.S.	Florida Statutes
HEC-RAS	Hydrologic Engineering Centers – River Analysis System
INTB	Integrated Northern Tampa Bay Model
KM or km	Kilometer
m	Meters
mg/L	Milligrams per Liter
mgd	Million gallons per day
NAVD 88	National American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NTBWUCA	Northern Tampa Bay Water Use Caution Area
NTBWRAP	Northern Tampa Bay Water Resource Assessment Project
PHABSIM	Physical Habitat Simulation Model or System
ppt	Parts per thousand
psu	Practical salinity units
SFWMD	South Florida Water Management District
SRWMD	Suwanee River Water Management District
SWFWMD	Southwest Florida Water Management District
U.S.	United States
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

EXECUTIVE SUMMARY

The Southwest Florida Water Management District is directed by the Florida Legislature to establish minimum flows for streams and rivers within its jurisdiction. Minimum flows are defined in Section 373.042(1) Florida Statutes as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." Once adopted into the District's Water Levels and Rates of Flow Rules within the Florida Administrative Code, minimum flows can be used for water supply planning, water use permitting and environmental resource regulation. This report identifies recommended minimum flows for the upper, freshwater and lower, estuarine segments of the Pithlachascotee River, which originates from Crews Lake in northern Pasco County and flows south and west approximately 43 kilometers (27 miles) before entering the Gulf of Mexico near Port Richey. For minimum flow purposes, the upper and lower river segments are delineated as the portions of the river upstream and downstream of the bridge at Rowan Road, which is located approximately 11.4 kilometers (7.1) miles upstream of the river mouth.

The recommended minimum flows were developed based on application of a percent-of-flow approach for three seasonal blocks, and identification of specific flow thresholds. A baseline flow record for the U.S. Geological Survey's Pithlachascotee River near New Port Richey, Florida gage site that was adjusted for existing withdrawal impacts was used to develop the minimum flow recommendations. Using the percent-of-flow approach, potential changes in environmental values or resources associated with potential baseline flow reductions were assessed to identify appropriate minimum flow recommendations. Similarly, thresholds, including Minimum Low Flow Thresholds and a Minimum High Flow threshold were associated with specific flow rates identified for resource protection. Resources evaluated for minimum flows development for the freshwater river segment included water levels for fish passage, wetted perimeter lengths on the river bottom, instream habitats for fish and invertebrates, and floodplain inundation. For the estuarine portion of the river, resource evaluations were focused on changes in salinity distributions, which exert a strong effect on the plant and animal communities of the water column, sediments and shoreline.

Recommended minimum flows for the upper segment of the river allow for withdrawal-related reductions of up to 18 percent of the daily flow (i.e., the preceding day's flow corrected for withdrawals) in the spring dry season (Block 1), 17 percent of the daily flow in the fall to winter moderate flow season (Block 2), and up to 16 percent of flow in the summer wet season (Block 3). However, to maintain sufficient inundation of the floodplain of the upper river when daily flows in Block 3 are greater than a Minimum High Flow Threshold of 50 cfs, the allowable reduction is limited to 9 percent of the daily flow. A Minimum Low Flow threshold of 11 cfs that is applicable to surface water withdrawals during all seasonal blocks is also recommended for the upper river. Minimum flows for the lower segment of the river allow for withdrawal-related reductions of up to 25 percent of the preceding four-day flow (corrected for withdrawals) during all three seasonal blocks when flows range up to a Minimum High Flow Threshold of 60 cfs. Flow reductions of up to 35 percent would be allowed when the four-day average of flow corrected for withdrawals exceeds the Minimum High Flow Threshold of 60 cfs. The recommended minimum flows for the upper and lower river segments are protective of all relevant environmental values identified in the State Water Resource Implementation Rule for consideration when establishing minimum flows and levels.

Streamflow analyses and simulations using the Integrated Northern Tampa Bay Model (INTB), a numeric surface/groundwater model, indicate that flows in the Pithlachascotee have been reduced by groundwater withdrawals. Effects of these withdrawals on flow have, however, been reduced in recent years, following cutbacks in groundwater withdrawals from area wellfields operated by Tampa Bay Water. Modeling results for an 11-year simulation period indicate that impacts associated with current wellfield withdrawal rates of 74.3 mgd and the 90 mgd wellfield withdrawal rate identified as part of the northern Tampa Bay Water Use Caution Area recovery strategy are not expected to exceed allowable river flow reductions associated the minimum flow recommendations for the lower river. Modeling results do, however, suggest that wellfield withdrawal impacts may exceed those associated with the recommended minimum flows for the upper river, with a median 0.6 cfs flow deficit associated with current and 90 mgd withdrawal rates.

To further assess the status of the river, District staff evaluated: the range of flow impacts predicted for the simulated wellfield withdrawals; numeric modeling uncertainty associated with possible rainfall variation, the spatial distribution of wellfield withdrawals and intrinsic model error; the usefulness of mean and median flow statistics for assessing flows; trends in observed flows in the river, and rainfall within Pasco County; status assessments for area water bodies with established minimum flows and levels; results from a wetland recovery assessment recently completed for Starkey Wellfield; and also considered potential effects of various sea level rise scenarios on salinity-based habitats in the lower river to help determine the potential need for reevaluation of the recommended minimum flows. Based on this status assessment, District staff concluded that the recommended minimum flows for the upper and lower segments of the Pithlachascotee River are currently being met and are expected to be met during the coming 20-year planning period. The need for development of additional recovery or preventions strategies is, therefore, currently not necessary. Current and projected flows in the river are, however, near the minima associated with the proposed minimum flows for the upper river.

Because of climate change, structural alterations and other changes in the watershed and groundwater basin contributing flows to the Pithlachascotee River may occur, and because additional information relevant to minimum flows development may become available, the District is committed to periodic reevaluation and if necessary, revision of minimum flows for this priority water body that will presumably be incorporated into District rules. In support of this commitment, the District will continue to monitor and assess flows in the Pithlachascotee River and continue to work on refinement of tools such as the INTB Model that were used for minimum flow development and assessment. Minimum flow status assessments will be completed on an annual basis by the District, on a five-year basis as part of the regional water supply planning process, and on an as-needed basis in association with permit and project activities. In the event that the need for recovery of minimum flows is identified for the Pithlachascotee River, the existing Northern Tampa Bay Water Use Caution Area recovery strategy would be applicable.

Stakeholder input on previous drafts of this report and recommendations from an independent scientific peer review completed in 2016 were used to develop the minimum flow recommendations included in this document. Following additional stakeholder review and any necessary revisions, this report will be presented to the District Governing Board for approval and initiation of rulemaking to incorporate recommended minimum flows for the Pithlachascotee River into District rules will be requested.

Chapter 1 - INTRODUCTION: CONTEXT AND PURPOSE

1.1 Purpose

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 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 or “F.S.”). As a result of this legislation, the Southwest Florida Water Management District (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 existing withdrawal-related impacts to the river, the District has prioritized the establishment of minimum flows for Pithlachascotee River, a 43 km (27 mile) watercourse that runs through urban and conservation lands and provides freshwater inflow to an estuary on the Gulf of Mexico. The river and its floodplain and estuarine reach provided critical habitat for numerous fish, macroinvertebrate, and plant species, which in turn provide food and habitat for various birds, mammals, and other organisms. The river runs through the cities of Port Richey and New Port Richey and acts as a draw for tourism and other recreational activities. Recommended minimum flows were developed for the Pithlachascotee River in accordance with the Florida Water Resources Act of 1972 and are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing minimum flows and levels (specifically Rule 62-40.473, Florida Administrative Code or “F.A.C.”). The recommended minimum flows were based on: previously peer-reviewed methods, input provided by the Florida Department of Environmental Protection (Appendix 1A), Florida Fish and Wildlife Conservation Commission (Appendix 1B) and Tampa Bay Water (Appendix 1C) on a 2014 version of this report; and an independent, scientific peer review of the proposed minimum flows conducted voluntarily by the District and completed by Bill Dunn, Sam Upchurch and Ray Walton in 2016 (Dunn, Salsano & Vergera Consulting, LLC, Barnes, Ferland and Associates, Inc., SDII Global and WEST Consultants, Inc. 2016, Flannery 2016, SWFWMD 2017, Dunn 2018, Upchurch 2018, SWFWMD 2018 a, b, c, Walton 2018) included as Appendices 1D through IL).

Based on additional insight that may be gained from continued stakeholder review (e.g., SWFWMD 2018d, included as Appendix 1M) and Governing Board considerations, the recommended minimum flows for the river presented in this report may be modified prior to adoption of associated minimum flow rule amendments into 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 river.

1.2 Legal Mandates

Three primary legal directives guide the District’s development of minimum flows for Pithlachascotee River:

1. Section 373.042, F.S., within the Florida Water Resources Act of 1972 directs the Florida Department of Environmental Protection (DEP) or the Southwest Florida Water Management District to establish minimum flows for all surface watercourses in the area;

2. Section 373.0421, F.S., within the Florida Water Resources Act of 1972 provides directives for establishment and implementation of minimum flows and levels; and

3. Section 62-40.473 of the Florida Administrative Code (F.A.C.), within the Florida Water Resource Implementation Rule provides goals, objectives and guidance regarding the establishment of minimum flows and levels.

The Florida Water Resources Act of 1972 directs the DEP or the state water management districts to establish minimum flows and levels for priority water bodies. As defined by Section 373.042(1)(a), F.S., "*[t]he minimum flow for a given watercourse is the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area."* Establishment of minimum flows and levels is to involve consideration of, and at the governing board or department's discretion, may provide for the protection of nonconsumptive uses (Section 373.042(1), F.S.). In addition, minimum flows and levels are to be established based upon the best information available, and when appropriate, may be calculated to reflect seasonal variations (Section 373.042(1), F.S.).

Although there is no statutory requirement for the District to acquire new information prior to establishing of a minimum flow or level, the District has routinely completed additional studies supporting minimum flows and levels development. The District's Water Levels and Rates of Flow rules (specifically Rule 40D-8.011(5), F.A.C.) address the use of best available information for setting minimum flows and levels and identifies the need, in some cases, for development of new methodologies and data collection and analyses programs to supplement the available information used for establishing and reviewing minimum flows and levels, stating:

> "*The Minimum Flows and Levels established in this Chapter 40D-8, Florida Administrative Code (F.A.C.), are based on the best available information at the time the Flow or Level was established. The best available information in any particular case will vary in type, scope, duration, quantity, and quality and may be less than optimally desired. In addition, in many instances the establishment of a Minimum Flow or Level requires development of methodologies that previously did not exist and so are applied for the first time in establishing the Minimum Flow or Level. The District has many ongoing environmental monitoring and data collection and analyses programs, and will develop additional programs over time."*

Sections 373.042 and 373.0421, F.S., of the Water Resources Act of 1972 also address the prioritization and scheduling of minimum flows and levels establishment, the independent peer review of scientific or technical data, methodologies, models and scientific and technical assumptions employed in each model used to establish a minimum flow or level, and exclusions that may be considered when identifying the need for minimum flows and levels establishment. The need to "…consider changes and structural alterations to watersheds, surface waters, and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer…" is also identified.

The Water Resource Implementation Rule, specifically Rule 62-40.473, F.A.C., provides additional guidance for 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 Water Resource Implementation Rule also indicates: "[m]inimum 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." It further indicates that, "…a minimum flow or level need not be expressed as multiple flows or levels if other resource protection tools, such as reservations implemented to protect fish and wildlife or public health and safety, that provide equivalent or greater protection of the hydrologic regime of the water body, are developed and adopted in coordination with the minimum flow or level." The rule also includes provision addressing: protection of minimum flows and levels during the construction and operation of water resource projects; the issuance of permits pursuant to Section 373.086 and Parts II and IV of Chapter 373, F.S.; water shortage declarations; development of recovery or prevention strategies, development and updates to a minimum flow and level priority list and schedule, and peer review for minimum flows and levels establishment.

The development of minimum flows and levels provides vital support for resource protection and recovery efforts, including regulatory and planning activities, by establishing standards below which significant harm will occur. Section 373.0421(2), F.S., requires adoption of new or modification of an existing recovery or prevention strategy and implementation of the strategy "[i]f at the time a minimum flow or minimum water level is initially established for a water body pursuant to s. 373.042 or is revised, the existing flow or water level in the water body is below, or is projected to fall within 20 years below, the applicable minimum flow or minimum water level…" Similarly, if the existing flow or water level in a water body falls below or is projected to fall below a previously established minimum flow or minimum water level, the expeditious adoption of a recovery or prevention strategy is required. Section 373.0421(2) F.S., also requires that recovery or prevention strategies be developed to: "(a) [a]chieve recovery to the established minimum flow or minimum water level as soon as practicable; or (b) [p]revent the existing flow or water level from falling below the established minimum flow or minimum water level." Periodic reevaluation and, as necessary, revision of established minimum flows and levels are required by Section 373.0421(5), F.S.

1.3 Flow Definitions and Concepts

To address all relevant requirements of the legal directives associated with minimum flows and levels and aid in the understanding of information presented in this report, District staff thinks it is appropriate to elaborate on several flow-related definitions and concepts found herein.

- Flow refers to streamflow or 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 is defined in Rule 40D-8.021(6), F.A.C. as an evaluation period for establishing minimum flows and levels that spans the range of hydrologic conditions which can be expected to occur based upon historical records.

- Reported flows are directly measured or estimated using a relationship with directly-measured flows. Examples include measured and estimated flows reported by the United States Geological Survey (USGS) and those included in the District Water Management Information System. Most reported flows are actually estimated using regressions or other models developed from empirical measurements. For example, reported flows are typically estimated from measured water levels using rating curve models. 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 *unimpacted or historical* 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.

1.4 Overview of Methods and Assumptions

The District has developed specific methods for establishing minimum flows and levels for lakes, wetlands, rivers, and aquifers, described the methods in technical reports, subjected them to independent, scientific peer-review, and in some instances, incorporated the methods into its Water Level and Rates of Flow Rule (Chapter 40D-8, F.A.C.). Components of recovery strategies needed to restore minimum flows and level that are not currently being met have been summarized in technical documents, incorporated into the District’s Recovery and Prevention Strategies for Minimum Flows and Levels Rule (Chapter 40D-80, F.A.C.) and/or incorporated into specific permit conditions. The District’s Minimum Flows and Levels Program (see Hancock et al. 2010), including the methods used for setting minimum flows and levels, addresses all relevant requirements expressed in the Water Resource Implementation Rule as well as those included in the Water Resources Act of 1972.

To date and using peer-reviewed methodologies, the District has established and codified (in Chapter 40D-8, F.A.C.) minimum flow rules for numerous river segments and springs. Minimum flows have been established for the Crystal River/Kings Bay Spring Group, Upper and Lower Alafia River, Upper and Lower Anclote River, Upper Braden River, Chassahowitzka River/Chassahowitzka

Spring Group, Blind Spring, Crystal Springs, Dona Bay/Shakett Creek System, Gum Slough Spring Run, Upper and Lower Hillsborough River, Homosassa River/Homosassa and Spring Group, Lithia and Buckhorn Springs Group, Upper and Lower Myakka River, three segments of the Upper Peace River, Middle and Lower Peace River, Rainbow River/Rainbow Spring Group, Sulphur Springs, Tampa Bypass Canal, and Weeki Wachee River/Weeki Wachee Spring Group. Information pertaining to the adoption of these minimum flows and other related issues is available from the District's Minimum Flows and Levels (Environmental Flows) Program web page at: www.WaterMatters.org/MFLReports.

1.4.1 Fundamental Assumptions

Implementation of the District's Minimum Flows and Levels Program is based on three fundamental assumptions. First, District staff assumes that many water resource values and associated features are dependent upon and affected by long-term hydrology and/or changes in long-term hydrology. Second, District staff assumes that relationships between some of these factors or variables can be quantified and used to develop significant harm thresholds or criteria that are useful for establishing minimum flows and levels. Third, the approach assumes that 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 scientific work addressing relationships between hydrology, ecology and human-use values associated with water resources (e.g., see reviews and syntheses by Postel and Richer 2003, Wantzen et al. 2008, Poff et al. 1997, Poff and Zimmerman 2010). 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 levels for hundreds of water bodies, as summarized in the numerous publications associated with these efforts (e.g., SFWMD 2000, 2006, Flannery et al. 2002, SRWMD 2004, 2005, Neubauer et al. 2008, Mace 2009).

With regard to the specific assumption associated with alternative hydrologic regimes, consider a historical 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 historical regime to large withdrawals that could substantially alter the regime. A threshold hydrologic regime may exist that is lower or less than the historical regime, but which 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. Minimum flows and levels may, therefore, represent minimum acceptable rather than historical or potentially optimal hydrologic conditions.

1.4.2 Significant Harm

Significant harm is the criterion on which the establishment of minimum flows must be made to protect 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. For establishing minimum flows, our solution to defining "significant harm" is to identify specific minimum flow thresholds or criteria associated with fish passage, maximization of stream bottom habitat with the least amount of flow and other environmental values. District staff also identify significant harm using a 15 percent change criterion as a threshold associated with potential loss or alteration of an important environmental value or values. For example, if an important habitat or a population was expected to decrease by 15 percent or more during a critical seasonal or flow-based period as a result of withdrawal-related flow reductions, this could constitute significant harm, and minimum flows would be set to prevent such losses. District staff typically assess and use both types of significant harm criteria, i.e., flow threshold and 15 percent change criteria, when developing minimum flows as part of a building-block, percent-of-flow approach implemented following identification of a baseline flow record or records. Appropriate criteria are selected for specific priority water bodies and understandably differ for estuarine vs. freshwater river segments.

1.4.3 Baseline Flows and Conditions

Use of significant harm criteria for development of minimum flows is predicated upon identification of a baseline flow record or records for characterization of 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 or discharge/augmentation 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. For example, in some instances we have developed separate baseline flow records for time periods associated with warm and cool phases of the Atlantic Multidecadal Oscillation (AMO), because sea surface temperatures during the AMO phases have been associated with differences in river flows (Kelly and Gore 2008).

1.4.4 Building Block Approach

As District staff typically do for establishing minimum flows, we used a building-block approach to develop proposed minimum flows for the Pithlachascotee River. Building-block approaches for environmental flow efforts frequently involve categorization of the flow regime into discrete blocks defined by flow volume, length of time, 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 a specified flow regime.

For systems exhibiting significantly different seasonal flows, the District’s building-block approach involves 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, that extends from the fall to early spring. 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.

1.4.5 Minimum Flow Thresholds

Our approach to developing minimum flows often includes identification of minimum low flow and minimum high flow thresholds. These thresholds are developed to protect selected environmental values from significant harm and may be applicable throughout the year or for specific seasonal blocks.

Minimum low flow thresholds are typically developed for freshwater river segments to limit when surface water withdrawals may occur and are considered applicable during all seasonal blocks. Criteria used to establish minimum low-flow thresholds in freshwater rivers, such as fish passage depths or potential changes in wetted perimeter (i.e., inundated stream bottom) generally do not apply in estuaries, because tides largely control water levels at low flows and these environmental values may not be strongly associated with flows in lower river segments. As discussed in the methods and results presented in later chapters of this report, District staff developed a recommended minimum low flow threshold for the upper, freshwater segment of the Pithlachascotee River, but did not develop a low flow threshold for the lower, estuarine portion of the river.

Minimum high flow thresholds, which are typically used to identify flow-based seasonal or annual allowable percent-of-flow reductions, may be developed for both freshwater and estuarine river segments. District staff developed minimum high flow thresholds separately for the upper and lower segments of the Pithlachascotee River, as discussed in the methods and results chapters of this document.

1.4.6 Percent-of-Flow Method and 15 Percent Change Criteria

In addition to identifying minimum flow thresholds, the District typically incorporates percent-of-flow methods into our building-block approach, using 15 percent change criteria associated with specific environmental values. 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. District staff have successfully used a percent-of-flow method to develop minimum flows for numerous freshwater (Holzwart et al. 2016, Kelly et al. 2005, 2007, SWFWMD 2002, 2005a, 2005b, 2005c, 2007, 2010a) and estuarine (Flannery et al. 2002, SWFWMD 2008a, 2008b, 2010a, 2010b, 2010c, 2012a, 2012b) river segments and incorporated the approach into the development of recommended minimum flows for both the upper and lower portions of the Pithlachascotee River. Since its introduction, the District's percent-of-flow method has received attention in the international technical literature as a progressive method for water management for both freshwater and estuarine systems (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. This goal is based on current understanding of linkages between the natural flow regime and physical and biological processes affecting the ecological integrity of flowing water bodies (Poff et al. 1997, Instream Flow Council 2002, Postel and Richter 2003). These processes include sediment transport, channel maintenance, fish passage, the inundation of instream and floodplain habitats, and maintaining water levels and velocities that support growth and reproduction of instream fish and invertebrate populations. The utility of percent-of-flow methods has recently been recognized in the development of presumptive, risk-based environmental flow standards that are recommended for river systems where data-intensive approaches to flow protection have not or are not likely to be implemented (Richter et al. 2011).

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 long-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, when river systems may be especially vulnerable to flow reductions. Similarly, larger volumes may be available for withdrawal during periods of higher flows. The approach has been effectively implemented for numerous permitted surface water withdrawals within the District, including those associated with water-supply withdrawals from the Peace, Alafia, and Little Manatee Rivers. 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 in which 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.

For implementation of its percent-of-flow method, District staff have used a 15 percent change criterion when evaluating potential flow-based changes in habitats or environmental values. The basis for this management decision 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 "[i]n general, instream flow analysts consider a loss of more than fifteen percent 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 Model (PHABSIM) for analyzing flow, water depth and substrate preferences that define aquatic species habitats. Use of a 15 percent change in habitat or resources as constituting significant harm and therefore, for development of minimum flow recommendations, has been extended by the District to evaluate changes in freshwater fish and invertebrate habitat, days of inundation of floodplains, snag habitat and woody debris in freshwater river segments, changes in abundances or population center-location tendencies of planktonic (free-floating) and nektonic (actively swimming) fish and invertebrates in estuarine river segments, spatial decreases in the availability of warm-water refuges for manatees during critically cold periods, and decreases in the volume, bottom area and shoreline length associated with specific salinity zones in estuarine river segments.

Peer-review panels convened to evaluate District recommendations subsequent to the findings put forth by Gore et al. (2002) for the upper Peace River have generally been supportive of the use of a 15 percent change criterion for evaluating effects of potential flow reductions on habitats or resources when determining minimum flows (see peer-review reports at the District's Minimum Flows and Levels Documents and Reports web page), and this was the case for the peer review by Bill Dunn, Sam Upchurch and Ray Walton that addressed minimum flows proposed for the Pithlachascotee River (Dunn, Salsano & Vergera Consulting, LLC, Barnes, Ferland and Associates, Inc., SDII Global and WEST Consultants, Inc. 2016; included as Appendix 1D). Based on these peer-review conclusions and findings from other environmental flow studies, the District is continuing to use the 15 percent habitat or resource change criteria for developing recommended minimum flows, including for development of the minimum flow recommendations for the Pithlachascotee River described in this report.

District staff acknowledge that allowable percentage changes in habitat or resources other than the 15 percent criteria utilized by the District have been used by others for environmental flow determinations. For example, Dunbar et al. (1998) in reference to the use of PHABSIM note, "…*an alternative approach is to select the flow giving 80 percent habitat exceedance percentile*," which is equivalent to an allowable 20 percent decrease from baseline conditions. For another habitat-based environmental flow study, Jowett (1993) used a one-third loss of existing habitat associated with naturally occurring low-flows as a guideline for determining flow recommendations. In Texas, the state established environmental flows for Matagorda Bay based on modeling that limited decreases of selected commercially important species to no more than twenty-percent reductions from historical harvest levels (Powell et al. 2002).

1.5 Vertical Datums

The District is in the process of converting 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. While the NGVD 29 datum is used for most elevation values included within this report, in some circumstances notations are made for elevation data that was collected or reported relative to mean sea level or relative to NAVD 88 and converted to elevations relative to NGVD 29. As necessary, these elevations were, or may be converted to elevations relative to NAVD 88 in accordance with the District's internal operating procedure for minimum flows and levels data collection, summarization, reporting and rule development (Leeper 2016).

Chapter 2 - BACKGROUND: PITHLACHASCOTEE RIVER WATERSHED CHARACTERISTICS

2.1 Introduction

In this chapter, District staff discuss physical and hydrological characteristics of Pithlachascotee River watershed, including its location, climate, physiography hydrogeology, land-use/cover and surface water hydrology. Modeling efforts to quantify the effects of regional groundwater withdrawals on streamflow and water quality information for the river are also summarized.

2.2 Watershed Size and Location

The Pithlachascotee River is 43 kilometers (27 miles) in length and is fed by groundwater seepage and surface runoff from a watershed (Figure 2-1) that drains approximately 518 square kilometers (200 square miles) in the Springs Coast region of western Florida (Wolfe 1990). The river originates in Hernando County and flows southwest into Pasco County before emptying into the Gulf of Mexico near the cities of Port Richey and New Port Richey (Figure 2-2). The northernmost headwaters flow into Crews Lake, which discharges into the upper reaches of the river. Principal tributaries downstream from Crews Lake include Gowers Corner Slough and Fivemile Creek. The Pithlachascotee River runs through several wilderness areas and parks, including the Crews Lake Wilderness Park, Jay B. Starkey Wilderness Park, Serenova Tract, and the James E. Gray Preserve.

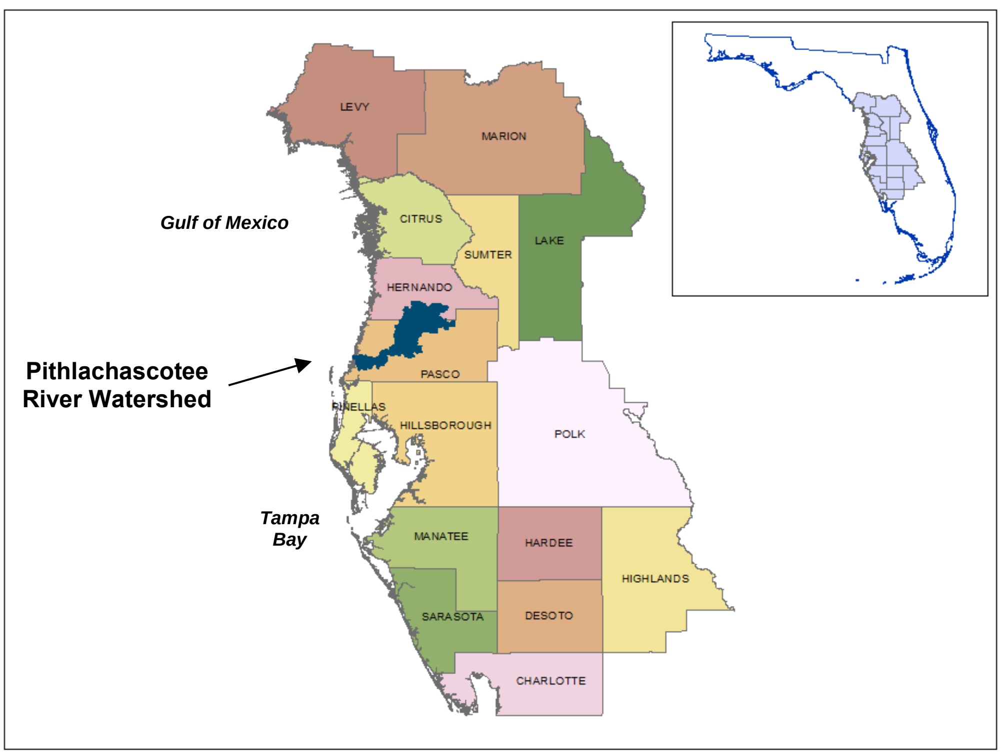


Figure 2-1. Location of the Pithlachascotee River watershed within the Southwest Florida Water Management District.

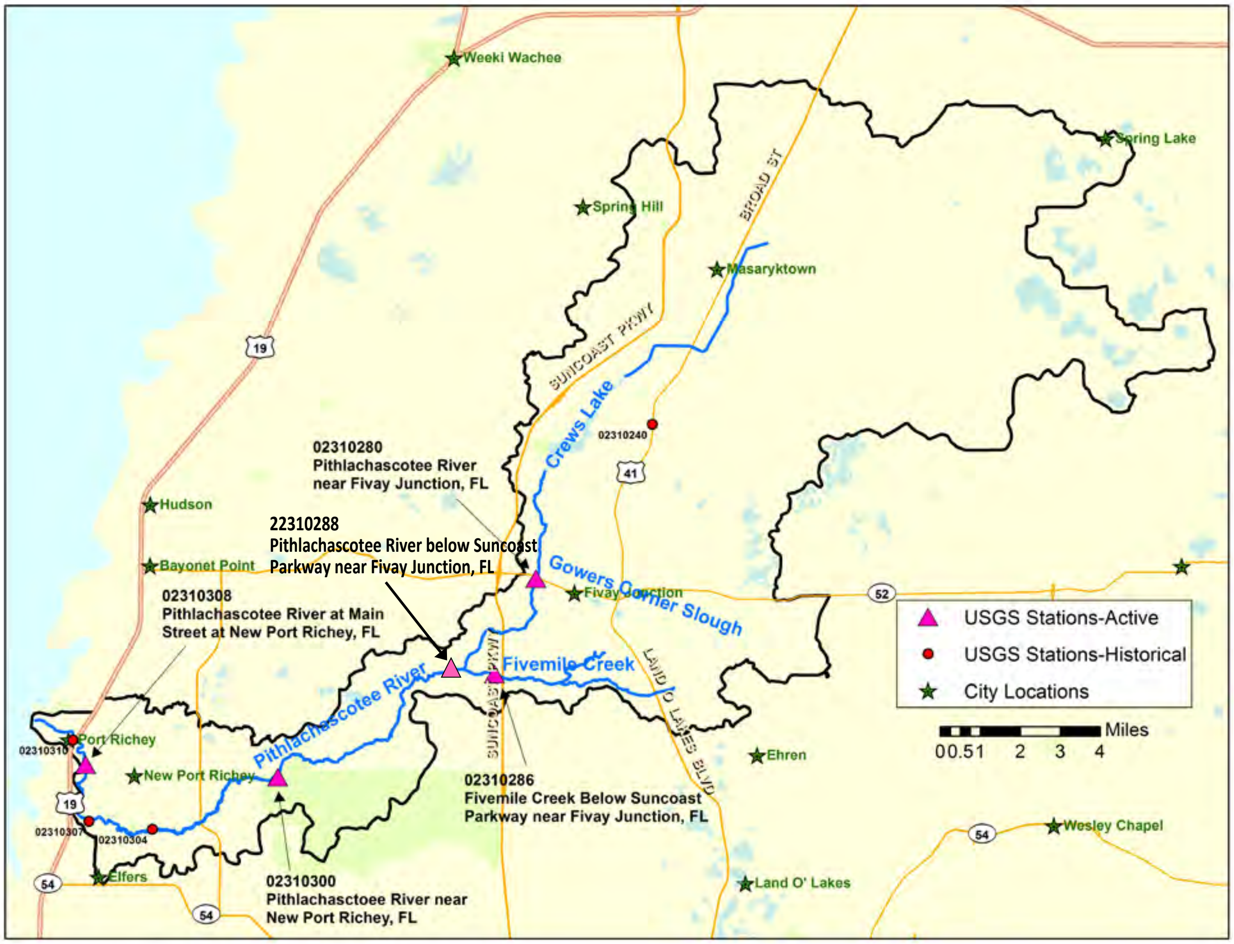


Figure 2-2. Location of the Pithlachascotee River watershed with active and historical USGS gages. Green shaded polygon depicts location of Starkey Wellfield.

2.3 Climate

The Pithlachascotee River watershed is characterized by a humid subtropical climate, affected largely by its location near the Gulf of Mexico. Winter cold fronts and high summer temperatures are moderated by the Gulf waters. The average mean daily temperature for the region is approximately 70° F, with mean summer temperatures in the low 80s and mean winter temperatures in the upper 50s. Summer temperatures are tempered by sea breezes. Winter temperatures are quite variable due to the passage of frontal systems.

Average rainfall is approximately 54 inches per year but varies widely from season to season and year to year. About 60 percent of annual rainfall occurs in the summer rainy season months of June through September, when convective thunderstorms are common due to daytime heating and afternoon sea breezes (Figure 2-3). In addition, summer and fall rainfall can be enhanced by tropical cyclone activity from June through November. An analysis of median decadal rainfall and 20-year moving average rainfall accumulated from the St. Leo, Brooksville, Inverness, and Ocala National Weather Service (NWS) stations from 1901 through 2015 shows an increasing trend up until the mid-1960s and then a declining trend thereafter (Figures 2-4 and 2-5). This is consistent with multi-decadal cycles associated with the Atlantic Multidecadal Oscillation (Enfield et al. 2001, Kelly and Gore 2008). The 20-year average was below the bottom 10^{th} percentile (P90) for most of the averages post-2000 (Figure 2-5). Recent 20-year periods (1994-2013, 1995-2014, and 1996-2015) have, however, exhibited increased rainfall, with averages lying between the P90 and P50 percentiles. Pasco County annual rainfall since 1970 is shown in Figure 2-6. During the last 45 years, the driest year was in 2000 when rainfall averaged for the county was 31.3 inches. The wettest year was in 1983 at 69.67 inches. From 2010 through 2015, rainfall has been slightly above normal averaging 55.5 in/yr.

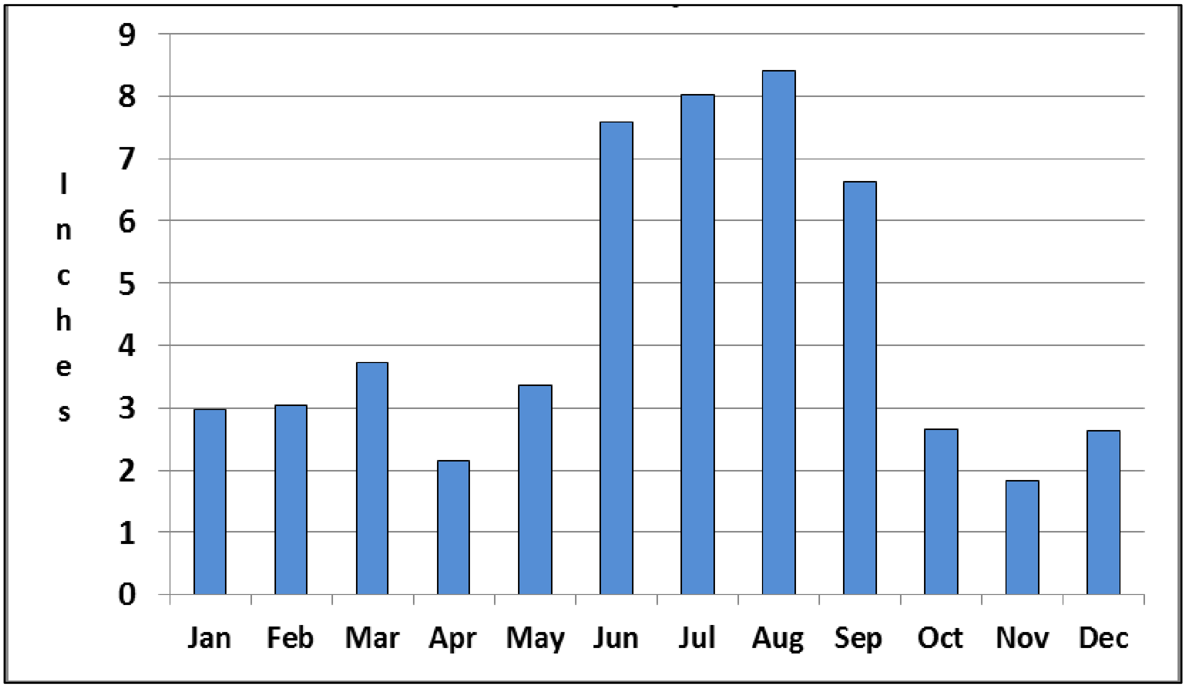


Figure 2-3. Average monthly rainfall in Pasco County based on data for a 50-year period from 1964 through 2013 and available from the District web site at: http://www.swfwmd.state.fl.us/data/hydrologic/rainfall_data_summaries/.

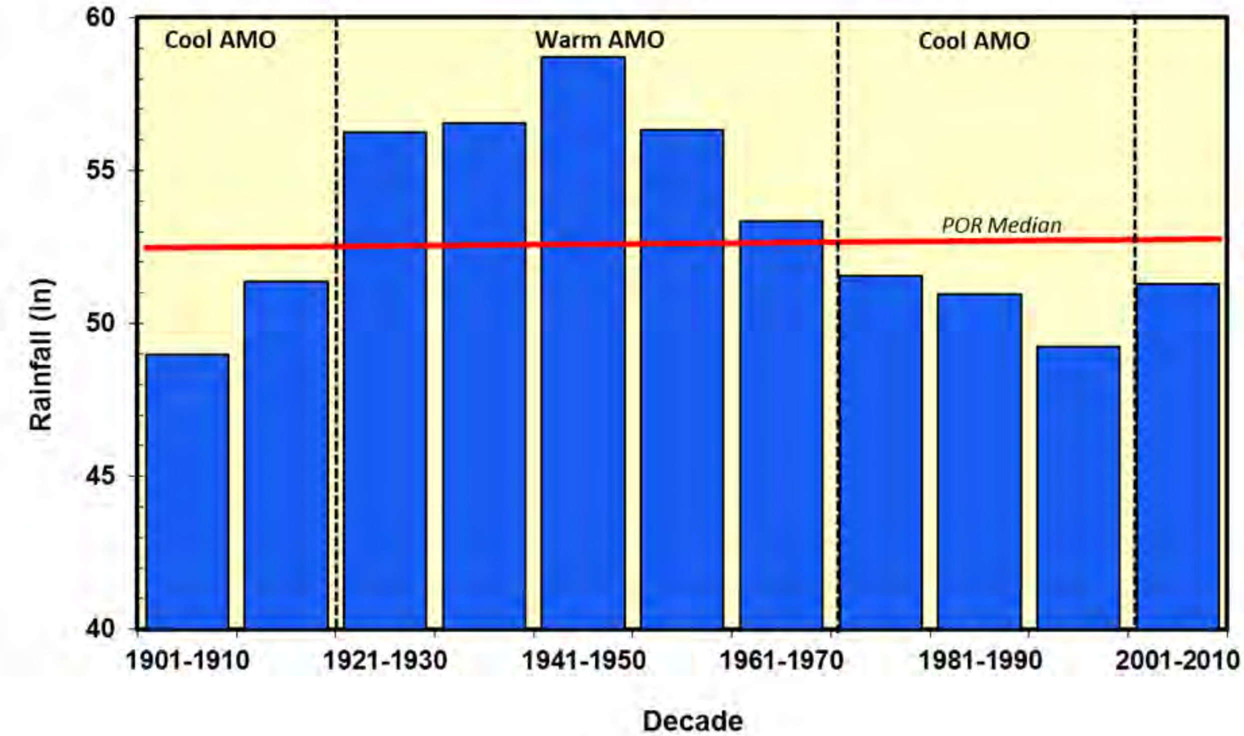


Figure 2-4. Atlantic Multidecadal Oscillation (AMO) periods, median decadal rainfall and period of record (POR) rainfall from the Brooksville, Inverness, and Ocala National Weather Service stations from 1901 through 2010.

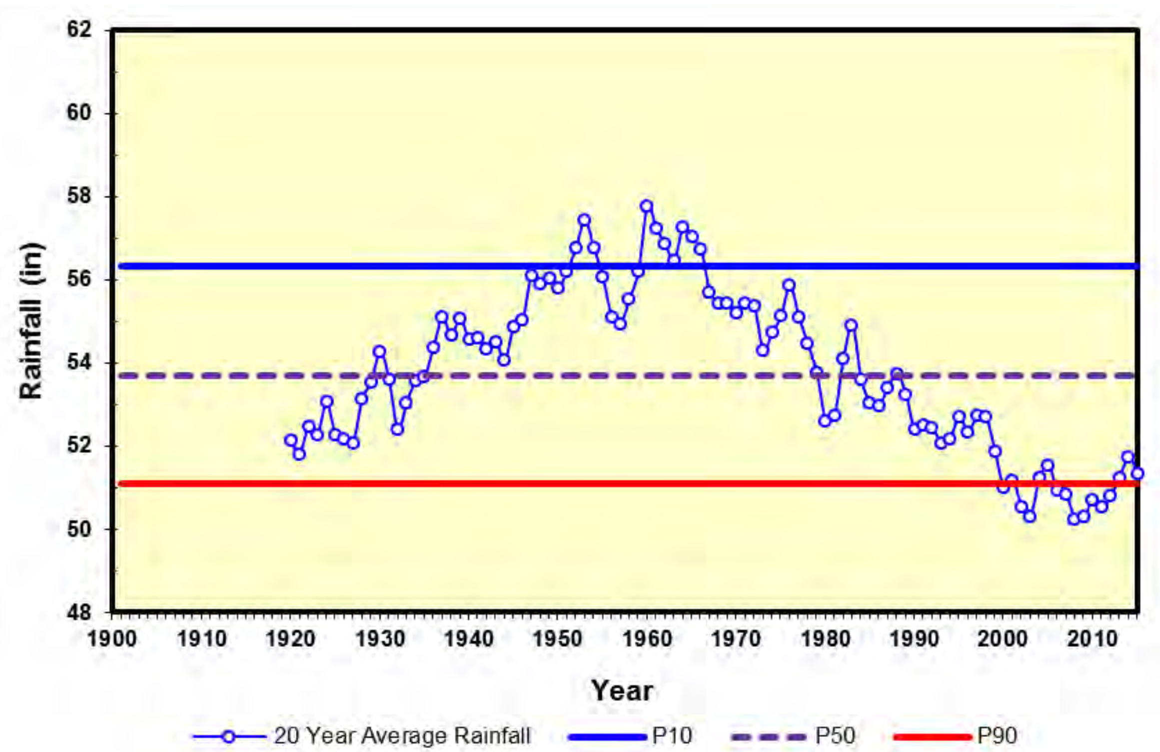


Figure 2-5. Twenty-year moving average rainfall and period of record tenth (P10), fiftieth (P50) and ninetieth (P90) percentile rainfall from the St. Leo, Brooksville, Inverness, and Ocala National Weather Service stations from 1901 through 2015.

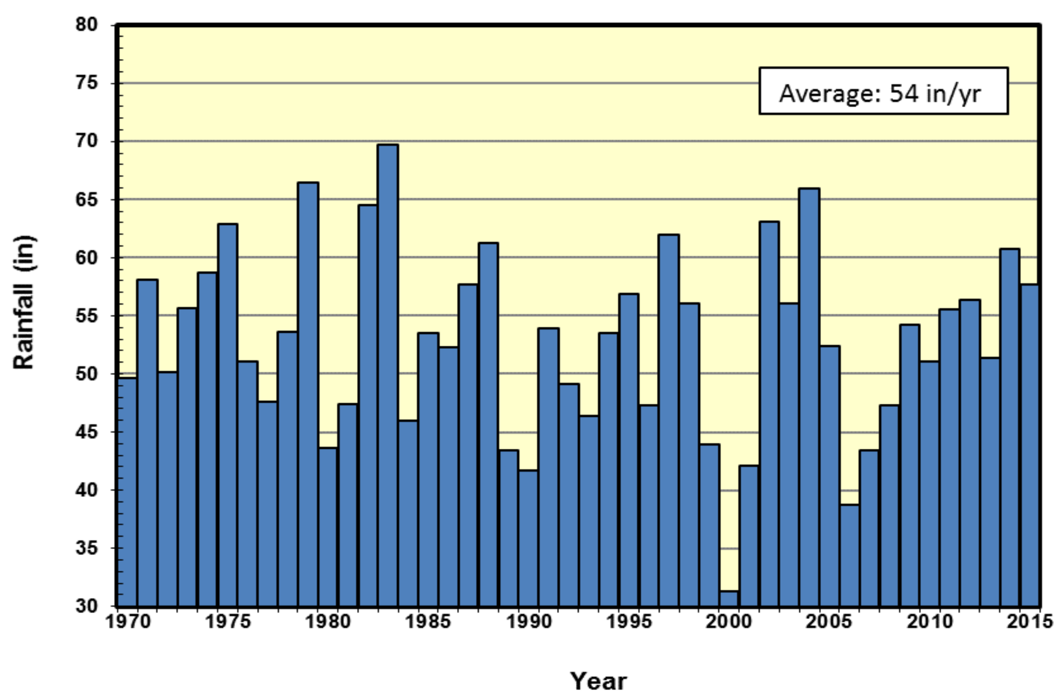


Figure 2-6. Pasco County annual rainfall from 1970 through 2015.

2.4 Physiography

The Pithlachascotee River watershed lies primarily within three physiographic provinces; the Northern Gulf Coastal Lowlands, Coastal Swamps, and the Brooksville Ridge Physiographic regions as defined in White (1970). The Coastal Swamp province parallels the coast and extends inland from two to five miles. This geomorphological province is ecologically typified by mangrove swamps and salt marshes. With elevations typically less than ten feet, poorly drained, organic soils directly overlie limestones of the Floridan aquifer system in much of the coastal swamp area. The Northern Gulf Coastal Lowlands lie between the Coastal Swamp and the Brooksville Ridge and range from about two to eight miles in width. Elevations range from sea level to about 100 feet. The topography consists of relatively flat plains to rolling hills made up of aeolian sand dunes. The most northeastern portion of the river watershed extends into the Brooksville Ridge province, which rises above the Central Upland and has irregular elevations from around 70 to 200 feet.

2.5 Hydrogeology

The hydrogeology of the District can generally be divided into three broad regions that correspond to major groundwater basins within the Upper Floridan aquifer (UFA) (Figure 2-7). Within the District, from north to south, 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). In general, 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 north to south.

The hydrogeology of the Pithlachascotee River Basin area includes a surficial aquifer; a discontinuous, intermediate clay confining unit and the thick carbonate UFA. In general, the surficial aquifer is in good hydraulic connection with the underlying UFA because the clay confining unit is generally thin, discontinuous, and breeched by numerous karst features (Figure 2-8). The surficial aquifer is generally comprised of fine-grained quartz sand that is a few tens of feet thick and overlies the limestone of the UFA that averages nearly 1,000 feet thick in the area (Miller 1986). The geologic units, in descending order, that form the freshwater portion of the UFA include the Oligocene Suwannee Limestone, the Upper Eocene Ocala Limestone and the Middle Eocene Avon Park Formation. In between the surficial aquifer and the UFA is undifferentiated Hawthorn Group clay that varies between zero to as much as 25 feet thick (Figure 2-8). Because the clay unit is breached by buried karst features and has previously been exposed to erosional processes, preferential pathways locally connect the overlying surficial aquifer to the UFA resulting in moderate-to-high leakage to the UFA (SWFWMD 1996). The base of the UFA generally occurs at the first, persistent sequence of evaporitic minerals such as gypsum or anhydrite that occur as nodules or discontinuous thin layers in the carbonate matrix. This low permeability unit is regionally extensive and is generally referred to as middle confining unit II (Miller, 1986).

In most of west-central Pasco County, a distinct, surficial aquifer overlies the semi-confined UFA. However, a rather sharp transition to a regionally unconfined UFA occurs along a line from northwest Pasco County through the northern part of Cross Bar wellfield to the Brooksville Ridge physiographic region (Figure 2-9). North of this boundary, the UFA is primarily unconfined except beneath the clay-rich, low infiltration soils of the Brooksville Ridge. On the east side of the Brooksville ridge the unconfined UFA extends south into eastern Pasco County to a line just west of the Withlacoochee River. East of this location, a leaky artesian aquifer system extends to the Green Swamp region.

The northern portion of the Pithlachascotee River Basin, where Crew's Lake is located, lies within the NWCFGWB where the UFA is largely unconfined. This is an internally-drained area of high recharge to the UFA and deep water table conditions (generally greater than 10 feet below land surface). Dissolution of limestone is an active process via infiltration of rainwater because the limestone units of the UFA are close to land surface and poorly confined. The carbonate rocks of this region have been extensively and repeatedly subjected to chemical dissolution and deposition processes in response to sea-level fluctuations. Wide-scale fluctuation in sea-level stands during the Miocene and throughout the Pliocene and Pleistocene epochs has led to multiple-horizons of concentrated karst features (Knochenmus and Yobbi, 2001). Numerous sinkholes, internal drainage, and undulating topography that are typical of karst geology dominate the landscape. These active karst processes lead to enhanced permeabilities within the UFA. Five first-magnitude springs (> 100 cfs discharge), including the Rainbow, Kings Bay, Chassahowitzka, Homosassa and Weeki Wachee spring groups are found within this region. In addition, the highest recharge rates to the UFA occur in west-central Hernando and Citrus Counties with values ranging between 15 and 22 inches per year (Ross et al., 2001).

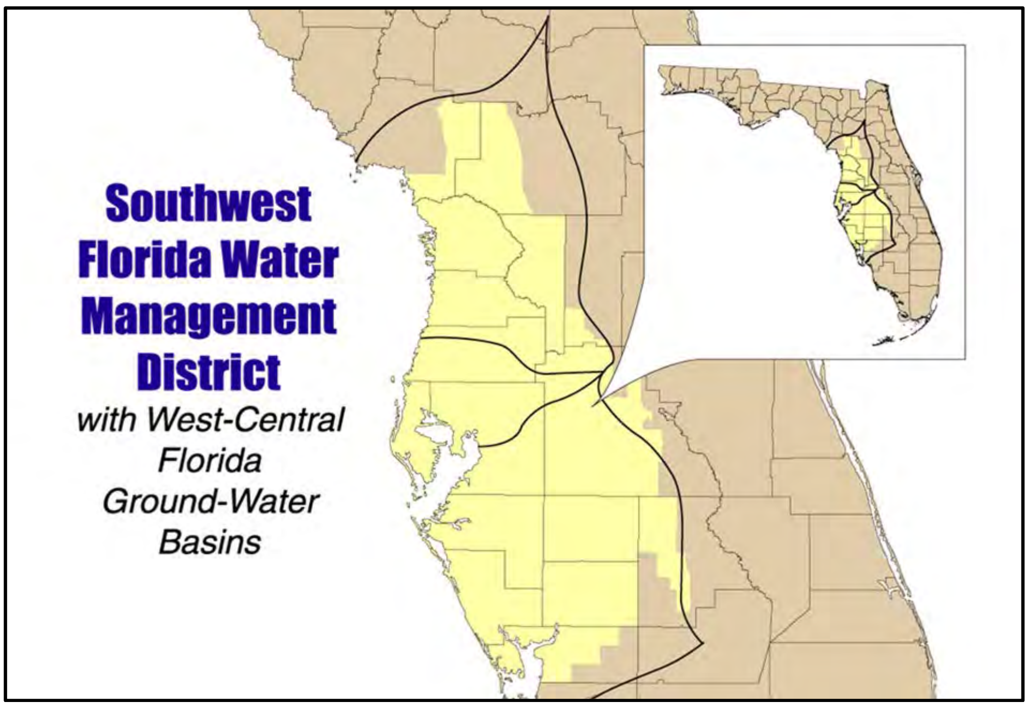


Figure 2-7. Location of major groundwater basins within the Southwest Florida Water Management District.

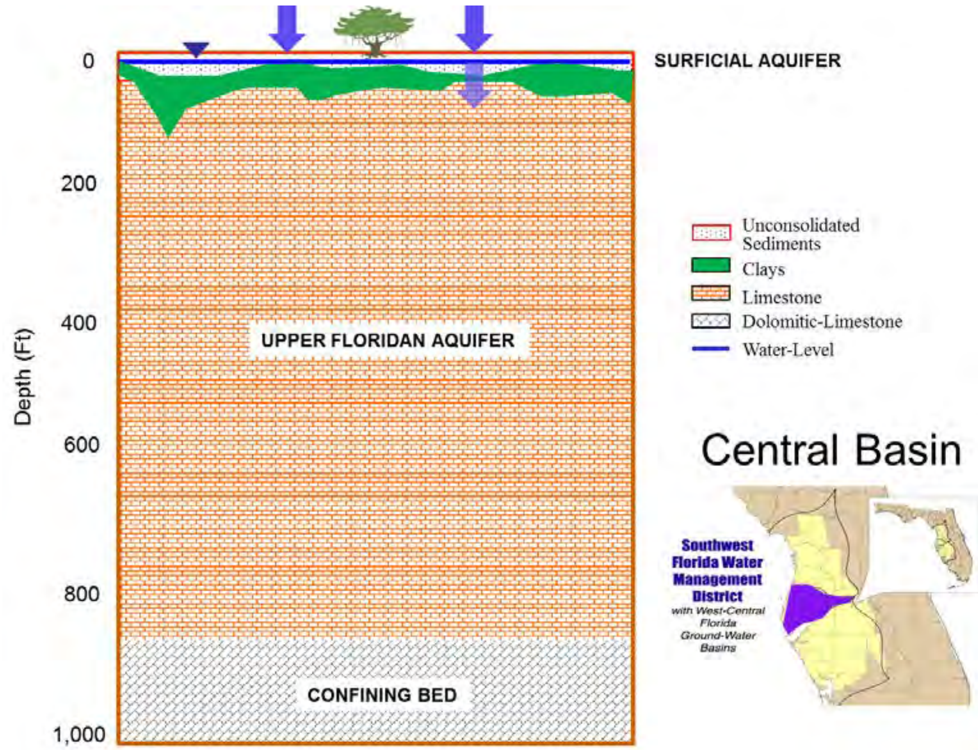


Figure 2-8. Generalized hydrogeology of the Pithlachascotee River Basin.

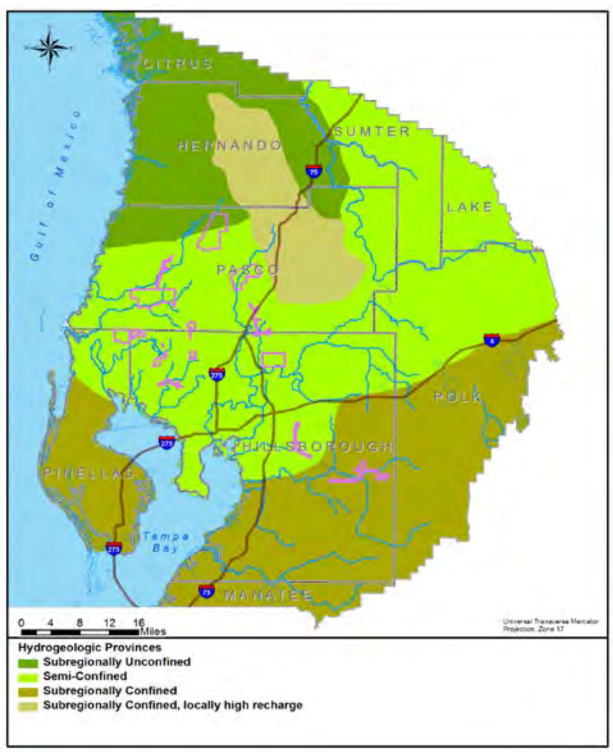


Figure 2-9. Degree of confinement overlying the Upper Floridan aquifer (from Geurink and Basso 2013).

2.6 Land Use/Cover

Land use and cover within the Pithlachascotee watershed have changed over time. These land-use/cover changes are quantified here because they have potential impacts on water quality and quantity within the Pithlachascotee River. Maps of the watershed in 1974, 1990, and 2011 illustrate the changes in land-use that have occurred in a 37-year history (Figure 2-10). The 1990 and 2011 land-use/land cover maps use the Florida Department of Transportation (FDOT 1999) Florida Land Use, Cover and Forms Classification System (FLUCCS). The FLUCCS minimum mapping unit is 5 acres for uplands and 0.5 acres for wetlands. The 1974 map used the USGS classification system, which has a minimum mapping unit of 10 acres for man-made features and 40 acres for non-urban and natural features (Anderson et al. 1976).

Changes in land-use through time indicated a shift toward urbanization (Table 2-1). Land use/cover within the watershed in 1974 was dominated by agriculture (39 percent) and secondarily by wetland (18 percent), forest (17 percent), and rangeland (13 percent). By 2011, land-use had shifted to a roughly even split between forest (29 percent), urban (25 percent), agriculture (22 percent), and wetland (19 percent). It is important to note that some of the changes in land-use/cover values between 1974 and more recent data collection events may reflect differences in the increased ability to resolve land-use/cover at finer spatial scales, rather than actual land-use changes.

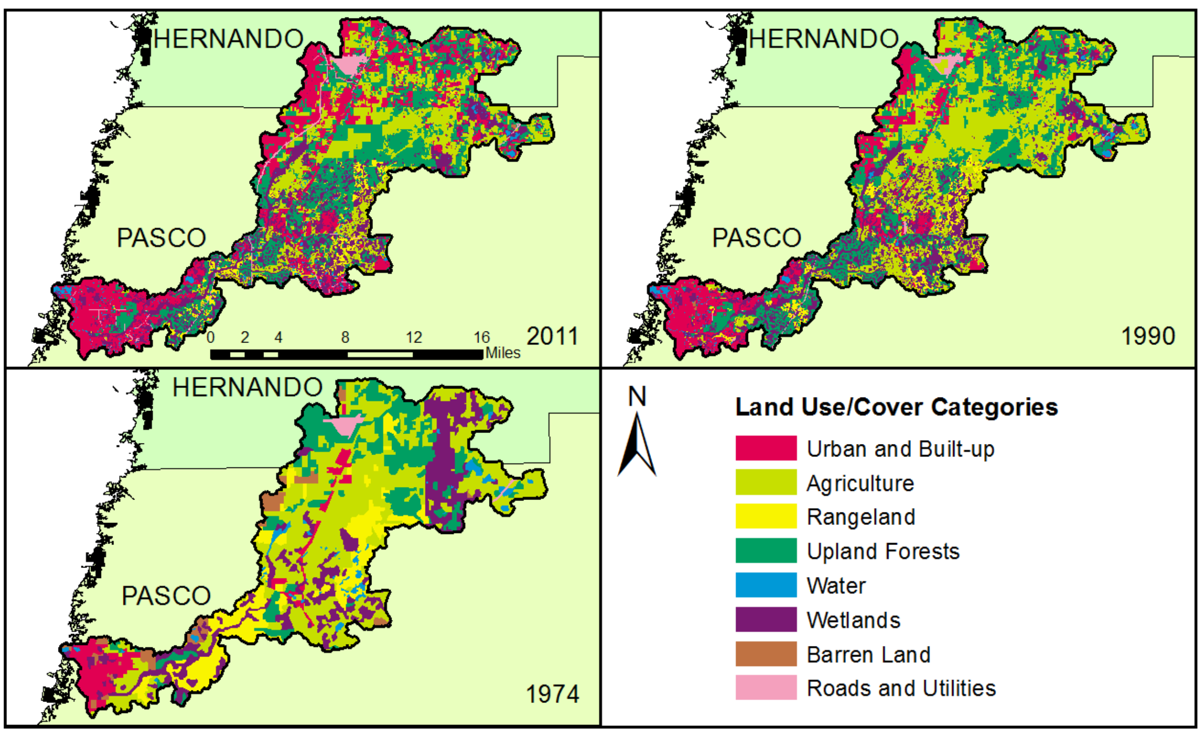


Figure 2-10. Map displaying land-use/cover within the Pithlachascotee watershed as measured in 1974, 1990, and 2011. Categories for 1990 and 2011 follow the Level I FDOT (1999) Florida Land Use, Cover and Forms Classification System (FLUCCS). Data from 1974 were assigned FLUCCS Level I codes based on USGS classification system Level 2 codes (Anderson et al. 1976).

Table 2-1. Land use/Land cover in the Pithlachascotee River watershed in 1974, 1990, and 2011. Categories follow the Level I FDOT (1999) Florida Land Use, Cover and Forms Classification System (FLUCCS). Data from 1974 were assigned FLUCCS Level I codes based on USGS classification system Level 2 codes (Anderson et al. 1976).

Land Use/Land Cover	1974		1990		2011	
	Acres	Percentage	Acres	Percentage	Acres	Percentage
Agriculture	46,194	39.2	38,833	33.0	25,617	22.2
Wetlands	21,727	18.5	20,953	17.8	21,625	18.7
Upland Forests	19,593	16.6	34,341	29.2	33,531	29.1
Rangeland	15,237	12.9	3,874	3.3	3,340	2.9
Urban and Built-up	7,291	6.2	16,699	14.2	28,876	25.0
Barren Land	3,719	3.2	227	0.2	154	0.1
Water	2,777	2.4	1,732	1.5	1,949	1.7
Roads and Utilities	1,209	1.0	1,097	1.0	334	0.3

2.7 Regional Water Withdrawals

Water use in the vicinity of the Pithlachascotee River watershed has been the subject of considerable study and management action in recent decades. A portion of the river watershed lies within what is known as the Northern Tampa Bay Water Use Caution Area (NTBWUCA), which was designated by the Southwest Florida Water Management District in 1989. The NTBWUCA was established due to concerns about the effects of groundwater withdrawals on water levels and flows in lakes, wetlands, and streams within the region.

Much of the technical basis for establishing the NTBWUCA was described in a 1996 District report (SWFWMD 1996) for the Northern Tampa Bay Water Resources Assessment Project (NTBWRAP). The study area of the NTBWRAP extended from south of Tampa into Hernando County, making it slightly larger than the NTBWUCA at the time. The boundaries of the NTBWUCA were expanded in 2007 to include all of Pasco County and the northeast corner of Hillsborough County. In addition to summarizing the climate and hydrogeological setting of the region, the NTBWRAP examined trends and relationships among historical water use, groundwater aquifers, and surface water features.

The NTBWRAP report presented data for five major water use categories: public supply, agriculture, industry, mining, and recreation. A total of 334 million gallons of water per day (mgd) was withdrawn in the NTBWRAP area in 1993, comprised of 246 mgd of ground-water and 88 mgd of surface water. The majority of the surface water withdrawals are from the Hillsborough River and Tampa Bypass Canal in Hillsborough County. Most of the water withdrawn in 1993 was for public supply, which accounted for seventy-five percent of the estimated total water use and seventy-four percent of the ground-water use in the NTBWRAP area.

Groundwater withdrawals from eleven wellfields maintained and operated by Tampa Bay Water provide water to approximately 2.3 million people (Figure 2-11). Of these wellfields, three are located within the boundaries of the Pithlachascotee watershed and a total of eight are located within 16 kilometers (10 miles) of watershed (Figure 2-6). Although there are other small groundwater users in the vicinity of the Pithlachascotee River, withdrawals from Tampa Bay Water’s wellfields comprise the large majority of the groundwater use and have the greatest effect on aquifer levels and surface water features in the region.

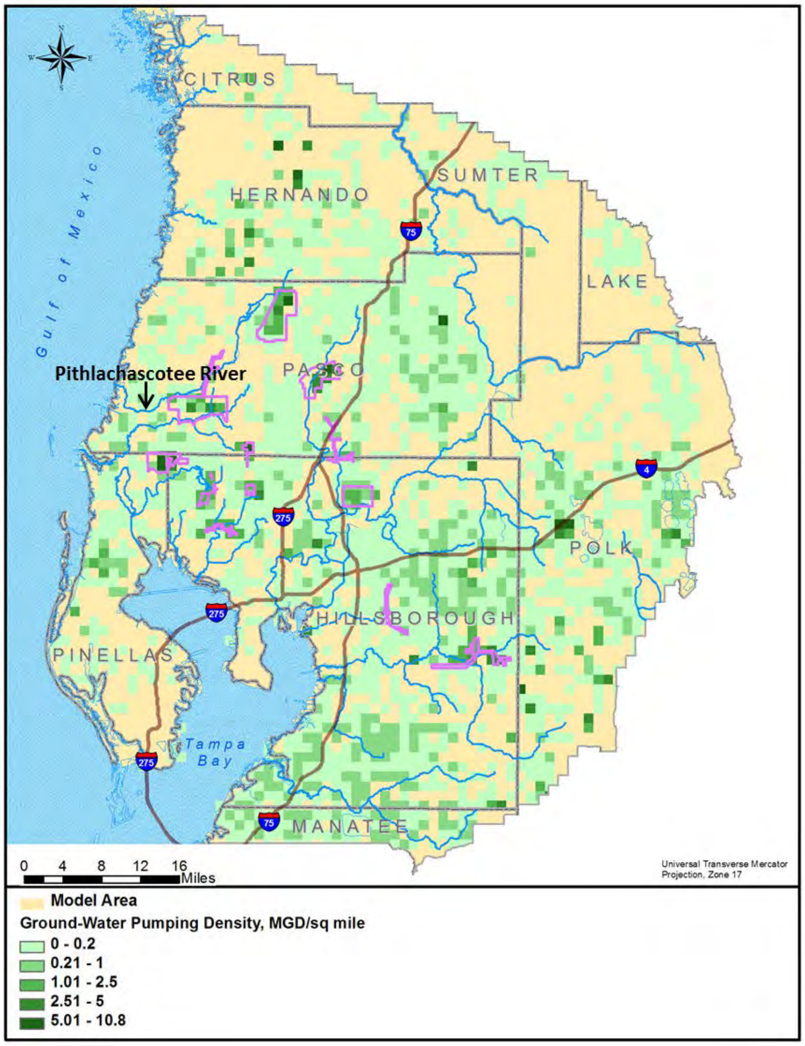


Figure 2-11. Average groundwater withdrawal rates in the geographic domain of the Northern Tampa Bay Integrated Model for the years 1989-2006. Boundaries of wellfields operated by Tampa Bay Water shown in purple. Image modified from Geurink and Basso (2013).

A portion of the Starkey wellfield lies within the watershed boundary (Figure 2-12). The North Pasco system is comprised of two production wells, one within the river watershed and one just north of the watershed boundary. The Cross Bar wellfield lies within the drainage basin to Crews Lake, in the northern portion of the river watershed. The Eldridge-Wilde and South Pasco wellfields are the two nearest wellfields located outside and to the south of the river watershed.

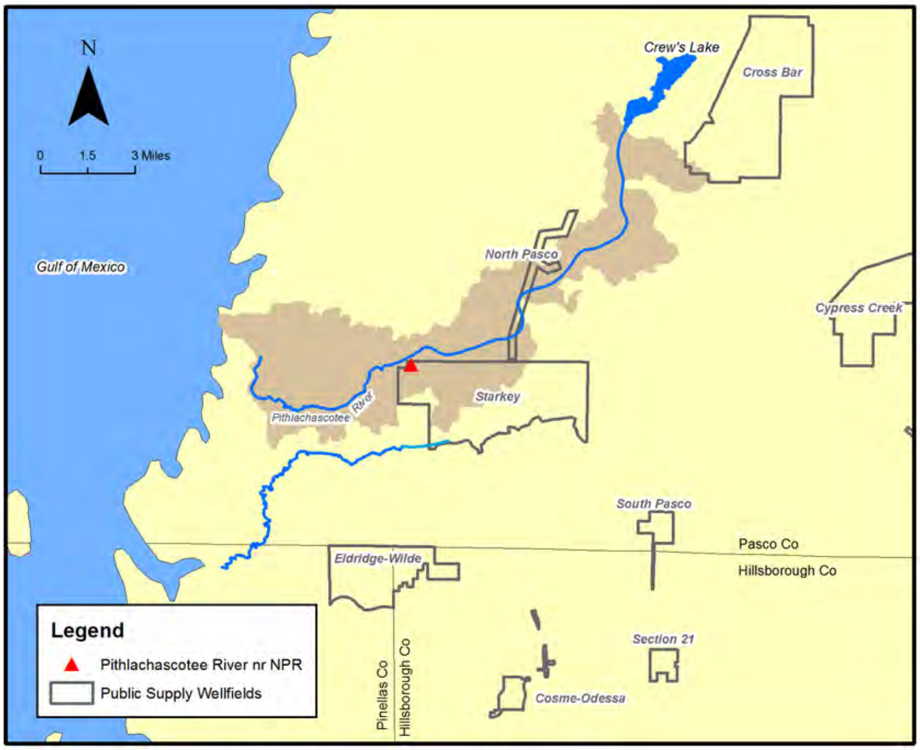


Figure 2-12. Locations of wellfields operated by Tampa Bay Water near the Pithlachascotee River, showing the river watershed below Crews Lake. The lower portion of the watershed is shaded brown.

The NTBWRAP report and other investigations provided technical support for long-standing concerns that groundwater withdrawals had resulted in lower aquifer levels in the region and lower water levels in a number of lakes, wetlands and streams, which had resulted in adverse ecological impacts to these resources. In response to these findings, the District adopted minimum flows and levels for several lakes, wetlands, and the UFA in the Northern Tampa Bay Region (Chapter 40D-8, F.A.C.). To address recovery of these natural systems, the District also adopted the Regulatory Portion of the Recovery Strategy for Pasco, Northern Hillsborough, and Pinellas Counties, also known as the "Recovery Strategy" (Rule 40D-80.073, F.A.C.). Among other stipulations, the Recovery Strategy required that groundwater withdrawals from Tampa Bay Water's central system facilities would be reduced so as not to exceed 90 mgd on a 12-month moving average basis by 2008.

Implementation of the Recovery Strategy prescribed greater reliance on alternative water supplies, including surface waters and a sea-water desalination facility. In keeping with the intent of the Recovery Strategy, Tampa Bay Water now obtains surface water supplies from the Tampa Bypass Canal, the Hillsborough and Alafia rivers, and maintains a 25 mgd capacity seawater desalination plant on Tampa Bay.

Implementation of the Recovery Strategy has resulted in a reduction in total groundwater withdrawals from Tampa Bay Water's wellfield network. For example, five-year average groundwater withdrawal rates for the eleven wellfields that comprise the central system facilities decreased from 151.8 mgd (1997-2001) to 81.6 mgd (2008-2016).

In 2010, the District adopted a second phase of recovery for the area, entitled the Minimum Flows and Levels Recovery Strategy and Environmental Resources Recovery Plan for the Northern Tampa

Bay Water Use Caution Area (Rule 40D-80.073, F.A.C.), or the “Comprehensive Plan.” Among other actions, the Comprehensive Plan requires Tampa Bay Water to assess the water resources of the area and identify unacceptable adverse impacts that may be caused by groundwater withdrawals associated with the maximum permitted withdrawal rate of 90 mgd. Furthermore, the Comprehensive Plan requires Tampa Bay Water to develop a plan to address any identified unacceptable adverse impacts by 2020.

Average annual withdrawal rates from the eight wellfields that are closest to the Pithlachascotee River show the effects of increased pumping and wellfield development from the 1930s to the 1980s followed by reductions due to the Recovery Strategy and Comprehensive Plan (Figure 2-13). The Cosme-Odessa, Eldridge-Wilde, and Section 21 wellfields represent the longest operating facilities with pumping starting in the 1930s, 1950s, and 1960s, respectively. The South Pasco, Starkey, Cross Bar, and Cypress Creek wellfields represent a second suite of wellfields coming on-line, with withdrawals beginning in the 1970s or 1980s. Combined average withdrawals from these seven systems peaked near 120 mgd from the late 1980s until 2000. Following implementation of the Comprehensive Plan, withdrawals from these wellfields has dropped to an average of 57.1 mgd for the six-year period from 2008 to 2013.

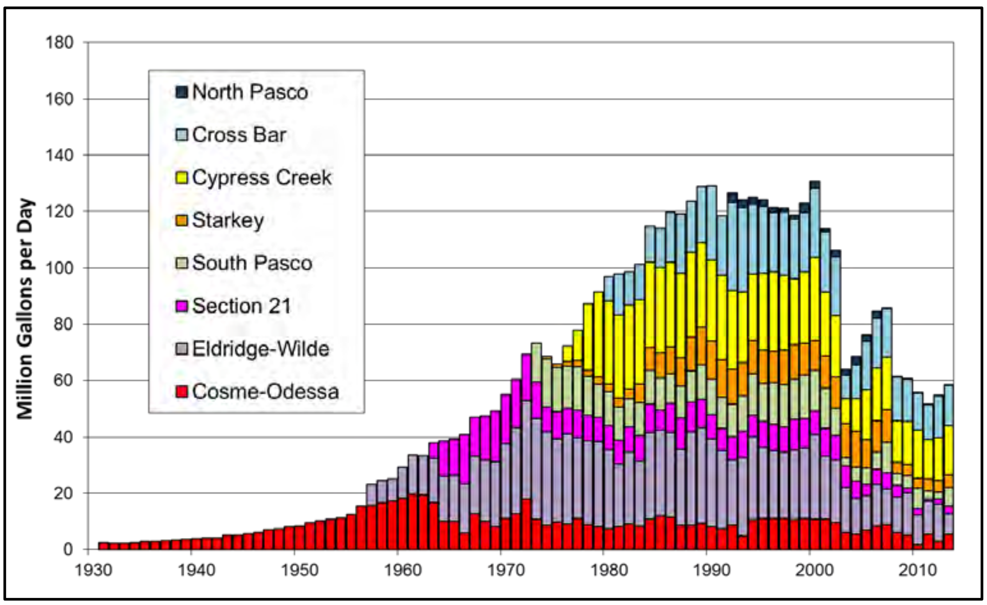


Figure 2-13. Average yearly withdrawal rates for the eight wellfields shown in Figure 2-6 for the years 1931 through 2013.

In addition to the regional wellfield withdrawals, there is a permitted (Water Use Permit Number 20013348.000) surface water withdrawal just downstream from the Pithlachascotee River near New Port Richey gage. In accordance with permit conditions, up to 180,000 gallons per day an annual basis and up to 720,000 gallons per day during the highest water use month the river can be withdrawn from the river. Water withdrawn from the river is pumped to Grassy Lake (a.k.a., Grass Prairie) to augment water levels in this small, natural basin on the Starkey Wellfield. The river withdrawals are balanced by an increase in discharge to the river associated with structural modifications made to reduce flooding in the Lake Worrell area of Pasco County, north of the river.

2.8 Flow Characteristics

Flow in the Pithlachascotee River is measured at (i.e., reported for) four USGS gaging stations: Pithlachascotee River near New Port Richey, FL (No. 02310300), Pithlachascotee River near Fivay Junction, FL (No. 02310280); Pithlachascotee River below Suncoast Parkway near Fivay Junction, FL (No. 02310288); and Pithlachascotee River at Main Street at New Port Richey, FL (No 02310308) (Table 2-2;Figure 2-2). Observed flows are also recorded at sites on two small tributaries to the upper river: Fivemile Creek below Suncoast Parkway near Fivay Junction, FL (No. 02310286) and were collected historically at Jumping Gully at Loyce, FL (No. 02310240). In addition to these tributaries, Crews Lake occasionally discharges to the upper reaches of the Pithlachascotee River during the wet season.

Flow from 180 square miles, or approximately ninety percent of the entire watershed area (Coble 1973) is measured at the Pithlachascotee River near New Port Richey gage. This gage was moved to its current location from a site located 1.1 miles downstream in May 1981, and this relocation has affected the continuity of the flow record for the site. The Pithlachascotee River near Fivay Junction gage is located about 21 miles upstream of the river mouth, and is used to measure flow from 150 square miles, including the outflow from Crews Lake.

Observed flow data for the Pithlachascotee River near New Port Richey and Pithlachascotee River near Fivay Junction gages were available through September 30, 2013 at the time of preparation of this report. To incorporate the most recent observed flow data possible, many of the analyses District staff present here are based on data from these two sites for water years that run from October 1st through September 30th, with the ending calendar year used to denote the water year (e.g., water year 2013 ended on September 30, 2013). District staff have not summarized flow data for the Pithlachascotee River below Suncoast Parkway near Fivay Junction and Pithlachascotee River at Main Street at New Port Richey gage sites, as flows for the sites were not available when our minimum flow analyses were conducted.

Table 2-2. USGS flow gages on the Pithlachascotee River and its tributaries.

Gage Name	Gage Number	Drainage Area	Period of Record
Pithlachascotee River near Fivay Junction, FL	02310280	150 mi^2	October 1, 1983 - present
Pithlachascotee River below Suncoast Parkway near Fivay Junction, FL	02310288	Not determined	March 8, 2014 - present
Pithlachascotee River near New Port Richey, FL	02310300	180 mi^2	April 1, 1963 - present
Pithlachascotee River at Main Street at New Port Richey, FL	02310308	195 mi^2	December 5, 2013 - present
Jumping Gully at Loyce, FL	02310240	NA	June 1, 1964 - January 10, 1988; and January 23, 1998 - September 30, 2010
Fivemile Creek below Suncoast Parkway near Fivay Junction, FL	03210286	8.8 mi^2	October 23, 2007 - present

The lower Pithlachascotee River is influenced by astronomical tides in the Gulf of Mexico. Tidal water levels have been measured by the USGS at four gage sites: Pithlachascotee River at Rowan Road near New Port Richey FL (No. 02310304); Pithlachascotee River at New Port Richey FL (No.

02310307); Pithlachascotee River at Main St at New Port Richey FL (No. 02310308); and Pithlachascotee River at Port Richey, FL (No. 02310310). See Figure 2-2 for locations of these gage sites and Section 3.2 of this report for additional discussion of tidal fluctuations in the river.

2.8.1 Mean Flow Rates and Area-Based Runoff

Water from precipitation within a drainage basin will eventually exit the basin as runoff, infiltration into the groundwater, evaporation, or transpiration. The unconfined UFA within the Pithlachascotee basin results in high rates of infiltration, which keeps streamflow in the river lower than would be expected based on rainfall alone. The mean flow for the Pithlachascotee River near New Port Richey gage for the entire period of record (April 1963 through September 2013) is 25.9 cfs, which is equivalent to an area-based runoff rate of 1.95 inches of water distributed over the 180 mi^2 drainage basin above the gage. A cumulative frequency distribution of daily flows for the period of record at the Pithlachascotee River near New Port Richey gage illustrates how often flows are very low in this small river (Figure 2-14). Approximately 23 percent of the time flows in the river are 1 cfs or less, often at or near zero flow. The median flow (50^{th} percentile) is 6.1 cfs. The highest flow recorded on the river (2,180 cfs) occurred on Jun 25, 2012, when over 17 inches of rain fell over a five-day period at the Starkey rainfall station located near the gage. The mean flow for Pithlachascotee River near Fivay Junction gage is 5.5 cfs, equivalent to an average runoff rate of 0.5 inches of water distributed over the 150 mi^2 drainage-basin area for this gage. Stream flow above the Fivay Junction gage only makes up about 20 percent of mean flow observed at the near New Port Richey gage. For the Pithlachascotee River between the near New Port Richey and near Fivay gages, mean flow is 20.4 cfs which is equivalent to an average runoff rate of 9.2 inches of water over the 30 mi^2 section of the drainage basin.

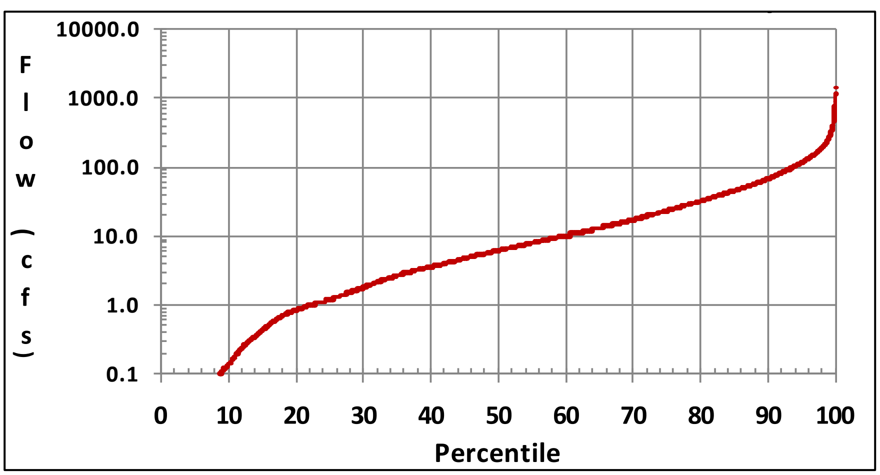


Figure 2-14. Cumulative frequency distribution curve for flows at the Pithlachascotee River near New Port Richey (No. 02310300) gage for the period of record (April 1, 1963 through September 30, 2013). Flows less than 0.1 cfs were converted to 0.1 cfs for plotting purposes.

These rates of basin runoff (1.95 in. over 180 mi^2 and 0.5 in. over 150 mi^2) are lower than for streams in other parts of west-central Florida. For example, over the same period for which flows are available for the Pithlachascotee River near New Port Richey gage (April 1963 through September 2013), the average runoff rate for the Hillsborough River near Zephyrhills was 12.8 inches, and the Peace River at Arcadia was 8.8 inches. The average runoff rate for the Anclote near Elfers gage, located just three miles south of the New Port Richey gage, was 10.8 inches.

The unusually low runoff rates for the Pithlachascotee River basin were first described by Coble (1973), who suggests that differences in runoff rates between the Pithlachascotee and the Anclote rivers were caused by differences in watershed and hydrogeological characteristics. Because watershed area is used to calculate area based runoff, the low runoff rates reported for the Pithlachascotee River basin are related to the relatively large watershed area reported for the river above the Fivay Junction gage, which includes the drainage basin for Crews Lake (see Figure 2-2). In addition, the lower runoff of the Pithlachascotee River watershed is attributable to its higher-infiltration sandy soils and a deeper water table relative to the neighboring Anclote River basin to its south. Also, the UFA is unconfined and internally drained with active karst processes in much of the northern portion of the Pithlachascotee River basin (Geurink and Basso 2013).

2.8.2 Seasonal Flow Characteristics

The typical seasonal distribution of flows in the Pithlachascotee River generally follows the seasonal pattern of rainfall in west-central Florida, with high flows occurring during a four-month summer wet season (June to September) that follows a dry season that extends from October to May. However, the relative range of seasonal streamflow is typically greater than for seasonal rainfall (Figure 2-15). Streamflow reaches its lowest values relative to rainfall in May and June, when potential evapotranspiration rates are high, groundwater levels are low, and there is surface water storage available in sinks, depressions and wetlands. In the late summer and fall, surface and ground-water levels are higher, soils are more saturated, and there is much greater streamflow production for each unit of rainfall, resulting in a response lag in the relationship between seasonal rainfall and flow, with peak flows typically occurring in August and September.

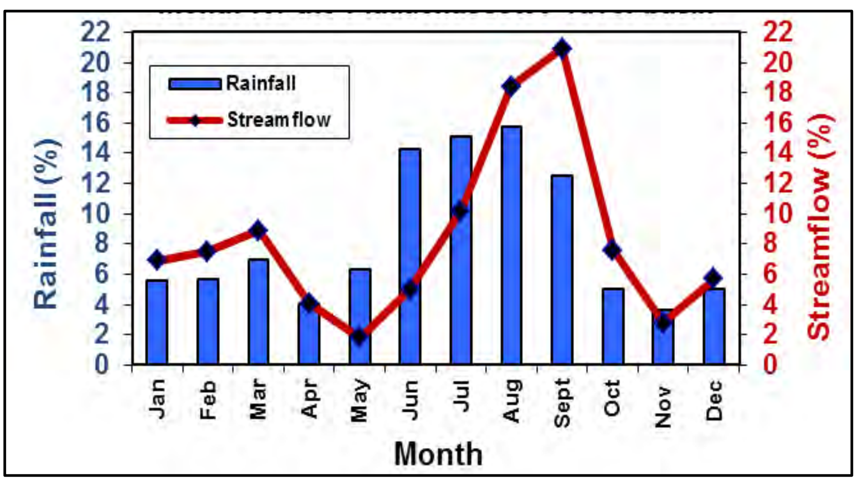


Figure 2-15. Monthly rainfall and streamflow for the Pithlachascotee River watershed. Data taken from the Pasco County rainfall estimates available from the District web site at: http://www.swfwmd.state.fl.us/data/hydrologic/rainfall_data_summaries, and flows at the Pithlachascotee River near New Port Richey gage (No. 02310300) for water years 1964 through 2013.

2.8.3 Flows Before and After Relocation of the Long-term Streamflow Gage

With over 50 years of flow records, the Pithlachascotee River near New Port Richey gage provides the longest period over which to examine temporal changes and trends in river flow. However, the location of the gage was moved 1.1 miles upstream to its present location on May 27, 1981, and the

USGS (2016) reports that that this relocation makes the pre-and post-relocation flow records not equivalent due to changes in the base flow characteristics between the two gage locations.

Relocation of the long-term gage was associated with changes in streamflow reported for the site. Following relocation, an increase in low-flow events is apparent (Figure 2-16). Mean flow for the period from 1964 through 1980, prior to relocation of the gage was 30.5 cfs (s.d. = 64.0 cfs), while mean flow from 1982 through 2013 was 23.9 cfs (s.d. = 62.5 cfs). Prior to 1981, there were no days with zero discharge; following relocation, zero discharge days have been common (Figure 2-17).

Factors other than relocation of the gage may have affected reported flows at the Pithlachascotee River near New Port Richey gage. District staff found no evidence, however, of annual or seasonal rainfall differences between the period prior to and after relocation of the gage (see Appendix 2A). As discussed in Section 2.7, historical groundwater withdrawals from nearby municipal supply wellfields have affected flows in the river, although this impact has been reduced in recent years as a result of withdrawal reductions.

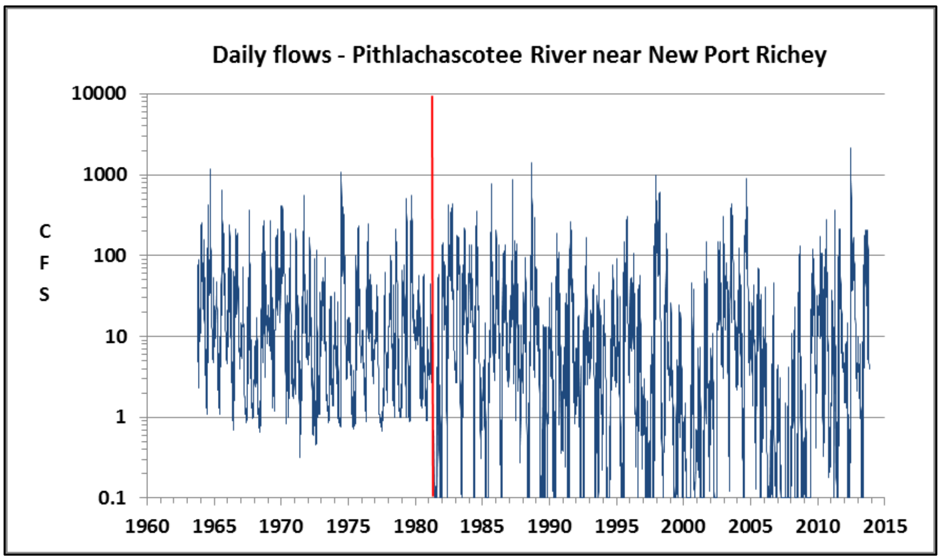


Figure 2-16. Daily streamflow at the Pithlachascotee River near New Port Richey gage (No. 02310300) for April 1, 1963 through September 30, 2013. Values less than 0.1 cfs converted to 0.1 cfs for plotting purposes. Red vertical line identifies date when the gage was moved 1.1 miles upstream.

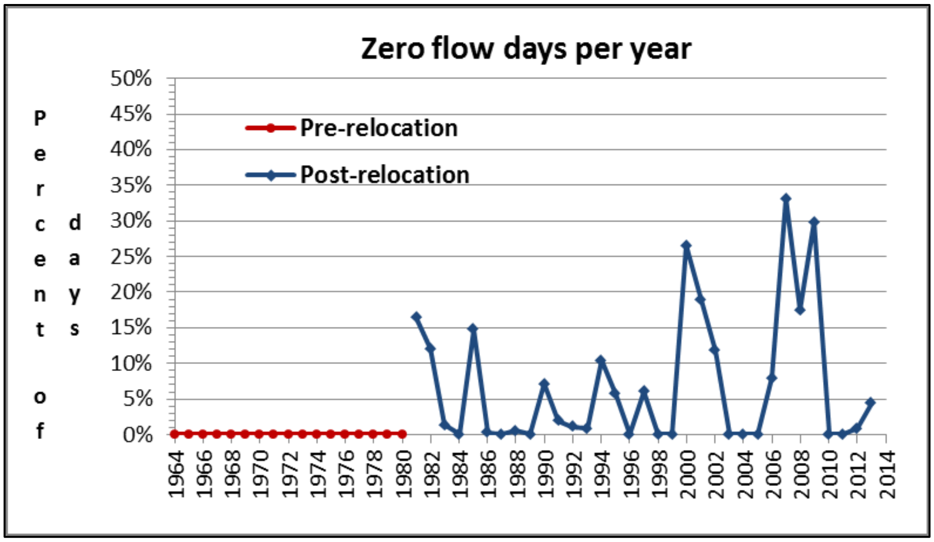


Figure 2-17. Percentage of zero flow days per year for the Pithlachascotee River near New Port Richey gage (No. 02310300) for water years 1964 through 2013. Pre-location versus post-relocation refers to periods before and after the gage was moved 1.1 miles upstream. Pre- and post-location flow records are not equivalent due to changes in base flow characteristics between the two locations and also due to temporal differences in groundwater withdrawals. Water year 1981 is assigned to the post-relocation period.

2.9 Model Simulations of the Effects of Historical Groundwater Pumping on River Flows

2.9.1 Numerical Models

A number of regional groundwater flow models have included the Pithlachascotee River area. Ryder (1982) simulated the entire extent of the Southwest Florida Water Management District. In 1993, the District completed the Northern Tampa Bay groundwater flow model that covered a 2,000 square mile area of Hillsborough, Pinellas, Pasco, and Hernando Counties (SWFWMD 1993). In 2002, the USGS simulated the entire Florida peninsula in their Mega Model of regional groundwater flow (Sepulveda 2002). The most recent and advanced simulation of southwest Pasco County and the surrounding area is the Integrated Northern Tampa Bay (INTB) model (Geurink and Basso 2013). The construction and calibration of this model was part of a cooperative effort between the District and Tampa Bay Water, a regional water utility that operates 11 major wellfields in the area. The INTB Model covers a 4,000 square-mile area of the Northern Tampa Bay region (Figure 2-18).

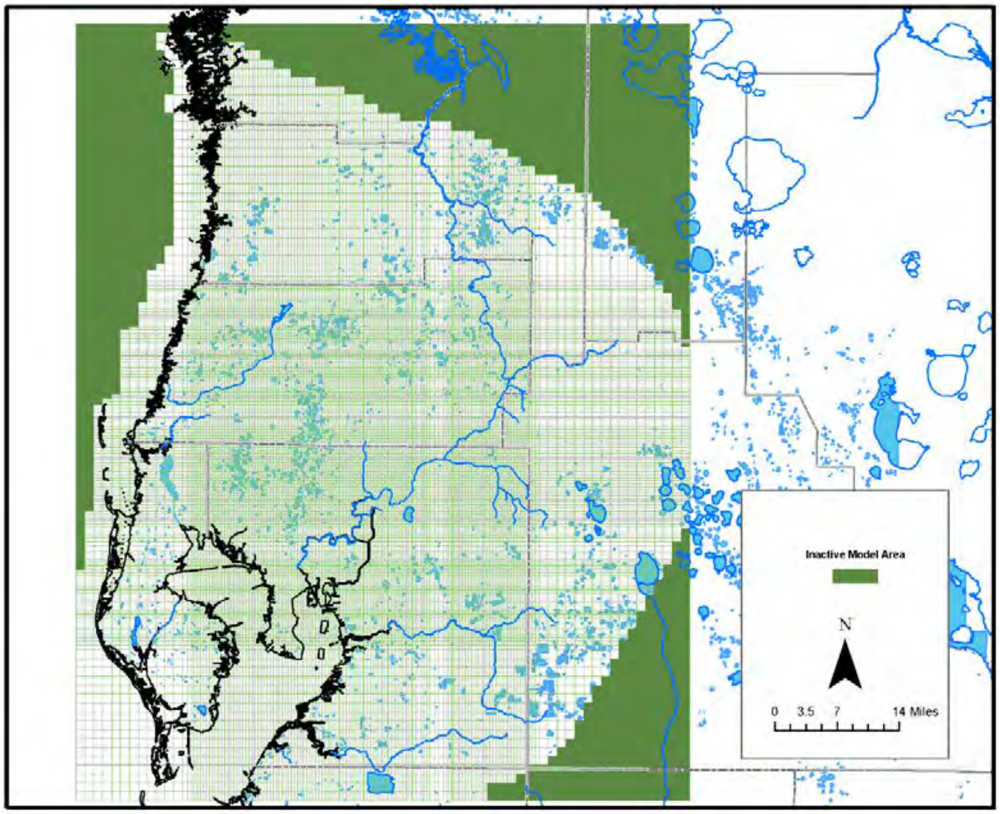


Figure 2-184. Groundwater grid used in the INTB model.

An integrated model represents the most advanced simulation tool available to the scientific community in water resources investigations. It combines the traditional ground-water flow model with a surface water model and contains an interprocessor code that links both systems. One of the many advantages of an integrated model is that it simulates the entire hydrologic system. It represents the "state-of-art" tool in assessing changes due to rainfall, drainage alterations, and withdrawals.

The model code used to run the INTB simulation is called the Integrated Hydrologic Model (IHM) which combines the HSPF surface water code and the MODFLOW ground-water code using interprocessor software. During the INTB development phase, several new enhancements were made to move the code toward a more physically-based simulation. The most important of these enhancements was the partitioning of the surface into seven major land-use segments: urban, irrigated land, grass/pasture, forested, open water, wetlands, and mining/other. For each land segment, parameters were applied in the HSPF model consistent with the land cover, depth-to-water table, and slope. Recharge and evapotranspiration (ET) potential were then passed to each underlying MODFLOW grid cell based on an area weighted-average of land segment processes above it. Other new software improvements included a new ET algorithm/hierarchy plus allowing the model code to transiently vary specific yield and vadose zone storages. The model underwent peer review by a team of outside consultants in early 2013 (WEST Consultants, Inc., et al. 2013). Their findings found that the INTB model was "…extremely well-conceived, that the model made good use of the tremendous amount of available data, and that the final model was well calibrated."

The INTB model contains 172 sub-basin delineations in HSPF (Figure 2-19). There is also an extensive time series of 15-minute rainfall data from 300 stations for the period 1989-1998, a well pumping database that is independent of integration time step (1-7 days), a methodology to incorporate irrigation flux into the model simulation, construction of an approximate 150,000 river cell package that allows simulation of hydrography from major rivers to small isolated wetlands, and GIS-based definition of land cover/topography. An empirical estimation of ET was also developed to constrain model derived ET based on land-use and depth-to-water table relationships.

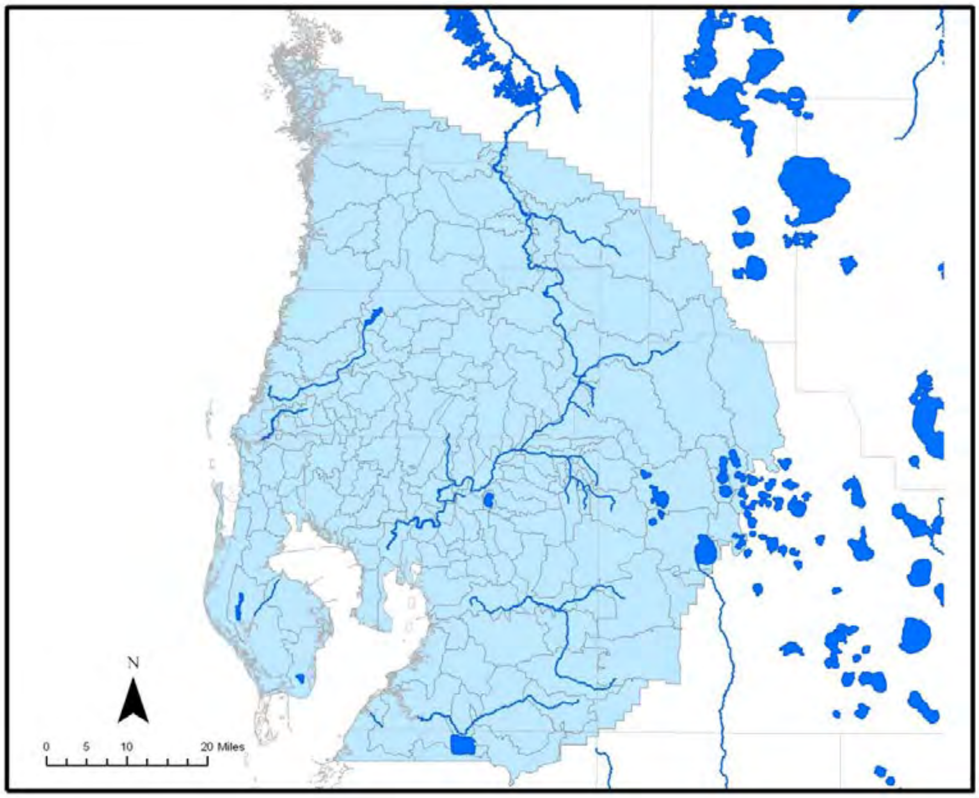


Figure 2-19. HSPF sub-basins in the INTB model.

The MODFLOW gridded domain of the INTB contains 207 rows by 183 columns of variable spacing ranging from 0.25 to one mile. The groundwater portion is comprised of three layers: a surficial aquifer (layer 1), an intermediate confining unit or aquifer (layer 2), and the UFA (layer 3). The model simulates leakage between layers in a quasi-3D manner through a leakance term.

The INTB model is a regional simulation and has been calibrated to meet global metrics. The model is calibrated using a daily integration step for a transient 10-year period from 1989-1998. A model verification period from 1999 through 2006 was added to assess the models performance outside of the calibration period. Model-wide mean error for all observation wells in both the surficial (SAS) and Upper Floridan aquifers is less than 0.2 feet. Mean absolute error was less than two feet for both the SAS and UFA. Total streamflow and springflow mean error averaged for the model domain is each less than 10 percent for both the calibration and verification periods. Further information regarding the construction and calibration of the INTB model is found in Geurink and Basso (2013).

Simulated flows of the Pithlachascotee River at both the USGS near (nr) New Port Richey gage and USGS near Fivay Junction gage further upstream were simulated well during the calibration period from 1989-98 (Appendix 2B). Average streamflow for the 10-year period was within five percent of measured at both stations. Simulated mean flows were higher for the verification period by 5.4 cfs or

28 percent above the observed mean value of 18.9 cfs from 1999-2006 at the nr NPR gage. This was primarily due to over simulation of flows during the hurricane events of 2004.

On the groundwater side, mean error for 66 surficial aquifer wells within the Pithlachascotee-Anclote sub-region of the INTB model was -0.2 feet (ft) for the 10-year calibration period. Mean absolute error for these same wells was 1.1 ft. Mean error for 48 upper Floridan aquifer wells within the Pithlachascotee-Anclote sub-region of the INTB model was -0.4 feet (ft). Mean absolute error for these same wells was 1.3 ft. Statistics for the verification period were slightly worse but still met calibration targets.

2.9.2 Numerical Modeling to Estimate Effects of Historic Groundwater Withdrawals

District staff used simulations completed with the INTB model to estimate the effects of historical groundwater pumping on flows in the Pithlachascotee River. Modeling results, which are described in detail in Basso (2014) included as Appendix 2C of this report, included predicted reductions in yearly mean and median flows from 1955 through 2007 based on Tampa Bay Water groundwater withdrawals from 1997 and all other user withdrawals from 1989-2000. Results for the Starkey Wellfield and the North Pasco wells are grouped together in Appendix 2C, so District staff refer to seven wellfields rather than eight in our discussion presented here.

The method used to estimate reduction in yearly mean and median streamflow values was based on assessing individual wellfield impacts by running several scenarios with the INTB model for a twelve year period, from 1989 through 2000. One scenario included simulation of zero groundwater withdrawals to simulate an INTB-modeled baseline flow condition. Another included all groundwater withdrawals that were in effect at that time of the model run, based on estimated and measured withdrawal values from all users except Tampa Bay Water's 11 central system wellfield which were held at a constant rate of 150 mgd based on their pumping distribution in 1997. Additional scenarios were run in which withdrawals at each of the seven wellfields were individually set to zero to examine the relative effect of each wellfield on flow in the river. Changes in the mean and median daily flows of the river from 1989 through 2000 for the various scenarios were compared to the INTB-modeled baseline flow condition.

District staff found that the relative effect of the different wellfields on river flows varied substantially, based on location within the river watershed. The Section 21 and Cosme-Odessa wellfields exhibited negligible effects, and the Starkey and North Pasco wellfields, which extend into the river watershed, exhibited the largest predicted impact on river flow.

The greatest reduction in mean and median flows was predicted in the 1990s when withdrawals from the seven wellfields averaged around 120 mgd (refer to Figure 2-7). Using the 1997 distribution of groundwater withdrawals from Tampa Bay Water wellfields (150 mgd) with a total of pumping rate of 239.4 mgd within the Central West-Central Florida Groundwater Basin, the predicted reductions in mean flows at the Pithlachascotee River near New Port Richey gage for a 12-year simulation was 8.3 cfs, and the predicted median flow reduction was 4.5 cfs. These results represented an approximate 31 percent reduction in mean flow and 57 percent reduction in median flow from non-pumping river flow in the model.

Reductions in pumping as part of the Comprehensive Plan for the Northern Tampa Bay Water Use Caution area have resulted in reduced impacts on Pithlachascotee River flow. From 2008-2016, groundwater withdrawals from Tampa Bay Water's 11 central system wellfields averaged 81.6 mgd. Using the 2008 distribution of pumping for all 11 central system wellfields and adjusting upward to equal a total of 90 mgd, mean and median flow impacts to the river averaged 4.6 and 2.0 cfs, respectively. These results were based on an 11-year simulation run (1996-2006) from the INTB model. All other users were pumping actual amounts from 1996-2006. This represented a 13 percent reduction in mean flow and 24 percent reduction in median flow from non-pumping river flow in the model under the 90 mgd Tampa Bay Water permitted withdrawal conditions. Current Tampa Bay Water withdrawal impacts using the 2014 actual distribution of pumping are included in Chapter 6 of this report.

2.10 Water Quality

2.10.1 Water Body Classification

Under Rule 62-302.200, F.A.C., Florida's surface water quality standards consist of four components: 1) the designated use or 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. Each surface water body in Florida is classified according to its present and future most beneficial use, referred to as its designated use, with class-specific water quality criteria for select physical and chemical parameters, which are established to protect the water body's designated use (Chapter 62-302, F.A.C.).

All waters of Pasco County, including the Pithlachascotee River, are classified as Class III waters with a designate uses of fish consumption; recreation; propagation and maintenance of a healthy, well-balanced population of fish and wildlife (Rule 62-302.400, F.A.C.). With regard to compliance with water quality standards, 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 after implementation of technology-based effluent limitations, and also requires development of Total Maximum Daily Loads (TMDLs) for the water bodies. Total Maximum Daily Loads are the amount of pollutant that a receiving water body can assimilate without causing violation of a pollutant-specific water quality standard. The TMDLs development process identifies allowable loadings of pollutants and supports implementation of management strategies for reducing pollutant loads and ensuring applicable water quality standards are attained.

The most recent 303(d) list of impaired Florida waters approved by the United States Environmental Protection Agency (USEPA) in 2010 indicates that the Pithlachascotee River is impaired for dissolved oxygen. This determination was made for a segment of the river identified as Water Basin Identification (WBID) number 1409, which extends from the outlet of Crews Lake to near kilometer 3.5 in the lower river. This segment was considered a Class III freshwater system, which is to be maintained with designated uses of recreation, propagation and maintenance of a healthy, well-balanced populations of fish and wildlife. In making this determination, the USEPA used the dissolved oxygen standard for freshwaters (5.0 mg/L) at the time of that assessment. Since the publication of the USEPA report, the Florida DEP has acknowledged that DO concentrations in many natural, unpolluted Florida water bodes periodically do not meet the 5.0 mg/L standard, and have since published dissolved oxygen standards that based on percent saturation values (Rule 62-302.533, F.A.C.). In an "ecosummary" report, the DEP (2009) notes that observed dissolved oxygen concentrations within WBID number 1409 may not be considered unusual, given expected inputs of nutrients and organic matter from the river's riparian wetlands. Based on the historical impaired DO determination, the USEPA (2013) has identified Total Maximum Daily Loads for WBID 1409 in the Pithlachascotee River.

Updates to the State's "verified list" of impaired waters in the Middle Coastal Planning Unit, which includes the Pithlachascotee River, were adopted by the Florida DEP in 2014, along with a comprehensive statewide "delist list" that identifies water body parameters that have been removed from the verified list based on delisting methods included in Chapter 62-303, F.A.C. The current verified list identifies two impaired WBIDs associated with the river. The Pithlachascotee River Tidal segment (WBID number 1409C) extends from river kilometer 3.5 to the mouth of the river and is classified as impaired due to mercury (in fish tissue). Oelsner Park Beach (WBID number 1409B) is classified as impaired due to beach advisories associated with bacteria levels. TMDLs have not been determined for WBID 1409B or 1409C. Neither of these WBIDs, nor the freshwater WBID, 1409, are currently listed as verified impaired for dissolved oxygen.

2.10.2 Water Quality Trends

Although flow can affect water quality, it is not expected that the adoption and maintenance of minimum flows in the Pithlachascotee River will necessarily lead to substantial changes in water quality. However, District staff reviewed selected water quality characteristics of the river to better understand temporal variation in water quality and potential relationships between water quality and flow.

2.10.2.1 Changes in Water Chemistry over Time

The chemical properties of water in the Pithlachascotee River vary with both time and flow. To address confounding of changes in time with changes due to flow, a two-step statistical process was used. First, water quality parameters were modeled with flow using a LOWESS smoother. The LOWESS residuals were then modeled as a function of time using the non-parametric Kendall rank correlation. Significant Kendall tau-b test statistics can be interpreted as indicative of trends in time, independent from trends associated with varying flow. District staff evaluated trends using data on selected water quality parameters and flow data collected by the USGS since 1965 at the Pithlachascotee near New Port Richey gage. Changes in dissolved oxygen concentrations exemplify the statistical process used for our analyses. As shown in Figure 2-20, dissolved oxygen varies with both time (top panel) and flow (middle panel). The LOWESS residuals of DO vs. flow, plotted against time (bottom panel) give a clearer picture of temporal DO changes unaffected by variation in flow.

There are both increases and decreases in water quality parameters over the time period investigated (Table 2-3). Decreasing trends have occurred for specific conductance, dissolved oxygen, fluoride and pH. These changes may be associated with land-use changes and retention time of water throughout the watershed, although District staff did not assess the effect of these factors on river water quality. Increasing temporal trends were noted for chloride, iron, magnesium, potassium, and sodium concentrations (Table 2-3). Among these parameters, iron, magnesium, and potassium are considered indicative of rock-matrix origin (Copeland et al. 2011) suggesting that groundwater has potentially become a larger portion of the streamflow due to low rainfall or other factors, or that the groundwater contributing to the streamflow has been in contact with the rock matrix for relatively longer periods of time than in the past. In contrast, a decreasing trend was observed for fluoride, which Copeland et al. (2011) also considered indicative of rock-matrix origin. Some of the assessed parameters exhibiting temporal trends may be indicative of fertilizer inputs or seawater contributions.

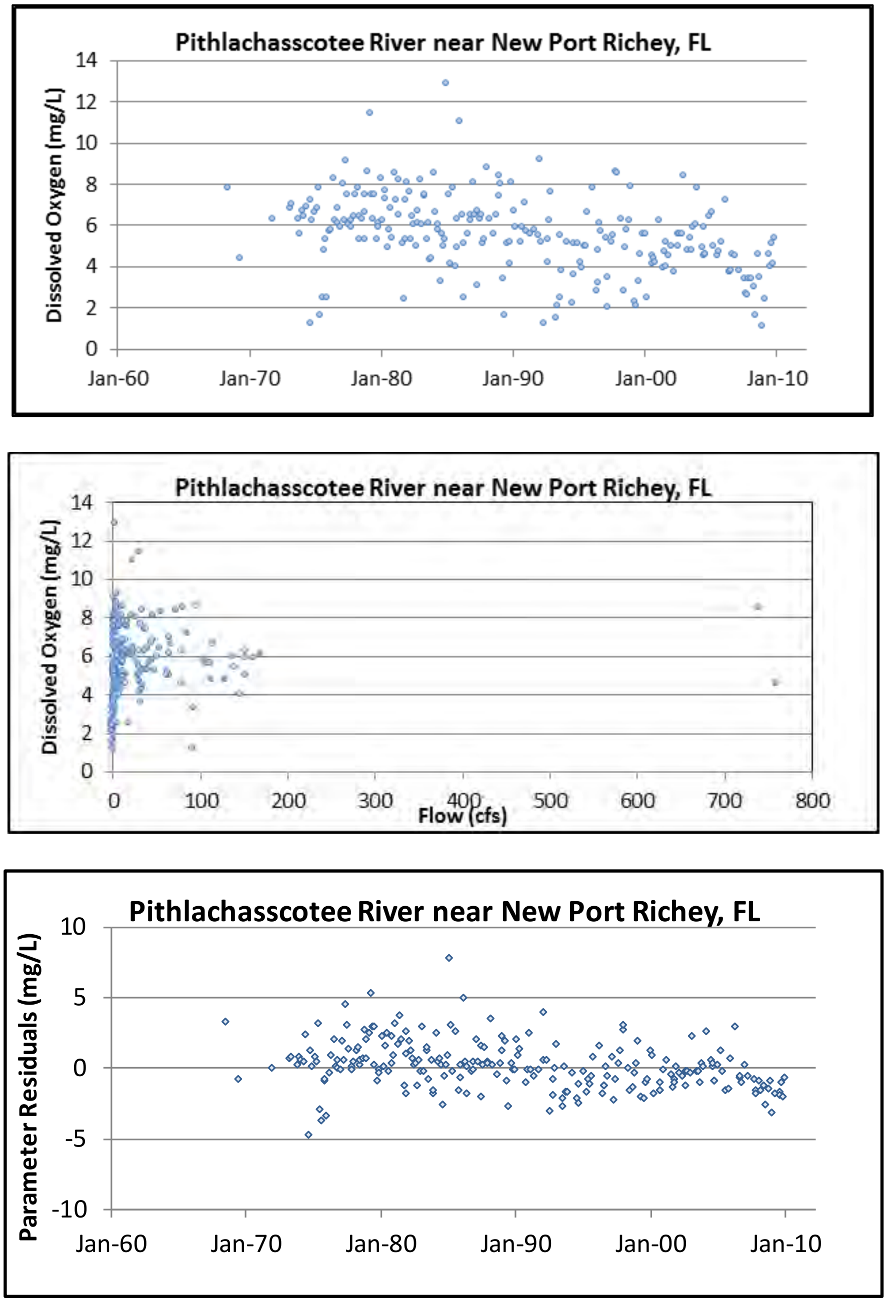


Figure 2-5. Dissolved Oxygen (DO) concentrations over time (top), DO concentration vs. flow (middle), and trends in DO concentration residuals over time (bottom) at the Pithlachascotee River near New Port Richey gage. Note that the bottom plot of residuals corresponds to the significant trend for DO identified in Table 2-3.

Table 2-3. Kendall rank correlations of residuals indicate significant temporal trends in water quality parameters after removing for confounding effects of varying flow. Asterisks identify statistically significant trends, based on an alpha level of 0.05.

Parameter Residual	n	tau-b
Ammonia	193	0.025
Calcium	111	0.095
Chloride	112	0.162*
Conductance	260	-0.021
Dissolved Oxygen	241	-0.267*
Fluoride	111	-0.358*
Hardness	112	0.090
Iron	38	0.401*
Magnesium	111	0.140*
NOx	144	-0.067
pH	232	-0.228*
Phosphorus	193	-0.093
Potassium	110	0.458*
Sodium	110	0.179*
Sulfate	112	0.087

2.10.2.2 Macronutrients: Phosphorus and Nitrogen

Concentrations of the two major macronutrients, phosphorus and nitrogen, have been monitored for Pithlachascotee River for 40 and 50 years respectively. The exact chemical form of the nutrients monitored has varied through time. Phosphorus data has variously been reported by the USGS as total phosphorus, dissolved phosphate, and as ortho-phosphate concentrations. District staff assumed that dissolved phosphate and ortho-phosphate are essentially equivalent for our analyses. Although some of the older data obtained from the USGS were reported as mg/L phosphate, District staff converted and expressed all as mg/L phosphorus (P). These various sources of phosphorus measurements and methodologies used over the 40 years of data collection likely had different method detection limits as indicated by Figure 2-21. Measurements at these limits were treated as measurements. Nitrogen has most often been reported by the USGS as either nitrate or nitrate+nitrite. For our analyses, District staff assumed that total nitrate, dissolved nitrate, and nitrate+nitrite are essentially equivalent, unless both were reported. In cases where both were reported, the highest concentration was used for analysis. Total Kjeldahl nitrogen, total organic nitrogen, ammonia nitrogen and total nitrogen concentrations were not assessed, because considerably fewer observations were available for these parameters.

Observed concentrations of phosphorus (Figure 2-21) in all samples from the river were below the 90^{th} percentile value of 0.87 mg/L P reported by Friedemann and Hand (1989) for Florida streams. No relationship was found between phosphorus concentration and flow (Table 2-3).

Concentrations of combined NO_2 and NO_3 (NOx-N) in the river appear to have increased in recent years relative to an approximate 30-year period of lower concentrations (Figure 2-22), however, the Kendall's Tau test was unable to detect a significant long-term temporal trend in flow-adjusted NOx-N (Table 2-3). The apparent, recent increase in NOx-N concentrations may be at least partially attributable to land-use changes, although District staff did not investigate this potential relationship.

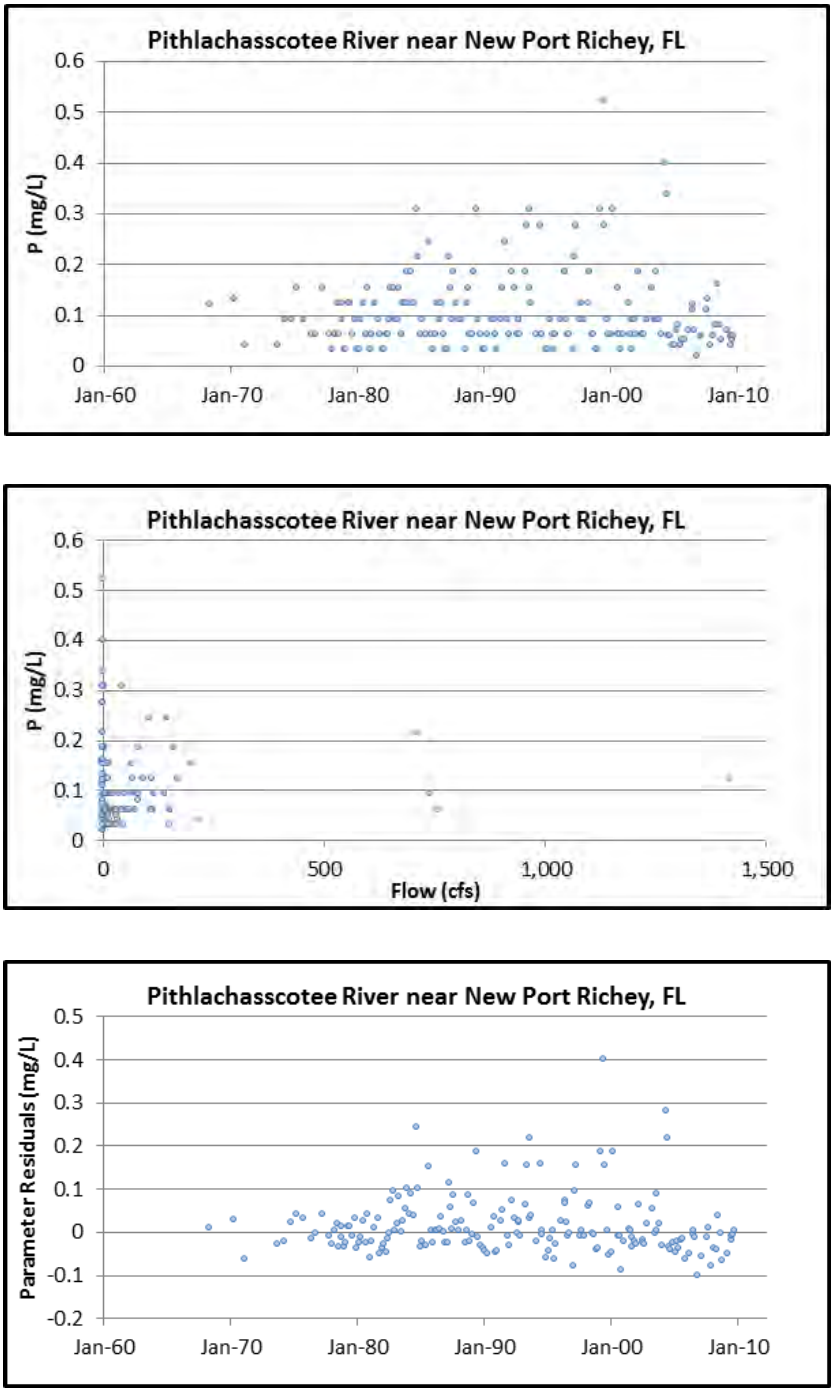


Figure 2-21. Phosphorus concentrations over time (top), phosphorus concentration vs. flow (middle), and trends in phosphorus concentration residuals over time (bottom) at the Pithlachascotee River near New Port Richey gage.

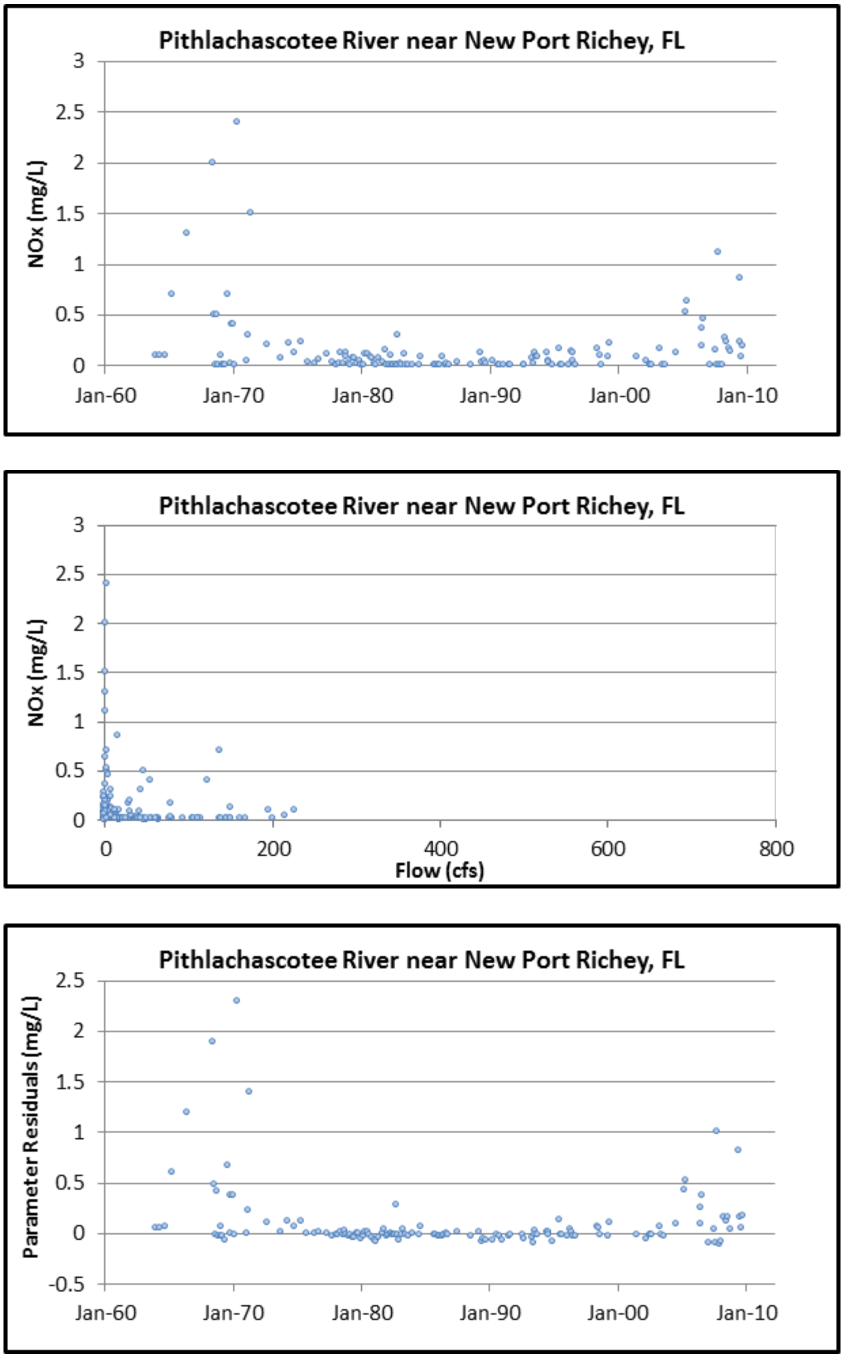


Figure 2-62. Nitrate-nitrite (NOx) concentrations over time (top), NOx concentration vs. flow (middle), and trends in NOx concentration residuals over time (bottom) at the Pithlachascotee River near New Port Richey gage.

2.10.3 Dissolved Oxygen

Because dissolved oxygen (DO) is essential for aquatic life and maintaining healthy aquatic ecosystems, District staff also reviewed DO concentrations in the lower Pithlachascotee River and investigated the potential relationship between DO concentrations and freshwater inflow. For the analyses, staff obtained dissolved oxygen data from a database maintained by DEP for stations within WBID 1409C and the portion of WBID 1409 that is downstream of Rowan Road. These data were combined with data collected by the District during vertical profile surveys on the lower river during May through September 2009. Data for dissolved oxygen were not available for the vertical profile runs that were made during 1985 to 1987. In most cases, the data obtained from the DEP included site-specific surface measurements for sampled dates, while data that the District collected were obtained from vertical profiles and therefore included multiple values for sampled sites on individual sampling dates.

District staff parsed the combined DO data set into a series of five river zones (Table 2-4), because the response of DO to inflow can differ considerably between the upper, middle and lower sections of tidal rivers (SWFWMD 2006, 2008b). The lowermost zone extended from the mouth of the river to KM 3.5, corresponding the boundary of WBID 1409C. The other zones were delineated at two kilometer intervals, extending from kilometers 3.5 to 5.5, 5.5 to 7.5, 7.5 to 9.5, and 9.5 to 11.5.

Hypoxia is the occurrence of low dissolved oxygen concentrations that are clearly detrimental to aquatic life, with DO values of < 2.0 mg/L and sometimes < 3.0 mg/L used to identify hypoxic concentrations (Ecological Society of America 2006, USGS 2006). Based on data collected from rivers within the District, District staff typically use a concentration of < 2.5 mg/L to identify hypoxic waters. Of the 941 DO measurement included in our assessment, only 3 percent were less than 2.5 mg/L, and were typically occurred in deeper zones in the river.

Table 2-4. Summary statistics of dissolved oxygen measurements at various depth in five segments in the Lower Pithlachascotee River for the combined District and Florida DEP databases.

River Zone by River Kilometer*	N	Mean (mg DO L^{-1})	Standard Deviation	Minimum (mg DO L^{-1})	Maximum (mg DO L^{-1})
0.0 to 3.5	292	6.1	1.8	3.1	10.4
3.5 to 5.5	122	4.5	1.1	2.3	7.0
5.5 to 7.5	151	4.1	1.1	2.2	7.0
7.5 to 9.5	194	4.2	1.1	2.5	7.4
9.5 to 11.5	182	4.0	1.2	2.0	8.3
Total	942	-	-	-	-

* River kilometer system for the lower Pithlachascotee River is shown in Figure 3-1.

Dissolved oxygen concentrations were negatively correlated ($p<0.001$) with flow in river zones up to kilometer 9.5 (Figure 2-23, Panels A-D). Reductions in flow associated with the implementation of minimum flows for the Pithlachascotee River area would therefore not be expected to result in reduced DO concentrations in the lower portion of the river. An opposite relationship occurred in the uppermost zone, between kilometers 9.5 and 11.5, where there was a positive correlation between DO concentration and flow (Figure 2-23, Panel E). Dissolved oxygen concentrations in the uppermost zone (above kilometer 9.5) were weakly correlated with flow ($r^2 = 0.28$; $p< 0.0001$), although the slope of the regression was low. A reduction of one cfs flow would result in a DO concentration change of only 0.024 mg/L. Given this weak relationship between DO and flow, District staff predict that implementation of minimum flows will have negligible effect on DO concentrations in the Pithlachascotee River.

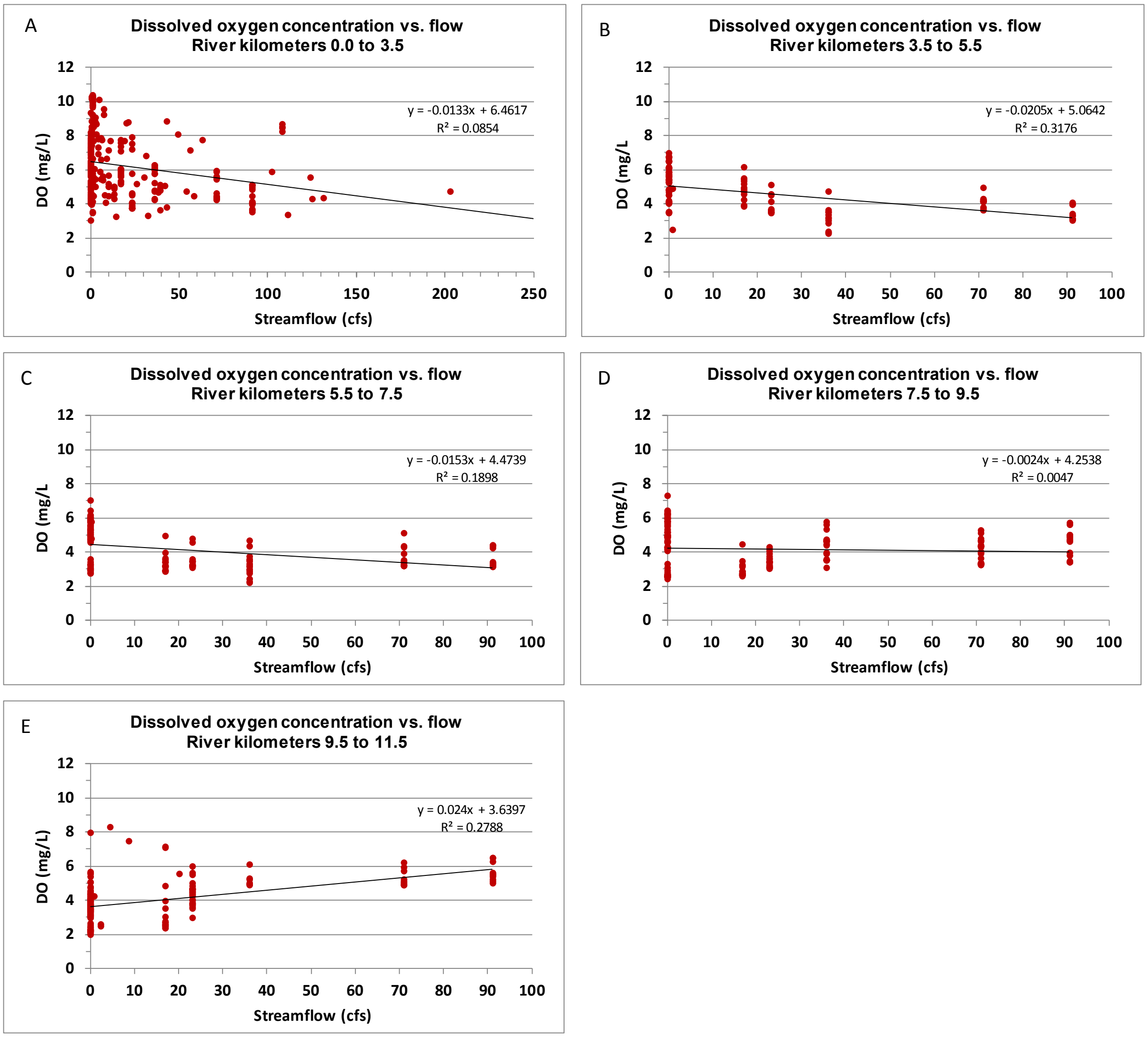


Figure 2-23. Relationship between dissolved oxygen (DO) concentrations in five zones in the Pithlachascotee River and flow measured at the Pithlachascotee River near New Port Richey gage.

Chapter 3 - BACKGROUND: LOWER PITHLACHASCOTEE RIVER CHARACTERISTICS

3.1 Lower River Physiography

The within-bank river channel width of the lower river (Figure 3-1) ranges from four to twenty meters near Rowan Road at river kilometer 11, i.e., 11 kilometers upstream from the Gulf or Mexico, to more than 500 meters at the river mouth. The river is tidally influenced to just above Rowan Road. Downstream from Rowan Road, the lower river meanders west-northwest through the James E. Grey Preserve where shorelines are naturally vegetated. Near river kilometer 7.7, the river flows through a residential zone with predominantly natural shorelines until reaching Grand Boulevard at river kilometer 6.7. From Grand Boulevard the river bends north and flows through the cities of New Port Richey and Port Richey where the river banks are substantially altered by urban development and shoreline hardening. The river bends west near river kilometer 1.8 and widens considerably near Miller's Bayou before reaching the Gulf of Mexico. This most-downstream portion of the lower river is characterized by shallow estuarine tidal flats and intermittent mangrove-fringe flanked by commercial and residential development.

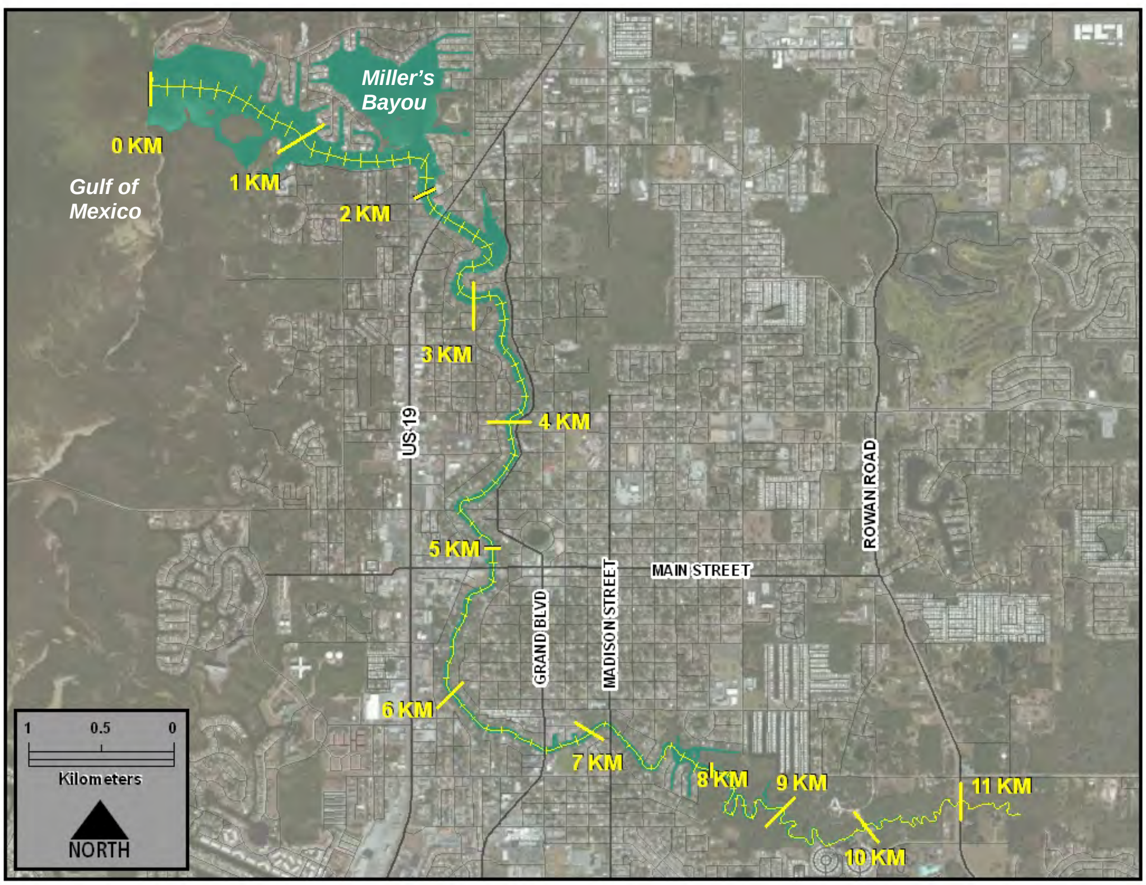


Figure 3-1. Map of the lower Pithlachascotee River depicting river kilometers (KM) upstream from the mouth along the river centerline.

3.2 Tides

The lower Pithlachascotee River is influenced by astronomical tides in the Gulf of Mexico. The USGS has operated four gages in the lower river where tidal water levels have been measured: Pithlachascotee River at Rowan Road near New Port Richey FL (No. 02310304); Pithlachascotee River at New Port Richey FL (No. 02310307); Pithlachascotee River at Main Street at New Port Richey FL (No. 02310308); and Pithlachascotee River at Port Richey, FL (No. 02310310). Locations of these sites are shown in Figure 2-2.

District staff consider data collected at 15-minute intervals at two of these gages to be representative of typical tidal fluctuations in water levels in the lower river. The Pithlachascotee River at Main Street at New Port Richey gage, where data collection began operation in 2005 and continues to the present, is located about 3.4 kilometers upstream of the mouth of the river. The Pithlachascotee River at Rowan Road near New Port Richey gage was operated for four years from July 27, 1982 to September 30, 1986 at a location near river kilometer 11.

Tides throughout the lower river typically fluctuate on a mix of diurnal (one high and one low tide each tidal day) and semi-diurnal tides (two high tides and two low tides of unequal heights each tidal day). An example mixed semi-diurnal tides is shown in Figure 3-2 for a three-day period in May 2007 at the Pithlachascotee River at Main Street at New Port Richey gage. The average diurnal tidal amplitude (from highest high to lowest low) at the site is 0.98 meters (3.22 feet) (Figure 3-3). At 0.97 meters (3.2 feet), the average diurnal tidal range at Pithlachascotee River at Rowan Road near New Port Richey gage is nearly identical (data not shown). Tidal fluctuations are nearly absent at the long-term gage site, Pithlachascotee River near New Port Richey located about 17 kilometers upstream of the river mouth.

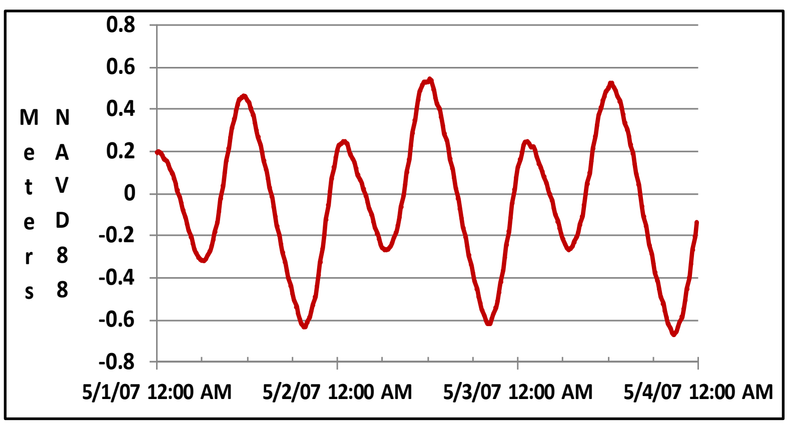


Figure 3-2. Mixed semi-diurnal tidal water level fluctuations at the Pithlachascotee River at Main Street at New Port Richey gage from May 1 through May 3, 2007.

Due to seasonal variations in gulf water temperatures, prevailing winds and astronomical factors, tides in the lower river tend to be lowest in the winter and highest in the late summer. Monthly median tide levels at the Pithlachascotee River at Main Street at New Port Richey site expressed relative to NAVD 88 ranged from -0.26 meters in January to 0.29 meters in September.

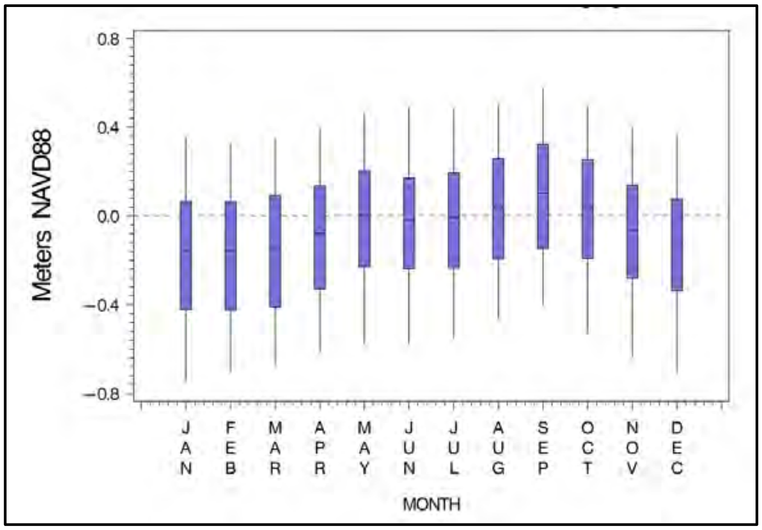


Figure 3-3. Box and whisker plot of monthly tidal levels at the Pithlachascotee River at Main Street at New Port Richey gage. Horizontal lines represent the median values, the box represents the 25th to 75th percentiles, and the whiskers represent the 5th and 95th percentile values.

3.3 Bathymetry

To support characterization of salinity-based habitats for minimum flows development, shoreline configuration and bathymetry of the lower river was mapped for the District (Wang 2008; included as Appendix 3A to this report). The limits of bathymetric survey and mapping extended from the river mouth (river kilometer 0.0) to river kilometer 11.3, 300 river meters upstream of Rowan Road (Figure 3-4).

The mean depth of the mapped extent of the lower river is 1.36 meters relative to an elevation 0.0 meters NAVD 88. The deepest area within the lower river was -3.25 meters. The deeper-water zones are primarily associated with an incised navigation channel west of U.S. Highway19, which bisects the shallow estuarine flats and mangrove islands. The channel extends upstream through Port Richey and New Port Richey gradually decreasing in depth until near river kilometer 8, above which only intermittent deeper water pockets are found.

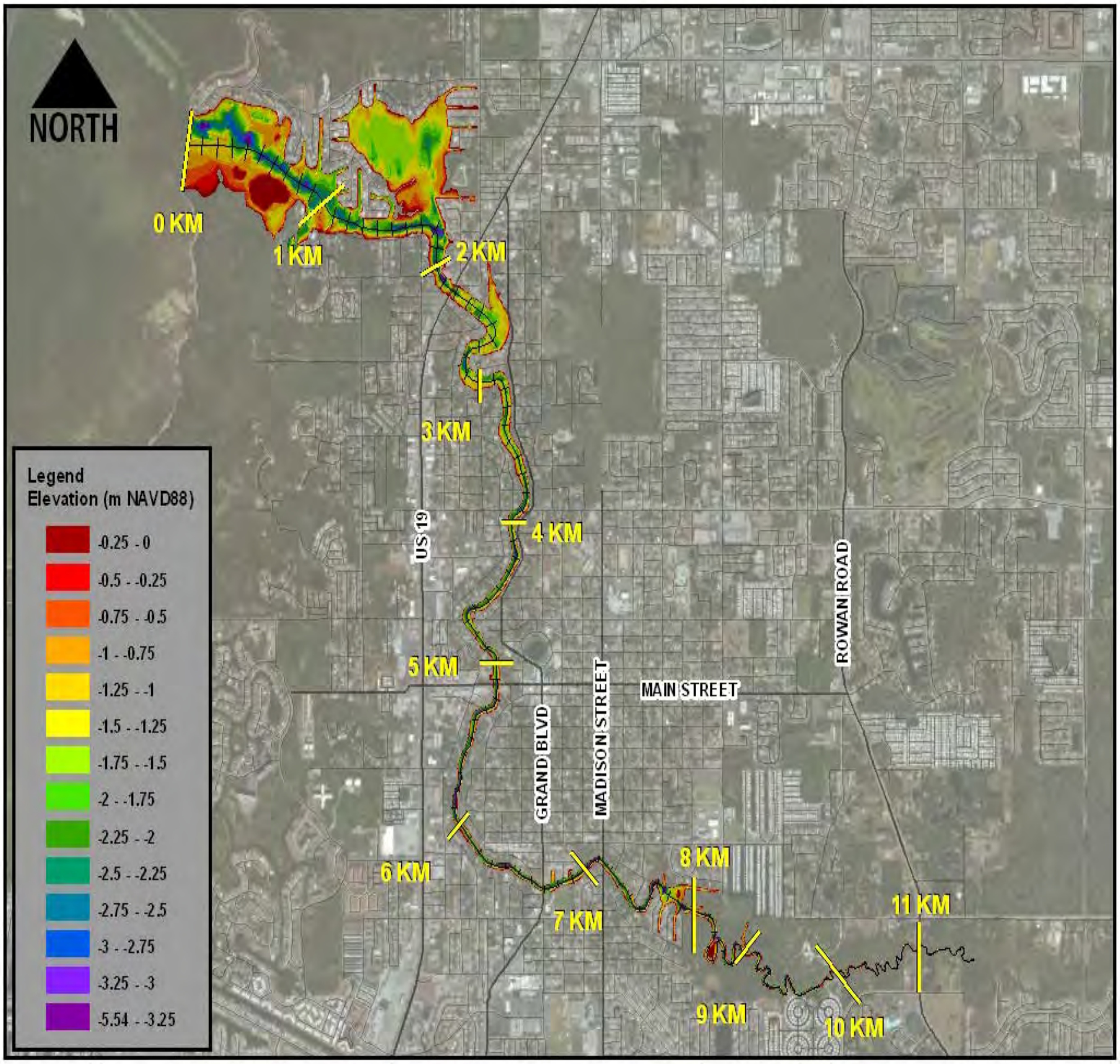


Figure 3-4. Bathymetric map of the lower Pithlachascotee River.

The total lower river volume below 0.0 meters NAVD 88 is estimated to be 1,756,429 m^3 and the total surface area is 1,287,058 m^2 (Figure 3-5) The system can be classified as a shallow river, as approximately 50 percent of the river volume is at depths shallower than about - 0.8 meters relative to a reference elevation of 0.0 m NAVD 88. The area and volume for waters deeper than -2.0 meters is also relatively small (18 percent of the area and 6 percent of the volume).

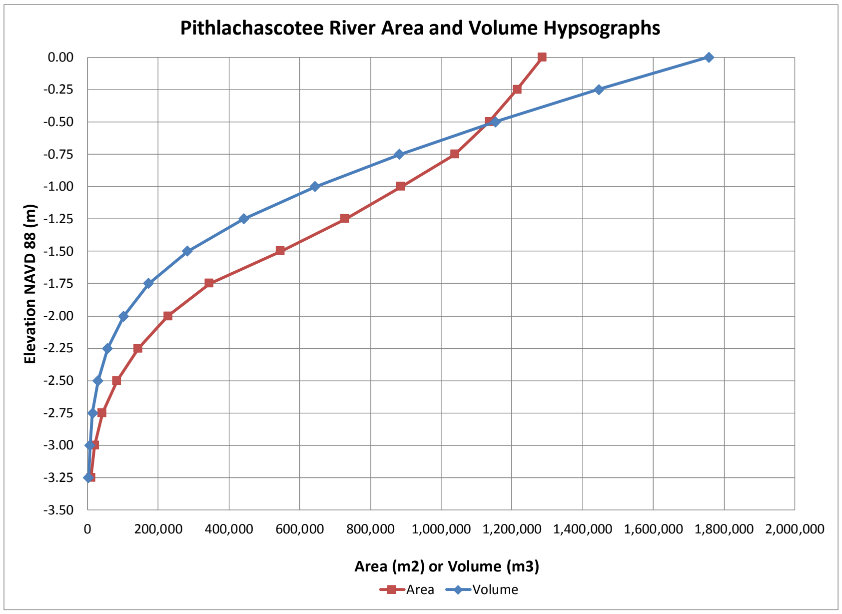
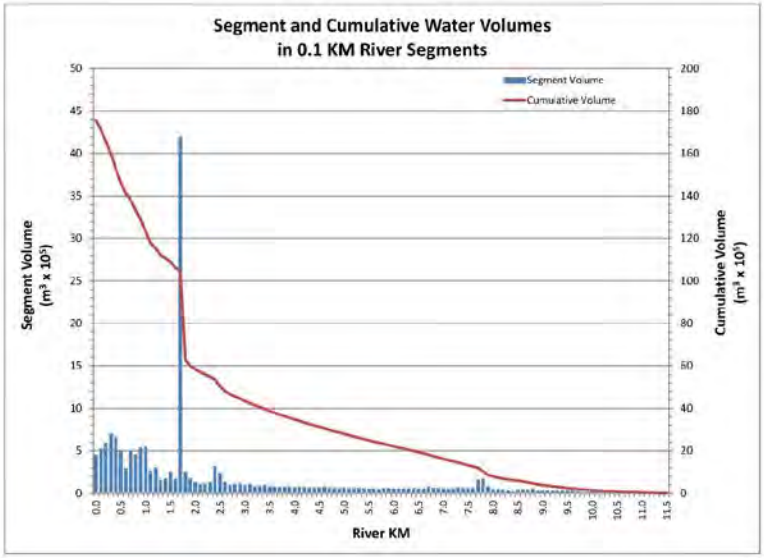


Figure 3-5. Lower Pithlachascotee River hypsographs of river volume and area versus water surface elevations relative to NAVD 88.

Water volume and area per river kilometer segment and on a cumulative basis summed toward the river mouth are shown in Figure 3-6. The volume and area of river segments downstream of river kilometer 2.5, where the boat channel becomes more pronounced and the river widens near Miller's Bayou, are greater than the values for upstream segments.



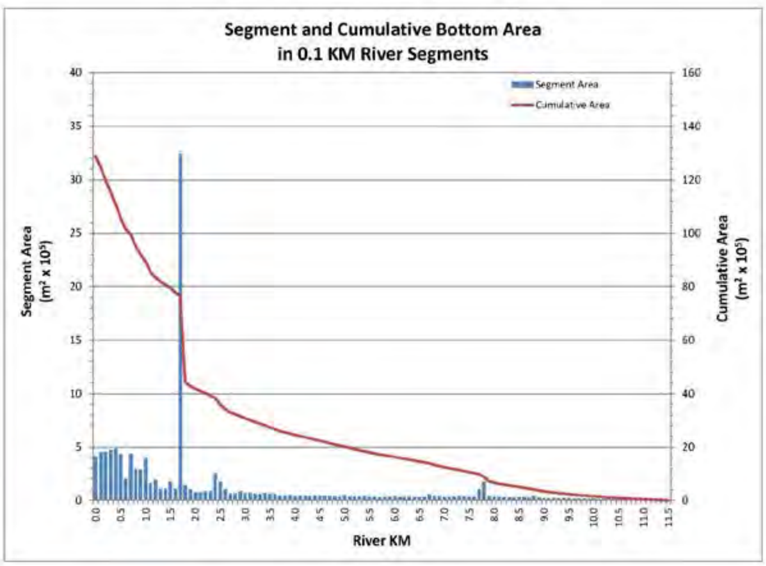


Figure 3-6. Lower Pithlachascotee River segment and cumulative volume (upper panel) and area (lower panel) below an elevation of 0.0 m NAVD 88.

3.4 Benthic Substrates and Organisms

Benthic substrates and macroinvertebates in the lower river were surveyed for the District in May 2009 (Water & Air Research, Inc. 2010a; included as Appendix 3B to this report). Based on sampling at 9 sites (at river kilometers 0.0, 2.0, 3.5, 5.0, 6.5, 8.0, 9.5, 10.5 and 11.2), silt and clay composition of the river sediments ranged from 6.4 percent to 17.4 percent, and were categorized as predominately sand. Organic content found in the sediments ranged from 1.3 percent to 9.7 percent dry weight.

The number of benthic macroinvertebrate taxa recorded at the 9 sampled sites was greatest near the river mouth, exceeding 70 taxa at river kilometer 2, and lowest between river kilometers 8 and 11.2, where 20 to 30 taxa were captured at individual sites. The amphipods, *Grandidierella bonnieroides* and *Apocorophium louisianum*, and the polychaete, *Fabricinuda trilobata*, were the most abundant taxa, collectively comprising 39 percent of the total number of sampled organism.

Other common taxa included the amphipod *Americorophium* sp. A Lecroy, the isopod *Uromunna reynoldsi, the polychaete Laeonereis culveri and* midges of the *Polypedilum halterale* group.

Five oyster bars were observed within the river channel near the river mouth between river kilometers 0.6 and 2.4. Upstream of this low polyhaline zone of the river where the river is highly urbanized, habitat for attached oysters consisted of bridge or dock pilings and seawalls. Live oysters were observed upstream to river kilometer 6.6.

3.5 Shoreline Characteristics

Much of the shoreline of the Lower Pithlachascotee River has been altered, especially within the cities of Port Richey and New Port Richey. These alterations, include hardening as a result of seawall installation that have reduced the extent of tidal wetlands associated with the lower river. Entrix, Inc. (2009; included as Appendix 3C) mapped the shoreline of the lower river upstream to near river kilometer 10.5 and grouped shoreline segments into classes based on degree and type of modification including unmodified, natural vegetation (Figure 3-7). The length of shoreline between kilometers 10.5 and 11.5 was also quantified, but these shorelines were not classified (i.e., were not surveyed). Subsequent site visits by District staff indicate the unclassified shorelines are largely comprised of natural floodplain forest.

The lengths of altered, man-made and vegetated shorelines along the lower river in 100-meter segments and cumulatively downstream from river kilometer 10.5 are shown in Figure 3-8. Approximately seventy-five percent of the shoreline is hardened by seawall throughout the highly urbanized area between river kilometer 0.9 and Grand Boulevard (river kilometer 6.7). These shorelines contained little to no vegetative cover. By comparison, only ten percent of the shoreline is hardened upstream of Grand Boulevard to the terminus of the shoreline survey. Although hardened shorelines occur intermittently, this stretch of river shoreline is predominantly vegetated. Natural, vegetated shoreline is most prevalent upstream of river kilometer beginning near river kilometer 6.0.and in the lower reach of the river, from Millers Bayou towards the gulf, where mangroves are common.

The majority of the lower Pithlachascotee River can be classified as mesohaline or oligohaline habitat capable of supporting a wide range of vegetation. Although much of the mesohaline habitat along the Pithlachascotee River has been impacted by shoreline hardening and no longer supports a contiguous vegetated edge, the upstream oligohaline and tidal freshwater zones remain largely intact, with a large proportion of these areas protected within the James G. Grey Preserve, which extends from river kilometer 7.9 to river kilometer 10.4.

Thirty-three plant species, ranging from salt tolerant to freshwater vegetation, were recorded along the nearly twenty-five kilometers of total shoreline surveyed by Entrix, Inc. Based on salinity tolerance identified by Clewell, et al. (2002), five mesohalophyte species (i.e., characteristic of salinities from 5 to 18 psu) were observed and included red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*) and salt grass (*Distichlis spicata*). Mangroves were found primarily downstream of river kilometer 0.9, although red mangroves occur upstream to river kilometer 7.6. Seven species were classified as glycophytes (i.e., characteristic of salinities of 0.5 psu or less), including buttonbush (*Cephalanthus occidentalis*), red maple (*Acer Rubrum*) and American elm (*Ulmus americana*). Twenty-one species were categorized as oligohalophytes, characteristic of salinities from 0.5 to 5 psu, and were observed within the oligohaline and mesohaline zones. Species common in these zones include leather fern (*Acrostichum danaeifolium*), needle rush (*Juncus roemerianus*), southern cattail (*Typha domingensis*) bald cypress (*Taxodium distichum*) and cabbage palm (*Sabal palmetto*). Near river kilometer 7.8, the vegetation transitioned to a more consistent oligohaline marsh, which continued nearly uninterrupted to river kilometer 9.0. Upstream, freshwater wetland species were common, with forested areas supporting species such as sweet bay (*Magnolia virginiana*) and swamp bay (*Persea palustris*).

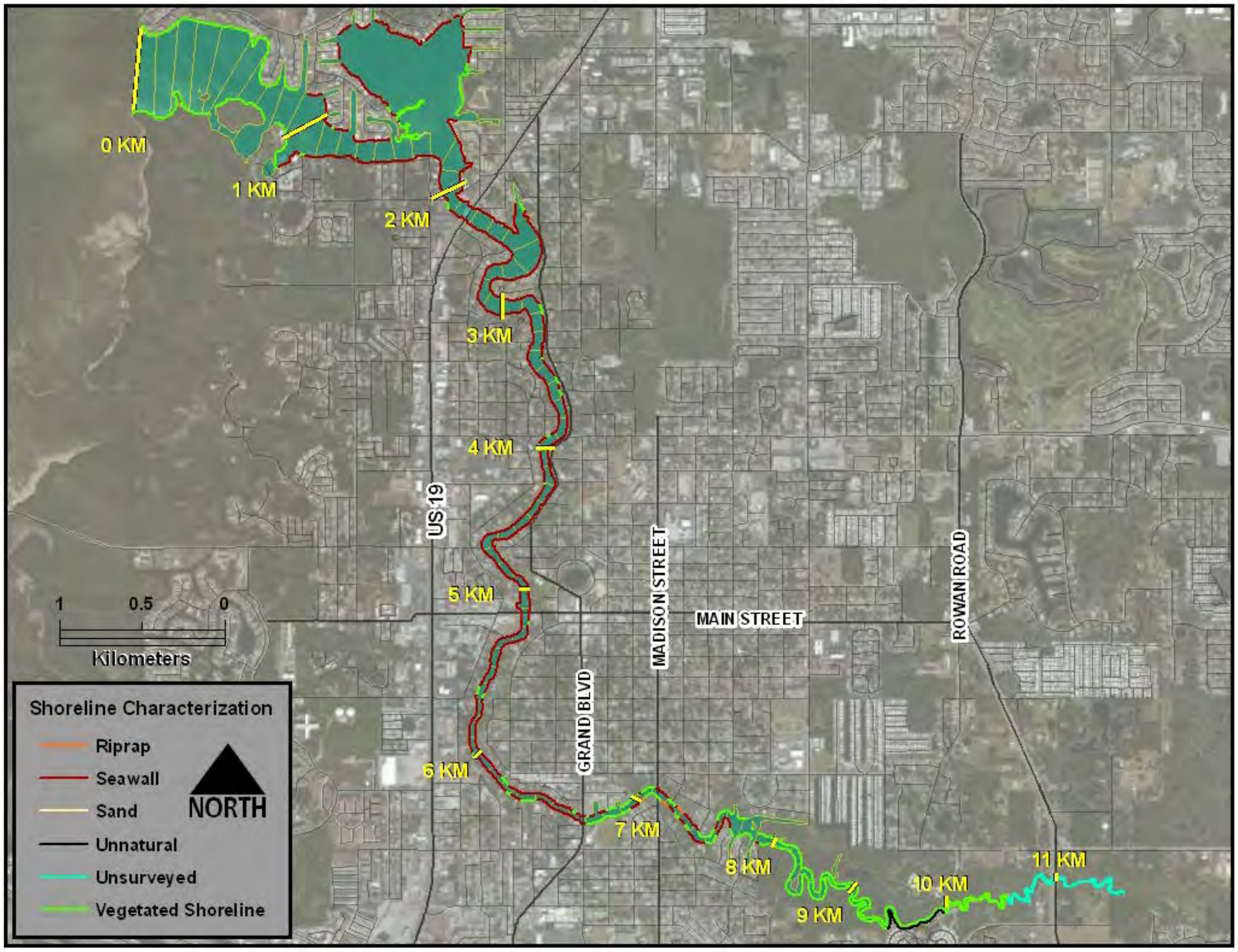


Figure 3-7. Distribution of general shoreline types along the lower Pithlachascotee River (image reproduced from Entrix, Inc., 2009).

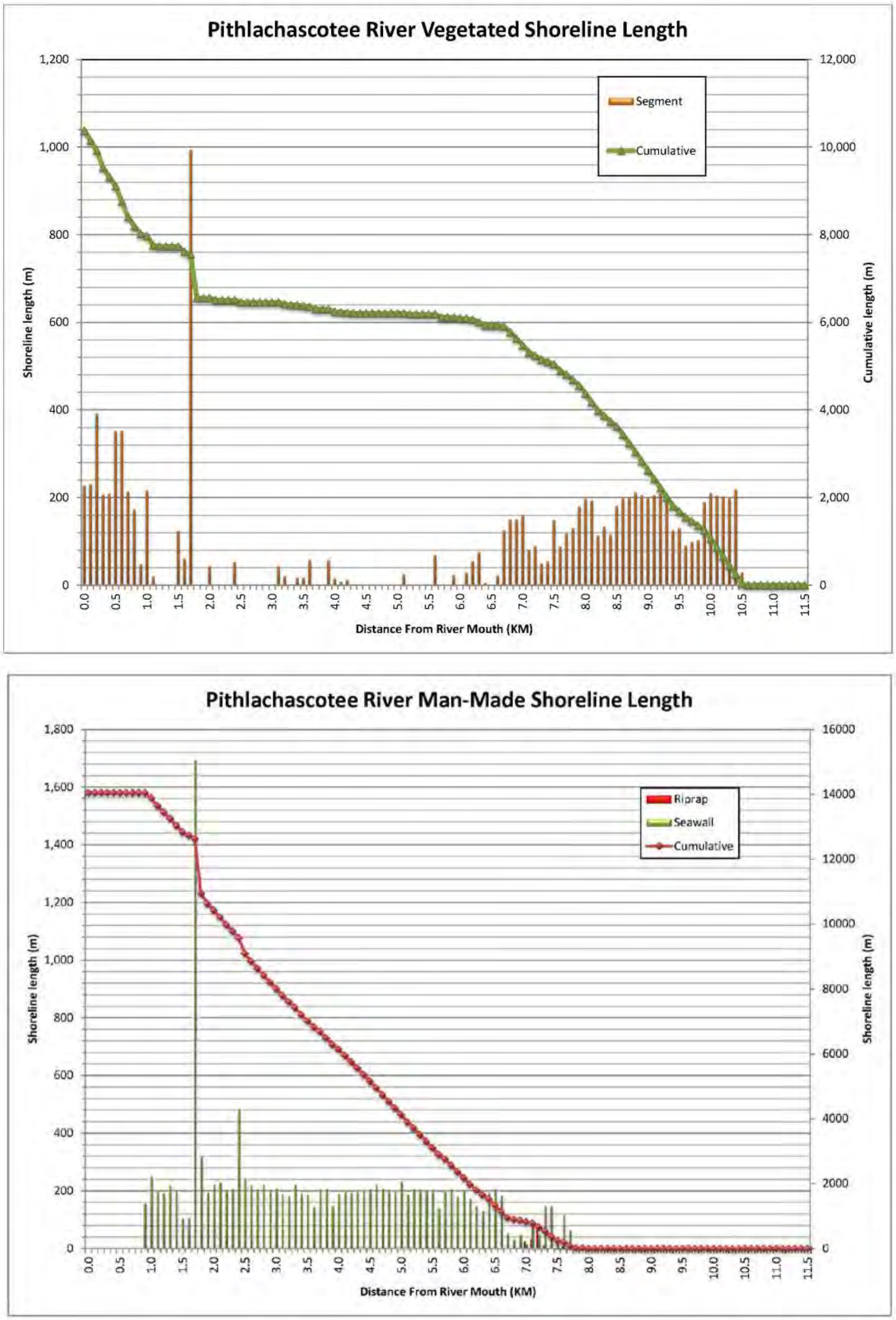


Figure 3-8. Length of total (upper panel) and vegetated (lower panel) shoreline per 100 meter segment and cumulatively summed toward the river mouth.

3.6 Salinity

3.6.1 Salinity at USGS Gages

3.6.1.1 Pithlachascotee River at Main Street at New Port Richey Gage

Salinity has been measured in the lower river at the Pithlachascotee River at Main Street at New Port Richey gage (No. 02310308) since May 2005. This gage is located about 3.5 kilometers upstream of the river mouth (Figure 3-9). Specific conductance values are measured at 15 minute intervals with a continuous recorder at a depth of 0.46 meters (1.5 feet) below mean tide level at the gage. These specific conductance data expressed in microsiemens per cm at 25° C were converted to salinity expressed as parts per thousand using the formulae of Jaeger (1973) that are reported here as practical salinity units (psu).

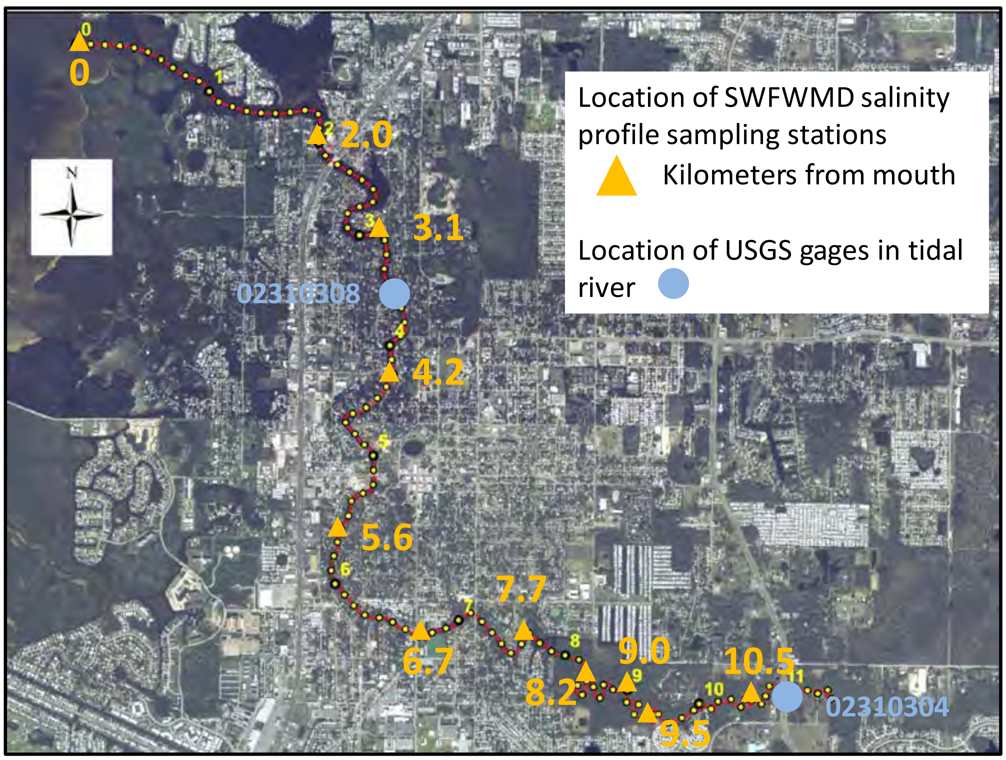


Figure 3-9. Location of two USGS gages and SWFWMD vertical profile stations in the Lower Pithlachascotee River showing USGS gage numbers and kilometer values corresponding to SWFWMD stations.

Salinity at the Main Street recorder averaged 13.1 psu for the over six year period of record from May 18, 2005 to October 13, 2011. A maximum salinity of 26 psu occurred during the end of a drought in the spring of 2009 (Figure 3-10). Peak salinity values in other years typically ranged between 15 to 20 psu. Minimum yearly values generally ranged between 5 and 10 psu, with lower values occurring during wet periods in 2010 and 2011. Based on the Venice System used for classification of marine systems according to salinity (tidal freshwater [< 0.5 psu]; oligohaline [0.5 to 5 psu]; mesohaline [5 to 18 psu], polyhaline 18 to 30 psu] and euhaline [>30 psu] zones; Anonymous 1958), the Main Street gage is located in what is predominantly a mesohaline zone of the river.

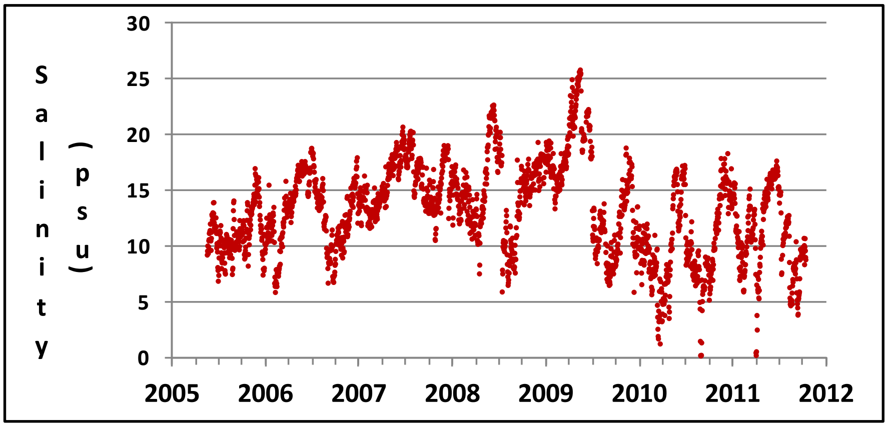


Figure 3-10. Average daily salinity at the Pithlachascotee River at Main Street gage recorded 0.46 meters below mean tide level at the site.

Although salinity typically varies within certain ranges at different locations in the lower river, salinity at all locations in the river is highly dynamic and may exhibit large variation with tides. As noted in section 3.2, the average diurnal range in tidal water levels at the Main Street gage is 0.98 meters (3.22 feet). On average, this tidal fluctuation is associated with a mean difference of 12.8 psu between the daily maximum and minimum salinity values, a value nearly as great as the mean salinity at this site.

Salinity at the Main Street gage also varies with the rate of freshwater inflow. The response of salinity to freshwater inflow at the gage in nonlinear, with salinity exhibiting greatest sensitivity to changes in low flows (Figure 3-11). Mean salinity values greater than 18 psu were restricted to periods of very low-flow. Highest salinities occurred after prolonged periods of low-flow in the spring dry seasons of several years (2007, 2008 and 2009). Tidal freshwater conditions (<0.5 psu) at the Main Street gage typically occurred when inflow was greater than 250 cfs, although freshwater conditions were also observed at flows of 180 and 220 cfs.

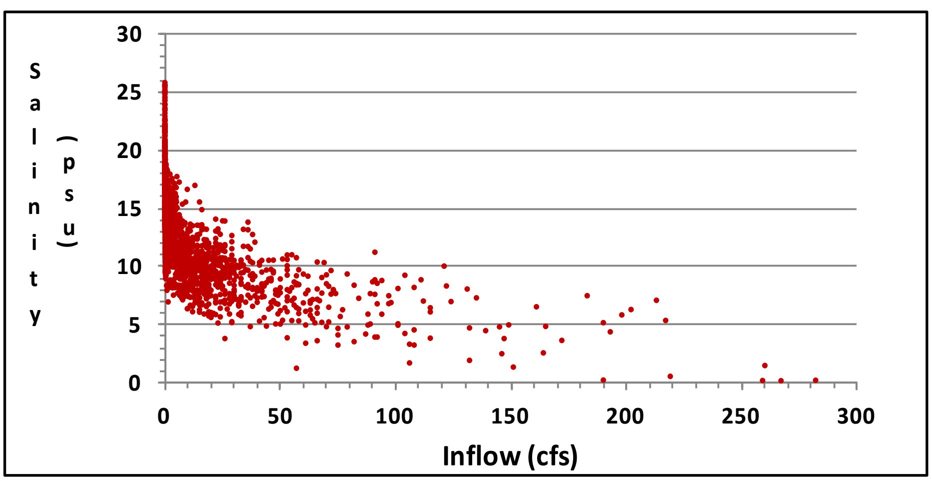


Figure 3-11. Average daily salinity at the Pithlachascotee River at Main Street gage vs. same-day flow at the Pithlachascotee River near New Port Richey gage.

3.6.1.2 Pithlachascotee River at Rowan Road near New Port Richey, FL

From March 1983 to September 1986, the USGS continuously measured specific conductance at the Pithlachascotee River at Rowan Road near New Port Richey, FL (Number 02310304) gage (Figure 3-12).This site is located about 11 kilometers upstream of the mouth of the river (see Figure 3-9). Salinity (converted from specific conductance) at the Rowan Road gage typically varied within the tidal freshwater range (<0.5 psu), with oligohaline conditions (0.5 to 5 psu) observed during periods of prolonged, low freshwater inflow. Salinities greater than 1 psu were rare, occurring only once, during the spring of 1985. This was during a drought when there was virtually no flow (mean = 0.1 cfs) at the long-term streamflow gage during the months April and May.

As noted in Chapter 3, there is a fairly large variation in tidal water levels at the Rowan Road gage, with a mean tide range of 0.97 meters (3.2 feet). However, due the channel geometry of the river, saline water only penetrates to this location when flows in the river are at or near zero.

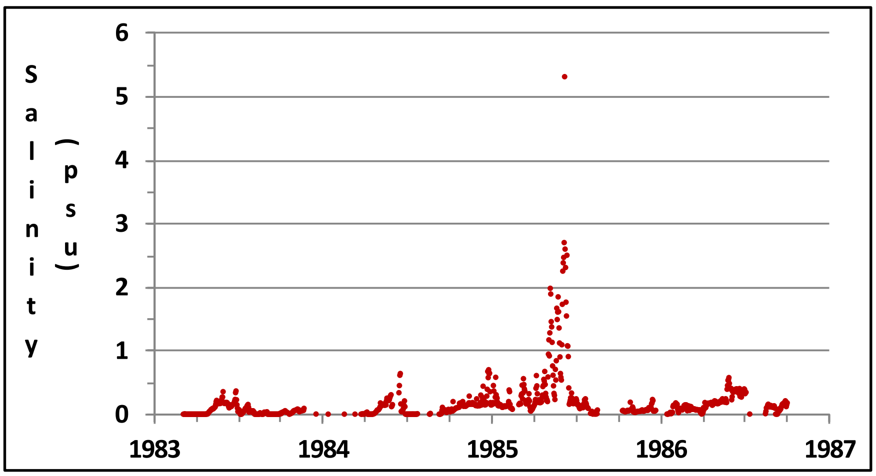


Figure 3-12. Average daily salinity at Pithlachascotee River at Rowan Road near New Port Richey, FL gage for the period May 18, 1983 through October 18, 1986.

3.6.2 Salinity at District Mid-Channel Stations

District staff measured vertical salinity profiles at a number of stations in the lower river on 32 sampling trips conducted during two periods. Twenty-three sampling trips were made between March 20, 1985 and April 30, 1987 and nine sampling events were conducted between May 5, 2009 and September 29, 2009. Sampling was conducted during a wide range of flow conditions. Flows greater than 50 cfs and up to 450 cfs occurred on eight sampling trips. Flows at or near zero cfs occurred on ten dates.

Staff measured salinity by boat at a series of fixed-location, mid-channel stations at 0.3 meters below the water surface, at one meter intervals through the water column, and at approximately 0.3 meters above the river bottom. Sampling was regularly conducted at 11 stations (see Figure 3-9), although fewer stations were sampled during some of the early trips in 1985 and sampling was only conducted at the station at the mouth of the river (river kilometer 0) for a subset of the trips. The number of sampling dates by station ranged from 23 to 32. Average profile depths ranged from 2.1 to 3.5 meters, so sampling effectively covered most of the water column in the river, as only six percent of the volume of the lower river occurs at elevations below 2 meters NAVD 88 (see Figure

3-4 and Figure 3-5). The largest average profile depth listed in Table 3-1 (3.5 m) is greater than the greatest depth reported by the bathymetric survey in part due to many of the profile measurements taken when water levels in the river were greater than the reference elevation of 0.0 meters NAVD88 used for the bathymetric data.

The salinity-profile data indicates the lower river is frequently fresh upstream of river kilometer 8, but higher salinity water can penetrate to the upstream stations during dry periods (Figure 3-13). Median salinity values at river kilometer 2.0 (17 psu) and 3.0 (19 psu), at the Pithlachascotee River at Main St. near New Port Richey gage site are similar to the upper limit for mesohaline waters (18 psu). Based on these data the lower river may be characterized as typically tidal freshwater upstream of about river kilometer 8, oligohaline from river kilometer 8 to near river kilometer 7, mesohaline from river kilometer 7 to near river kilometer 2, and polyhaline from river kilometer 2 downstream to mouth of the river.

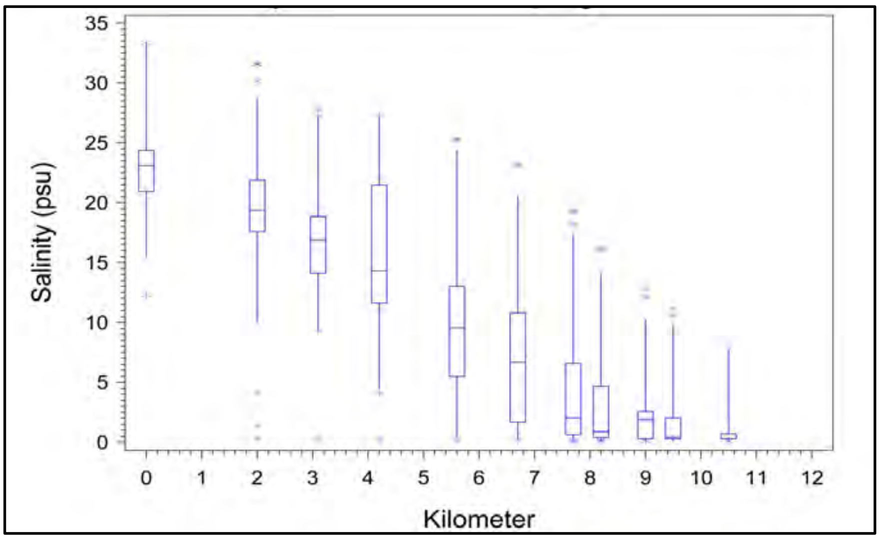


Figure 3-13. Box and whisker plot of salinity in the lower river at District river kilometer stations based on data from two meters to surface. Horizontal lines represent the median salinity at each station, boxes represent the 25th and 75th percentile values, and the whiskers represent the 5th and 9th percentiles, with values above and below those percentiles are shown as stars.

Mean salinities of approximately 20 psu were observed at the two most downstream stations, with mean salinity decreasing upstream to a mean value of 0.8 psu at station (i.e., river kilometer) 10.5, near the gage at Rowan Road (Table 3-1). Maximum salinity values at the station near the mouth of the river approached salinities of Gulf water (> 30 psu) and was 5.9 psu at the most upstream station.

Table 3-1. Summary statistics for salinity (psu) at each station calculated from average water column salinity values for each station on the sampling dates. The maximum salinity value recorded at any depth at each station is also listed.

Station Kilometer	Mean (psu)	Standard Deviation	Minimum Mean Value	Maximum Mean Value	Maximum Value at Any Depth
0.0	20.5	4.6	11.6	32.9	33.3
2.0	19.0	5.8	1.2	31.2	31.6
3.1	17.0	6.0	0.2	28.4	29.6
4.2	14.0	6.6	0.2	27.1	27.3
5.6	9.5	6.8	0.2	25.2	25.3
6.7	6.6	6.4	0.2	22.3	23.2
7.7	4.0	5.1	0.1	17.3	19.3
8.2	3.0	4.2	0.1	14.6	16.2
9.0	2.2	3.3	0.1	11.6	12.8
9.5	1.8	2.9	0.1	10.2	11.2
10.5	0.8	1.5	0.1	5.9	7.8

Density stratification of the water column often occurs in tidal rivers when less-dense fresh water that flows in from the watershed tends to flow over more-dense saltier water encroaching landward from the Gulf. The degree of density stratification can vary greatly depending on the geometry of the river channel and the rate of freshwater inflow. Well mixed conditions can occur when inflows are very low and the water column is fairly saline from top to bottom, or at high freshwater inflows when the water column may be completely fresh. Maximum salinity values at depth (Table 3-1) were similar to the maximum water column values at the river kilometer station 5.6 and downstream stations, as the water column was generally well-mixed at these locations during low-flows. Differences between the maximum salinity at depth and the water column were generally greatest at the upstream stations, where a slight salt wedge extended upstream along the river bottom during low-flows.

The difference between salinity at the surface and at a depth of two meters was used to characterize salinity stratification at the sampled stations (Table 3-2). Mean stratification values ranged from 1.2 to 1.9 psu for stations downstream from river kilometer 7.7, suggesting that this portion of the lower is well-mixed much of the time. Mean stratification values were smaller at more upstream stations, although stratification was noted in this portion of the lower river during periods of low-flow when saline water would extend along the river bottom to these sites. A stratification value of 5.0 psu at river kilometer station 10.5 occurred during June 1985, near the date of when maximum salinity at the Pithlachascotee River at Rowan Road near New Port Richey gage was recorded by the USGS.

Table 3-2. Mean, minimum and maximum salinity stratification values (psu) at the sampling stations based on data at or above 2 meters depth.

Station Kilometer	Mean	Minimum	Maximum
0.0	1.2	0.0	4.8
2.0	1.2	0.0	5.8
3.1	1.3	0.0	7.9
4.2	1.4	0.0	8.3
5.6	1.9	0.0	7.5
6.7	1.1	0.0	4.3
7.7	1.2	0.0	6.4
8.2	0.5	0.0	5.5
9.0	0.2	0.0	2.8
9.5	0.3	0.0	2.4
10.5	0.2	0.0	5.0

Salinity distributions in the lower river can vary greatly with changes in freshwater inflow. This variable response is likely a function of longitudinal differences in channel morphology and increasing influence of Gulf waters toward the river mouth. Plots of salinities at all depths as a function of freshwater inflow for four of the eleven District stations illustrate the longitudinal variation in the response of salinity to inflow (Figure 3-14).

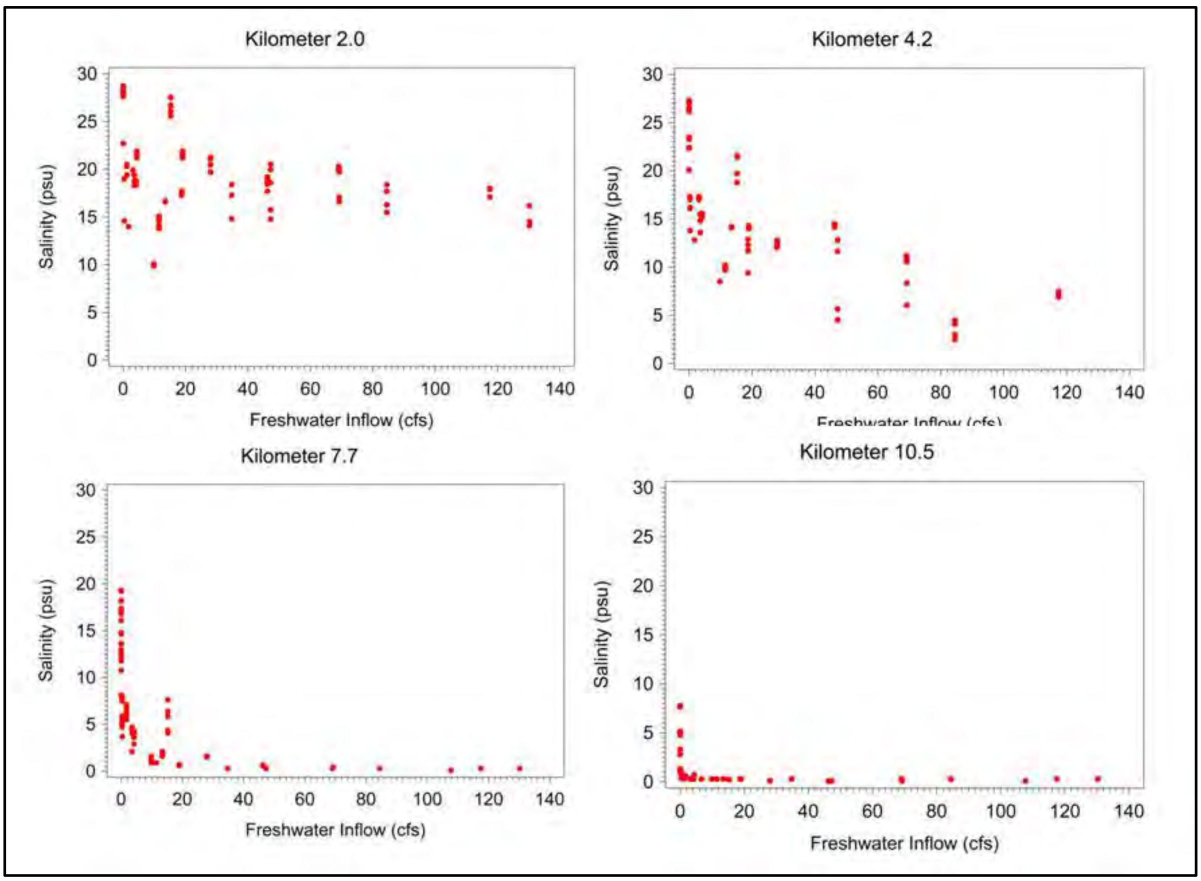


Figure 3-14. Salinity at four fixed location stations in the lower river vs. four-day average flow at the Pithlachascotee River near New Port Richey gage

Chapter 4 - METHODS: RESOURCES OF CONCERN AND TECHNICAL APPROACH

4.1 Study Area

For development of minimum flows, District staff evaluated estuarine and freshwater segments of the Pithlachascotee River that in combination extend from the mouth of the river at the Gulf of Mexico upstream to State Road 52 (Figure 4-1). The upper extent of the study area was based on the location of USGS gaging stations with relevant flow records.

The study area for the estuarine, lower segment of the river extended from the mouth of the river upstream to Rowan Road near river kilometer 11 (river mile 7.1). Tidal water level fluctuations in the river extend upstream of Rowan Road, but are not evident at the long-term Pithlachascotee River near New Port Richey gage (No. 02310300) located at river kilometer 18. Although the tidal reach of the river extends upstream of Rowan Road, the upper boundary of the lower river study area ended near Rowan Road because brackish waters extend upstream of that location only under prolonged conditions of river flows near zero flow (see Section 3.6).

The study area for the freshwater, upper reach of the river extended from the Pithlachascotee River near New Port Richey gage upstream to the Pithlachascotee River near Fivay Junction gage (No. 02310280). Areas upstream of the gage near Fivay Junction, e.g., Crews Lake, and for a tributary, Five Mile Creek, were not directly assessed as part of the analyses supporting minimum flows development for the upper river. These upstream areas were, however, implicitly assessed for baseline flow development and the evaluation of withdrawal impacts based on their contributions to downstream flow. It is also worth noting that the District has established minimum levels for Crews Lake and several other lakes and a few isolated wetlands in the upper portion of the Pithlachascotee River watershed.

The distance between Rowan Road, the upper boundary of the estuarine study area, and the long-term Pithlachascotee River near New Port Richey gage, the lower boundary of the freshwater study area, is approximately seven kilometers (4.4 miles). Because this portion of the river exhibits ecological characteristics that are similar to the upstream freshwater study reach, District staff recommend that minimum flows developed based on assessment of the freshwater reach of the river should extend downstream to Rowan Road.

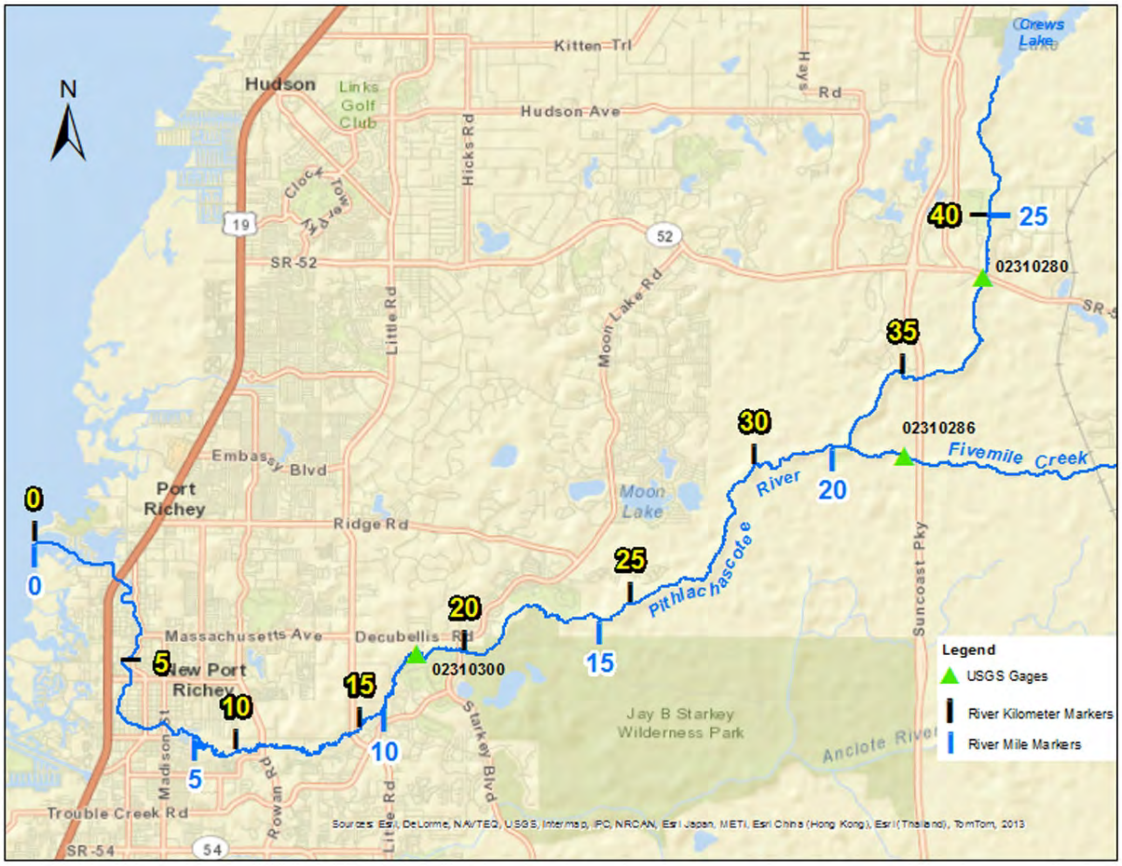


Figure 4-1. Map of the Pithlachascotee River minimum flows study area from the mouth of the river to State Road 52, plus the upstream reach that extends from State Road 52 to Crews Lake and a portion of the tributary, Fivemile Creek.

4.2 Baseline Flows for Minimum Flows Analyses

To support minimum flow analyses, District staff constructed a baseline flow regime or record for the Pithlachascotee River that was adjusted for groundwater withdrawal impacts. The baseline record was used to characterize environmental conditions expected in the absence of withdrawals that could serve as the basis for identifying potential reductions in streamflow that would not result in significant harm to the river's environmental values. The baseline flow record was also used to aid in determining whether current or projected flows are or would be sufficient to meet minimum flows recommended for the river.

As described in Chapter 2 and Appendix 2C, District staff used the INTB model to evaluate withdrawal effects on flows at the Pithlachascotee River near New Port Richey gage for a zero groundwater pumping and other scenarios for the period from 1989 through 2000. Comparing model output among the various scenarios was considered a reasonable approach for estimating the net effects of groundwater pumping over long periods. However, District staff determined that an alternate method would be needed to construct a daily baseline flow regime for minimum flows analyses, which are typically performed on measured daily streamflow values.

Although streamflow predicted for the existing conditions scenario with the INTB model corresponded fairly-well with observed streamflow (Figure 4-2), there were short-term differences in the timing of flow events that were difficult for the model to capture given the complexity of hydrologic interactions in the river watershed. District staff therefore concluded that results from the INTB model baseline flow scenario would not be used directly as the baseline flow record for minimum flows analysis. Many of the ecological factors assessed for the minimum flows analysis are associated with temporal variation in flow, including daily flow rates, and prediction of daily flows was considered beyond the scope and intent of the INTB model.

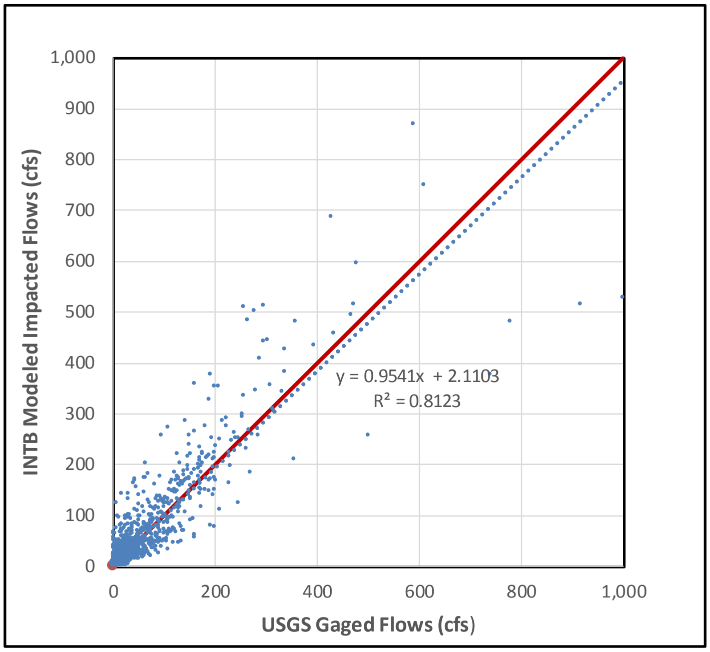


Figure 4-2. Gaged daily flows at the Pithlachascotee River near New Port Richey gage vs. INTB-modeled daily impacted flows for the period from January 21, 1989 through December 31, 2000. Dashed blueline represents regression line; solid red line shows one-to-one relationship.

Rather than using INTB model output directly for the baseline flow record, statistical relationships between groundwater withdrawal impacted and non-impacted flows and these relationships were used to modify the gaged flow record and estimate daily baseline flows adjusted for the effects of groundwater withdrawals. For this process, Janicki Environmental, Inc. (2011; included as Appendix 4A) initially developed a regression model between baseline flows and impacted flows from the INTB model output, with 150-day average groundwater withdrawals from the combined Starkey and North Pasco wellfields included as an additional explanatory variable. The 150-day lagged term for withdrawals from the Starkey and North Pasco wellfield was based on consideration of various lag terms, including 7-day, 14-day, 30-day, 60-day, 90-day, 120-day, 150-day and 180-day moving average pumping values for individual wellfields in the area. Wellfield pumping values for the various lag-times and wellfield combinations (Cross Bar-Cypress Creek, Eldridge-Wilde, South Pasco, Section 21 and Cosme-Odessa) that did not exhibit statistical significance were excluded from model development.

Analyses of regression residuals indicated that a large number of low-flow days in the impacted model scenario negatively affected model fit, especially for zero groundwater withdrawal flows less than 1.6 cfs. District staff concluded that use of the regression would therefore be limited to prediction of baseline flows greater than 1.6 cfs, and direct model output would be used for when baseline flows were less than 1.6 cfs.

The residual analysis also revealed a curvature that was indicative of quadratic behavior, so a quadratic term was added to the regression. The recommended regression equation was:

$$\ln(Q_{base}) = -1.15 + 0.48 \ln Q_{imp} + 0.06 \left(\ln \mathrm{Q_{imp}}\right)^2 + 0.84 \left(\ln Q_{pump150}\right) \quad \text{[Equation 1];}$$

where Q_{base} = INTB-modeled baseline flow (daily, cfs) at the gage;
Q_{imp} = INTB-modeled impacted flow (daily, cfs) at the gage; and
$Q_{pump150}$ = 150-day average groundwater withdrawal daily, cfs) from the Starkey and North Pasco wellfields.

The model was fit with over 3,000 observations and resulted in an r^2 value of 0.97. The regression was highly significant with a probability of a greater |F| value of < 0.0001. Slope and parameter coefficients for the model were all also highly significant.

During District review of Equation 1, the slope of the pumpage term raised questions about multicollinearity between the groundwater withdrawal term and the impacted flow terms in the regression, because the groundwater withdrawal rates used in the simulations affect the impacted flow values produced by the model output. In response to this concern, District staff developed a second regression that did not include a groundwater withdrawal term for predicting baseline flows as a function of impacted flows. This regression equation, which also had an r^2 value of 0.97, was:

$$\ln(Q_{base}) = 1.409 + 0.484 \ln Q_{imp} + 0.058 \left(\ln Q_{imp}\right)^2 \quad \text{[Equation 2];}$$

where Q_{base} = INTB-modeled baseline flow (daily, cfs) at the gage; and
Q_{imp} = INTB-modeled impacted flow (daily, cfs) at the gage.

Baseline flow values predicted using Equation 2 were very similar to values predicted using Equation 1 (Figure 4-3). Because differences between predictions based on the two regressions would have negligible effect on development of a baseline flow record for use in minimum flows analyses for the river, and because considerable initial analyses had been completed using Equation 1, District staff determined that Equation 1, rather than Equation 2, would be used for development of a baseline flow record for minimum flow determinations.

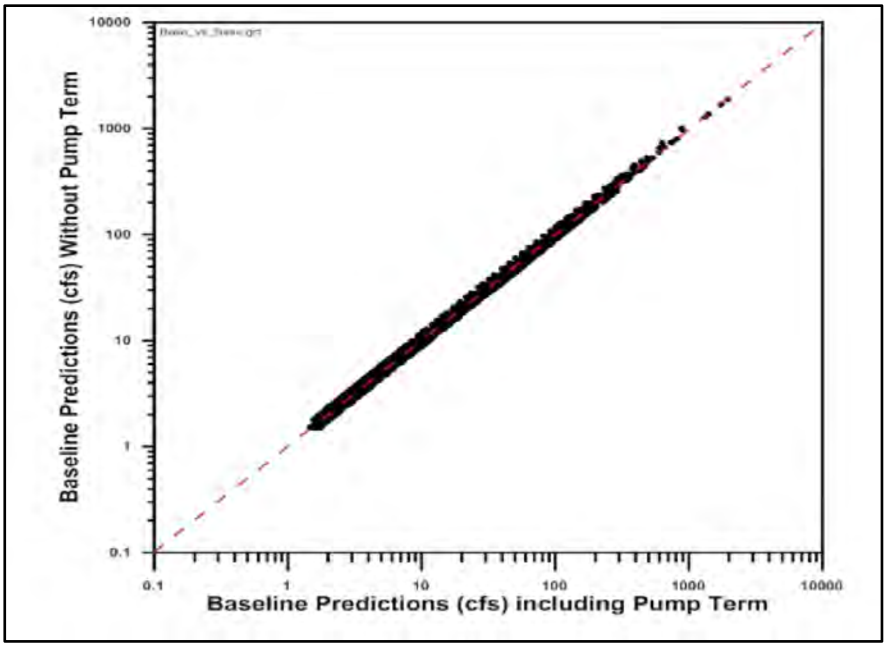


Figure 4-3. Similarity between baseline flow predictions using regression equations with a groundwater withdrawal term (Equation 1, x-axis) and without a groundwater withdrawal term (Equation 2, y-axis).

The baseline flow record used for minimum flow analyses was developed using Equation 1, with gaged, i.e., reported or observed flows substituted for INTB-modeled impacted flows at the gage (Figure 4-4). Because Equation 1 includes a term for preceding 150-day wellfield withdrawals, the predicted baseline flow values begin on June 19, 1989 rather than January 1, 1989, with the baseline record extending to December 31, 2000.

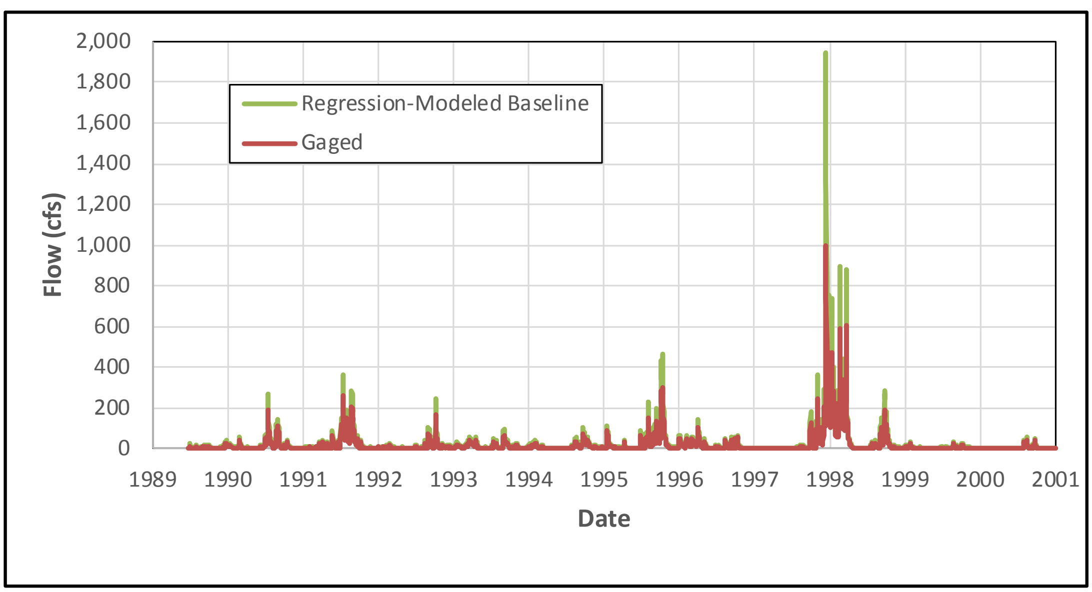


Figure 4-4. Regression-modeled daily baseline flows at the Pithlachascotee River near New Port Richey gage for the period from January 21, 1989 through December 31, 2000 developed using gaged flow records and Equation 1.

Although some differences between gaged flows and INTB-modeled impacted flows at the gage were noted, the generally good agreement between the two data sets provided support for the approach (Figure 4-5, Table 4-1). Median (P50) and lower percentile gaged and INTB-modeled impacted flows differed by 0.1 cfs or less (Table 4-1). Differences were also relatively small for higher percentile flows, ranging up to 3.3 cfs for P90 and P95 flows. Based on these minimal differences, baseline flows developed with Equation 1 using gaged flows exhibited good agreement with INTB-modeled baseline flows. Median (P50) and lower percentile flows for the two records differed by 0.3 cfs or less (Table 4-1). Differences were also relatively small for higher percentile flows, ranging up to 4.8 cfs for P90 flows. Flow duration curves for the regression-modeled and INTB-modeled baseline flows illustrate the high level of correspondence for the two records and provide some indication of the magnitude of withdrawal impacts when compared to a flow duration curve for the impacted, gaged flows (Figure 4-6).

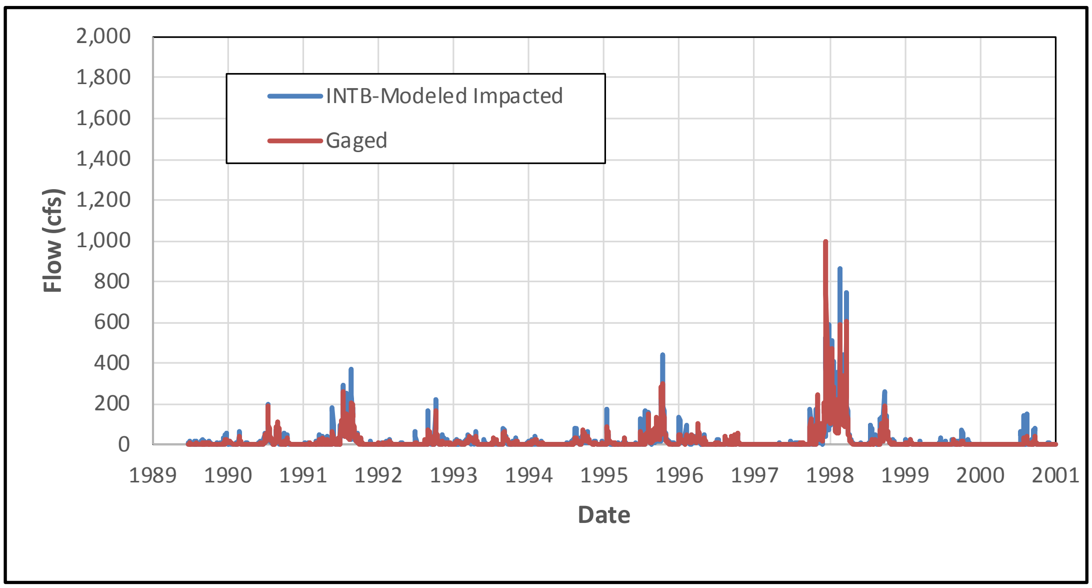


Figure 4-5. Time-series of gaged daily flows and INTB-modeled impacted flows at the Pithlachascotee River near New Port Richey gage for the period from January 21, 1989 through December 31, 2000.

Table 4-1. Percentile flows for USGS gaged flows, INTB-modeled impacted flows, INTB-modeled baseline flows and Regression-modeled baseline flows at the Pithlachascotee River near New Port Richey gage for the period from June 19, 1989 through December 31, 2000.

Percentile	Gaged Flows (cfs)	INTB Modeled Impacted Flows (cfs)	INTB-Modeled Baseline Flows (cfs)	Regression-Modeled Baseline Flows (cfs)
P5	0.0	0.0	0.1	0.1
P10	0.0	0.0	0.6	0.6
P25	0.4	0.4	2.9	2.6
P50	3.3	3.4	8.0	7.8
P75	12.0	12.4	21.1	19.3
P90	41.7	45.0	61.8	57.0
P95	90.0	92.6	122.1	119.9

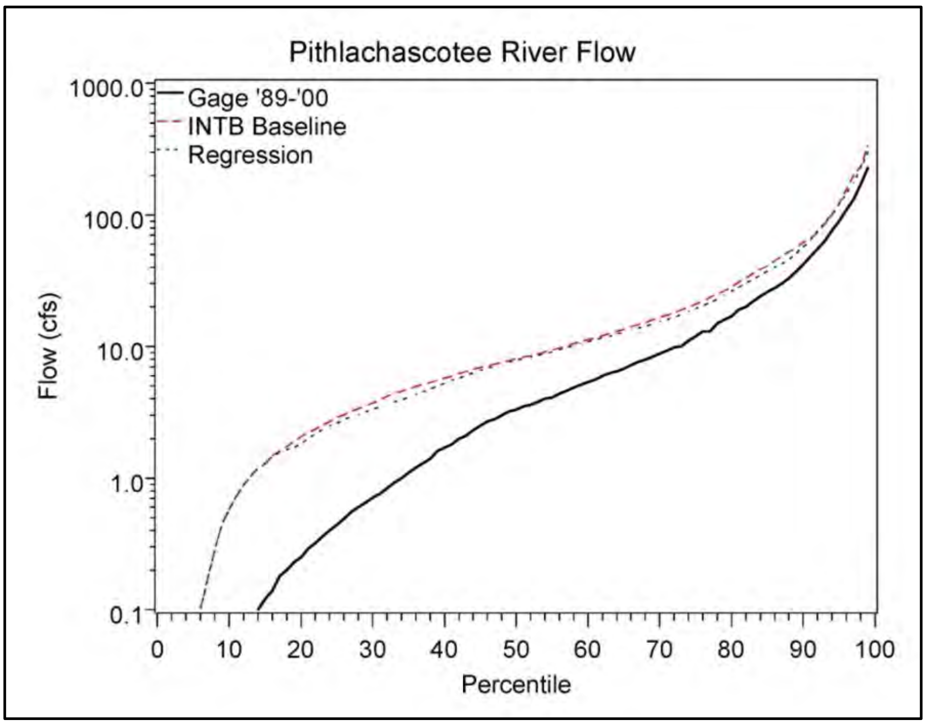


Figure 4-6. Comparison of INTB-modeled baseline (INTB Baseline) flows, baseline flows predicted by substitution into Equation 1 (Regression), and observed (Gage '89-'00) flows at the Pithlachascotee River near New Port Richey gage (reprinted from Janicki Environmental, Inc. 2011). There is little visible difference between the two estimates of baseline flows and both are greater than the observed, gaged flows, as expected.

The period used for baseline flow development was moderately dry and was also a period of relatively high regional groundwater withdrawals. Average rainfall for the 11 complete years (1990 through 2000) for which baseline flows were calculated was 50.9 inches for the rainfall stations in the Pithlachascotee River watershed, compared to an average of 53.9 inches for the longer-term period from 1982 through 2013 corresponding to the period after the long-term gage on the river was moved by the USGS. Groundwater pumpage in the region was at near maximum levels during the baseline flow period (see 13), which also likely contributed to lower river flows.

4.3 Seasonal Flow Blocks

District staff identified seasonal blocks for the Pithlachascotee River following procedures established for development of minimum flows for other District rivers (e.g., SWFWMD 2005a, 2007, 2010a). The beginning of Block 1, which is the late spring dry season, was identified near the day of year when the median daily flow dropped and stayed below the 75 percent exceedance flow. The initiation of Block 3, which sequentially follows Block 1 and corresponds with the summer wet season, was identified near the day when the median daily flow exceeded and remained above the 50 percent exceedance flow. The beginning of Block 2, a period of intermediate flows, was assigned near the day the median daily flow fell below the 50 percent exceedance flow.

Flow records used for identification of the seasonal blocks included observed flows at the Pithlachascotee River near New Port Richey gage site for years with a full set of daily values, after the gage was moved to its current location, i.e., from 1982 through 2013, and the baseline flows developed for minimum flow analyses for years with a full set of daily values, i.e., from 1990 through 2000. District staff considered use of the baseline flows appropriate for block identification given that regional groundwater withdrawals have been shown to affect flow in the river. Reported flows for the gage site were considered to incorporate additional information on flow seasonality imbedded in the relatively longer gaged-flows record. Although the periods of record differed for the two flow data sets, median daily values exhibited similar seasonal patterns, with flows declining to minimum values from late April to late June (approximately from days 110 to 170), increasing in early summer to peak values in September (approximately from days 244 to 273), and intermediate flows from the late fall (after about day 290) to early spring (Figure 4-7).

Based on the two flow records, District staff identified seasonal blocks for the Pithlachascotee River flows as: Block 1, running from April 25 or day 115 of the calendar year through June 23 or day 174; Block 3, starting on June 24 or day 175 and ending on October 16 or day 289; and Block 2, beginning on October 17 or day 290 and continuing through April 24 or day 114) (Figure 4-7).

Selected percentile values for gaged flows at the Pithlachascotee River near New Port Richey for the time interval used for baseline flow record, i.e., for the period from June 19, 1989 through December 31, 2000, the baseline flows, and the and for the baseline flows segregated by the three seasonal blocks are presented in Table 4-2. The block-specific percentiles illustrate the seasonal variability in flow characteristics of the river. Also, as noted previously in Section 2.9, differences between percentiles for the baseline and gaged flows illustrate the magnitude of groundwater withdrawal effects on the river’s flows.

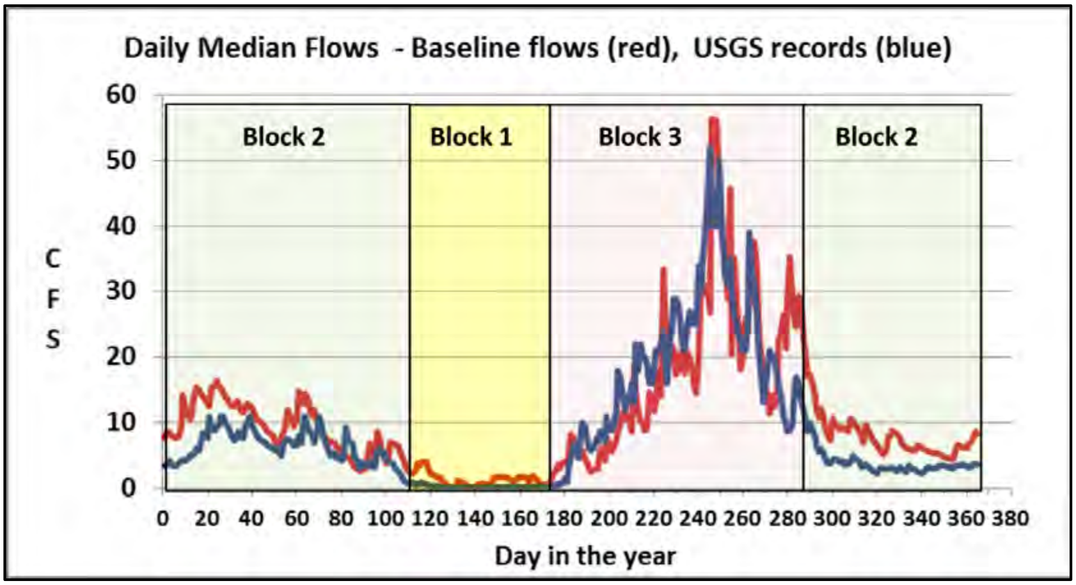


Figure 4-7. Median daily flows for each day of the calendar year for flows recorded at the Pithlachascotee River near New Port Richey gage for years 1982-2012 and baseline flows calculated at the site for the years 1990-2000. Also shown are the three seasonal blocks used for the minimum flows analyses.

Table 4-2. Percentile values of gaged flows at the Pithlachascotee River near New Port Richey gage, baseline flows at the same location and baseline flows segregated into three seasonal blocks used for minimum levels development.

Percentile	Gaged Flows (cfs)	Baseline Flows (cfs)	Baseline Flows for Block 1 (April 25 – June 23) (cfs)	Baseline Flows for Block 2 (Oct. 17 – April 24) (cfs)	Baseline Flows for Block 3 (June 24–Oct. 16) (cfs)
P5	0.0	0.1	0.0	1.0	0.5
P10	0.0	0.6	0.0	1.7	1.5
P25	0.4	2.6	0.1	3.6	4.9
P50	3.3	7.8	1.1	8.1	13.6
P75	12.0	19.3	2.9	16.8	38.8
P90	41.7	57.0	8.5	44.6	93.7
P95	90.0	119.9	15.9	132.3	145.7

4.4 Resources of Concern and Methods for Determining Minimum Flows for the Upper, Freshwater Segment of the Pithlachascotee River

4.4.1 Resources of Concern for the Upper River

The District approach for setting minimum flows for freshwater river segments is habitat-based. Because river systems include a variety of aquatic and wetland habitats that support a diversity of biological communities, it is necessary to identify key habitats for consideration, and, when possible, determine the hydrologic requirements for the specific biotic assemblages associated with the habitats. It is assumed that addressing protection of key habitats will also provide for other ecological functions of the river system that are more difficult to quantify, such as organic matter transport and the maintenance of river channel geomorphology.

Also, because “[a]quatic species have evolved life history strategies primarily in direct response to the natural flow regimes” (Bunn and Arthington 2002), a primary objective of the District’s development of minimum flows for freshwater river segments is to ensure the hydrologic requirements of ecological communities associated with the river channel and its floodplain are maintained. Human use and valuation of the river system, for fishing, swimming, wildlife observation, aesthetic enjoyment, and boating are also important considerations.

District staff identified several specific resource management goals to support minimum flows development for the upper Pithlachascotee River. The goals were established to address all relevant environmental values identified in the Water Resource Implementation Rule for consideration when establishing minimum flows (and levels) and were associated with appropriate ecological criteria supporting development of minimum flow recommendations.

The goals, relevant environmental values, and specific criteria used to address the goals and develop recommended minimum flows for the upper river are summarized below, and are followed by report sub-sections that describe the field sampling and analytical methods use for developing the flow recommendations.

a. Goal: maintenance of minimum water depths in the river channel for fish passage and recreational use.

   Relevant environmental values: recreation in and on water, fish and wildlife habitats and the passage of fish, water quality, and navigation.

   Criteria: fish passage/recreational use depth of 0.6 feet considered for minimum low flow threshold; 40 percent of mean annual flow.

b. Goal: maintain water depths above inflection points in the wetted perimeter of the river channel to maximize aquatic habitat with the least amount of flow.

   Relevant environmental values: fish and wildlife habitats and the passage of fish, sediment loads, and navigation.

   Criteria: wetted perimeter inflection points considered for minimum low flow threshold; 40 percent of mean annual flow.

c. Goal: maintain in-channel habitat availability for selected fish species and macroinvertebrate assemblages.

   Relevant environmental values: fish and wildlife habitat and the passage of fish, transfer of detrital material, and sediment loads

   Criterion: limiting instream habitat changes to 15 percent based on Physical Habitat Simulation (PHABSIM) modeling.

d. Goal: maintain inundation of woody habitats including snags and exposed roots in the stream channel.

Relevant environmental values: fish and wildlife habitat and the passage of fish, transfer of detrital material, and sediment loads.

Criterion: limiting temporal changes in the inundation of woody habitats to 15 percent based on long-term inundation analyses.

e. Goal: maintain seasonal hydrologic connections between the river channel and floodplain to ensure persistence of floodplain habitats.

Relevant environmental values: fish and wildlife habitat 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 and navigation

Criterion: limiting temporal changes in floodplain inundation to 15 percent based on long-term inundation analyses.

Although development of minimum flows for the upper river is expected to provide protection for the lower river, District staff did not specifically consider the environmental value “estuarine resources” when developing minimum flow recommendations for the upper river. Staff did, however, explicitly consider the river’s estuarine resources through assessment of management goals, indicators and criteria associated with minimum flow recommendations for the lower river.

Similarly, staff did explicitly consider the environmental value “maintenance of freshwater storage and supply” for the upper river minimum flows. This value is expected to be protected through inclusion of conditions in water use permits which stipulate that permitted withdrawals will not lead to violation of any adopted minimum flows and levels.

4.4.2 Methods for the Upper River

4.4.2.1 HEC-RAS Modeling Used to Support Minimum Flow Threshold and Percent-of-Flow Methods

A HEC-RAS model (the Pithlachascotee River HEC-RAS model; Engineering and Applied Science, Inc. 2010; included as Appendix 4 B to this report) and available flow records for the Pithlachascotee River near New Port Richey (No. 02310300), Fivemile Creek below Suncoast Parkway near Fivay Junction (No. 02310235), and Pithlachascotee River at Fivay Junction (No. 02310280) gages were used to simulate flows at 42 cross-sections within the study reach (Figure 4-8).

The HEC-RAS model is a one-dimensional hydraulic model that can be used to analyze river flows. Version 4.0 of the HEC-RAS model was released by the U.S. Army Corps of Engineers Hydrologic Engineering Center in March 2008 and supports water surface profile calculations for steady and unsteady flows, including subcritical, supercritical, or mixed flows. Profile computations are initiated at a cross-section with a known or assumed starting condition and then completed in a sequential upstream iterative process for subcritical flow or downstream for supercritical flow. The model resolves the one-dimensional energy equation. Energy losses between two neighboring cross-sections are computed by the use of Manning’s equation in the case of friction losses and derived from a coefficient multiplied by the change in velocity head for contraction/expansion losses. For areas where the water surface profile changes rapidly (e.g., hydraulic jumps, bridges, river confluences), the momentum equation is used (USACE 2001).

Data required for performing HEC-RAS simulations for the river included geometric data and steady-flow data, connectivity data for the river system, reach length, energy loss coefficients due to friction and channel contraction/expansion, stream junction information, and hydraulic structure data, including information for bridges and culverts. Working in conjunction with Engineering and Applied Science, Inc., District staff compiled elevation data used for development of the HEC-RAS model from multiple sources, including: surveyed transects from the District Survey Section assessed specifically to support development of minimum flows for the river, data provided by Ardaman & Associates, Inc., that was originally developed for the District's Watershed Management Program, and LiDAR data maintained by the District's GIS and Mapping Section. Topographic data used in the HEC-RAS model were expressed relative to NAVD 88. For use in the modeling, data that were originally referenced to the NGVD 29 (e.g., the USGS gage stage data and rating curves), a site-specific datum conversion factor determined using the National Oceanic and Atmospheric Administration's VERTCON software "VERTCON" was used to reference the data to NAVD 88.

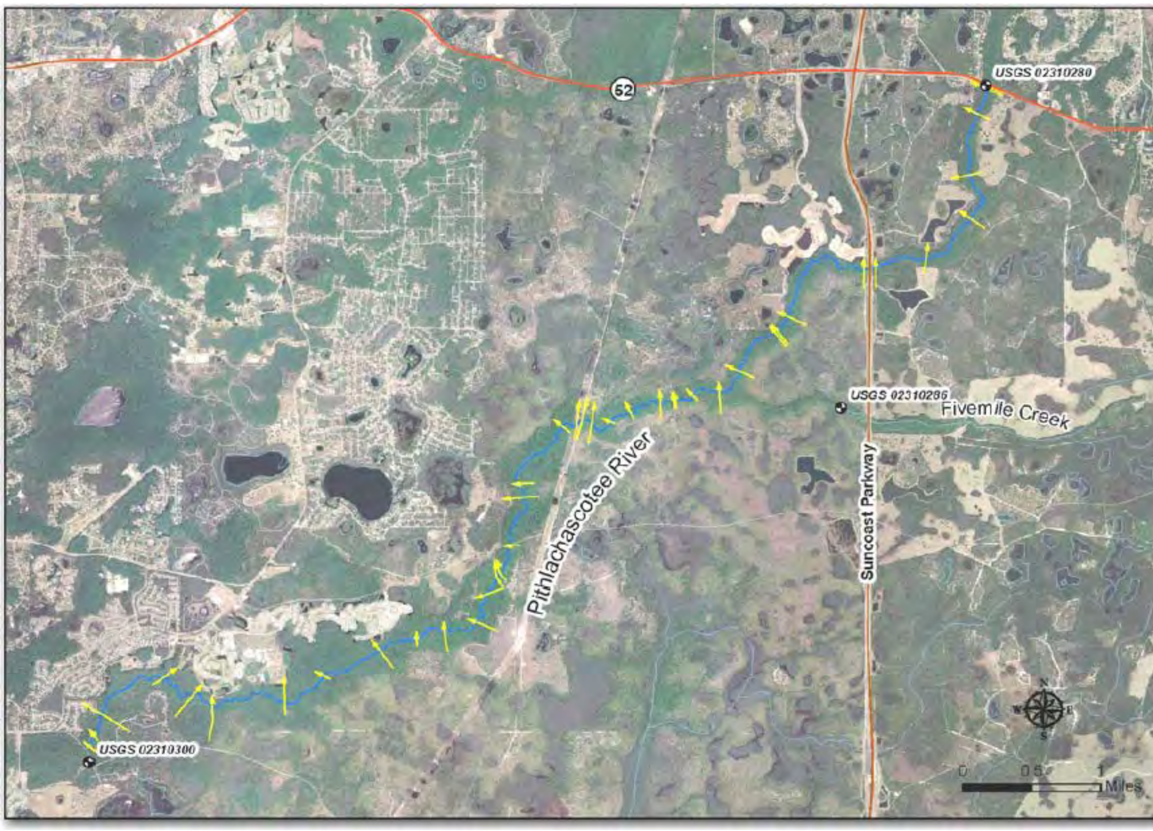


Figure 4-8. Location of the HEC-RAS cross-sections and USGS gages in the freshwater reach of the Pithlachascotee River (image reproduced from Engineering & Applied Science, Inc., 2010).

4.4.2.2 Development of a Minimum Low Flow Threshold for the Upper River

Development of minimum flows for the upper, freshwater segment of the Pithlachascotee River included identification of a minimum low flow threshold. A minimum low flow threshold, which is a flow rate below which no surface water withdrawals are allowed, is developed for some river systems because the environmental values of the river may exhibit high sensitivity to impacts at very low rates of flow. Minimum low flow thresholds have been established as part of minimum flow rules adopted for the freshwater reaches of the Alafia, Anclote, Braden, Hillsborough, Myakka, and middle Peace rivers and Gum Slough Spring Run.

Two low-flow metrics are typically assessed for development of a minimum low flow threshold. One is based on the lowest wetted perimeter inflection point (a measure of gain in available habitat per unit flow); the other is based on maintaining fish passage along the river corridor. The minimum low flow threshold is established at the higher of the two low-flow metrics, provided that comparison of that criterion with historical flow records indicates that it is reasonable. Although flows less than the minimum low flow threshold may occur at any time of year and the threshold is therefore considered applicable throughout the year, they are most likely to occur during Block 1.

For the freshwater reach of the Pithlachascotee River, a recommended minimum low flow threshold was developed for the Pithlachascotee River near New Port Richey gage site. The threshold was based on consideration of fish passage and wetted perimeter metrics as well as consideration of a flow identified using the Tennant Method, which is a widely-used approach for determining environmental flow requirements.

4.4.2.2.1 Assessment of Fish Passage and Recreational Use

For development of a "building block" approach for South African rivers, Tharme and King (1998) as cited by Postel and Richter (2003) listed the retention of a river's natural perenniality or non-perenniality as one of eight general principles for managing river flows. Ensuring sufficient flows supporting the longitudinal connectivity along a river corridor that allows for the natural passage or movement of fishes is an important component of the development of minimum flows. Maintenance of these flows is expected to ensure continuous flow within the channel or river segment, allow for recreational navigation (e.g., canoeing), improve 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 secure the benefits associated with connectivity and sustained low-flows, a 0.6-ft fish-passage criterion was used to develop a low-flow metric for the Pithlachascotee River. The fish-passage criterion is routinely used by the District for development of minimum flows and was considered acceptable by the panel that reviewed the recommended upper Peace River flows (Gore et al. 2002) as well as subsequent peer review panels. Further, Shaw et al. (2005) note "the 0.6-ft standard represents best available information and is reasonable".

Output from multiple runs of the Pithlachascotee River HEC-RAS model was used to assess flow-related water depths at each of the 42 HEC-RAS cross-sections on the main-stem of the river (see Figure 4-8). Flows at the Pithlachascotee River near New Port Richey gage that were associated with flows at each cross-section that resulted in at least 0.6 feet of water in the deepest part of the channel were identified. The mean of these flows at the gage site was calculated for use as a fish passage metric to be considered for development of a minimum low flow threshold.

4.4.2.2.2 Wetted Perimeter Assessment

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 aquatic habitat, in general. Studies on streams in the southeast have demonstrated that the greatest amount of macroinvertebrate biomass per unit reach of stream occurs on the stream bottom (e.g., Benke et al. 1985). Although production on a unit area basis may be greater on snag and root habitat, the greater area of stream bottom along a reach makes it the most productive habitat under low-flow conditions. By plotting the response of wetted perimeter to incremental changes in discharge, an inflection may be identified in the resulting curve where small decreases in flow result in increasingly greater decreases in wetted perimeter. This point on the curve represents a flow at which the water surface recedes from stream banks and habitat 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 considers wetted perimeter to be an important ecological criterion for evaluating minimum flows at the low end of the flow regime. The wetted perimeter inflection point in the channel provides for large increases in bottom habitat for relatively small increases of flow, and for minimum flows development is defined as the “lowest wetted perimeter inflection point.” It is not assumed that flows associated with the lowest wetted perimeter inflection point meet fish passage needs or address environmental values associated with wetted perimeter inflection points outside the river channel. However, identification of the lowest wetted perimeter inflection 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 flow plot for each of the 42 HEC-RAS cross-sections on the Pithlachascotee River. Plots were visually examined for the lowest wetted perimeter inflection point at each cross-section and used along with calculated changes in wetted perimeter on a per cfs basis to identify flow at the Pithlachascotee River near New Port Richey gage that were associated with relatively large changes in wetted perimeter within the river channel. Most cross-sections did not exhibit apparent inflection points for wetted perimeter at elevations within the channel. For cross-sections that displayed no distinct inflection point or where the majority of the in-channel wetted perimeter was inundated at the lowest modeled flow, the lowest wetted perimeter inflection point was established at the lowest modeled flow. The lowest wetted perimeter inflection point flows at each HEC-RAS cross-section were used as a metric for consideration when developing a minimum low flow threshold.

4.4.2.2.3 Tennant Method

The Tennant or Montana method is the most commonly used hydrologically-based environmental flow methodology worldwide (Tharme 2003). The method or modified versions of the method are frequently used for identifying low-flow metrics (Pryce 2004). In his original work on a number of streams in the western United States, Tennant (1975, 1976) notes that maintenance of 20 percent and 40 percent of the mean annual flow was considered “good” for instream flow regimens for fish, wildlife, recreation and associated environmental resources for dry and wet seasons, respectively.

The District applied the Tennant method to develop a low-flow metric for the upper Pithlachascotee River based on concerns with HEC-RAS model predictions for low-flow conditions that were identified by Bill Dunn, Sam Upchurch and Ray Walton as part of the independent scientific peer review of originally proposed minimum flows for the river (Dunn, Salsano & Vergara, Consulting, LLC, Barnes, Ferland and Associates, Inc., SDII Global, and WEST Consultants, Inc. 2016; included as Appendix 1-A). For application of the Tennant method, 40 percent of the mean annual flow was conservatively identified as an appropriate metric for consideration when developing a minimum low flow threshold. The mean annual flow used to derive the 40 percent flow value was developed using daily records for full years from the baseline flow record, i.e., from 1990 through 2000.

4.4.2.3 Percent-of-Flow Methods: Instream Physical Habitat Simulation Modeling

The purpose of the Physical Habitat Simulation System (PHABSIM) is to simulate relationships between streamflow and physical habitat for various life stages of a species of fish or other organism or a recreational activity (Milhous and Waddle 2012). The two basic components of PHABSIM are the hydraulic and habitat simulations of a stream reach using defined hydraulic parameters and habitat suitability criteria. Hydraulic simulation is used to describe the area of a stream having various combinations of depth, velocity, and channel index as a function of flow. This information is used to calculate a habitat measure called Weighted Usable Area for the steam segment from suitability information based on field sampling of the various species of interest. Weighted Usable Area is then used to compare habitat availability between unaltered, baseline and altered flow regimes. If reducing flow is predicted to result in a greater than 15 percent reduction in the usable habitat for a particular species or guild, then these PHABSIM results will be used to determine minimum allowable flows.

PHABSIM is a component of the Instream Flow Incremental Methodology (Bovee et al. 1998) and is the single most widely used methodology for establishing environmental flows for rivers (Postel and Richter 2003). Use of PHABSIM protocols was recommended in the peer review of recommended minimum flows for the upper Peace River (Gore et al. 2002) and it has been successfully used for development of minimum flows for numerous District rivers. All relevant peer reviews conducted for the District to date have supported the use of PHABSIM analyses as a component of the District's development of minimum flows for flowing freshwater systems. Some review panel reports have identified weaknesses associated with the PHABSIM tools and recommended that enhanced hydraulic modeling tools (e.g., 2-D models or hydrodynamic models) could be considered to improve habitat-based assessments. The District has investigated use of 2-D models for assessing freshwater lotic habitats and currently believes they offer little enhancement beyond the 1-D PHABSIM tools. Hydrodynamic models have been employed for assessing and establishing minimum flows for some estuarine systems and the District may consider their use for future application in selected freshwater river systems.

One argument against the use of PHABSIM is that it is too narrow in scope, focusing on a few select species, typically fish of economic or recreational value, and therefore ignores many ecosystem components. This criticism is largely overcome by the District's multifaceted approach in which PHABSIM modeling represents only one of several tools used to evaluate flow requirements. Moreover, our use of PHABISM modeling includes assessment of fish guilds associated with a variety of hydrologically-based habitats.

The approach used for application of PHABSIM analyses for the upper Pithlachascotee River (see Appendix 4C) was comparable to previous use of the model suite for determining minimum flows for flowing freshwater systems within the District. There were no significant variations from previous PHABSIM data collection or analysis activities. Staff notes, however, that the District has used differing approaches for summarization and use of PHABSIM results supporting minimum flow development.

For the PHABSIM modeling, cross-sections were established at three representative sites to quantify specific habitats for fish and macroinvertebrates within the river channel at differing flow conditions (Figure 4-9). The PHABSIM sites were co-located at three of the 15 cross-section sites used for characterization of floodplain vegetation/soils/hydrologic indicators and instream woody habitats. Where possible, the PHABSIM sites were selected to include shoals, pools and runs. Shoals were included because these features represent hydraulic controls used in developing hydraulic simulation models with PHABSIM software, and loss or reduction of hydraulic connection at these locations during low-flow periods may also present barriers to fish migration or hamper recreational use. Field reconnaissance of shoals within the entire study reach was conducted to aid in the selection of PHABSIM sites. Pools and runs were included in the PHABSIM sites based on their common occurrence in the river. Based on the geomorphology of the river channel and to ensure adequate representation of the river corridor, runs were included at all three PHABSIM sites, shoals were included at two sites (PHABSIM CTE 1 and PHABSIM CTE 2) and a pool was included at one of the sites (PHABSIM CTE 1).

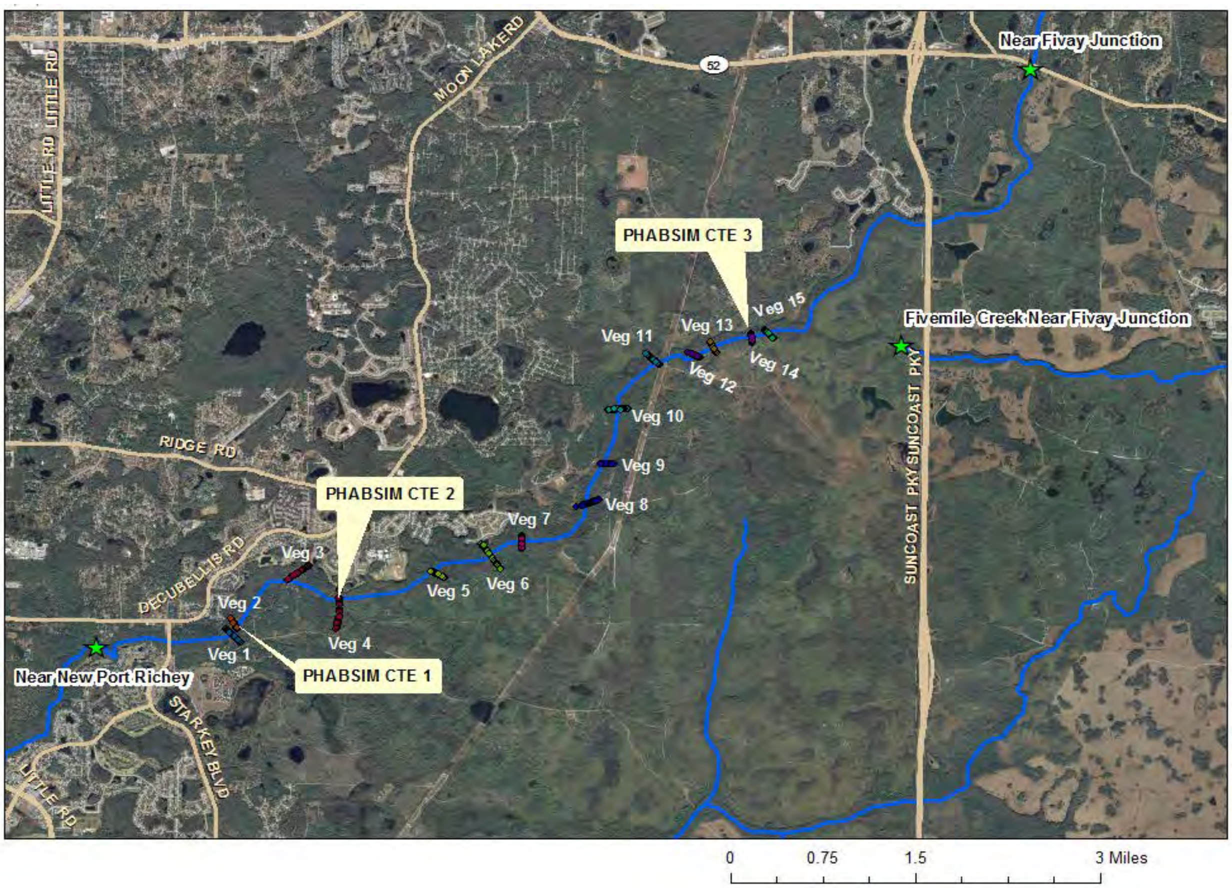


Figure 4-9. Location of PHABSIM (CTE 1 through 3) and floodplain inundation (Veg 1 through Veg 15) cross-section study sites and USGS gages in the freshwater reach of the Pithlachascotee River.

The PHABSIM analyses required acquisition of field data concerning channel habitat composition and hydraulics. At each PHABSIM site, tag lines were used to establish up to three cross-sections corresponding to shoal, run and pool habitats, as applicable, across the channel to the top of bank on either side of the river. At each cross-section, stream depth, substrate type and habitat/cover were recorded and water velocity was measured with a StreamPro Acoustic Doppler Current Profiler and/or a Sontek Flow Tracker Handheld Acoustic Doppler Velocimeter at intervals determined based on cross-section width. Interval selection was based on collecting a minimum of 20 sets of measurements per cross section. Other hydraulic descriptors measured included channel geometry (river bottom-ground elevations), water surface elevations across the channel and water surface slope determined from points upstream and downstream of the cross-sections. Elevation data were collected relative to temporary bench marks that were subsequently surveyed by District surveyors to establish absolute elevations, relative to the NAVD 88. Data were collected under a range of flow conditions (low, medium and high flows) to provide information needed to run the PHABSIM models for each site.

Hydraulic and physical data were used in the PHABSIM analyses to predict changes in velocity in individual cells of the channel cross-section as water surface elevation changes. Hydraulic modeling of water surface elevations and velocities for the PHABSIM sites was conducted using the IFG4 component of the suite of PHABSIM models. Water surface predictions were made through a series of back-step calculations using either Manning's equation or Chezy's equation. Predicted velocity values were used in a second program routine (HABTAT) to determine cell-by-cell the amount of weighted usable area (WUA) or habitat available for various organisms at specific life history stages or for spawning activities (see the next section of this report for information on the assessed groups). The WUA/discharge relationships for individual species/life history stage/guild guilds spawning activities were then used to evaluate modeled habitat gains and losses with changes in discharge.

Once the relationships between hydraulic conditions and WUA were established, a time-series analysis routine (TSLIB) from the USGS Mid-Continent Research Laboratories (Milhous et al. 1990) was used to simulate of WUA for the baseline flow record and baseline flow records reduced by 10, 20, 30 and 40 percent were conducted for 16 species/lifestages/guilds at each of 3 PHABSIM sites. Appendix 4C includes additional information regarding simulation of hydraulic conditions for the river that were used with Habitat Suitability Curves and discharge data to evaluate changes in habitat availability associated with changes in flows.

For development of minimum flow and level metrics for the upper Pithlachascotee River, WUA estimates for each or the 16 species/life stages/guilds from three PHABSIM sites were combined for analysis and maximum flow reductions associated with less than a 15 percent change in WUA were identified. Separate analyses were completed for Blocks 1 and 2, which correspond with the periods of low and medium flow, respectively.

The process used for the analysis and reporting included the following steps:

a. Identifying the WUA by month for each taxon/life history stage/guild for each PHABSIM site for the baseline and four (10, 20, 30 and 40 percent) flow reduction simulations.

b. Compositing (adding together) the WUA values for the three PHABSIM sites to develop taxon/life history stage/guild WUA values for the study reach for the baseline and flow reduction scenarios.

c. Determining percent changes from the composited, baseline WUA values for each flow reduction scenario by month.

d. Identifying flow reductions associated with a 15 percent decrease in the WUA values, typically through linear interpolation of results for the 10, 20, 30 and 40 percent flow reduction scenarios.

e. Identifying monthly flow reductions associated with the 15 percent decrease in WUA values by Block (May and June results for Block 1 and October through April results for Block 2) and identifying the most restrictive, blocks-specific monthly value for each taxon/life history stage/guild.

f. Summarizing (in Table 5-1) block-specific responses associated with 15 percent habitat availability changes that were less than the maximum 40 percent flow reduction scenario.

4.4.2.3.1 Development of Habitat Suitability Curves for PHABSIM Analyses

Habitat suitability criteria used for PHABSIM modeling for the upper Pithlachascotee River included continuous variable or univariate curves designed to encompass the expected range of suitable conditions for water depth, water velocity, and substrate/cover type and proximity. Habitat suitability curves are generally classified into three categories based on the types of data and data summarization approaches used for their development (Waddle 2012).

Type I curves are not dependent upon acquisition of additional field-data but are, instead, based on personal experience and professional judgment. Informal development of Type I curves typically involves a roundtable discussion (Scheele 1975); stakeholders and experts meet to discuss habitat suitability information to be used for prediction of habitat availability for specific target organisms. A more formal process, known as the Delphi technique (Zuboy 1981) involves submission of a questionnaire to a large respondent group of experts. Results from this survey process are summarized by presenting a median and interquartile range for each variable. Several iterations of this process must be used in order to stabilize the responses, with each expert being asked to justify why his/her answer may be outside the median or interquartile range when presented the results of the survey. The Delphi system lacks the rapid feedback of a roundtable discussion, but does remove the potential biases of a roundtable discussion by creating anonymity of expert opinion. The Delphi system does assume that experts are familiar with the creation of habitat suitability criteria and can respond with sufficient detail to allow development of appropriate mathematical models of habitat use.

Type II curves are based upon frequency distributions for use of certain variables (e.g., flow), which are measured at locations utilized by the target species. Curves for numerous species have been published by the U.S. Fish and Wildlife Service (USFWS) or the USGS and are commonly referred to as “blue book” criteria.

Type III curves are derived from direct observation of the utilization and/or preference of target organisms for a range of environmental variables (Manly et al. 1993). These curves are weighted by actual distribution of available environmental conditions in the stream (Bovee et al. 1998). Type III curves assume that the optimal conditions will be “preferred” over all others if individuals are presented equal proportions of less favorable conditions (Johnson 1980).

Based on the abundance and distribution of spotted sunfish (*Lepomis punctatus*) in rivers within the District, modified Type III habitat suitability curves were created for adult, juvenile, spawning and fry life stages of this species and used for evaluating habitat availability at the Pithlachascotee River PHABSIM sites. Development of these curves involved the initial creation of Type I curves that were subsequently modified based on field sampling efforts. Initially, since most of the regional experts in fish ecology that were consulted were unfamiliar with development of habitat suitability criteria, a hybrid of the roundtable and Delphi techniques was used to develop Type I curves for the species. For this effort, a proposed working model of habitat suitability criteria was provided to 14 experts for evaluation. The proposed suitability curves were based on flow criteria reported by Aho and Terrell (1986) for another member of the Family Centrarchidae, the redbreast sunfish (*Lepomis auritus*) that were modified according to published literature on the biology of spotted sunfish. Respondents were given approximately 30 days to review the proposed habitat suitability criteria and to suggest modifications. Six of the 14 experts provided comments. In accordance with Delphi techniques, the suggested modifications were incorporated into the proposed Type I curves. Suggested modifications that fell outside of the median and 25 percent interquartile range of responses were not considered unless suitable justification could be provided. The resulting Type I curves were later modified following fish sampling conducted on the Peace River. Data obtained from these field collections were considered sufficient to classify the modified curves as Type II to Type III curves.

Modified Type II habitat suitability criteria for adult, juvenile, spawning and fry life stages of largemouth bass (*Micropterus salmoides)* and bluegill (*Lepomis macrochirus*), two other common fish species in the Pithlachascotee River, were established using USFWS/USGS “blue book” criteria (Stuber et al. 1982). Curves for these species have been widely used in PHABSIM applications and were used for the Pithlachascotee River PHABSIM analyses.

Type III habitat suitability criteria for macroinvertebrate community diversity were established based on suitability curves published by Gore et al. (2001). Modified substrate and cover codes used for criteria development were established through consultation with District and Florida Fish and Wildlife Conservation Commission staff. For this effort, emphasis was placed on invertebrate preference for macrophytes, inundated woody snags and exposed root habitats common in the Pithlachascotee River and other Florida streams.

A Type II habitat suitability curve for combined adult life stages of minnows (the Family Cyprinidae) was developed based on electrofishing conducted at several Florida rivers. The sampling involved quantification of all cyprinid minnows, without segregation by species, in association with observed flow velocities, water depth and substrate types. The curve is, therefore, based on total occurrence of cyprinids in the sampled Florida systems. It may be considered a generalized curve applicable for all Cyprinidae and could certainly be refined for individual taxa or for specific water bodies based on data availability. This generalized curve was considered suitable for use in the PHABSIM analyses for the Pithlachascotee River.

Type III curves developed for a suite of habitat guilds representative of fish habitat diversity were also used for the PHABSIM analyses for the Pithlachascotee River. The habitat guild curves include shallow-slow, shallow-fast, deep-slow and deep-fast guilds and serve as generalized indicators of habitat diversity associated with ranges of flow velocity, water depth and substrate type. They are used to improve understanding of results based on taxon-specific curves and to address potential habitat changes for taxa currently lacking specific life-history stage curves. The habitat guild criteria are based on information developed by Leonard and Orth (1988) for a suite of fish and habitat types occurring in a number of streams in Virginia. Their use for the Pithlachascotee River and other Florida systems is considered appropriate as they specify habitat characteristics that may be expected to be populated by local fish fauna.

4.4.2.4 **Percent-of-Flow Methods: Assessment of Additional Instream and Woody Habitat Inundation**

Stream ecosystem theory emphasizes the role of instream habitats in maintaining ecosystem integrity. These habitats form a mosaic of geomorphically defined substrate patches (Brussock et al. 1985), each with characteristic disturbance regimes and macroinvertebrate assemblages (Huryn and Wallace 1987). For instance, invertebrate community composition and production in blackwater rivers vary greatly among different habitat types, where the habitats are distinguished by substrates of different stability (e.g. , sand, mud and woody debris) (Benke et al. 1984, Smock et al. 1985, Smock and Roeding 1986). Ecosystem dynamics are influenced by the relative abundance of these different habitat types. 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.

Among the various instream habitats that can be influenced by different flow conditions, woody habitats (snags and exposed roots) are especially important (Cudney and Wallace 1980; Benke et al. 1985, Wallace and Benke 1984; Thorp et al. 1990; Benke and Wallace 1990). Wood provides a relatively stable, structurally complex habitat 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 larger debris dams. These resulting habitats provide the same functions as woody substrata in addition to enhancing instream habitat diversity. Sustained inundation of instream woody habitats for sufficient periods is considered critical to secondary production (including fish and other wildlife) and the maintenance of aquatic food webs.

To characterize instream habitats, including woody habitats, cross-sections were assessed at fifteen sites (thirteen vegetation only and two PHABSIM/vegetation) on the upper Pithlachascotee River (see Figure 4-6). Three instream cross-sections, from the top of bank on one side of the channel to the top of the opposite bank were established at each site perpendicular to flow in the channel. Typically, one of three instream cross-sections at each site was situated along the floodplain vegetation transect line and the other two cross-sections were located 50 feet upstream and downstream. A total of 45 instream cross-sections were sampled (15 sites x 3 cross-sections at each site).

For each instream habitat cross-section, the range in elevations (feet above NAVD 88) and linear extent along the cross-section were determined using standard surveying equipment for the following habitat types:

- bottom substrates (sand, mud and leaf litter);
- woody habitats (exposed roots and woody debris or snags);
- vegetation (wetland vegetation, i.e., herbaceous plants and shrubs), emergent vegetation and wetland trees)

Additional elevation information was collected for exposed root and snag woody habitats at each instream habitat site. Minimum and maximum, i.e., top and bottom elevations of up to 15 samples of exposed root and snag habitats located between the center and upstream site cross-sections were measured along each bank and averaged for each sample. If the water surface elevation between the two cross-sections differed by more than 0.5 feet, woody habitat sampling was extended upstream along each bank an additional 50 feet. Mean exposed root and snag habitat elevations were determined for each site based on the sample averages.

The Pithlachascotee River HEC-RAS model was run using multiple steady-flow rates to identify flow-stage relationships at the instream habitat sites. Based on these relationships, corresponding flows at the Pithlachascotee River near New Port Richey gage necessary to inundate the mean elevations of exposed roots and snags were determined. This information was used along with the baseline flow records and sequentially reduced baseline flow records (10, 20, 30 and 40 percent reductions) in a spreadsheet-based long-term inundation analysis to identify the number of days during the baseline period of record that the specified flow or level (i.e., the mean exposed root and snag elevation) was equaled or exceeded at each site. For the purpose of developing minimum flows recommendations, maximum percent-of-flow reductions that would result in 15 percent fewer days of inundation of the mean elevations associated with the two woody habitat types relative to the baseline condition were determined.

4.4.2.5 Percent-of-Flow Methods: Assessment of Floodplain Habitat Inundation and Development of a Minimum High Flow Threshold for the Upper River

Junk et al. (1989) note that the "driving force responsible for the existence, productivity, and interactions of the major river-floodplain systems is the flood pulse". Floodplain vegetation development and persistence does not, however, necessarily depend wholly on inundation from the river channel. Groundwater seepage, hyporheic inputs, discharge from local tributaries and precipitation can also lead to floodplain inundation (Mertes 1997). However, because river channel-floodplain connections are important, can be influenced by water use, and are a function of out-of-bank flows, it is valuable to characterize this connectivity for development of minimum flows.

The District's approach to protection of flows associated with floodplain habitats, communities and functions involves consideration of the frequency and duration of direct connection between the river channel and the floodplain. As part of this process, plant communities, soils and hydrologic indicators are identified across the river floodplain at a number of sites, and periods of inundation/connection with the river are reconstructed on an annual or seasonal basis. These data are used to characterize the frequency and duration of direct connection/ inundation of these communities to, or by the river and to develop criteria for minimum flow development based on temporal loss of habitat (Munson and Delfino 2007). This approach for assessment of floodplain inundation is a standard approach that has been used for nearly all of the minimum flow recommendations developed for freshwater river segments within the District and subjected to numerous peer-reviews.

Floodplain vegetation, soil, and hydrologic indicator data collection and analyses for the Pithlachascotee River were completed by SWRF, LLC and Dooris & Associates, LLC (2010), included as Appendix 4D to this report, for 15 representative cross sections perpendicular to the river channel (see Figure 4-Figure 4-9). Floodplain cross-sections were selected based on review of 2007 land-use and National Wetland Inventory mapping, historical aerial imagery and following site reconnaissance in December 2008. Cross section lengths extended up to the estimated one percent exceedance level of expected inundation.

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. At each change in vegetation zone, plant species composition, density, basal area and diameter at breast height (dbh) for woody vegetation with a dbh greater than 1 inch were recorded. At least three samples located within each vegetation zone were collected using the Point Centered Quarter method (see Cottam and Curtis 1956, as cited in SWRF, LLC and Dooris & Associates, LLC 2010).

Soils along the floodplain cross-sections were evaluated for the presence of hydric or flooding indicators, as well as saturation and/or inundation condition. At least three soil cores were examined to a minimum depth of 20 inches within each vegetation zone at each cross section. Soils were classified as upland (non-hydric), hydric or non-hydric with the presence of flooding indicators. Key physical indicators of historical inundation were also identified, including lichen and/or moss lines and hummocks. The number of sampled physical indicators varied by transect, depending on their availability and reproducibility.

Ground elevation data were used to compare vegetation, soils and indicators within and among cross-sections. For some comparisons, elevations were normalized to the lowest channel elevations at the cross-section to account for differences in absolute elevations among the cross-sections.

As was done for the instream habitat cross-sections, District staff used the Pithlachascotee River HEC-RAS model to determine corresponding flows at the Pithlachascotee River near New Port Richey gage necessary to inundate specific floodplain elevations (e.g., mean vegetation zone, soils, and hydrologic indicator elevations). By assessing elevations associated with a variety of floodplain features that occur across the range of floodplain elevations, the flow-reduction assessments used for minimum flow determination were expected to be representative of changes in environmental values associated with inundation patterns at the high-end of the flow regime.

District staff then used this stage-flow information along with the baseline flow records and sequentially reduced baseline flow records in a spreadsheet-based long-term inundation analysis to identify the number of days during the baseline period of record that the specified elevations were equaled or exceeded at the individual floodplain cross-sections. District staff determined percent-of-flow reductions that would result in greater than a 15 percent reduction in the total number of days of inundation of floodplain features for the baseline condition at each cross-section and plotted the percentage flow reductions as a function of the corresponding flows at the Pithlachascotee River near New Port Richey gage.

Through inspection of these plots, District staff identified percent-of-flow reductions associated with acceptable temporal changes in habitat inundation that have been shown to correspond with potential habitat changes on a spatial basis (Munson and Delfino 2007). Because inundation of the floodplain by river flows occurs predominately during Block 3 in most years, District staff used the identified percent-of-flow reductions for developing minimum flow recommendations for Block 3. Also, because flows during Block 3 included a range of lower flows that do not require flow limitations to be limited to those determined for higher Block 3 flows, District staff identified two percent-of-flow reductions applicable for Block 3. One was identified as the mean of allowable percent-of-flow reductions that exhibited stabilization for a range of higher flows. The second was established as the 25th percentile of the allowable percent-of-flow reductions associated with a range of lower flows, i.e., for flows that are less than a Minimum High Flow Threshold, which is described in the following section of this report.

4.4.2.5.1 Development of a Minimum High Flow Threshold for the Upper River

A minimum high flow threshold provides a flow-based means to differentiate between two allowable percent-of-flow reductions identified for a specific seasonal block or blocks. Minimum high flow thresholds are developed for freshwater river segments because the environmental values of these systems typically exhibit differing sensitivity to withdrawal impacts over the range of flows that occur during the seasonal period of higher flows, i.e., during Block 3. Use of a high minimum flow threshold allows for the use of two-tier percent-of-flow reductions during Block 3 that will protect floodplain features and habitats and allow for variable withdrawal rates for the ranges of Block 3 flows that exhibit differing sensitivity to flow reductions.

Minimum high flow thresholds have been established as part of minimum flow rules adopted for the freshwater segments of the Alafia, Braden, Hillsborough, Myakka, and middle Peace rivers. The minimum flows adopted for the upper Anclote River also include a high flow threshold although the rule associated with the minimum flows does not specifically identify the threshold as a minimum high flow threshold.

As noted in the Section 6.5.1.2, development of a high minimum flow threshold for the upper Pithlachascotee River was based on assessment of the potentially allowable percent-of-flow reductions at the Pithlachascotee River near New Port Richey gage that resulted in 15 percent fewer days that a given flow reached elevations associated with identified floodplain habitats and features. This assessment indicated the allowable percent-of-flow reduction tended to stabilize at moderate to high flows and exhibited more variation at lower flows. The upper limit of the range of lower flows was defined as the flow necessary to exceed bank elevations at the Pithlachascotee River near New Port Richey, and was proposed as a minimum high flow threshold for the upper river.

4.5 Resources of Concern and Methods for Determining Minimum Flows for the Lower, Estuarine Segment of the Pithlachascotee River

4.5.1 Resources of Concern for the Lower River

Estuaries are tidally influenced ecosystems where fresh water flow from a contributing watershed mixes with salt water from a receiving ocean, bay, or gulf. Given their physiographic setting and influence of both fresh and marine waters, the interactions of physical, chemical, and biological variables that occur in estuaries are complex and dynamic. The District has established minimum flows for the estuarine zones of ten rivers that geographically range from the Lower Peace River in Charlotte County to the Homosassa River in Citrus County. Various physical, water quality and biological factors have been evaluated to support their development. In all rivers that have been previously studied, salinity distributions were typically one the most sensitive criteria assessed for minimum flows establishment.

The resource management goals for the lower river were associated with maintaining various salinity zone habitats that are associated with the environmental values identified in the Water Resource Implementation Rule for consideration when establishing minimum flows. Salinity responds to changes in freshwater inflow in a predictable manner that can be assessed and simulated using various modeling techniques for development of metrics supporting the identified goals. The nature and rates of many physicochemical processes, such as nutrient uptake and detrital deposition, vary spatially within estuaries along the salinity gradient from fresh to marine waters. Similarly, the abundance and distribution of biological assemblages in estuaries are strongly affected by salinity distributions.

Potential flow-related changes in salinity zones were evaluated using regression modeling techniques. The location or four isohalines, i.e., the locations of specific salinity concentrations in the lower river were predicted using regression models develop based on field sampling conducted during 1985 to 1987 and 2009. Isohaline locations expressed as river kilometer were then used to calculate the extent of upstream shoreline, river bottom and water-column volume associated with the specified salinities using cumulative physical metrics described in Sections 3.3 and 3.5. The isohalines selected for the minimum flow analyses were chosen to represent the boundaries of salinity zones that are important to shoreline plant communities, benthic macroinvertebrates, and nekton (free swimming fish and invertebrates).

The goals identified for minimum flow development for the lower river, relevant environmental values, and specific criteria used to address the goals are listed below. Field sampling and analytical methods used to address the goals and develop minimum flow recommendations are addressed in subsequent report sub-sections.

a. Goal: maintain surface isohaline locations within ranges that protect the distribution of shoreline vegetation communities associated with low-salinities.

   Relevant environmental values: fish and wildlife habitats and the passage of fish; estuarine resources; and water quality.

   Criteria: limit flow-related changes in vegetated shoreline length upstream of selected isohalines to no more than 15 percent of those associated with baseline flows.

b. Goal: maintain river bottom areas within biologically-important salinity zones for the protection of benthic macroinvertebrates.

   Relevant environmental values: fish and wildlife habitats and the passage of fish; estuarine resources; and water quality.

   Criteria: limit flow-related change in river bottom area upstream of selected isohalines to no more than 15 percent of those associated with baseline flows.

c. Goal: maintain salinity zone volumes for the protection of free-swimming fish and invertebrates (nekton).

   Relevant environmental values: fish and wildlife habitat and the passage of fish; estuarine resources; and water quality.

   Criteria: limit flow-related change in water-column volume upstream of selected isohalines to no more than 15 percent of those associated with baseline flows.

All environmental values included in the State Water Resource Implementation Rule are expected to be protected by the resource management goals and ecological indicators identified for the estuarine segment of the Pithlachascotee River. Due to the strong tidal characteristics of the lower river and it's relatively low rates of freshwater inflow, District staff reasonably conclude that implementation of the recommended minimum flows should have a negligible effect on water levels in the lower river. The environmental values navigation and recreation in and on the water identified in the rule should, therefore, not be adversely affected by implementation of any recommended minimum flows for the lower river.

Similarly, assuming that water quality and other ecological characteristics of the river will not be adversely affected through implementation of minimum flows that support maintenance of appropriate salinity-based habitats, aesthetic and scenic attributes are also expected to be protected. As noted in Chapter 2, District staff found minor or no relationships between freshwater inflow and dissolved oxygen and nutrient concentrations in the river, suggesting that these important water quality parameters are not expected to substantially change in response to flow reductions that may be associated with implementation of proposed minimum flows.

Other environmental values identified in the Water Implementation Rule concern complex physical and biological processes, including: transfer of detrital material, filtration and absorption of nutrients and other pollutants, and sediment loads. These processes can be difficult in to quantify, but are likely linked to the rate of freshwater inflow. Accordingly, the resource protection goals and the associated criteria identified for the Pithlachascotee River that are strongly linked to the rate of freshwater inflow are expected to be protective of these environmental values. In addition, the environmental value, maintenance of freshwater storage and supply, is also expected to be protected by the minimum flows established for the river, based on inclusion of conditions in District-issued water use permits that stipulate permitted withdrawals will not lead to violation of adopted minimum flows and levels.

4.5.2 Methods for the Lower River

4.5.2.1 Calculation of Isohaline Locations and Development of Empirical Isohaline Regression Models to Support Minimum Flow Thresholds and Percent-of-Flow Methods

District staff examined the movement of isohalines in the lower Pithlachascotee River as a function of freshwater inflow. In a bay or broad estuary, an isohaline represents a line of equal salinity that is distributed two-dimensionally over the area of the estuary. However, in a narrow estuary such as the lower Pithlachascotee River, the location of an isohaline typically varies little from bank to bank. Therefore, the terms isohaline and isohaline location are used in this report to denote the location of a specific salinity value in the lower river, expressed in river kilometers upstream from the river mouth along the centerline of the river.

Using the data from the 32 District sampling trips discussed in Chapter 3, District staff linearly interpolated locations of the 2, 5, 12, and 18 psu isohalines for each sampling date based on the nearest upriver and downriver stations. If the stations that bounded a particular isohaline value were greater than three kilometers apart, then an isohaline position was not calculated. Separate locations were computed for surface, bottom, and water column isohalines. Surface isohalines were calculated from field measurements collected at depths less than 0.5 meters (typically 0.3 meters); bottom isohalines were calculated from field measurements made at the greatest depth at each station; and the water column isohalines were based on mean salinity measurements at each station.

Isohaline locations move upstream and downstream in the river channel with changes in both tide and freshwater inflow, moving toward the mouth of the river during high flows and moving upstream during low flows. A complete set of isohaline locations were not calculated for some sampling dates, as one or more isohalines occurred beyond the river mouth in the Gulf of Mexico. Also, on some of the trips during the 1985 through 1987 sampling period, salinities for the full set of sampling stations were not collected. The number of salinity measurements used for identification of the various isohalines therefore varied, with generally more observations available for the lower salinity, 2 and 5 psu isohalines (Table 4-3). The number of observations and percentile values for the calculated locations of 2 psu, 5 psu, 12 psu, and 18 psu surface and water column isohalines based on District sampling trips are listed in Table 4-3.

District staff considered the surface and water column isohalines to be most representative of river salinity, because the calculation of bottom isohaline locations was subject to differences in the maximum depth of sampling at each station. Accordingly, the locations of bottom isohalines were not incorporated in the final minimum flows analysis and are not discussed further in this report.

Median (50th percentile) locations of the isohalines ranged from river kilometer 8.2 for the 2 psu surface isohaline to river kilometer 2.8 for the 18 psu water column isohaline. The differences between the 5th and 95th percentile locations of the isohalines listed in ranged from 5.5 to 7.0 kilometers, indicative of their seasonal migration in the river channel. However, these values are based on the inflow conditions that occurred during the District sampling trips, and a greater range of values would likely have been observed if sampling had been conducted over a greater range of inflows.

Table 4-3. Percentile values of river kilometer locations of the 2 psu, 5 psu, 12 psu and 18 psu surface and water column isohalines developed based on District sampling conducted during 1985-1987 and 2009-2010. Number of observations (n) for each isohaline also listed.

	Type	n	5th Percentile	25th Percentile	50th Percentile	75th Percentile	95th Percentile
2 psu	Surface	30	4.6	6.3	8,2	9.8	10.9
	Water Column	31	4.9	6.5	7,7	9.8	11.0
5 psu	Surface	29	3.5	5.3	6.3	7.6	10.5
	Water Column	31	4.0	5.6	6.6	8.2	10.5
12 psu	Surface	28	2.4	3.3	4.6	5.8	7.9
	Water Column	30	2.8	3.5	4.9	6.0	8.5
18 psu	Surface	23	1.1	1.8	2.5	4.7	6.9
	Water Column	24	1.0	2.1	2.8	5.1	7.3

To assess the potential effects of reductions of freshwater inflow on salinity distributions in the lower river, HDR Engineering, Inc., under contract to the District, developed regression models for predicting isohaline locations in the river as a function of freshwater inflow. This approach has been used to examine salinity-inflow relationships in various rivers in the District (Giovannelli 1981, Stoker 1992, Hammett 1992) and has been used for developing minimum flow recommendations for numerous District rivers, including the lower Alafia, lower Myakka, lower Peace, Homosassa River, and the lower Anclote River, which is located immediately to the south of the Pithlachascotee River (SWFWMD 2008a, 2010a, 2010b, 2010c, 2012a).

Working with HDR Engineering, Inc., District staff developed multiple-regression models to predict the location of selected isohalines in the river based on inflow rate and tide stage. Data used for model development included salinity measurements from the 32 District sampling trips completed in 1985-1987 and 2009, concurrent freshwater inflow data from the Pithlachascotee River near New Port Richey gage, and tidal elevation at the Pithlachascotee River at Main Street gage. To account for antecedent flows in the river, four-day mean flows calculated as the average of the flow on the day of the salinity data collection and the preceding three days were used for model development. Data associated with a single, four-day flow of 645 cfs were excluded from the record used for development of the regression models to avoid skewing regression parameters based on an unusual, single high-flow event. In addition, the models were developed using data associated with predicted isohaline river kilometer locations (see Figure 3.7) greater than 0.5 and this led to the exclusion of a single record from the data used to develop the predictive regression for the 18 psu water-column isohaline. Data used for model development is included in Appendix 4E. Effects of estimated ungaged runoff below the gage were not accounted for in the regression models, but staff assumed ungaged inflows tended to vary in synchrony with the gaged streamflow in response to seasonal rainfall patterns.

Tide stage (elevation) values for model development included 15-minute data from the Pithlachascotee River at Main Street gage. Because there were some dates during 2009 when tide-stage values were not available at the site, and because only one tide-stage value for the site was available for association with the isohalines based on sampling completed in 1985 through 1987, tide-stage values predicted from tidal harmonics were developed. HDR Engineering, Inc. produced the predicted tide stage values by first generating 15-minute tidal predications for the period from January 1, 1985 through August 31, 2010 for the Pithlachascotee River at New Port Richey gage using the program Tides & Currents Pro (available at http://www.marinecomp.com/ tides_and_current.htm). A regression model was then developed for associating the 15-minute values for the synthetic New Port Richey gage data with reported tide-stage data for the Main Street gage site. The regression, with a coefficient of determination of 0.74, was:

$$Main\ Street_t = -1.74942 + 0.90768 \times SYN\ at\ New\ Port\ Richey_{t+3} \quad \text{[Equation 3];}$$

where: $Main\ Street_t$ = Tide stage elevation in feet (NAVD 88) at the Pithlachascotee River at Main Street gage at time *t; and*

$SYN\ at\ New\ Port\ Richey_{t+3}$ = Synthetic Pithlachascotee River at New Port Richey gage water level at time *t+3, i.e.,* at a three-step lead time or 45 minutes ahead of time *t*.

Using a composite of measured and model-predicted (with Equation 3) tide stage values for the Pithlachascotee River at Main Street gage and the square root of the four day average freshwater flow at the Pithlachascotee River near New Port Richey gage as independent variables and the natural logarithm of the isohaline locations expressed by river kilometer as the dependent variable, District staff developed a series of multiple linear regression models using the SAS procedure Proc Reg (Table 4-4; Appendix 4F). Tidal elevation values at the Pithlachascotee River at Main Street gage nearest the time of the salinity sampling used for isohaline development were used for all models.

Inflow rate was a highly significant explanatory variable for all surface and water column isohaline models. Tide stage was significant for all surface isohaline models, and for the 12 and 18 psu water-column isohaline models. Coefficients of determination for the models ranged from 0.70 to 0.90, with the best fits observed for the 2 and 5 psu isohaline regressions. Models developed for the 12 and 18 psu isohalines were less robust. These isohalines are located further downstream, where tidal influences from the Gulf of Mexico are greater, and ungaged stormwater runoff from urbanized areas in the downstream reach likely exerts greater influence on their location. Plots of observed isohaline positions relative to locations predicted using all of the regression models are provided in Appendix 4G.

Table 4-4. Regression coefficients for predicting the location of the 2, 5, 12, and 18 psu surface and water-column isohalines in the lower Pithlachascotee River. Model form is: In River Kilometer = a + b1 * Square Root of the four-day average flow at the Pithlachascotee River near New Port Richey gage in cubic feet per second + b2 * Gage Height at Pithlachascotee River at Main Street Gage in feet above NAVD 88.

Type	Isohaline	n	a	b1	b2	Mean Square Error	r^2
Surface	2	29	2.24350*****	-0.07630 *****	0.06975 **	0.007	0.90
	5	28	2.06925 *****	-0.08281 *****	0.08022 *	0.019	0.81
	12	28	1.64683 *****	-0.09798 *****	0.18929 ***	0.036	0.76
	18	23	1.18853 *****	-0.14542 *****	0.27771 *	0.130	0.70
Water Column	2	30	2.30405 *****	-0.06292*****	NS	0.010	0.84
	5	30	2.16888 *****	-0.06564 *****	NS	0.018	0.89
	12	29	1.65724 *****	-0.08950 *****	0.21454 ****	0.025	0.79
	18	23	1.22552 *****	-0.12464 *****	0.29498 **	0.098	0.70

p< 0.10 (*); p< 0.05 (**); p< 0.01 (***); p< 0.001 (****); p< 0.0001 (*****); NS (not significant)

4.5.2.2 Percent-of-Flow Methods: Assessment of Salinity-Based Shoreline Habitat

Numerous studies indicate that assessment of potential shifts in selected isohalines in river channels can be used to evaluate potential impacts to tidal wetland communities. District staff, the South Florida Water Management District and Suwannee River Water Management District have used the location of the 2 psu isohaline to evaluate the protection of tidal freshwater floodplain wetlands (SFWMD 2002, SWFWMD 2008a, 2010b, 2010c, 2012a, Water Research Associates et al. 2005). In a survey of seven rivers on the coast of west central Florida, Clewell et al. (2002) similarly found that sensitive freshwater plants were mainly located upstream of the median location of 2 psu salinity in the river channels. They also found that freshwater plants that are tolerant of low salinity, which are often dominant in brackish marshes (e.g. cattails, sawgrass, and bulrush), were most common where median surface salinity values were less than 4 psu. These plants also occurred in somewhat higher salinity waters, but were rarely found where median salinity values exceeded 12 ppt. Similarly, in a study of the Suwannee River estuary, Clewell et al. (1999) found that the transition from sawgrass to saltmarsh species occurred where maximum salinities in the dry season were near 10 psu.

Vegetated shorelines comprised of native, low-salinity and tidal freshwater plant communities are common in the lower Pithlachascotee River upstream of river kilometer 6.6. These low-salinity wetlands provide valuable functions with regard to shoreline stability and wildlife habitat (Odum 1988, FFWCC 2005, Shellenbarger-Jones 2008). District staff assessed potential flow-related changes in these habitats using the empirical regressions developed to predict the location of the 2 and 5 psu isohalines. For the assessments, the daily locations of the 2 and 5 psu surface isohalines were predicted using tide stage data, the baseline flow record and a series of seven baseline flow records that were reduced from ten to forty percent in five-percent increments. Mean daily vegetated shoreline length upstream of the isohaline locations was determined based on the bathymetric and shoreline survey information described in Sections 3.3 and 3.5 of this report. Daily vegetated shoreline lengths were summarized by seasonal flow blocks and used to identify block-specific percent-of-flow reductions that would not result in more than a fifteen percent decrease in mean shoreline habitat length associated with the low-salinity, 2 and 5 psu isohalines.

Regression models for predicting locations of the 12 and 18 psu isohalines were not used for the assessment of salinity-based shoreline habitat because changes in those isohalines are typically located downstream of the low-salinity and tidal freshwater vegetated zones, occurring in the more urbanized section of the lower river.

4.5.2.3 Percent-of-Flow Methods: Assessment of Salinity-Based River Bottom Habitat

Benthic macroinvertebrates play a critical role in estuarine food webs that support many estuarine-dependent sport and commercial fisheries. Numerous studies, including those conducted on the lower Pithlachascotee River, have shown that salinity gradients exert a strong influence on the distribution of macroinvertebrate assemblages (Water and Air Research 2010b, Janicki Environmental, Inc. 2007, Montagna et al. 2008). Many invertebrate taxa, including important prey items for fishes, exhibit high densities in the oligohaline and mesohaline zones of tidal rivers along the west coast of Florida (Peebles 2005, Peebles et al. 2006, Janicki Environmental, Inc. 2007). Based on sampling conducted by Mote Marine Laboratory in ten rivers in the region, Montagna et al. (2008) report that several common mollusks, such as *Polymesoda caroliniana*, *Rangia cuneata*, and *Tagelus plebius* are most frequently collected in low salinity waters. Janicki Environmental (2007) has identified salinity zones of 0 to 7 psu, 7 to 18 psu, and 18 to 29 psu that are related macroinvertebrate community structure in several area rivers.

Potential changes in the extent of selected salinity-based river bottom zones or habitat were used to assess potential impacts to benthic macroinvertebrate communities in the lower Pithlachascotee River. The assessments were conducted using regressions developed for predicting the average locations of water column isohalines with salinities less than 2, 5, 12 and 18 psu based on tide stage and freshwater inflow. The less than 2 psu zone was used to assess the extent of low salinity zones in the lower river that approach the salinity of fresh water. The less than 5 psu zone corresponds to the upper limit of the oligohaline zone in the Venice system. The less than 12 psu zone was assessed as being representative of the Venice system mesohaline (5 to 18 psu) zone and is near the median salinity of in the middle portion of the lower river. The less than 18 psu zone corresponds to the upper limit of the mesohaline zone identified in the Venice system, and the upper limit of the 7 to 18 psu zone identified by Janicki Environmental, Inc. (2007).

District staff used water column isohaline locations rather than bottom isohaline locations to characterize salinity-based benthic habitats because the bottom isohalines are oriented to the deepest part of the river channel and do not reflect salinity over most of the river bottom. Salinity in the lower Pithlachascotee River is typically well-mixed vertically, and District staff believe water column isohalines best represent salinities for bottom areas located in deep, mid-depth, and shallow regions of the lower river. However, to best represent sub-tidal regions of the river where the benthic macroinvertebrate data were collected, only bottom areas of the river deeper than elevations of -0.75 meters NAVD 88 were included in the assessment of potential flow-related habitat changes.

Positions of the 2, 5, 12 and 18 psu water column isohalines and corresponding bottom areas upstream of the respective isohalines were determined using tide stage data (12 and 18 psu analyses only), the daily baseline flow record and a series of seven baseline flow records that were reduced by ten to forty percent in five-percent increments. Mean bottom areas were determined for each scenario by seasonal block and used to identify block-specific percent-of-flow reductions that would not result in more than a fifteen percent decrease in mean bottom area associated with the respective salinity isohalines.

4.5.2.4 **Percent-of-Flow Methods: Assessment of Salinity-Based Water Column Habitat**

Free-swimming fishes and larger invertebrates, i.e., nekton, often exhibit differences in community composition in association with estuarine salinity gradients (e.g., Bulger et al. 1993, Greenwood et al. 2007, SWFWMD 2010b). The migration of the early life stages of estuarine dependent fish species into low salinity nursery areas is well documented, including studies of tidal rivers of west-central Florida (Peebles and Flannery 1992, Matheson et al. 2005, Peebles et al. 2006). The avoidance of predators in low salinity waters may be a factor associated with these migrations, but of possibly greater importance is the availability of abundant food sources in low salinity waters, which is driven by the input of nutrients and organic matter from the watershed. Peebles et al. (2007) found that juvenile bay anchovies were concentrated in low salinity waters in twelve estuaries in the region, but the salinity at capture for this species varied among rivers. They suggested that the low salinity at capture in each river reflected that bay anchovies were migrating into regions that provided food-rich habitats, which were related to the geomorphology of each river and their respective freshwater inflows.

The
same salinity zones (less than 2, 5, 12 and 18 psu) that were used for assessing salinity-based habitats for benthic invertebrates were used to evaluate potential changes in the volumes of salinity-

based habitat available for nekton. The less than 2 psu zone was selected to represent the very low salinity fauna, including tidal freshwater species, which were identified by Greenwood et al. (2007) in the Lower Alafia and by Janicki Environmental in the Lower Peace (SWFWMD 2010b). The less than 5 psu zone corresponds to the upper limit of the Venice system oligohaline zone and is near the upper limit of the lowest salinity zone (less than 4 psu) identified by Bulger et al. (1993). The less than 12 psu zone is near upper limit of the less than 14 psu and the 3 to 14 psu salinity zones were selected to correspond to the combined oligohaline to low mesohaline ranges important for fish community structure that were identified for fishes in the Lower Peace River (SWFWMD 2010b). The 18 psu zone is the upper limit of the mesohaline zone identified in the Venice system.

District staff determined positions of the 2, 5, 12 and 18 psu water-column isohalines using tide-stage data (12 and 18 psu analyses only), the daily baseline flow record and a series of seven withdrawal scenario flows consisting of baseline flows reduced by ten to forty percent in five-percent increments. Although nekton likely use habitats occurring during high tide periods, bathymetric data were only available for elevations up to 0.0 feet above NAVD 88. Volume below this elevation upstream from the predicted isohaline locations were determined based on daily baseline flows and a series of flow reduction scenarios to determine the maximum percent-of-flow reductions that would not result in a 15 percent or greater reduction in the upstream water volume.

4.5.2.5 Development of a Minimum High Flow Threshold for the Lower River

Flow-based thresholds have been incorporated into minimum flows adopted for several estuarine river segments within the District. For example, based on nonlinear relationships of salinity with flow, a flow threshold of 625 cfs was used to identify different allowable percent-of-flow reductions for the minimum flows adopted for the lower Peace River (SWFWMD 2010b). When appropriate, identification of separate allowable percent-of-flow reductions using a flow-based threshold is expected to enhance resource protection and potentially allow for greater water withdrawals under less-sensitive, higher-flow conditions.

District staff developed a recommended minimum high flow threshold for the lower Pithlachascotee River based on the potential need for refining the percent-of-flow reductions identified through the block-specific salinity-habitat modeling. First, using the most sensitive salinity-based habitat in terms of its response to flow reductions, daily values for the percentage of remaining salinity-based habitat were plotted as a function of baseline flows to determine whether a specific flow threshold could be associated with substantially greater, relative habitat reductions with changes in flow. Once identified, the threshold was used to segregate the flow record within each block into records above and below the threshold, and the block-specific salinity-based habitat modeling was repeated using the segregated flow records. Results were then compared with the original salinity-habitat modeling results to determine whether the originally identified percent-of-flow reductions or percent-of-flow reductions based on analyses of the segregated flow records should be used to propose minimum flows for the lower river. If the latter was the case, the identified flow threshold was proposed as a minimum high flow threshold for the lower river.

Chapter 5 - RESULTS OF THE MINIMUM FLOWS ANALYSES AND RECOMMENED MINIMUM FLOWS

5.1 Introduction

A single baseline flow record and series of baseline flow records reduced by various percentages were used to evaluate minimum flows for the upper, freshwater and lower, estuarine segments of the river. Ecological criteria and metrics used to assess potential flow-related changes in environmental values differed between the two segments and results for each are presented.

5.2 Results of Minimum Flows Analyses for the Upper River

District staff used results from modeling and field investigations to develop freshwater minimum flow recommendations intended to prevent significant harm to environmental resources and values associated with the upper Pithlachascotee River. All analyses were conducted using the baseline flow record for the Pithlachascotee River near New Port Richey gage for the period from 1989 through 2000 and a series of baseline flow records reduced by 10, 20, 30 and 40 percent. The analyses were based on evaluating potential reductions in instream and floodplain habitats and identification of flow-based thresholds using hydraulic and habitat-based models.

5.2.1 Minimum Low Flow Threshold Results

For determining a recommended minimum low flow threshold for the upper Pithlachascotee River near New Port Richey gage, District staff developed and assessed three low-flow metrics. Two of the metrics were based on output from the HEC-RAS model developed for the river. The first of these was based on the lowest wetted perimeter inflection point, a measure of gain in available wetted stream bottom or habitat per unit flow; the other was based on maintaining fish passage and recreational use along the river corridor. A third metric, which did not rely on output from the HEC-RAS model, was developed using the Tennant Method and the baseline flow record.

5.2.1.1 Fish Passage and Recreational Use Results

Flows necessary to maintain a minimum water depth of 0.6 foot to allow for fish passage and recreational use at 42 cross-sections in the HEC-RAS model are shown in Figure 5-1. At many cross-sections, the minimum water surface elevation that would allow for fish passage was equal to or lower than the elevation associated with the lowest modeled flow. A flow of 8 cfs or less was sufficient to meet the fish passage/recreational use criteria at all but four of the modeled cross-sections. A flow or 25 cfs was sufficient to meet the fish passage/recreational use criterion at all modeled cross-sections.

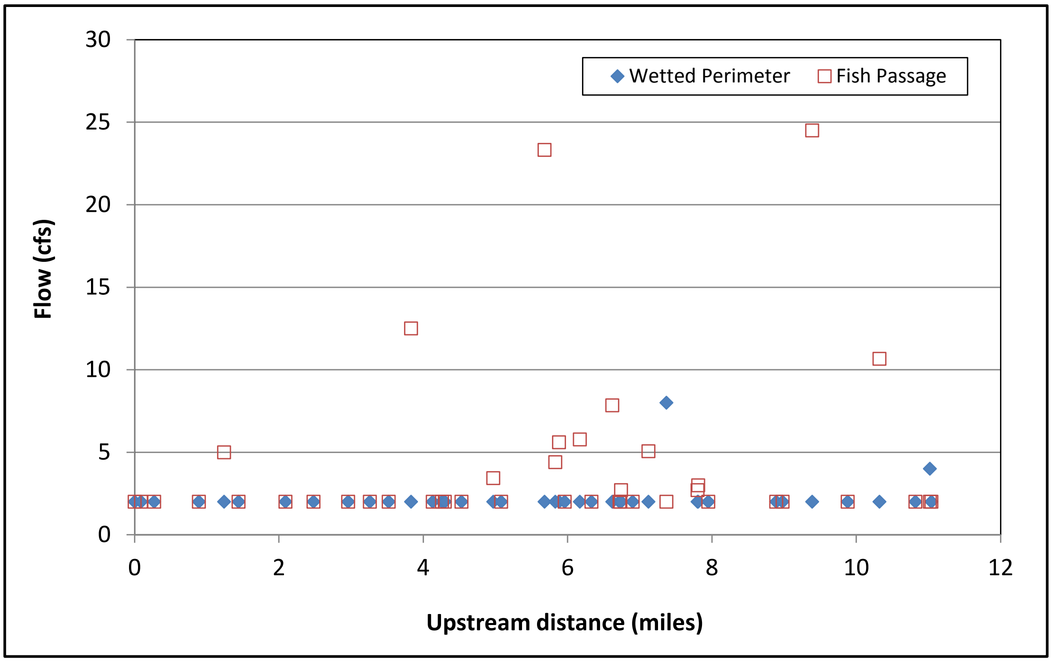


Figure 5-1. Plot of flow at the Pithlachascotee River near New Port Richey gage required to inundate the lowest wetted perimeter inflection point and maintain fish passage criteria at HEC-RAS cross-sections plotted by distance upstream from gage. A low-flow criterion of 25 cfs was chosen based on fish passage requirements.

5.2.1.2 **Wetted Perimeter Results**

Wetted perimeter plots (wetted perimeter versus local flow) and the lowest wetted perimeter inflection point were developed for each of the 42 HEC-RAS cross section in the upper Pithlachascotee River study reach. Figure 5-2 provides an example of results for site XCF-530. Result for all wetted perimeter analyses are included in Appendix 5A. The lowest wetted perimeter inflection point was below the lowest modeled flow for most sites (see Figure 5-1) and a flow of 8 cfs at the Pithlachascotee River near New Port Richey gage was sufficient to inundate the lowest wetted perimeter inflection point at all modeled cross sections.

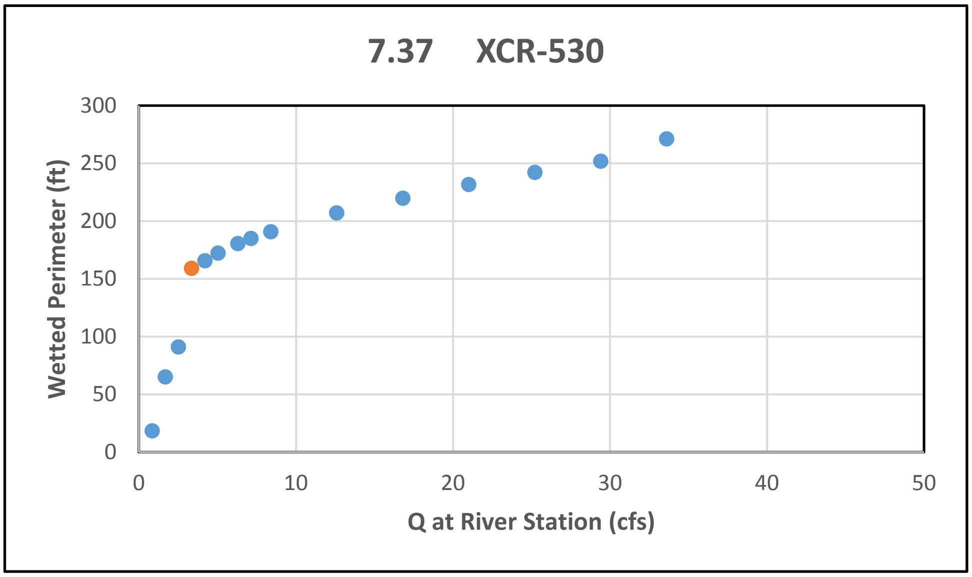


Figure 5-2 Example plot of wetted perimeter as a function of discharge (Q) at the XCF-530 site in the Pithlachascotee River. Orange symbol identifies flow used to identify a site-specific lowest wetted perimeter inflection point.

5.2.1.3 **Tennant Method**

Mean annual flow for full years in the baseline flow record with daily flow records (1990 through 2000) ranged from 4.8 to 80.1 cfs and averaged 27.9 cfs. Based on the Tennant Method, a flow of 11 cfs (11.2 rounded-down), corresponding to 40 percent of the mean annual flow of 27.9 cfs was identified as a low-flow metric for consideration when developing a minimum low flow threshold for the upper river.

5.2.1.4 **Recommended Minimum Low Flow Threshold for the Upper River**

A minimum low flow threshold of 11 cfs at the Pithlachascotee River near New Port Richey gage is recommended for the freshwater reach of the river. This threshold was established using the low-flow metric develop through application of the Tennant Method.

The low-flow metric derived using the Tennant Method was considered more appropriate than the fish passage/recreation and wetted perimeter metrics developed using the HEC-RAS model for the river. This determination was based on potential uncertainty associated with use of the HEC-RAS model for predicting river stage under low flow conditions. Use of the Tennant method obviated this concern, as the method does not rely on HEC-RAS model output.
The recommended minimum low flow threshold is most applicable to the low-flow period of Block 1, but is considered applicable throughout the year. Eleven cfs is a relatively high flow for the upper Pithlachascotee River, corresponding to the 60th exceedance percentile for the baseline flow record. It is important to note that the minimum low flow threshold is established to protect environmental values of the river from significant harm associated with surface water withdrawals and does not apply to groundwater usage. The threshold is recommended for establishment to serve as a criterion that can be used solely for assessment of proposed or any existing surface water withdrawals.

5.2.2 Percent-of-Flow: Instream PHABSIM Results

Physical Habitat Simulation (PHABSIM) analyses were conducted for three representative sites on the freshwater reach of the Pithlachascotee River to evaluate potential changes in fish and invertebrate habitat availability associated with potential flow reductions. Bottom substrata at the PHABSIM sites consisted mainly of sand with extensive muck deposits along the banks. Large quantities of woody habitats were common at all sites. Simulations were conducted for a total of 16 species/life stages/guilds using the baseline flow record for the Pithlachascotee River near New Port Richey gage and baseline flow records reduced by 10, 20, 30 and 40 percent.

Using the TSLIB (time-series library) from the USGS Mid-Continent Research Laboratories, simulations of WUA for the baseline flow period were conducted for the 16 species/lifestages/guilds at each of 3 PHABSIM sites. Figure 5-3 provides an example of results for juvenile bluegill sunfish at the VEG 2 PHABSIM site. In this case, the habitat availability reduction criterion of 15 percent based on changes in weighted usable area (WUA) for the baseline condition was exceeded in both the 30 percent (April and September) and 40 percent (April, September and October) flow reduction scenarios. Result for all PHABSIM analyses are included in Appendix 5B.

For development of minimum flow and level criteria, WUA estimates for each species/life stage/guild from the 3 PHABSIM sites were combined and maximum flow reductions associated with a 15 percent change in WUA were identified. Separate analyses were completed for Blocks 1 and 2, which correspond with the periods of low and medium flow, respectively, and are summarized in (Table 5-1). Adult spotted sunfish were the most sensitive group in Block 1, with the 15 percent habitat reduction criterion reached at an 18 percent reduction in baseline flows. The Deep-Slow Guild (a group of representing species that prefer deeper water with low velocities) was the most sensitive group in Block 2, reaching the 15 percent decreased in habitat availability criterion with a 17 percent reduction in baseline flows.

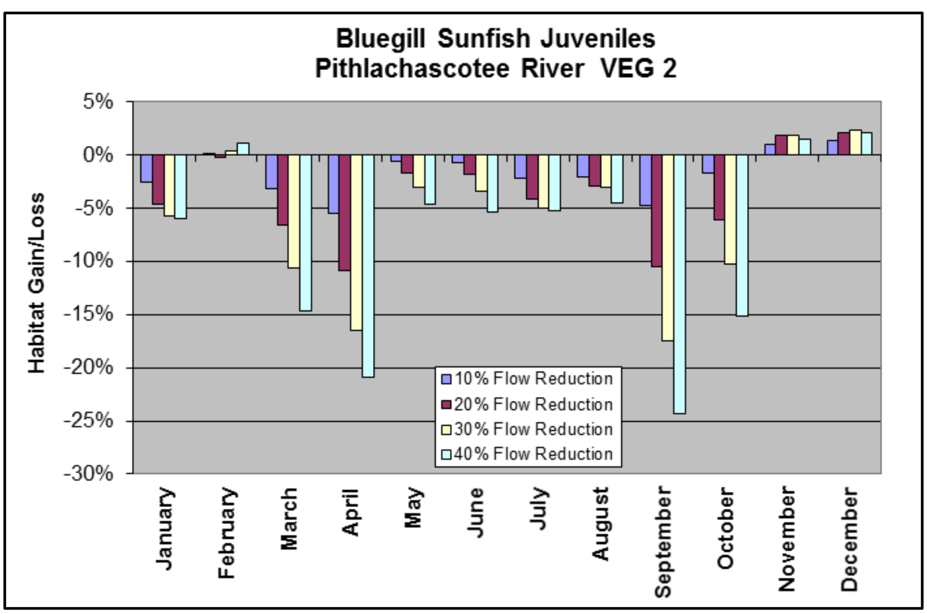


Figure 5-3. Example plot of habitat gain/loss based on weighted usable area for bluegill sunfish juveniles at VEG 2 PHABSIM site in the Pithlachascotee River relative to 10, 20, 30, and 40 percent reductions in flows from baseline conditions.

Table 5-1 Maximum percent-of-flow reductions that resulted in less than a 15 percent reduction in habitat availability for all species/life stage/guild groups evaluated using PHABSIM models.

Species/Life Stage/Guild	Maximum Allowable percent Flow Reduction Block 1	Species/Life Stage/Guild	Maximum Allowable percent Flow Reduction Block 2
Spotted Sunfish - Adult	18	Deep-Slow Fish Guild	17
Deep-Slow Fish Guild	19	Shallow-Slow Fish Guild	18
Large Mouth Bass - Spawning	21	Bluegill - Spawning	19
Bluegill - Adult	21	Cyprinidae	19
Spotted Sunfish - Juvenile	21	Spotted Sunfish - Adult	20
Bluegill - Juvenile	22	Bluegill - Adult	21
Largemouth Bass - Fry	24	Bluegill - Juvenile	21
Spotted Sunfish - Spawning	24	Spotted Sunfish - Juvenile	21
Cyprinidae	24	Benthic Macroinvertebrates	21
Largemouth Bass - Juvenile	25	Largemouth Bass - Juvenile	23
Spotted Sunfish - Fry	25	Spotted Sunfish - Spawning	23
Bluegill - Spawning	27	Bluegill - Fry	24
Largemouth Bass - Adult	28	Largemouth Bass - Adult	25
Bluegill - Fry	29	Largemouth Bass - Spawning	29
Benthic Macroinvertebrates	31	Spotted Sunfish - Fry	33
Shallow-Slow Fish Guild	37	Largemouth Bass - Fry	>40

5.2.3 Percent-of-Flow: Additional Instream and Woody Habitat Inundation Results

Based on sampling conducted at 15 instream habitat cross-sections, bottom substrates in the freshwater reach of the Pithlachascotee River area is dominated by sand or mucky (i.e., mud) sediments that support little to no submersed aquatic vegetation (Figure 5-4). The lack of vegetation is likely associated with the abundant leaf litter and organic matter that covers much of the river bottom (Figure 5-4) and is also likely influenced by light limitation associated with the tannin-stained water. Woody habitats, including exposed roots and woody debris (e.g., snags) are also common in the channel (Figure 5-5).

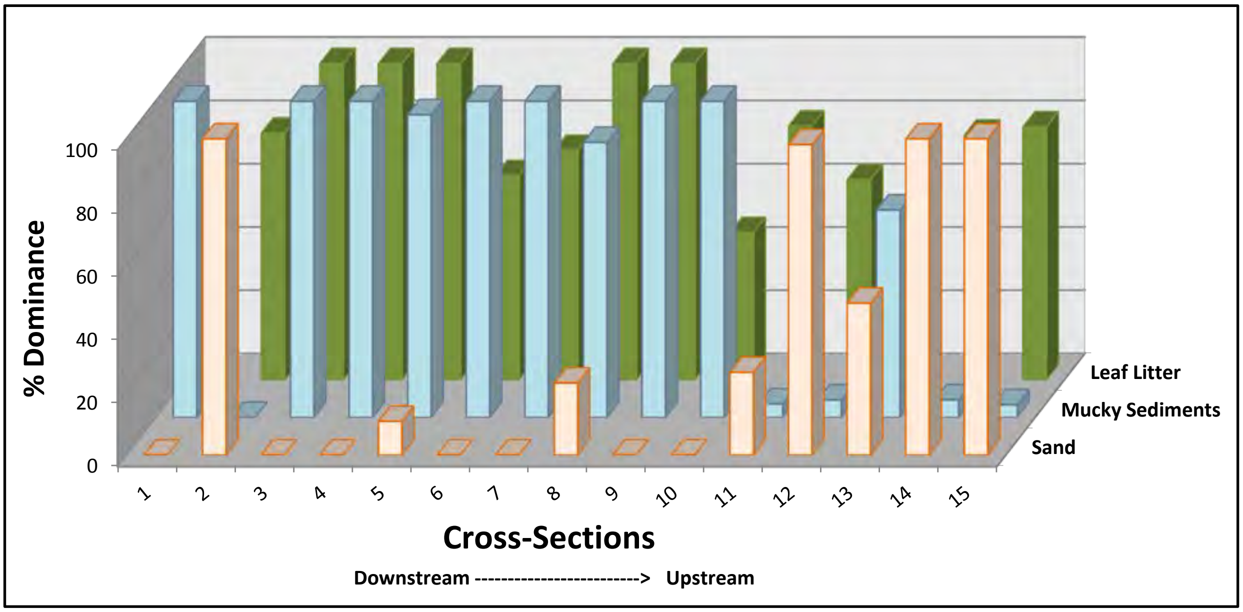


Figure 5-4. Percent dominance (percent of linear cross-section extent) substrates at 15 instream cross-sections.

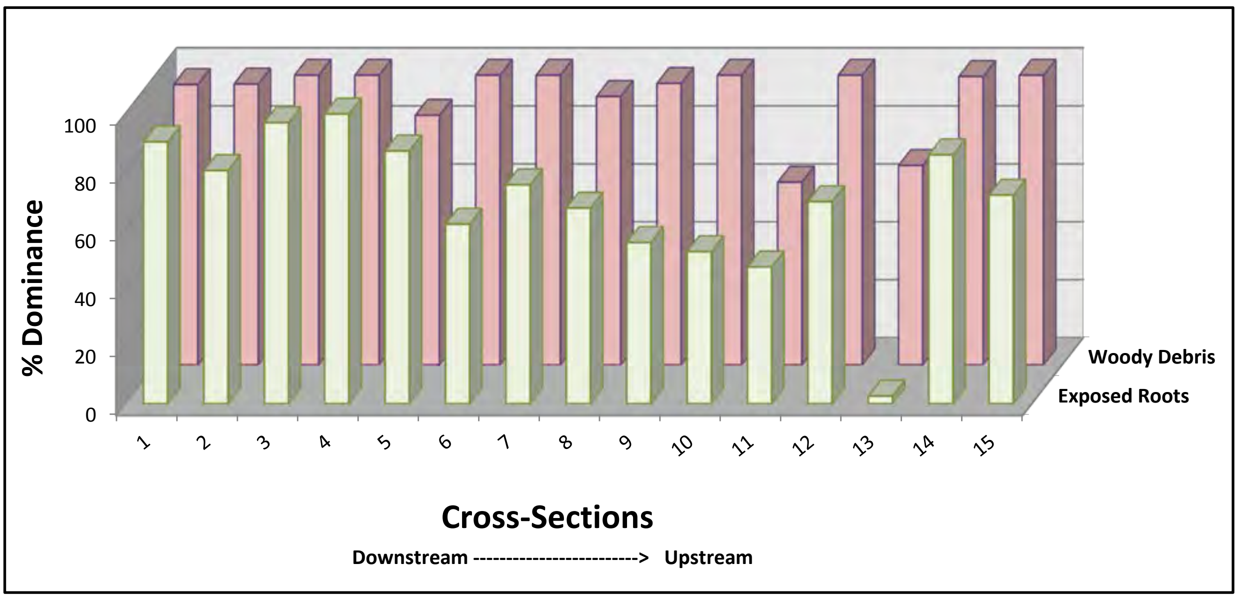


Figure 5-5. Percent dominance (percent of linear cross-section extent) of woody habitats (exposed roots and woody debris, including snags) at 15 instream cross-sections.

Relative elevations of the habitats were consistent among the cross-sections (Figure 5-6). Wetland trees were typically situated near the top of the banks with wetland plants, snags and exposed roots occurring at slightly lower elevations. Predictably, there were not many submerged aquatic plants due to the substrates, which were dominated by woody debris.

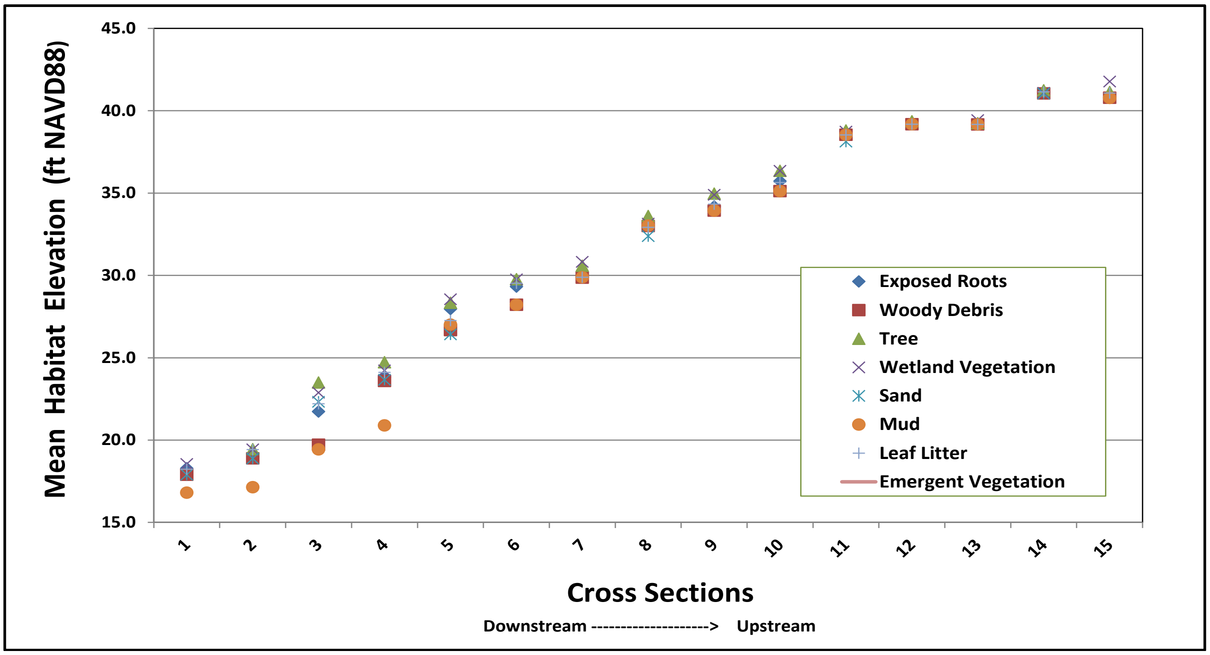


Figure 5-6. Mean elevations of instream habitats at fifteen cross-section sites on the Pithlachascotee River.

Inundation patterns of exposed root and snag habitats were evaluated at 15 instream habitat cross-section sites in the freshwater reach of the river. Flows at the Pithlachascotee River near New Port Richey gage necessary to inundate mean elevations of exposed root habitats ranged from 2 to 184 cfs and averaged 58 cfs for the 15 cross section sites (Table 5-2). Flows ranging from 2 to 310 cfs, with an average of 47 cfs were sufficient to inundate snag habitat at the sites.

Based on these flow requirements, long-term inundation analyses conducted using the baseline flow record was used to identify percent-of-flow reductions that could occur without reducing the number of days of inundation of the respective habitats at each site by 15 percent or more (Table 5-2). Using allowable-percent-of-flow reductions for sites associated with reduction of less than 40 percent, mean allowable percent-of-flow reductions of 20 and 25 percent were determined for exposed roots and snags, respectively.

Table 5-2. Mean (and standard deviation, S.D.) elevation of instream woody habitats (exposed roots and snags) at 15 instream habitat cross-section sites, corresponding flows at the Pithlachascotee River near New Port Richey gage required for inundation of the mean elevations, and maximum allowable percent-of-flow reductions from baseline conditions associated with less than a 15 percent reduction in the number of days flow sufficient to inundate the mean habitat elevations.

Habitat	Site	Mean Elevation (ft NAVD 88)	S.D.	Flow (cfs) at Gage Required for Inundation	Allowable Percent-of-Flow Reduction
Exposed Roots	1	18.37	0.82	15	>40
Exposed Roots	2	19.49	0.94	38	11
Exposed Roots	3	22.07	1.31	39	10
Exposed Roots	4	24.48	0.91	20	>40
Exposed Roots	5	28.37	0.83	21	>40
Exposed Roots	6	30.15	0.65	110	20
Exposed Roots	7	31.12	0.66	145	9
Exposed Roots	8	30.03	0.65	2	>40
Exposed Roots	9	35.08	0.58	45	33
Exposed Roots	10	36.86	0.46	55	32
Exposed Roots	11	39.19	0.21	184	7
Exposed Roots	12	39.58	0.37	14	>40
Exposed Roots	13	40.46	0.55	60	37
Exposed Roots	14	42.05	0.44	100	25
Exposed Roots	15	41.68	0.65	28	21
Mean	**-**	**-**	**-**	**58**	**20**[a]
Snags	1	17.74	1.02	7	>40
Snags	2	19.63	1.07	45	33
Snags	3	20.94	1.41	19	>40
Snags	4	23.63	1.22	2	>40
Snags	5	27.3	0.81	4	>40
Snags	6	30.25	1.3	110	20
Snags	7	30.53	0.82	41	14
Snags	8	29.91	0.73	2	>40
Snags	9	35.22	0.81	60	37
Snags	10	36.69	1.01	45	33
Snags	11	39.63	0.78	310	11
Snags	12	39.74	0.85	20	>40
Snags	13	39.88	0.57	22	>40
Snags	14	41.05	0.42	4	>40
Snags	15	41.43	0.74	13	>40
Mean	**-**	**-**	**-**	**47**	**25**[a]

[a] *Mean based on allowable percent-of-flow site values less than 40 percent.*

5.2.4 Percent-of-Flow: Floodplain Habitat Inundation and Minimum High Flow Threshold Results

5.2.4.1 Floodplain Geomorphology and Wetted Perimeter Results

The floodplain of Pithlachascotee River has been shaped by many years of low-flow and a relatively low longitudinal elevation gradient, with the channel averaging 5 feet of change in elevation per linear mile for the freshwater reach of the river. Elevation gradients across the floodplain are also low, averaging a total of 3.0 feet, based on the 15 sampled floodplain vegetation cross-sections (transects) that ranged in length from 469 to 1,706 feet (Table 5-3). This low topographic relief has contributed to the formation of many flow channels that shape and contour the flow path.

Table 5-3. Changes in elevations by gradients and lengths of floodplain vegetation/soils cross-sections (transects) for the freshwater reach of the Pithlachascotee River. Table reproduced from SWRF, LLC and Dooris & Associates, LLC (2010).

Transect #	Length (feet)*	Elevation change (feet)	Gradient (feet/foot)	Flow Ways Having Depths ≥ 2.0 feet	Number of Flow Ways in Transect Cross Section
1	854	4.5	0.0053	2	5
2	544	3.3	0.0061	1	4
3	776	3.4	0.0044	1	5
4	1706	4.6	0.0027	3	6
5	648	2.8	0.0043	1	7
6	1407	3.9	0.0028	1	8
7	533	1.8	0.0034	1	7
8	1050	3.5	0.0033	3	11
9	604	3.4	0.0056	2	7
10	829	4.3	0.0052	1	5
11	810	2.6	0.0032	3	8
12	551	1.5	0.0027	1	6
13	589	2.5	0.0042	2	7
14	469	1.5	0.0032	1	16
15	525	1.8	0.0034	1	5

** Length refers to the distance (feet) between the edges of wetland on each side of the river.*

Floodplain profiles were developed, and vegetation communities were identified for the 15 floodplain vegetation/soils/hydrologic indicator cross-sections (see Figure 5-7 for an example; refer to Appendix 4D for all profiles). Flows needed to inundate one side or both sides of the floodplain by breaching the top of bank varied considerably between sites.

Floodplain wetted perimeter plots (patterned after the wetted perimeter plots used for identification of the lowest in-channel wetted perimeter inflection point) were developed for each floodplain vegetation cross-section (see Appendix 4D). The plots show the linear extent of inundated floodplain (wetted perimeter) associated with measured floodplain elevations, including the mean elevations of the floodplain vegetation communities and some hydrologic indicators. For example, Figure 5-8 shows a floodplain wetted perimeter plot for floodplain vegetation Transect 3. Based on the plot, approximately 150-200 linear feet of floodplain bottom would be inundated when the river is staged at the mean elevation of the floodplain swamp community. This is in contrast to the approximately

700 linear feet of floodplain that would be inundated at the mean elevation of the hydric hammock community.

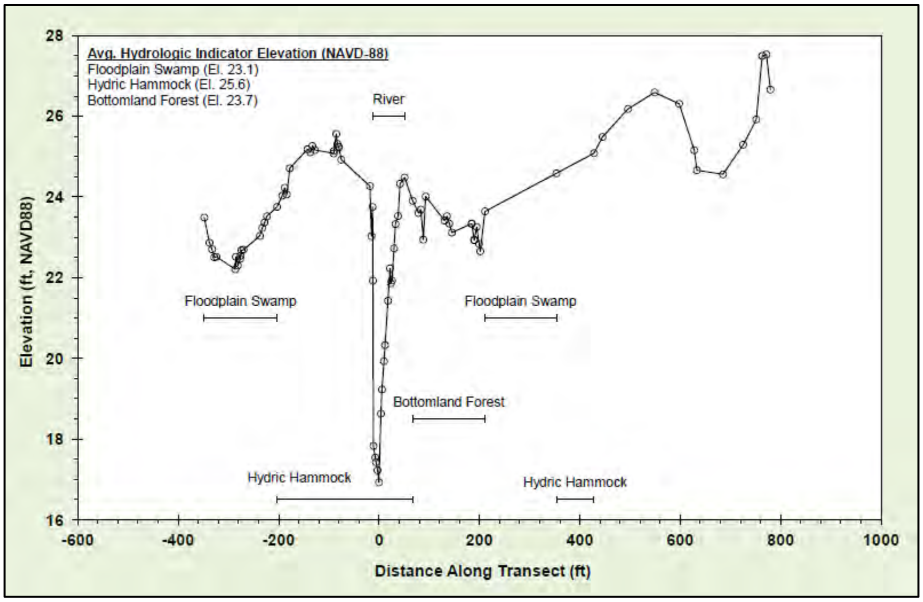


Figure 5-7. Elevation (feet in NAVD 88) profile for floodplain vegetation/soils/hydrologic indicator cross-section (Transect) number 3. Distances (cumulative length) along the transect are shown centered on the middle of the river channel. Image reproduced from SWRF, LLC and Dooris & Associates, LLC (2010) included as Appendix 4D.

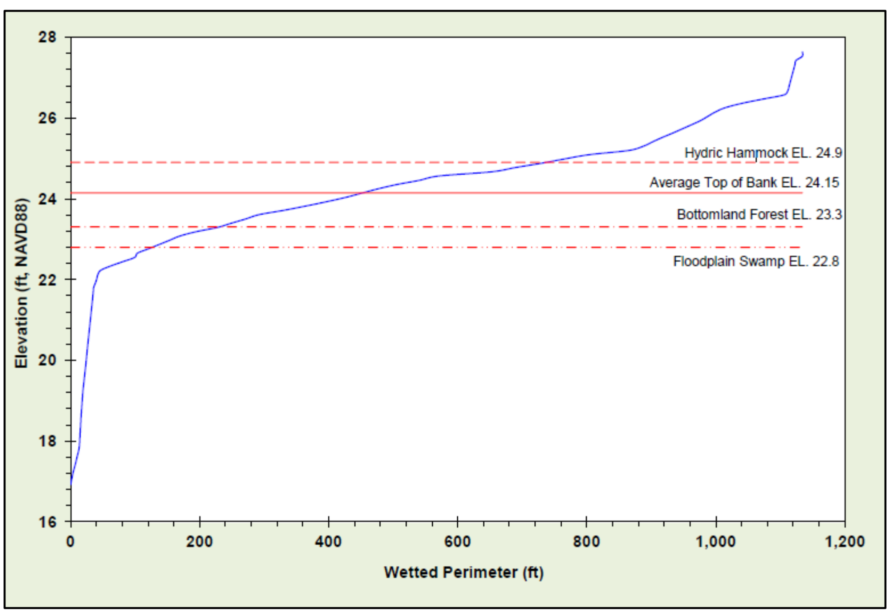


Figure 5-8. Floodplain wetted perimeter versus elevation at a sample floodplain vegetation/soils cross-section (Transect 3). Horizontal lines indicate mean elevations (EL.) of three floodplain vegetation communities (Floodplain Swamp, Bottomland Forest and Hydric Hammock) and the top of the bank at the site. Image reproduced from SWRF, LLC and Dooris & Associates, LLC (2010) included as Appendix 4D.

5.2.4.2 **Floodplain Features and Habitats**

Three wetland vegetation community types, floodplain swamp, bottomland forest and hydric hammock, were characterized along the Pithlachascotee River study corridor (SWRF, LLC and Dooris & Associates, LLC 2010; included as Appendix 4D). Floodplain forest was the most common community type in 9 of the 15 sampled transects, while hydric hammock and bottomland forest were each most prevalent in 3 transects (Figure 5-9).

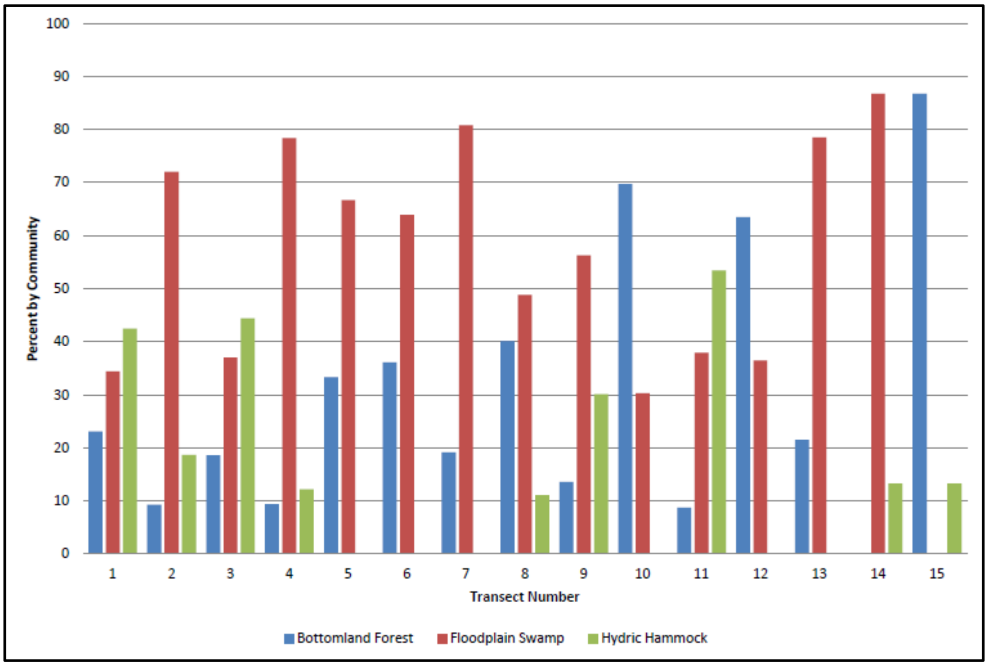


Figure 5-9. Percent cover of community type by transect along the Pithlachascotee River. Image reproduced from SWRF, LLC and Dooris & Associates, LLC (2010) included as Appendix 4D.

Soils of the Chobee Series, which are soils typical of swamps, tidal marshes and river floodplains were the most commonly encountered soils along the 15 floodplain transects. Soils of the Tavares-Adamsville-Narcoossee series, which are characteristic of uplands, and soils of the Smyrna-Sellers-Myakka Series, which are commonly encountered in flatwoods and depressional areas, were found on both sides of the river adjacent to the Chobee series soils. Among the soils observed along the transects, the Chobee Series are considered to be hydric soils and the Myakka and Smyrna fine sands may exhibit hydric components (Carlisle et al.1978 as cited in SWRF, LLC and Dooris & Associates, LLC 2010). Based on a soil index numbering system described in Appendix 4D, 97 to 100 percent of the soil samples from the floodplain swamp, Bottomland Forest and Hydric Hammock wetland communities were classified as hydric soils.

Several hydrologic indicators were evaluated within the riverine floodplain to determine how these indicators compared with other vegetative and elevation data. The lower or bottom elevation of moss collars on mature trees was more common than other indicators such as lichen lines, lenticels, hummocks and the waterward limit of saw palmetto or edge of wetland along the 15 floodplain transects.

5.2.4.3 Floodplain Inundation Results and Recommended Minimum High Flow Threshold for the Upper River

Modeled flows at the Pithlachascotee River near New Port Richey gage developed with the Pithlachascotee River HEC-RAS model were used to predict the flows necessary to inundate the mean elevations of the floodplain features and habitats (i.e., geomorphological features, vegetation classes, hydric soils, and hydrologic indicators) at 15 river floodplain cross-sections (Table 5-4). Assessing changes in the inundation of a wide range of floodplain features, including specific wetland plant assemblage distributions and more generally, ground elevations across the floodplain from the top of bank to the upper edge of the floodplain, is considered a reasonable means to promote persistence of floodplain structure and function and prevent significant harm.

Based on these flow requirements, long-term inundation analyses conducted using the baseline flow record was used to identify percent-of-flow reductions that could occur without reducing the number of days of inundation of the respective features and habitats at each cross-section by 15 percent or more. The allowable percent-of-flow reductions varied from 5 to more than 40 percent for the features and habitats across the 15 transects (Table 5-4).

Flow reductions at the Pithlachascotee River near New Port Richey gage that resulted in a 15 percent reduction in the number of days that a given flow reached the elevations associated with the floodplain features and habitats tended to stabilize around 9 percent for moderate to higher flows (n = 91 flow values > 50 cfs; mean = 9.0 percent; standard deviation = 3.5 percent) (Figure 5-10). At low flows, flow reductions greater than 9 percent of flow are required to produce a 15 percent reduction in floodplain inundation days. Using the 50 cfs flow at the Pithlachascotee River near New Port Richey gage required for out-of-bank flow as an upper limit for this range of flows, an additional allowable percent-of- flow reduction that may be applicable for lower flow conditions that occur during the typical high-flow seasonal period, i.e., for Block 3, was developed. Based on the 25th percent exceedance value of potentially allowable percent-of-flow reductions identified for Block 3 flows, a 16 percent reduction in flows could be allowed when flows are at or below 50 cfs. So, in combination, the two allowable flow reductions based on use of a 50 cfs minimum high flow threshold would allow percent-of-flow reductions of 9 percent when flows at the gage exceed 50 cfs and up to 16 percent when flows at the gage are at or below 50 cfs (Figure 5-10). The allowable 16 percent flow reduction was considered reasonable, based on its similarity to the potentially allowable percent-of-flow reductions derived for the lower-flow Blocks 1 and 2 based on the PHABSIM analyses.

While additional threshold-based flow reduction percentages could be identified, or an algorithm applied to determine allowable percent-of-flow reductions as a function of flow, the use of two allowable percent-of-flow reductions during Block 3 based on the recommended minimum high flow threshold provides a reasonable means for assuring that unidentified or unquantified floodplain features and habitats are likely to be protected and that flows not necessary for prevention of significant harm may be available for consumptive use.

Table 5-4. Flow range at the Pithlachascotee River near New Port Richey gage required for inundation of floodplain features (mean elevation of vegetation classes, wetland soils, and selected geomorphological features) at all transects which have the feature or class. Percent-of-flow reductions associated with up to a 15 percent reduction in the number of days of flow sufficient to inundate the mean feature elevations are also listed.

Floodplain Feature	Number of Floodplain Transects Containing Feature and Number of Floodplain Transects Containing Feature that Exceeded Modeled Flow Range (n)	Mean Elevation Range among Floodplain Transects Containing Feature (in feet NAVD 88)	Flow Range Required for Inundation (cfs)	Range of Percent of Flow Reduction (percent)
Floodplain Swamp	14	19.1 to 41.2	2 to 250	5 to >40
Hydric Hammock	9	20.9 to 42.4	12 to 350	4 to 24
Bottomland Forest	14	20 to 41.6	2 to 800	5 to >40
Moss Collar Hydrologic Indicator in Floodplain Swamp	14	19.4 to 41.6	2 to 450	4 to >40
Moss Collar Hydrologic Indicator in Hydric Hammock	8	22 to 42.9	100 to 850	6 to >40
Moss Collar Hydrologic Indicator in Bottomland Forest	14	20.9 to 41.9	2 to 950	4 to >40
Hydric Soils	14	20.1 to 42.5	2 to 750	5 to 68
Hydric Mucky Soils	7	33.66 to 41.77	2 to 55	13 to 40
Hydric Saturated Soils	7	19.14 to 39.4	2 to 250	5 to >40
Hydric Mucky Saturated Soils	6	41.2	2 to 250	5 to >40
Low Floodplain WP	15	19.1 to 41.6	2 to 80	13 to >40
High Floodplain WP	15	19.28 to 42.5	2 to 250	5 to >40
Top Of Bank to One Side	15	18.9 to 41.2	2 to 800	5 to >40
Top of Bank to Two Sides	15	20.1 to 42	4 to 1000	5 to >40
Left Wetland Edge	15	20.7 to 42.8	65 to 850	5 to >40
Right Wetland Edge	15	22 to 42.5	2 to 750	5 to >40

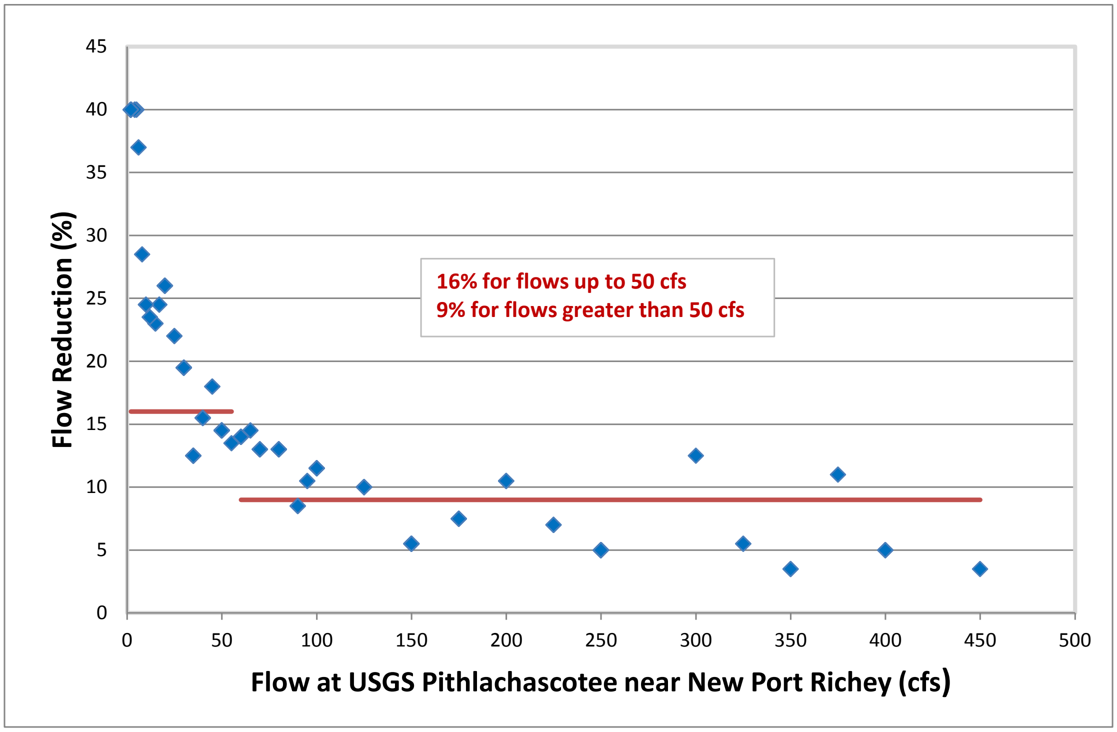


Figure 5-10. Maximum percent-of-flow reductions that result in less than a 15 percent reduction in the number of days that floodplain features and habitats are inundated, relative to the inundation pattern associated with the baseline flow record.

Based on concerns associated with HEC-RAS model output uncertainty identified during the peer review of originally proposed minimum flows for the river, staff assessed potential model-error effects on the allowable percent-of-flow reductions identified for Block 3. A sensitivity analysis was conducted by increasing and decreasing flows estimated from HEC-RAS at each transect by 5, 10 and 20 percent. Then, for each of these flow-change scenarios, the allowable percent-of-flow reduction that would not result in more than 15 percent fewer days of inundation was computed.

Comparison of the flow-change scenario results with the percent-of-flow reductions associated with the unmodified baseline flow record (Table 5-5) indicated the relative insensitivity of the assessed flow-changes on potential Block 3 percent-of-flow reductions. Baseline flow changes of 5 percent resulted in no or a 1 percent change, respectively, in potentially allowable percent-of-flow reductions for flows greater than and less than or equal to 50 cfs. Greater baseline flow changes, resulted in less than 2 percent differences in potentially allowable flow reductions. This relative insensitivity in allowable percent-of-flow reductions identified for Block 3 is based on the direct relationship of the allowable-percent-of-flow reductions to the flow exceedance curve, which is, of course for the range of higher flows, approximated by flows needed to inundate floodplain features (as depicted in Figure 5-10). We believe these results indicate the existing HEC-RAS model is suitable for identifying the allowable percent-of-flow reductions for Block 3 that were incorporated into the minimum flows recommended for the upper river.

Table 5-5. Allowable Block 3 percent-of-flow reductions identified based on unmodified baseline flows (as depicted in Figure 5-10) and for flow scenarios based on 5, 10 and 20 percent increases and decreases in baseline flows.

Flow Scenario	Allowable Percent-of-Flow Reduction for Flows ≤ 50 cfs	Allowable Percent-of-flow reduction for flows >50 cfs
Baseline flows increased 20 percent	16	10.0
Baseline flows increased 10 percent	15	8.8
Baseline flows increased 5 percent	17	9.3
Unmodified baseline flows	16	9.0
Baseline flows reduced 5 percent	16	9.2
Baseline flows reduced 10 percent	18	9.2
Baseline flows reduced 20 percent	17	10.7

5.3 Summary of Recommended Minimum Flows for the Upper River

To support development of minimum flows for the freshwater reach of the Pithlachascotee River, flow requirements associated with maintaining or meeting criteria associated with fish passage/recreational use, maximizing wetter perimeter within the river channel for the least amount of flow, and a percentage of the mean annual flow rate were evaluated for implementation during all seasonal flow blocks, i.e., for the entire year. In addition, effects of reductions in flows from baseline conditions were evaluated for criteria associated with habitat availability for fish and invertebrates based on PHABSIM analyses and inundation of instream woody habitats, floodplain habitats and features. Potentially allowable percent-of-flow reductions associated with these criteria were developed for implementation during specific seasonal periods of low, medium and high flows, referred to respectively, as Block 1, Block 2 and Block 3.

Based on results from these analyses (summarized in Table 5-5) and identification of the most reasonable metric for the minimum low-flow threshold, the most restrictive criterion for each seasonal block, and identification of a minimum high flow threshold for Block 3, recommended minimum flows were developed for the freshwater upper segment of the Pithlachascotee River. The recommendations include a minimum low flow threshold of 11 cfs, which is applicable surface water withdrawals and applies at all times. In addition, the recommended minimum flows for the upper river would allow reductions from baseline flows of up to: 18 percent during the seasonally low-flow period (Block 1); 16 percent during the seasonal high flow period (Block 3) when flow is at or below a minimum high flow threshold of 50 cfs; 9 percent during Block 3 when the flow is above the minimum high flow threshold; and 17 percent during the seasonal period of intermediate flows (Block 2). Recommended minimum flows are shown in Figure 5-11 along with annualized measured and baseline flows for the Pithlachascotee River at New Port Richey gage. As has been done previously for other river segments, the block-specific allowable percent-of-flow reductions will be associated with the withdrawal-corrected previous day's flow in the river, in this case corrected flows at the Pithlachascotee River near New Port Richey gage site.

Table 5-5. Flow thresholds and maximum allowable percent-of-flow reduction criteria evaluated and recommended for development of recommended minimum flows for the upper, freshwater segment of the Pithlachascotee River at the Pithlachascotee River near New Port Richey gage.

Block	Criteria Type	Measure / Goal	Flow Thresholds (cfs) and Allowable Percent-of-Flow Reductions for Consideration	Recommended for Minimum Flows (Type of Minimum Flow)
ALL	Fish Passage	Maintaining water depth of 0.6 feet at shoals	25 cfs	No
ALL	Wetted Perimeter	Maximizing inundated river channel	8 cfs	No
ALL	Tennant Method	Maintain 40% of mean annual flow for fish, wildlife, recreation and associated environmental resources	11 cfs	Yes
1	PHABSIM	Avoid reductions > 15 percent in habitats for various species	18 percent	Yes (allowable percent-of-flow reduction)
2	PHABSIM	Avoid reductions > 15 percent in habitats for various species	17 percent	Yes (allowable percent-of-flow reduction)
2	Instream Habitat - Exposed Roots	Avoid reductions > 15 percent in exposed root availability	20 percent	No
2	Instream Habitat - Snags	Avoid reductions > 15 percent in snag availability	25 percent	No
3	Floodplain Inundation	Avoid reductions > 15 percent in temporal floodplain habitat	16 percent for flows up to 50 cfs 9 percent for flows greater than 50 cfs	Yes (allowable percent-of-flow reductions and minimum high flow threshold)

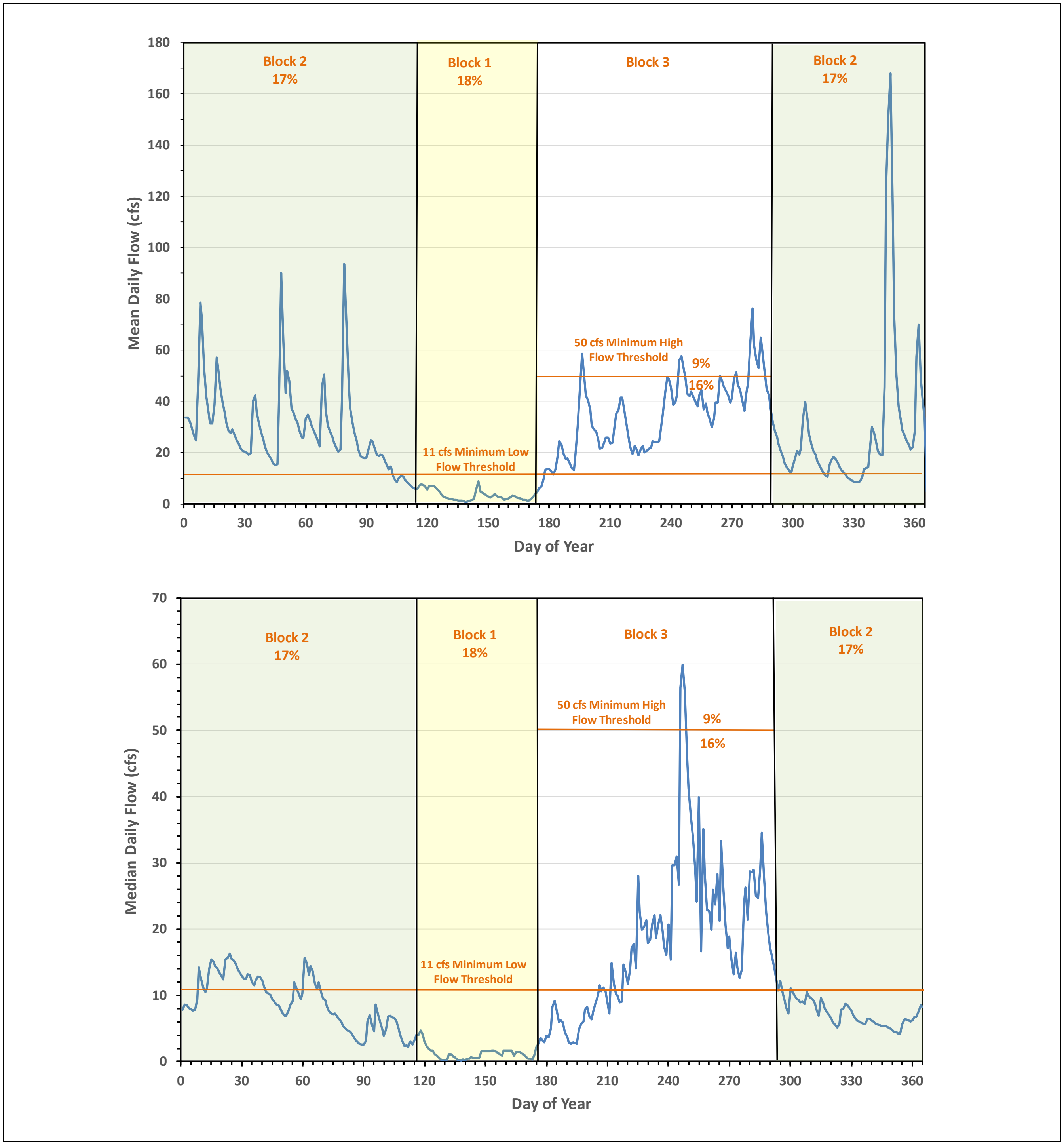


Figure 5-11. Recommended minimum flows (block-specific allowable percent-of-flow reductions and minimum low flow thresholds) for the upper Pithlachascotee River shown with mean (upper panel) and median (lower panel) daily baseline flows for Pithlachascotee River near New Port Richey gage.

5.4 Protection of Environmental Values for the Upper River

The recommended minimum flows for the upper Pithlachascotee River are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing minimum flows and levels. The methods used for their development are largely habitat based and included consideration of minimum water depths for fish passage, maintenance of water depths above inflection points in the wetted perimeter of the channel to maximize aquatic habitat for fish and wildlife with the least amount of flow, and protection of floodplain wetland and in-channel habitat, including woody habitats and exposed roots, for fish, invertebrates, and other organisms. The criteria used for development of the recommended minimum flows are associated with: 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, and navigation. In addition, the environmental value, maintenance of freshwater storage and supply, is expected to be protected by the recommended minimum flows based on inclusion of conditions in water use permits that stipulate that permitted withdrawals will not lead to violation of adopted minimum flows and levels.

Although development of minimum flows for the upper river is expected to provide protection for the lower river, District staff did not directly consider the environmental value “estuarine resources” when developing of minimum flow recommendations for the upper river. Staff did, however, explicitly consider the river’s estuarine resources through assessment of management goals, indicators and criteria associated with minimum flow recommendations for the lower river.

5.5 Results of Minimum Flows Analysis of the Lower River

Results from modeling and field investigations were used to develop minimum flow recommendations intended to prevent significant harm to environmental resources and values associated with the lower Pithlachascotee River. All analyses were conducted using the baseline flow record for the Pithlachascotee River near New Port Richey gage for the period from 1989 through 2000 and a series of seven baseline flow records reduced from 10 to 40 percent in five percent increments. The analyses were focused on evaluating potential reductions in salinity-based habitats and identification of flow-based thresholds using regression models.

5.5.1 Percent-of-Flow: Assessment of Salinity-Based Habitats Results

The District’s approach for determining minimum flows for lower Pithlachascotee River involved applying a series of seven percentage withdrawal scenarios to the baseline flow regime for the river. For each withdrawal scenario, reductions in salinity-based habitats were assessed relative to baseline conditions within three seasonal blocks using empirical regression models to predict isohaline locations based on freshwater inflow and in some cases, tide stage. Staff focused on identifying potential flow changes that would not result in more than a fifteen percent change in the respective habitats.

5.5.1.1 Salinity-Based Shoreline Habitat Assessment Results

Based on predicted shifts in the location of the 2 psu and 5 psu surface isohalines, salinity-based shoreline vegetation habitats were relatively insensitive to changes in flow (Table 5-6). The largest simulated reduction in shoreline habitat, relative to that under baseline conditions, was the vegetated shoreline associated with a salinity of 2 psu, which decreased by 8 percent during Block 1 for the forty percent flow reduction scenario.

Table 5-6. Percent reductions in mean vegetated shoreline lengths upstream of the 2 psu and 5 psu surface isohalines for seven flow reduction scenarios relative to baseline flow conditions.

		Vegetated Shoreline Length Reduction		
Block (Dates)	**Flow Reduction (percent)**	**< 2 psu (percent)**	**< 5 psu (percent)**	**< 12 psu (percent)**
Block 1 (April 25 – June 23)	10	2	0	NA
	15	3	1	NA
	20	4	1	NA
	25	5	1	NA
	30	6	2	NA
	35	7	2	NA
	40	8	2	NA
Block 2 (October 17 – April 24)	10	2	0	NA
	15	2	1	NA
	20	3	1	NA
	25	4	1	NA
	30	5	1	NA
	35	6	2	NA
	40	7	2	NA
Block 3 (June 24 – October 16)	10	1	0	NA
	15	2	1	NA
	20	3	1	NA
	25	4	1	NA
	30	4	1	NA
	35	5	2	NA
	40	6	2	NA

NA = shoreline lengths associated with salinities less than 12 psu were not assessed

5.5.1.2 Salinity-Based Benthic Habitat Assessment Results

Salinity-based bottom areas exhibited greater sensitivity to flow reductions than those simulated for the vegetated shoreline habitats (Table 5-7). Percent reductions in mean bottom habitats relative to baseline conditions were greatest for habitats associated with salinities up to 2 psu, ranging from a 4 percent reduction during Block 1 for the ten percent flow reduction scenario to a 22 percent reduction in habitat for the forty percent flow reduction during Block 2. Reductions of 25 to 30 percent were associated with a 15 percent or greater change in bottom habitat relative to baseline conditions during Block 2. A 20 percent flow reduction was associated with a 15 percent change in bottom habitat relative to baseline conditions during Block 3 and a 35 to 40 percent flow reduction was associated with a 15 percent or greater change in bottom habitat. Flow-related reductions for bottom habitats associated with salinities of less than 5 and less than 12 psu were less sensitive than those for habitat associated with salinities less than 2 psu. Flow reductions of 40 percent resulted in habitat reductions that did not exceed 14 and 8 percent, respectively.

Flow-related changes in bottom habitats associated with salinities less than 18 psu were less sensitive than those determined for the lower salinity zones, so these results were not summarized for presentation in this report. This lack of sensitivity in flow-related changes to mesohaline (5 to 18 psu) bottom habitat in the lower Pithlachascotee River is similar to findings associated with minimum flows development for the Alafia and Peace rivers (SWFWMD 2008b, 2010b) and is likely associated with longitudinal gradients in river morphology and the greater importance of freshwater flow in the mixing characteristics of the lower salinity zones.

Table 5-7. Percent reductions in mean river bottom areas upstream of 2, 5 and 12 psu water-column isohalines for seven flow reduction scenarios relative to baseline flow conditions.

		River Bottom Area Reduction		
Block (Dates)	**Flow Reduction (percent)**	**< 2 psu (percent)**	**< 5 psu (percent)**	**< 12 psu (percent)**
Block 1 (April 25 – June 23)	10	4	2	1
	15	6	4	1
	20	8	5	1
	25	10	6	2
	30	12	8	2
	35	14	9	3
	40	16	10	3
Block 2 (October 17 – April 24)	10	5	3	2
	15	8	5	2
	20	11	6	3
	25	13	8	4
	30	16	10	5
	35	19	12	5
	40	22	14	6
Block 3 (June 24 – October 16)	10	5	3	2
	15	7	4	3
	20	10	6	4
	25	13	8	5
	30	15	9	6
	35	18	11	7
	40	21	13	8

Reductions in daily values of bottom area for the three salinity zones were related to the rate of freshwater inflow. As an example, daily values for percent of remaining bottom area with salinities less than 2, 5, and 12 psu for the 35 percent flow reduction scenario are plotted as a function of baseline flows in Figure 5-12. Reductions in habitat for a given rate of flow were typically greatest for the habitat with salinities less 2 psu, intermediate for the 5 psu zone, and least for the 12 psu zone. However, the percent of habitat reduction associated with each salinity varied with the rate of flow. For the less than 2 psu bottom area, the largest reductions in habitat occurred at flow rates of around 18 to 20 cfs. For bottom areas with salinities less than 5 psu, the largest rates of habitat reduction occurred at flow rates of approximately 4 cfs. These responses are likely associated with the location of the respective isohalines near river kilometer 7.8 under differing flows. Upstream migration of isohalines in this relatively wide portion of the river (see Figure 3-1) results in substantial changes in habitat area.

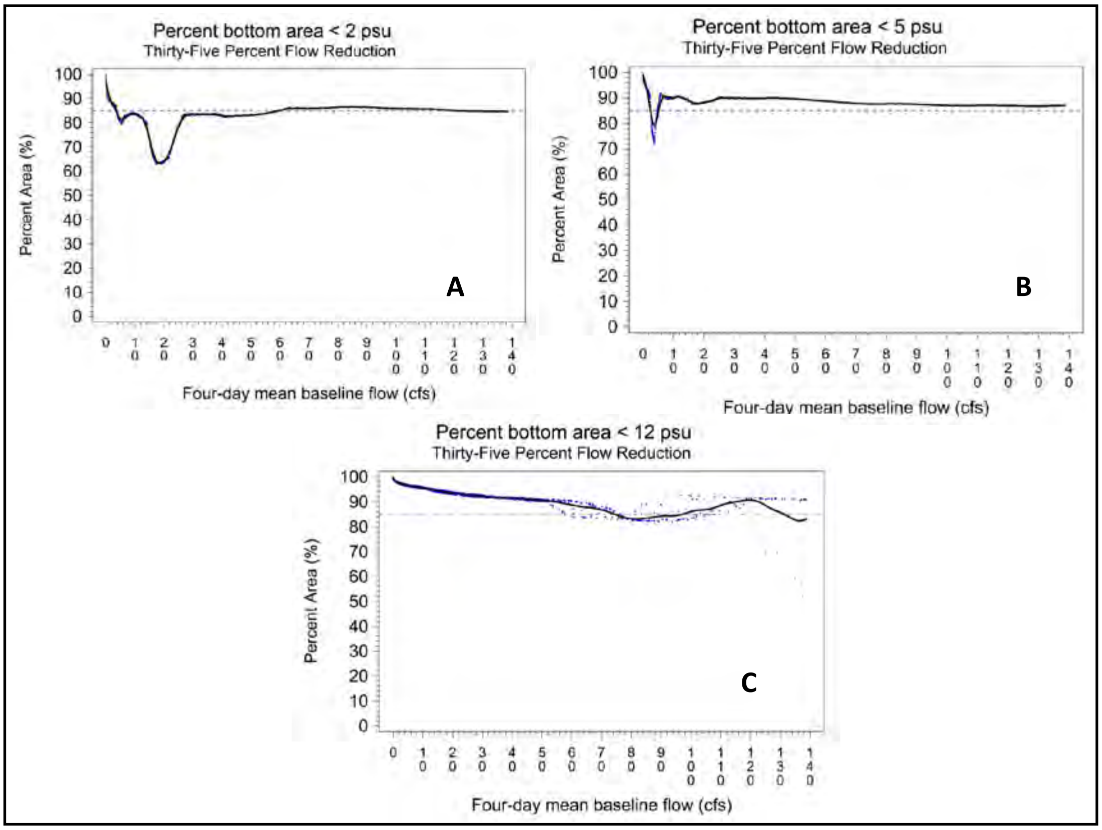


Figure 5-11. Daily values of percent of bottom area for the < 2, <5, and < 12 psu salinity zones (panels A, B and C, respectively) for the 35 percent flow reduction scenario vs. the preceding four-day mean baseline flow.

5.5.1.3 **Salinity-Based Water Column Habitat Assessment Results**

Reductions in salinity-based water-column volumes were assessed using shifts in the location of the 2, 5 and 12 psu water column isohalines. Although water column isohaline locations were used for both the salinity-based bottom area and water column assessments, responses for the two habitat types differed slightly. These differences can be attributed to calculations for volumes vs. areas and also because volumes were estimated up to an elevation of 0.0 meters above NAVD 88, while bottom area calculations were based on water surface elevations up for elevations 0.75 meters and deeper.

Mean values for percent reductions in salinity-based water volumes were similar to and show the same patterns as those observed for bottom area (Table 5-8). For all the flow scenarios, the mean reduction values for water volume are within one percent of the mean reduction values for bottom area for the < 12 psu salinity zone. However, for < 2 and < 5 psu salinity zones, the reductions in water volume were slightly greater for the higher flow reduction scenarios, with mean reductions about 2 percent greater than for bottom area for the 25 percent flow reduction scenarios and greater

As was the case for the bottom habitats, salinity-based water column volumes associated with salinities less than 18 psu were less sensitive to flow changes than those associated with lower salinity zones and these results are not included in this report.

Table 5-8. Percent reductions in mean water-column volume upstream of the 2, 5 psu and 12 psu water column isohalines for seven flow reduction scenarios relative to baseline flow conditions.

		Water Column Volume Reductions		
Block (Dates)	**Flow Reduction (percent)**	**< 2 psu (percent)**	**< 5 psu (percent)**	**< 12 psu (percent)**
Block 1 (April 25 – June 23)	10	4	3	1
	15	7	4	1
	20	9	5	1
	25	11	7	2
	30	14	8	2
	35	16	10	2
	40	18	11	3
Block 2 (October 17 – April 24)	10	6	3	1
	15	8	5	2
	20	11	7	3
	25	14	9	4
	30	17	11	4
	35	21	13	5
	40	24	15	6
Block 3 (June 24 – October 16)	10	5	3	2
	15	8	5	3
	20	11	7	4
	25	14	8	5
	30	17	10	6
	35	20	12	7
	40	23	14	8

5.5.2 Development of a Minimum High Flow Threshold for the Lower River

Our determination of minimum flows for the lower Pithlachascotee River was based on changes in salinity distributions within the river, using regression modeling to predict changes in the locations of key isohalines that would result from a series of percent reductions in daily freshwater inflows. These results were then used in conjunction with physical data for the lower river to determine reductions in the vegetated shoreline length, river bottom area, and water volume with salinities less than 2, 5, 12 and 18 psu resulting from the flow reductions. Potentially allowable percent-of-flow reductions associated with these criteria were developed for implementation during specific seasonal periods of low, medium and high flows, referred to respectively, as Block 1, Block 2 and Block 3.

The regression approach differs from methods employed for larger rivers in the District, for which staff has developed and applied two-dimensional or three-dimensional mechanistic, hydrodynamic models to evaluate reductions in salinity zone habitats (SWFWMD 2006, 2008b, 2010b, 2010c, 2012a, 2012b). These more sophisticated models can be used to perform continuous simulations of hydrodynamic mixing in the estuary and salinity distributions that account for short and long-term variation in tides and freshwater inflows. Regression models have been used previously for development of minimum flows in other District rivers. For some (the Alafia, Peace, Myakka, Homosassa river systems), empirical salinity regression models were also developed for comparison with the results from hydrodynamic modeling (SWFWMD 2008b, 2010b, 2010c, 2012a). Regression modeling was the only method used to examine changes in salinity distributions for establishing minimum flows for the Anclote River (SWFWMD 2010a).

Although potentially less rigorous, results from the regression-based approach used for the Pithlachascotee River provides results that are appropriate for determining minimum flows. District staff acknowledge that the regression approach only accounted for the previous four-day mean flow and did not address longer-term, antecedent flow conditions that could affect salinity distributions in the estuary. However, the regressions that were principally used to determine the minimum flow recommendations accounted for high percentages of the variance in the isohaline locations (r^2 values of 0.88 and 0.89 for the 2 and 5 water column isohalines).

Based on the salinity regression modeling results and identification of the most restrictive salinity-habitat criteria, minimum flow metrics for the lower, estuarine segment of the Pithlachascotee River could be developed that would allow percent-of-flow reductions from baseline flows of up to: 30 to 35 percent during the seasonally low-flow period (Block 1); and 25 to 30 percent during the seasonal high flow (Block 3) and intermediate flow (Block 2) periods (see Tables 5-6, 5-7 and 5-8). Linear interpolation of these results yielded potentially allowable percent-of-flow reductions of 33, 27 and 27 percent, respectively for Blocks 1, 2 and 3.

Because reductions in salinity-based habitats varied as a function of flow (see Figure 5-12), District staff investigated development of a flow-based threshold to differentiate between allowable percent-of-flow reductions for the lower river. For water volume < 2 psu, which was the most sensitive habitat metric, reductions in habitat were near the 15 percent threshold for the 35 percent flow reduction at flows greater than about 60 cfs and were greater than 15 percent at flows less than 60 cfs (except at extremely low flow rates). Using 60 cfs as a flow threshold, the water volume with salinity of up 2 to psu was more sensitive at flows up to and including 60 cfs (Table 5-9). Because the domain of flows used for development of the flow-isohaline regressions was limited to 130 cfs, the number of values (N) used for analysis of habitat responses to flow reductions for flows greater than 60 cfs was limited to include only days when flows were between 60 cfs and 130 cfs.

Within Block 1, all the flows during the study period were below 60 cfs, so results presented in Table 5-9 for Block 1 are identical to the habitat reduction values included in Table 5-8 for the block based on analysis of all flows. For both Blocks 2 and 3, which included flows greater than 60 cfs, a 25 percent reduction in flow was associated with a 15 percent reduction in mean water volume when flows were less than or equal to 60 cfs. For flows greater than 60 cfs during Blocks 2 and 3, a flow reduction of 35 percent was associated with a habitat reduction of 15 percent.

Based on these results, a flow of 60 cfs is recommended as a minimum flow threshold for the lower river. During the baseline flow period, flows on 100 percent, 92 percent and 84 percent of the days in blocks 1, 2, and 3, respectively, were at or below 60 cfs, so this flow rate is recommended as a minimum high flow threshold for the lower river.

Table 5-9. Percent reductions in mean water-column volume upstream of the 2 psu isohaline for seven flow reduction scenarios relative to baseline flows less than or equal to 60 cfs and for baseline flows greater than 60 cfs.

		Water Column Volume Reduction	
Block (Dates)	**Flow Reduction (percent)**	**< 2 psu (Flows <= 60 cfs) (percent and n)**	**< 2 psu (Flows > 60 cfs) Percent and n**
Block 1 (April 25 – June 23)	10	4 (n = 660)	ND (n = 0)
	15	7 (n = 660)	ND (n = 0)
	20	9 (n = 660)	ND (n = 0)
	25	11 (n = 660)	ND (n = 0)
	30	14 (n = 660)	ND (n = 0)
	35	16 (n = 660)	ND (n = 0)
	40	18 (n = 660)	ND (n = 0)
Block 2 (October 17 – April 24)	10	6 (n = 1,915)	4 (n = 65)
	15	9 (n = 1,915)	6 (n = 65)
	20	12 (n = 1,915)	8 (n = 65)
	25	15 (n = 1,915)	11 (n = 65)
	30	18 (n = 1,915)	13 (n = 65)
	35	21 (n = 1,915)	15 (n = 65)
	40	24 (n = 1,915)	18 (n = 65)
Block 3 (June 24 – October 16)	10	6 (n = 1,039)	4 (n = 146)
	15	9 (n = 1,039)	6 (n = 146)
	20	12 (n = 1,039)	8 (n = 146)
	25	15 (n = 1,039)	11 (n = 146)
	30	18 (n = 1,039)	13 (n = 146)
	35	21 (n = 1,039)	15 (n = 146)
	40	25 (n = 1,039)	18 (n = 146)

5.6 Summary of Recommended Minimum Flows for the Lower River

Based on use of a 60 cfs minimum high flow threshold, recommended minimum flows for the lower, estuarine segment of the Pithlachascotee River during Blocks 2 and 3 are 25 percent of baseline flow when flows at the Pithlachascotee River near New Port Richey gage are at or below 60 cfs and 35 percent when flows at the gage are above 60 cfs.

Flow-related habitat reductions during Block 1 are not as sensitive as those in Blocks 2 and 3, due to the morphology of the river and given that potential flow reductions during low-flow periods would be relatively small based on use of the percent-of-flow approach for limiting withdrawals. However, because Block 1 is associated with the driest time of year, when prolonged low-flows are common, a conservative approach to resource protection is warranted and the threshold-based allowable percent-of-flow reductions proposed for Blocks 2 and 3 are also recommended for Block 1. Use of the 25 percent and 35 percent allowable percent-of-flow reductions for flows above and below 60 cfs, as compared to the 33 percent allowable flow reduction determined for Block 1 without consideration of a minimum high flow threshold will provide enhanced protection for the river during Block 1 when periods of medium to higher flows (10 to 30 cfs) occur and changes in the area and volume of low salinity habitats become more sensitive to freshwater flows. Although periods of medium flows are not frequent in Block 1, they are important for reducing salinity during what is normally the driest time of the year, when salinity in the river is at its highest. Results from minimum flow studies of other area rivers support the use of conservative minimum flows criteria during low-flow periods. Nursery use of these rivers by estuarine dependent fishes is high during low-flow periods in the spring (Peebles and Flannery 1992, Matheson et al. 2005, Peebles et al. 2006) and in the case of the lower Hillsborough River, which is an impounded, regulated system, the independent scientific panel that reviewed the minimum flows for that system recommended higher flow releases to the river during the months April through June based to support the increased biological use of the tidal river (Montagna et al. 2007).

As indicated in Table 5-10, recommended minimum flows for the lower, estuarine segment of the Pithlachascotee River would allow for reductions of up to a 25 percent of baseline flows at the Pithlachascotee River near New Port Richey streamflow gage when flows are at or below a minimum high flow threshold of 60 cfs and up to a 35 percent of baseline flows when flows at the gage are greater than 60 cfs. These minimum flows would be applicable for all three seasonal blocks. Minimum flow criteria associated with results based on block-specific analyses that did not include use of a minimum high flow threshold are also included in Table 5-10 for comparison with the recommended minimum flows.

Table 5-10. Flow threshold and maximum allowable percent-of- flow reduction criteria evaluated and recommended for development of minimum flows for the lower, estuarine segment of the Pithlachascotee River.

Block	Criteria Type	Measure / Goal	Flow Thresholds and Allowable Percent-of-Flow Reductions for Consideration	Recommended for Minimum Flows (Type of Minimum Flow)
1	Water column volume < 2 psu	Avoid reductions > 15 percent in low salinity habitat for nekton	33 percent	No
2	Water column volume < 2 psu	Avoid reductions > 15 percent in low salinity habitat for nekton and benthic invertebrates	27 percent	No
3	Water column volume < 2 psu	Avoid reductions > 15 percent in low salinity habitat for nekton and benthic invertebrates	27 percent	No
ALL	Water column volume < 2 psu	Maximizing inundated river channel	25 percent for flows up to 60 cfs 35 percent for flows greater than 60 cfs	Yes (allowable percent-of-flow reductions and minimum high flow threshold)

Although the regression analyses upon which the propose minimum flows for the lower river were based on use of a four-day mean flow term, for practical purposes either same-day or preceding-day flows can be used for application of the minimum flow percentages when daily flow rates are at or below the minimum high flow threshold of 60 cfs. Within the flow range of 0 to 60 cfs, single-day and four-day flows are highly correlated (r = 0.94 Pearson product moment coefficient for flows during the baseline flow period). Based on this correlation, when daily flow rates are at or below 60 cfs, implementation of allowable percent-of-flow withdrawals based on same-day, preceding-day or four-day mean flows will result in the same withdrawal quantities.

Use of preceding four-day flows is, however, recommended for determining potential withdrawal quantities when flows are greater than 60 cfs. Variation in daily flows in the river is typically greater at higher flows, and use of the preceding four-day mean flow for implementation of the allowable 35 percent withdrawal percentage is expected to minimize impacts to estuarine resources that could result from daily shifts in withdrawal quantities associated with use of the two allowable percent-of-flow reductions when flows are in the range of the 60 cfs minimum high flow threshold.

5.7 Protection of Environmental Values for the Lower River

The recommended minimum flows for the lower Pithlachascotee River are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing minimum flows and levels. The methods used for their development were based on the maintenance of maintain salinity-based habitats associated with shoreline vegetation communities, the river bottom and water column. The criteria used for development of the recommended minimum flows are specifically associated with: fish and wildlife habitats and the passage of fish, estuarine resources, and water quality. Given the tidal nature of the lower river and it's relatively low rates of freshwater inflow, District staff reasonably conclude that implementation of the recommended minimum flows should have a negligible effect on water levels in the lower river. The environmental values navigation and recreation in and on the water identified in the rule should, therefore, not be adversely affected by implementation of any recommended minimum flows for the lower river.

Similarly, assuming that water quality and other ecological characteristics of the river will not be adversely affected through implementation of minimum flows that support maintenance of appropriate salinity-based habitats, aesthetic and scenic attributes are also expected to be protected. As noted in in Chapter 2, District staff found minor or no relationships between freshwater inflow and dissolved oxygen and nutrient concentrations in the river, suggesting that these important water quality parameters are not expected to substantially change in response to flow reductions that may be associated with implementation of recommended minimum flows.

Other environmental values identified in the Water Implementation Rule concern complex physical and biological processes, including: transfer of detrital material, filtration and absorption of nutrients and other pollutants, and sediment loads. These processes can be difficult in to quantify, but are likely linked to the rate of freshwater inflow. Accordingly, the resource protection goals and the associated criteria identified for the Pithlachascotee River that are strongly linked to the rate of freshwater inflow are expected to be protective of these environmental values. In addition, the environmental value, maintenance of freshwater storage and supply, is also expected to be protected by the recommended minimum flows based on inclusion of conditions in water use permits that stipulate that permitted withdrawals will not lead to violation of adopted minimum flows and levels.

Chapter 6 - MINIMUM FLOWS STATUS ASSESSMENT AND IMPLEMENTATION

6.1 Introduction

The current status of the flow regime of the Pithlachascotee River and other supporting information are assessed in this chapter to determine whether flows in the river are currently and are projected over the next twenty years to remain above limits associated with the recommended minimum flows for the river. 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 applicability of the existing Minimum Flows and Levels Recovery Strategy and Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution Area (i.e., the Comprehensive Plan), bodies and the need for any additional recovery or prevention strategies for the river is also discussed in this chapter. General information relevant to use of the minimum flows in District permitting programs is, therefore, also briefly summarized.

6.2 Model Simulations of the Effects of Groundwater Withdrawals

6.2.1 INTB Model Results

As noted in Chapter 2 and Appendix 2C to this report, regional groundwater withdrawals in previous decades have resulted in flow declines in the Pithlachascotee River. However, beginning in 2002 when the off-stream C.W. Bill Young Regional Reservoir came online as part of the Comprehensive Plan, groundwater withdrawals at Tampa Bay Water's 11 Central System Facility wellfields have declined from about 150 mgd in the late-1990s to an average of 82.1 mgd from 2008 through 2014. In 2014, groundwater withdrawals from the 11 wellfields were 74.3 mgd.

To address the effects these reductions in water use are expected to have on flows in the river, the Integrated Northern Tampa Bay (INTB) model was run to simulate the impacts from all groundwater withdrawn within the Central West-Central Florida Groundwater Basin (CWCFGWB) plus all of Cross Bar Ranch Wellfield (Figure 6-1). The northern part of Cross Bar wellfield lies just outside the northern extent of the CWCFGWB. The analyses were based on three scenarios: 1) a 90 mgd scenario that included a theoretical pumping distribution where Tampa Bay Water wellfield withdrawals for the period from 1996-2006 was adjusted to match the 90 mgd withdrawal rate from their Central System Facility wellfields identified in the Comprehensive Plan; 2) a current pumping scenario which included a pumping rate of 74.3 mgd that occurred at the 11 central system wellfields in calendar year 2014; and 3) a non-pumping scenario in which all of the withdrawals within the CWCFGWB, including all of Cross Bar Ranch Wellfield were set to zero. The two scenarios that included Central System Facility wellfield withdrawals, i.e., the 90 mgd and the current, 74.3 mgd scenarios, also included estimated and metered groundwater use that occurred from 1996 through 2006 in the CWCFGWB that was not associated with the Tampa Bay Water wellfields. All three simulations were run for an 11-year period using a daily integration step from 1996 through 2006. Results from the 90 mgd and the 74.3 mgd pumping scenarios were compared with results for the non-pumping scenario to characterize withdrawal effects on river flows.

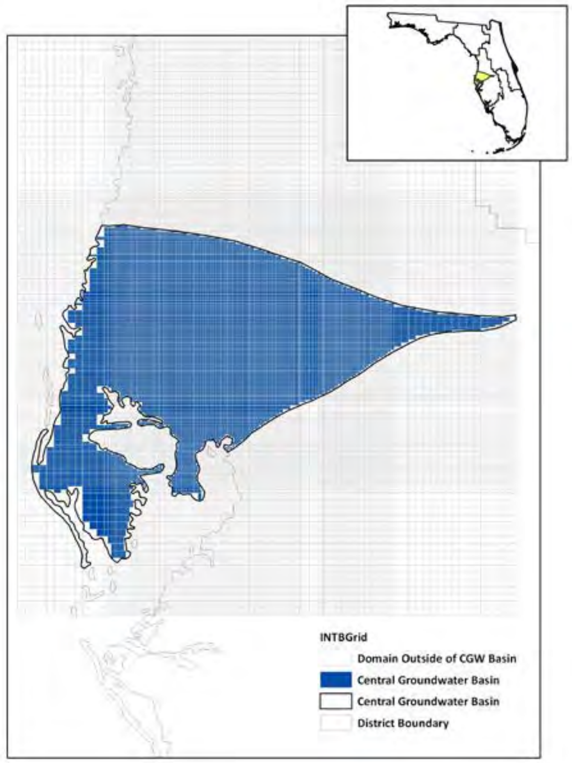


Figure 6-1. INTB scenario 1 where impacts to the hydrologic system were simulated due to groundwater withdrawals of 184.3 mgd (1996-2006 average) in the shaded area. Note: Included all of Cross Bar wellfield as its northern portion lies out the basin.

For the 90 mgd scenario, District staff used the 2008 withdrawal distribution and rate of 86.9 mgd that was scaled-up to 90 mgd based on proportional increases in the magnitude of pumping at the 11 Central System Facility wellfields (Table 6-1). Based on comparison of the 90 mgd and non-pumping scenario results, mean and median withdrawal impacts to flow at the Pithlachascotee River near New Port Richey gage from all area groundwater users were 4.56 and 2.04 cfs, respectively (Figure 6-2). These flow rates represent about a 13 percent reduction in the mean flow and a 24 percent reduction in median flow. Pumping from the Central System Wellfields accounted for mean and median flow reductions of 4.0 and 1.6 cfs, respectively at the Pithlachascotee River near New Port Richey gage of the total impact

Varying the distribution of individual Central System Facility wellfield pumping rates could result in differing predicted withdrawal impacts to the Pithlachascotee River. For our analyses, District staff assumed a distribution of wellfield withdrawals that closely matched withdrawals that occurred in 2008. Actual wellfield withdrawals may vary significantly from this distribution in the future, and would be expected to result in differing groundwater withdrawal impacts to the river. Changes in withdrawal rates at the Starkey and North Pasco wellfields have the greatest flow impact based on their proximity to the river. However, since 2008, combined withdrawals from the Starkey-North Pasco wellfields have been relatively constant, ranging between 4.2 and 4.6 mgd.

Table 6-1. Metered Central System Facility groundwater withdrawals in 2008 and modeled withdrawals used in the 90 mgd scenario.

Central System Facility Wellfield	2008 Withdrawals (mgd)	Modeled Withdrawals (mgd) for 90 mgd Scenario
Starkey	4.0	4.1
North Pasco	0.2	0.3
Cypress Creek	14.8	15.3
Cross Bar	15.4	16.0
Cypress Bridge	10.4	10.8
South Pasco	4.2	4.4
Cosme	6.0	6.2
Section 21	4.0	4.2
Northwest Hillsborough	7.3	7.6
Morris Bridge	7.1	7.3
Eldridge-Wilde	13.4	13.8
Total	86.9	90.0

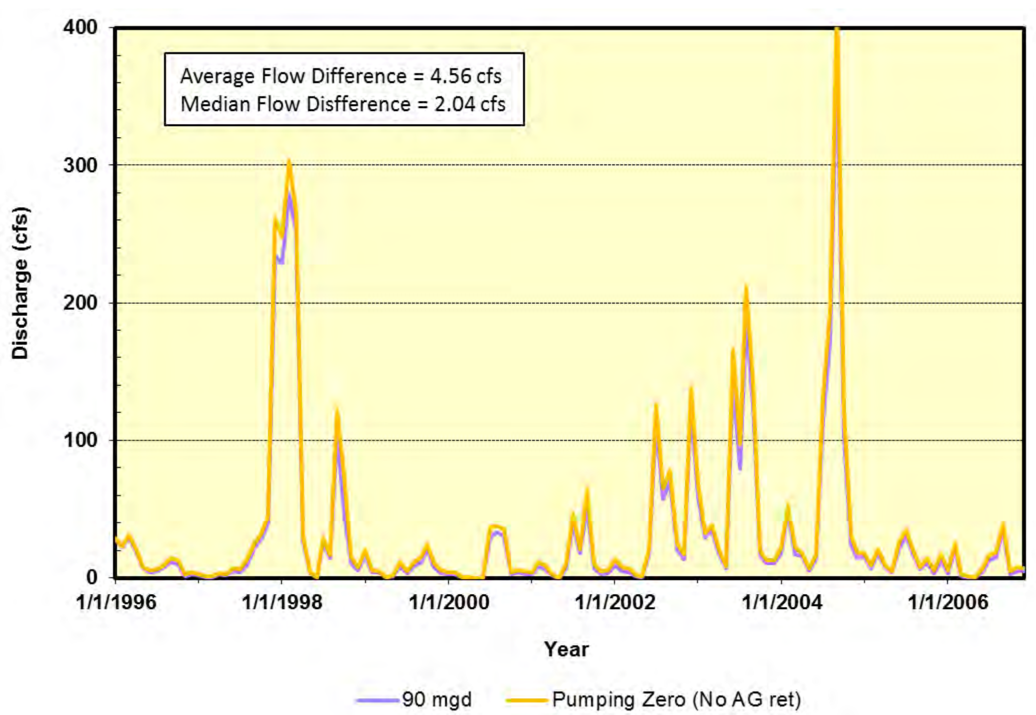


Figure 6-2. Predicted monthly streamflow impact at the Pithlachascotee River near New Port Richey gage due to Central System Facility groundwater withdrawals of 90 mgd and all other user's actual withdrawals from 1996 through 2006.

For the current pumping scenario, metered withdrawals in 2014 from the Central System Facility wellfields (74.3 mgd) were simulated from 1996 through 2006 (Table 6-2), and withdrawals by all other users were maintained at the same rates as occurred from 1996 through 2006. Based on comparison with results from the non-pumping scenario, current mean and median withdrawal impacts to flows at the Pithlachascotee River near New Port Richey gage from all water users were 4.33 and 1.96 cfs, respectively (Figure 6-3). These flow rates represent about a 12 percent reduction in mean flow and a 23 percent reduction in median flow due to all withdrawals. Mean and median withdrawal impacts to river flows from withdrawals at the Central System Facility wellfields represented 3.8 and 1.5 cfs, of the total impact, respectively.

Table 6-2. Metered Central System Facility groundwater withdrawals in 2014 used for the current pumping (74.3 mgd) scenario and comparison with modeled withdrawals used in the 90 mgd scenario.

Central System Facility Wellfield	2014 Withdrawals (mgd)	Difference (mgd) from 90 mgd Scenario
Starkey	4.3	0.2
North Pasco	0.3	0.0
Cypress Creek	14.5	-0.8
Cross Bar	13.3	-2.7
Cypress Bridge	11.2	0.4
South Pasco	4.2	-0.2
Cosme	5.8	-0.4
Section 21	1.1	-3.1
Northwest Hillsborough	2.6	-5.0
Morris Bridge	6.5	-0.8
Eldridge-Wilde	10.4	-3.4
Total	74.3	-15.7

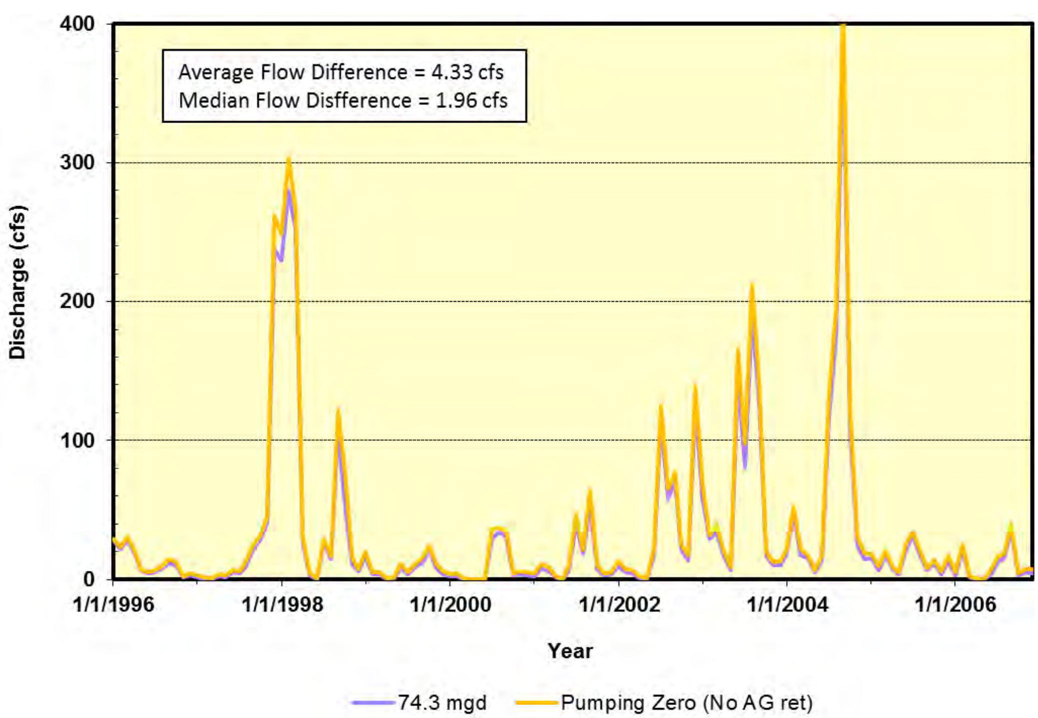


Figure 6-3. Predicted monthly streamflow impact at the Pithlachascotee River near New Port Richey gage due to Central System Facility groundwater withdrawals of 74.3 mgd and all other user's actual withdrawals from 1996 through 2006.

6.2.2 Minimum Flow Assessments Based on Model Simulations

To help determine if the flow regime of the Pithlachascotee River is meeting and will continue to meet the minimum flow requirements proposed for the upper, freshwater and lower, estuarine segments of the river, flow simulated for the non-pumping scenario with the INTB model was reduced for the period from 1996 through 2006 by the maximum seasonal percentage flow reductions specified for the recommended minimum flows. The resulting flows, which are identified here as “minimum flow assessment flows”, were compared to those predicted from the current pumping (74.3 mgd wellfield pumping plus all other user’s withdrawals) scenario to assess whether the river’s current flow rate is above or below the recommended minimum flow limits. The minimum flow assessment flows were also compared with results from the 90 mgd (90 mgd wellfield withdrawals plus all other user’s withdrawals) scenario to assess river flows under the permitted maximum withdrawal rate for the Central System Facility wellfields. This latter analysis was completed to assess potential, future withdrawal impacts to minimum flows in the river, with the expectation that the 90 mgd wellfield withdrawal limit is applicable for the next 20-year planning horizon.

Based on mean and median flows predicted for the current withdrawal scenario, the recommended minimum flow criteria for the lower river are being met, although the median predicted flow under current pumping conditions is sufficient to just meet the upper river minimum flow criteria (Table 6-3). Similarly, the mean predicted flow under current pumping conditions is sufficient to just meet the minimum flow criteria for the upper river. The predicted median flow associated with current withdrawals is, however, 0.6 cfs less than allowable with the proposed criteria for the upper river, suggesting that the minimum flows recommended for the freshwater river segment are potentially not being met.

Table 6-3. Comparisons of mean and median flows at the Pithlachascotee River at New Port Richey gage derived using results from INTB model simulations for a period from 1996 through 2006 for: a non-pumping scenario, minimum flow assessment flows (non-pumping scenario flows adjusted using allowable flow reductions associated with proposed minimum flow allowances), and a current 74.3 mgd plus all other water users pumping scenario. Negative differences between current and minimum flow assessment flows indicate flow deficits relative to minimum flow requirements; positive difference values indicate potential flows in excess of minimum flow requirements.

Flows for Comparison	Upper (Freshwater) Segment		Lower (Estuarine) Segment	
	Mean (cfs)	Median (cfs)	Mean (cfs)	Median (cfs)
Non-pumping scenario flows	36.3	8.4	36.3	8.4
Minimum flow assessment flows (Non-pumping scenario flow reduced by allowable minimum flow criteria)	31.4	7.0	24.6	6.3
Current flows (74.3 mgd wellfield withdrawals plus other users scenario)	32.0	6.4	32.0	6.4
Difference between current and minimum flow assessment flows	+0.6	-0.6	+7.4	+0.1

Based on mean and median flows predicted for the 90 mgd scenario, the proposed minimum flow criteria for the lower river would be met, although the median predicted flow would be only 0.1 cfs above the allowable median associated with the proposed criteria (Table 6-4). Results from the 90 mgd simulation suggest that minimum flow requirements for the upper river are potentially not being met. The predicted mean and median flows associated with the 90 mgd withdrawals are, respectively, 0.3 cfs greater and 0.6 cfs less than the allowable with the proposed criteria for the freshwater portion of the river. The small differences (<1 cfs) between mean and median minimum flow assessment flows and the 90 mgd wellfield withdrawals results indicate that under the 90 mgd wellfield withdrawal conditions flows would be very close to the recommended minimum flow requirements.

Table 6-4. Comparisons of mean and median flows at the Pithlachascotee River at New Port Richey gage derived using results from INTB model simulations for a period from 1996 through 2006 for: a non-pumping scenario, minimum flow assessment flows (non-pumping scenario flows adjusted using allowable flow reductions associated with proposed minimum flow allowance), and a permitted 90 mgd plus all other water users pumping scenario. Negative differences between current and minimum flow assessment flows indicate flow deficits relative to minimum flow requirements; positive difference values indicate potential flows in excess of minimum flow requirements.

Flows for Comparison	Upper (Freshwater) Segment		Lower (Estuarine) Segment	
	Mean (cfs)	Median (cfs)	Mean (cfs)	Median (cfs)
Non-pumping scenario flows	36.3	8.4	36.3	8.4
Minimum flow assessment flows (Non-pumping scenario flow reduced by allowable minimum flow criteria)	31.4	7.0	24.6	6.3
90 mgd wellfield withdrawals plus other users scenario flows	31.7	6.4	31.7	6.4
Difference between 90 mgd wellfield withdrawals plus other users scenario and minimum flow assessment flows	+0.3	-0.6	+7.1	+0.1

Evaluation of the range of flow impacts predicted with the INTB model provides context for using the identified impacts for the current (74.3 mgd) and 90 mgd withdrawal scenario results for determining whether the proposed minimum flow criteria for the Pithlachascotee River are being met and will be met under future, maximum permitted wellfield-withdrawal conditions. Comparison of the allowable 1.4 cfs median flow impact with the daily flow impacts predicted with the model for the current 74.3 mgd and 90 mgd withdrawal scenarios for the 11-year INTB simulation period indicates that the allowable impact falls within the 90^{th} percentile envelope (or range from the 5th to the 95^{th} percentile) of the model-predicted impacts (Figure 6-4). This suggests that impacts to the median flow in the river associated with withdrawals of up to 90 mgd from the Central System Facility wellfields under the modeled withdrawal distribution would not be expected to exceed the allowable flow reductions associated with the proposed minimum flow criteria for the upper, freshwater river segment. It should be noted, however, that the allowable median flow impact lies in the lower portion of the 90^{th} percentile envelop of predicted impacts, indicating that current and predicted flows are close to the allowable minimum flow requirements. Given that the proposed minimum flow requirements for the lower, estuarine river segment are less restrictive on withdrawals than those for the upper river, the modeling results also indicate that withdrawals of up to 90 mgd from the Central System Facilities would likely not be associated with reductions in flows that would exceed minimum flow requirements for the lower river.

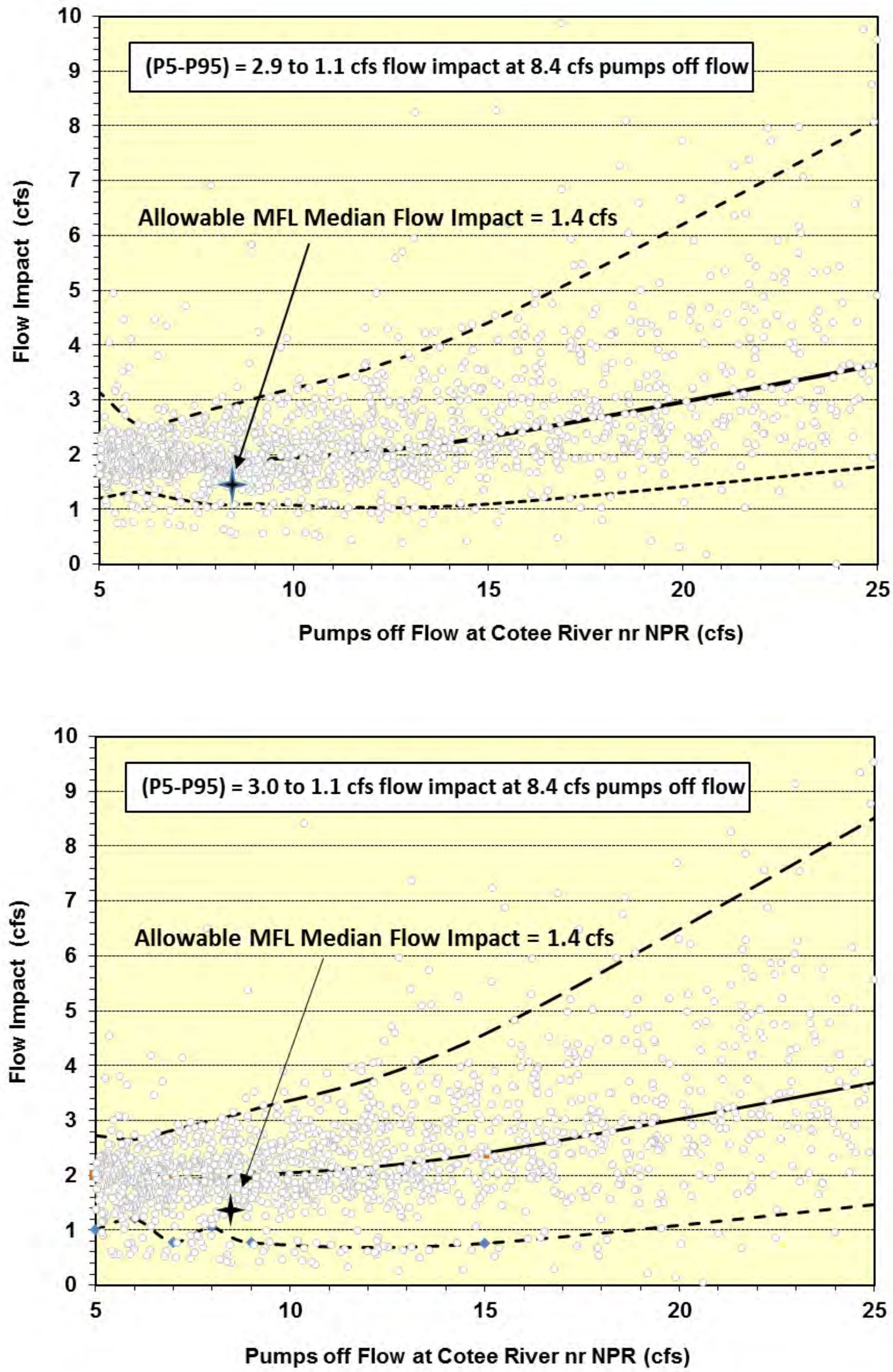


Figure 6-4. Allowable median flow impact and predicted daily flow impact percentiles (P5, P50, P90) due to 74.3 mgd (upper plot) and 90 mgd (lower plot) Central System Facility wellfield pumping and other area user's withdrawals versus "pumps off" flow for the Pithlachascotee River near New Port Richey gage.

6.2.3 INTB Model Uncertainty

District staff also considered uncertainty associated with use of the INTB model as part of the assessment of flows in the Pithlachascotee River relative to the proposed minimum flow requirements. Sources of this uncertainty included variability in river flows that could result from rainfall changes, the spatial distribution of wellfield withdrawals, and intrinsic model error.

To assess modeling uncertainty associated with spatial rainfall variation, Tampa Bay Water staff conducted 334 different rainfall realizations with the INTB model for the period 1996-2006. These simulations spanned the plausible range of rainfall observed over the last 100 years and were conducted using a constant pumping condition to focus on rainfall-related effects. The modeling effort indicates that the predicted median flow impact from withdrawals at the Pithlachascotee River near New Port Richey gage may vary by 0.6 cfs over the full range of expected rainfall conditions. This suggests – although it would represent a low probability of occurrence – that much of the potential 0.6 cfs median flow deficit for the freshwater segment of the river predicted for the current (74.3 mgd) withdrawal scenario could be accounted for solely based on rainfall variation.

Uncertainty in the INTB model results is also associated with the magnitude and distribution of groundwater withdrawals among and within the Central System Facility wellfields. For example, District staff found that redistribution of a one mgd withdrawal from the northwest corner of Starkey Wellfield to the eastern portion of the wellfield resulted in a simulated 0.5 cfs increase in the median river flow. This withdrawal redistribution simulation resulted in a moderate, 0.25 to 0.5 foot drawdown in the surficial aquifer in the eastern wellfield area.

Intrinsic model error also contributed to uncertainty in our interpretation and use of model results for assessment of river flows. The mean error in simulated versus observed flow from the INTB model for the calibration period from 1989-1998 was 0.8 cfs or 3.9 percent at the Pithlachascotee River near New Port Richey gage. For the model verification period, from 1999-2006, the error in simulated flows at the gage site was 5.4 cfs, or 28 percent of the observed flow. These model error statistics likely are larger than error associated with the pumping scenario results because we are matching particular flow rates during calibration rather than a relative change in flows due to pumping stress. District staff do, however, acknowledge that use of a “pumps off” scenario introduces uncertainty into our modeling efforts. The INTB model was extensively calibrated during “stressed” conditions, during a period (1989 through 2006) of high rates of groundwater extraction and relatively dry climatic conditions. Using a model for periods with stress conditions (e.g., groundwater withdrawal rates, rainfall) that differ from the calibrated stresses may contribute to some prediction bias. However, staff believe that the fully integrated, INTB surface water/ground-water model is appropriate for evaluating non-stressed conditions (e.g., the pumps off withdrawal scenario used in our analyses) given that it incorporates rainfall, evapotranspiration, runoff, and parameters associated with the groundwater system.

6.3 Other Supporting Information

6.3.1 Changes in Pithlachascotee River Flow

For several rivers where minimum flows have been adopted, the District has identified minimum five-year and ten-year moving mean and median flow values to serve as tools to assess whether flows in each river remain above the flow rates that are expected to occur with implementation of the minimum flows. The values represent the lowest respective five and ten-year flows that would occur over a defined period of record if all the water potentially available for withdrawal based on the established minimum flows is removed from the river.

Because only seven five-year statistics and two ten-year statistics could be calculated for the 11-year (1990 through 2000) baseline flow record used to develop recommended minimum flows for the Pithlachascotee River, District staff considered them to be of limited use for assessing whether the proposed minimum flows are or will be met in the future. Development and use of these or other flow statistics may be used for tracking the status of flows in the river relative to any adopted minimum flows if a longer baseline flow record can be developed.

6.3.2 Consideration of Surficial and Upper Florida aquifer Water Level Changes

Groundwater-level history within and around the Pithlachascotee River watershed was examined by reviewing data from 43 surficial aquifer and 11 Upper Floridan aquifer monitor wells. Specifically, on-site water levels from Starkey Wellfield monitor wells were examined for changes from conditions that existed prior to the onset of wellfield withdrawals to conditions occurring from 2010 through 2015.

For the analyses, District staff employed a hydrograph separation technique to determine water level change due to groundwater withdrawals. Using this graphical approach, mean annual water levels from two separate wells, one on the wellfield, and another outside the zone of influence of wellfield withdrawals (background) were matched, i.e., aligned using differing y-axis scales, for a period prior to the onset of wellfield pumping. Temporal deviation or “separation” between mean annual water levels for the background well and on-site well was inferred to be associated with drawdown due to pumping. This methodology has previously been applied to determine wellfield drawdown at some of Tampa Bay Water’s wellfields as part of the 1999 establishment of recovery levels in the northern Tampa Bay area (SWFWMD 1999).

Four long-term monitor wells located on Starkey wellfield, the 707, 728, and the SM-2 surficial aquifer wells and the 10-Dp (Deep) UFA well, had sufficient period-of-record to use in the hydrograph separation technique (Figure 6-5). For each well, District staff matched pre-pumping water levels for a one or two-year period with the background well water level to create the y-axis offset in vertical elevation. Pumping from the western part of Starkey wellfield began in 1976. Pumping began in the central part of the wellfield in 1980. Background sites used for the analysis included the SR 52 Dp near Fivay Junction and Moon Lake SH (shallow) wells.

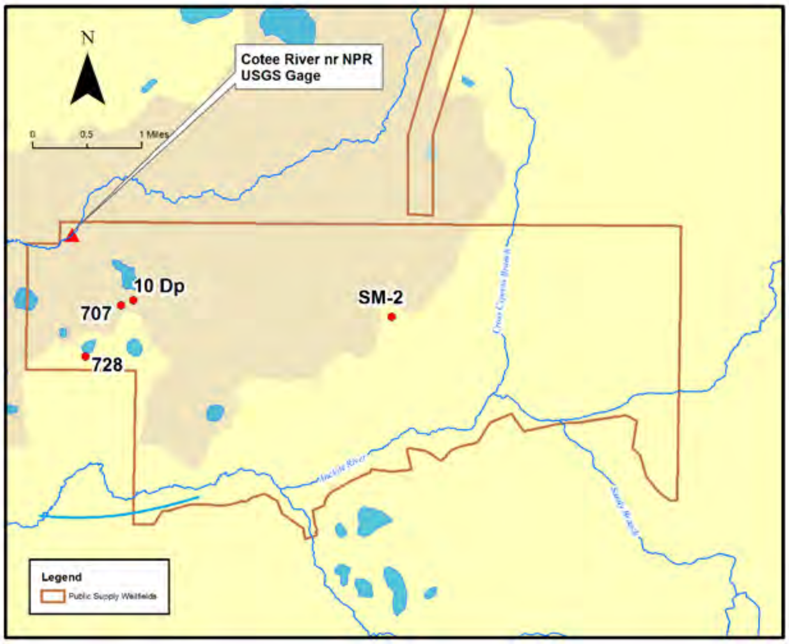


Figure 6-5. Starkey Wellfield monitoring wells used for a hydrograph separation analysis.

The hydrograph separation technique indicated that during the 1990s when groundwater withdrawals from Starkey Wellfield averaged close to 12 mgd, drawdown varied from one to four feet at the 707, 728, SM-2 and 10 deep UFA wells. From 2010 through 2015, after significant wellfield withdrawal reductions in 2008, mean water levels in the 10 deep UFA and 728 wells, which are the closest to the river, differed from background well water levels by only 0.07 and 0.03 feet (Figure 6-6 Figure 6-7). Mean water level in the 707 well was almost 0.79 feet above the mean background well water level during the same period (Figure 6-8). Mean water level at the SM-2 well, located near the centroid of heaviest groundwater extraction on Starkey Wellfield, was 0.46 feet below the background water level (Figure 6-9).

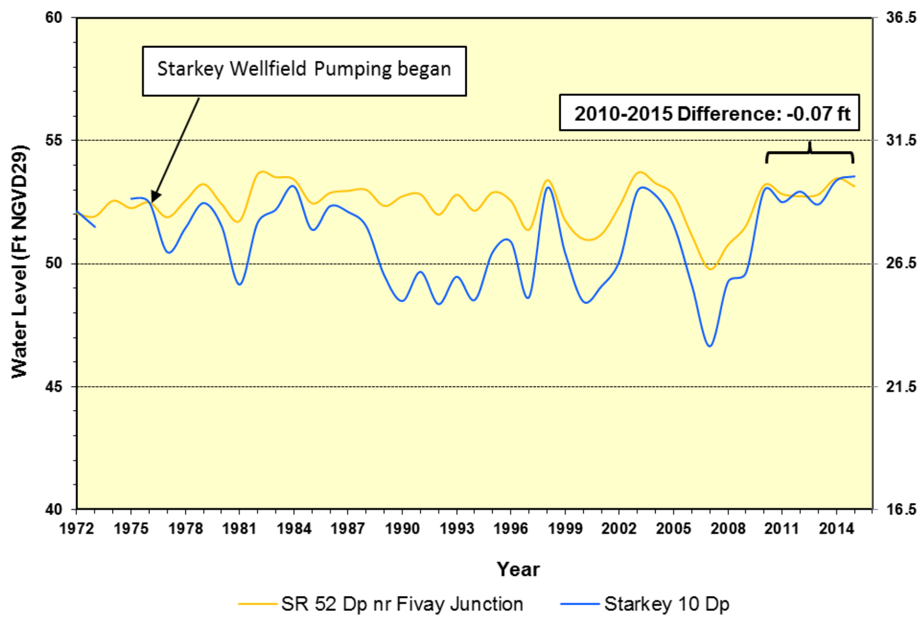


Figure 6-6. Comparison of water levels at Starkey Wellfield 10-Dp monitor well with the SR 52 Dp near Fivay Junction background monitor well using the hydrograph separation technique.

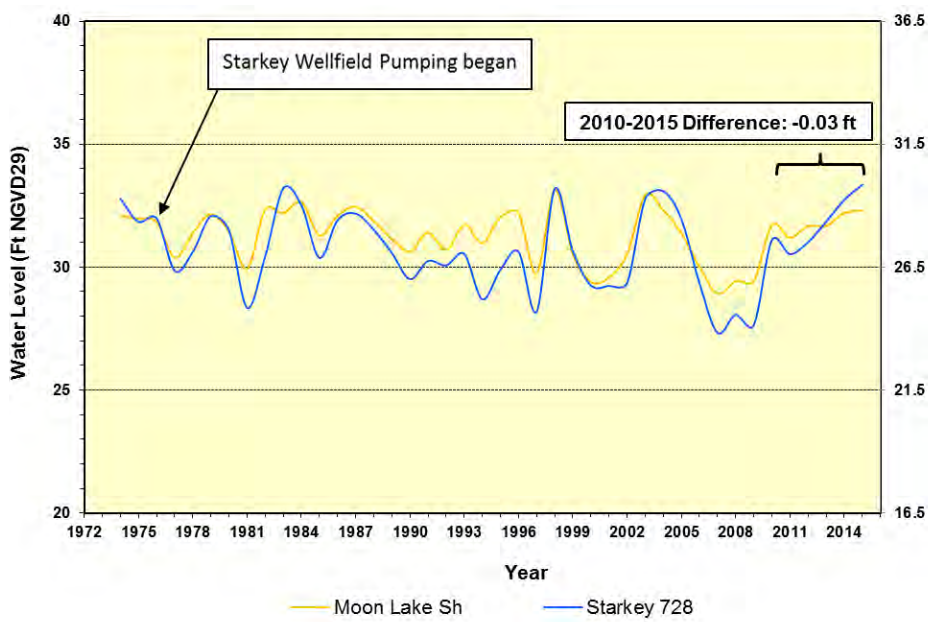


Figure 6-7. Comparison of water levels at Starkey Wellfield 728 monitor well with the Moon Lake Sh background monitor well using the hydrograph separation technique.

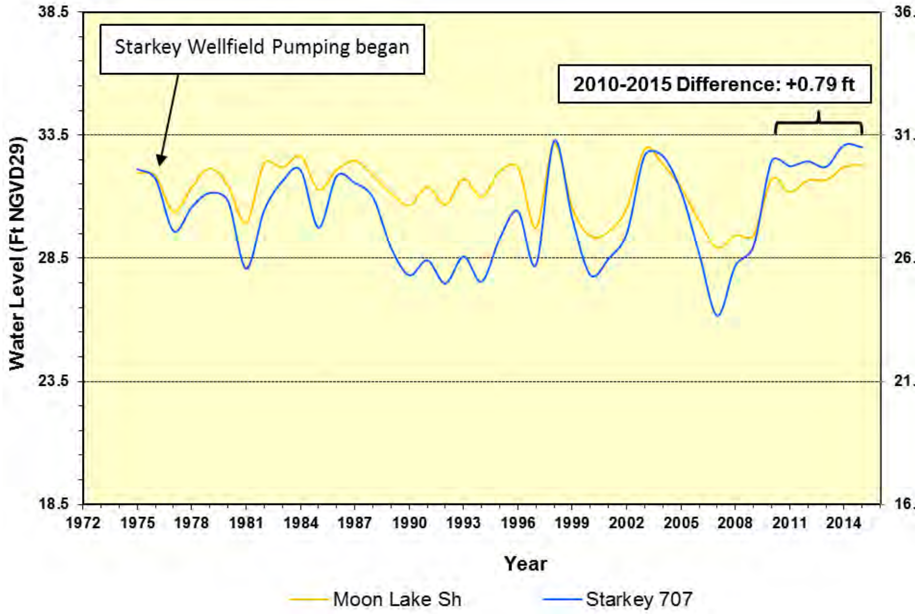


Figure 6-8. Comparison of water levels at Starkey Wellfield monitor well 707 with the Moon Lake Sh background monitor well using the hydrograph separation technique.

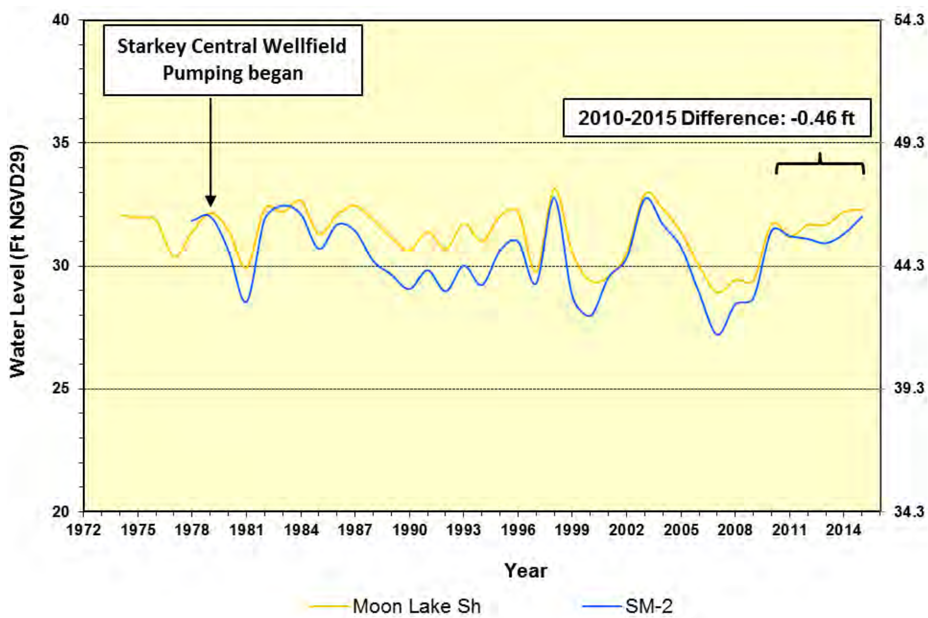


Figure 6-9. Comparison of water levels at Starkey wellfield SM-2 monitor well with the Moon Lake Sh background monitor well using the hydrograph separation technique.

Another method to evaluate groundwater levels at Starkey Wellfield was used to take advantage of many of the on-site monitor wells that were installed in the late-1990s, after the initiation of wellfield pumping. For this analysis, median water levels were calculated for 35 on-site, surficial aquifer monitor wells (Figure 6-10) and 3 off-site, background wells for the period from 2010 through 2015. Staff then compared the elevation from the 2010-2015 period as to its percentile within the 17-year period from 1999 through 2015. The background wells uninfluenced by groundwater withdrawals, included the SR 52 west nr Fivay Junction, Moon Lake Shallow and Cross Bar 2SW. The 1999 through 2015 period used for percentile identification was based on when most on-site monitor wells were installed at Starkey Wellfield and their recorded water level history began.

Median water levels at the 35 Starkey Wellfield surficial wells from 2010 through 2015 period corresponded to the 21st through 42nd long-term exceedance percentile (Figure 6-10), with an average at the 33rd exceedance percentile (Figure 6-10; Table 6-5). On average, the more recent water levels therefore correspond with the upper third of measured water levels from 1999 through 2015. Background water level percentiles for the Cross Bar 2 SW monitor well and SR 52 west nr Fivay Junction shallow wells were also at the 33rd percent exceedance, while the Moon Lake Shallow well was at its 31st percentile. These results confirm that recent water level percentiles from a wide array of monitor wells on Starkey Wellfield were at or close to percentiles at wells not impacted by withdrawals.

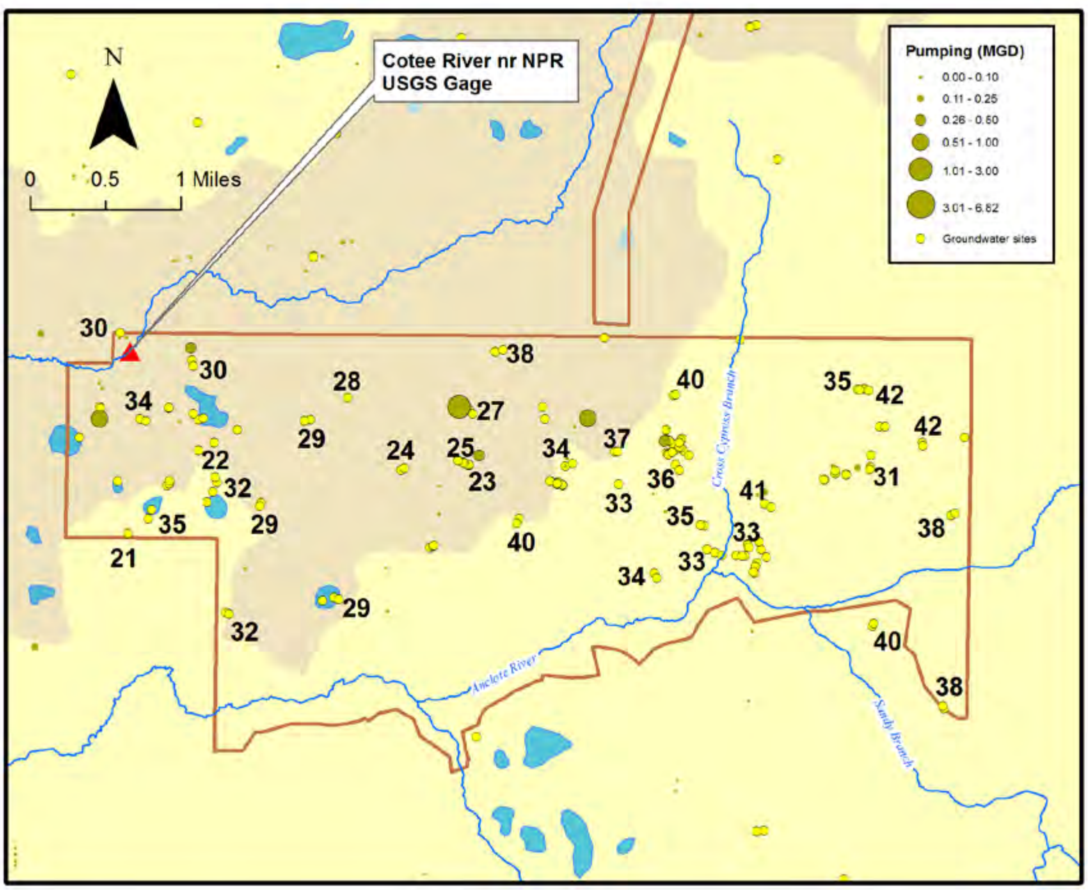


Figure 6-10. Median 2010-2015 water level expressed as and exceedance percentile for the 1999 through 2015 period for 35 surficial aquifer monitor wells at Starkey Wellfield.

Table 6-5. Median water level from 2010 through 2015 for 35 Starkey Wellfield and 3 background wells expressed as an exceedance percentile for the period 1999 through 2015.

Surficial aquifer Well on Starkey Wellfield	Median Water Level Percentile (2010 through 2015)
D Upland	30
B Upland	34
U Upland	29
V Upland	28
CC (S-10)	21
E Upland	32
Bay Upland	29
W Upland	24
J Upland	27
K Upland	40
O wetland	40
BB wetland	40
Wet Prairie	35
Starkey 1B East	33
SM-2	34
TGG Upland	38
M Upland	41
X wetland	33
T Upland	36
N Upland	38
R Upland	42

Surficial aquifer Well on Starkey Wellfield	Median Water Level Percentile (2010 through 2015)
South-central Upland	29
EE Upland	42
FF Upland	40
C Upland	38
728 shallow	35
3B west	25
3A west	23
L Upland	37
Y Upland	31
Coniferous Forest	32
SM-1	30
707 Shallow	21
Z Upland	34
S Upland	35
Average:	33

Surficial aquifer Background Well	Median Water Level Percentile (2010 through 2015)
Cross Bar 2SW	33
SR 52 west at Fivay Rd.	33
Moon Lake Shallow	31

6.3.3 INTB Model Drawdown

The Pithlachascotee River is in direct hydraulic connection with the surficial aquifer with a semi-confining clay unit separating it from the underlying UFA below. To further investigate hydrologic conditions in the vicinity of the Pithlachascotee River, INTB model simulations were run to characterize water level drawdown in the surficial aquifer and the UFA. Average aquifer heads from the current pumping scenario (74.3 mgd) were subtracted from the non-pumping scenario.

Predicted drawdown in the surficial aquifer was 1 to 2 feet near the centroid of withdrawals in the central portion of Starkey Wellfield and was 0.5 feet or less at the Pithlachascotee River (Figure 6-11). Within much of the river basin upstream of the Pithlachascotee River near New Port Richey gage site, predicted surficial drawdown was also less than 0.5 feet. Model results for the UFA exhibited a similar drawdown pattern, with the largest drawdown (3 to 5 feet) in the central Starkey Wellfield, less than one foot at the river and within much of the river drainage basin (Figure 6-12). These modeled drawdowns for current wellfield withdrawal conditions are greater than those identified using the hydrograph separation technique. Again, based on that empirically-based analysis, groundwater levels in much of the Starkey Wellfield over the last 5-6 years are similar to background levels.

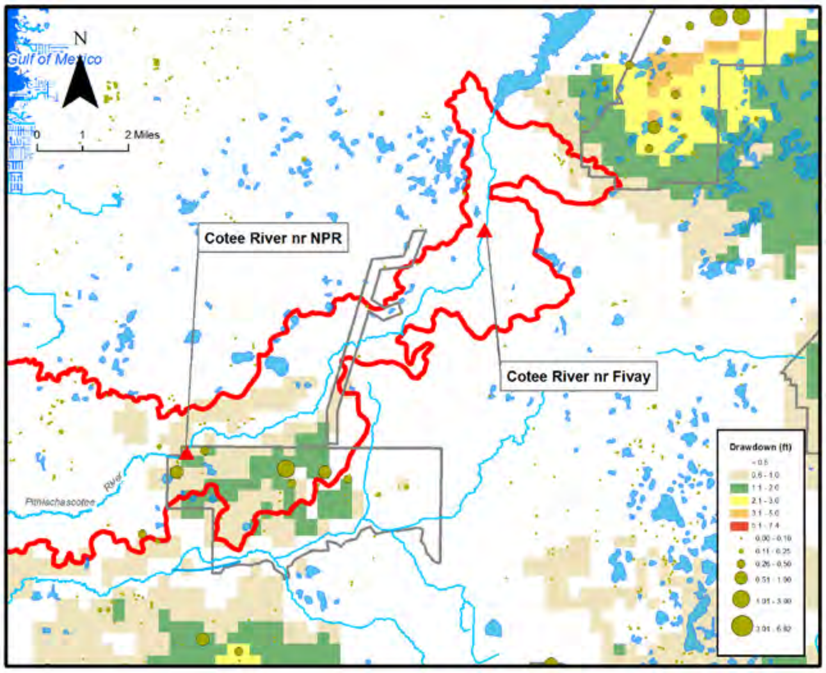


Figure 6-11. Predicted mean surficial aquifer drawdown from the INTB model based on 2014 groundwater withdrawals from the Central System Facility wellfields (74.3 mgd) and all other users pumping at their 1996-2006 quantities. Superimposed is the average magnitude of estimated and metered groundwater use from 2008-2012.

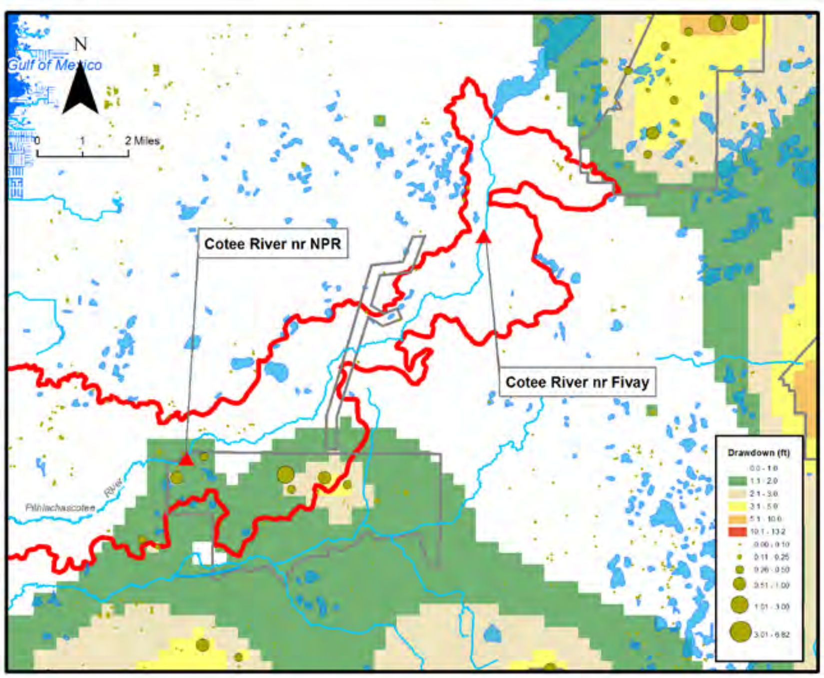


Figure 6-5. Predicted mean Upper Floridan aquifer drawdown from the INTB model based on 2014 Tampa Bay Water groundwater withdrawals (74 mgd) and all other users pumping at their 1996-2006 quantities. Mean estimated and metered groundwater pumping from 2008 through 2012 is also shown.

6.3.4 Pithlachascotee River Flow Changes and Rainfall

Mean annual flow of the Pithlachascotee River near New Port Richey gage was plotted from 1964 through 2015 to assess trends in flows. A fourth-order polynomial fit to the data displays an upward trend since 2007 (Figure 6-13). Median flow for the 1970 through 1975 period was 6.9 cfs compared with a median flow of 8.9 cfs from 2010 through 2015. The 1970-1975 period corresponds to a period immediately prior to the initiation of pumping from the Starkey Wellfield. Because river flows are strongly correlated to climate, Pasco County rainfall was also examined from the District's hydrologic database. There were very similar rainfall conditions between the two periods, with the 1970 through 1975 rainfall averaging 55.9 inches per year and the 2010 through 2015 rainfall averaging 55.5 inches per year (Figure 6-14).

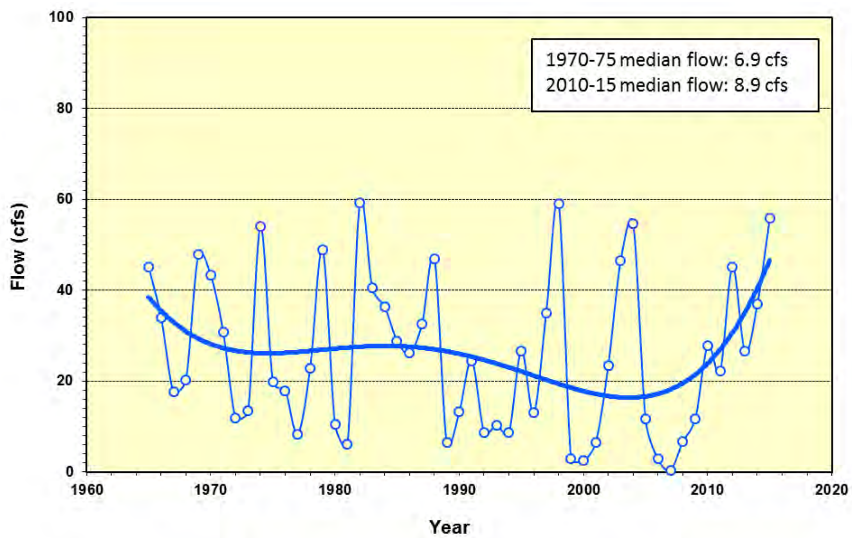


Figure 6-13. Mean annual flow of the Pithlachascotee River at the New Port Richey gage from 1964 through 2015 with a 4th-order polynomial fit to the data.

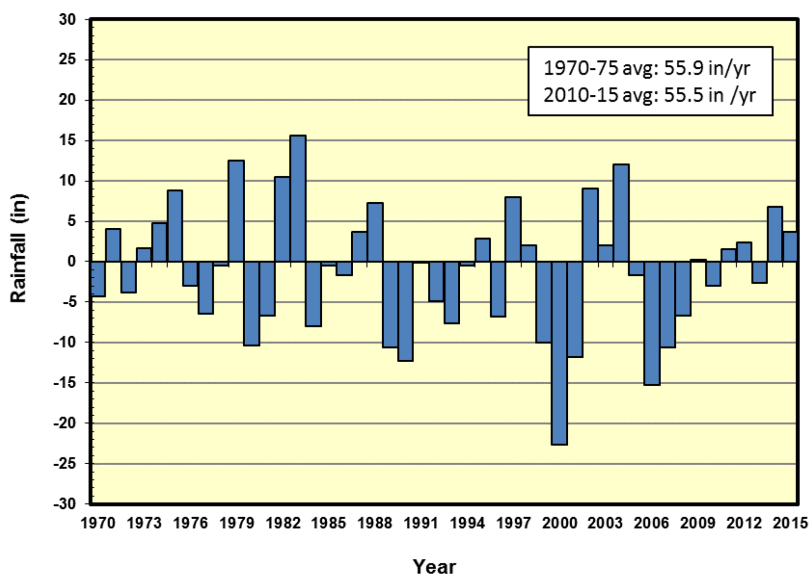


Figure 6-14. Annual rainfall departure from the long-term mean for Pasco County, Florida from 1970 through 2015. Data source: http://www.swfwmd.state.fl.us/data/wmdbweb/rainfall_data_summaries.

6.3.5 Consideration of Area Minimum Flows and Levels Status Assessments and Wetland Recovery Status near Starkey Wellfield

To further support assessment of the status of the Pithlachascotee River, regional conditions were also reviewed based on the status of area water bodies with established minimum levels and a recent recovery assessment of wetlands in the vicinity of Starkey Wellfield.

Many, but not all minimum flows and levels established for water bodies in the region are being met. Six of seven wetlands with minimum levels that are located on Starkey Wellfield and two wetlands located near the North Pasco Wellfield, just to the north of Starkey Wellfield, are being met (Figure 6-15). All minimum levels established for lakes within the Pithlachascotee watershed, including Crews Lake are also being met. Minimum wetland levels are not being met at one wetland on the Starkey Wellfield and at several wetlands on the Cross Bar Ranch Wellfield in the upper Pithlachascotee watershed and at the Cypress Creek Wellfield east of the central portion of the river's watershed. Minimum flows established for the Anclote River, which runs through the southern portion of the Starkey Wellfield are also not being met.

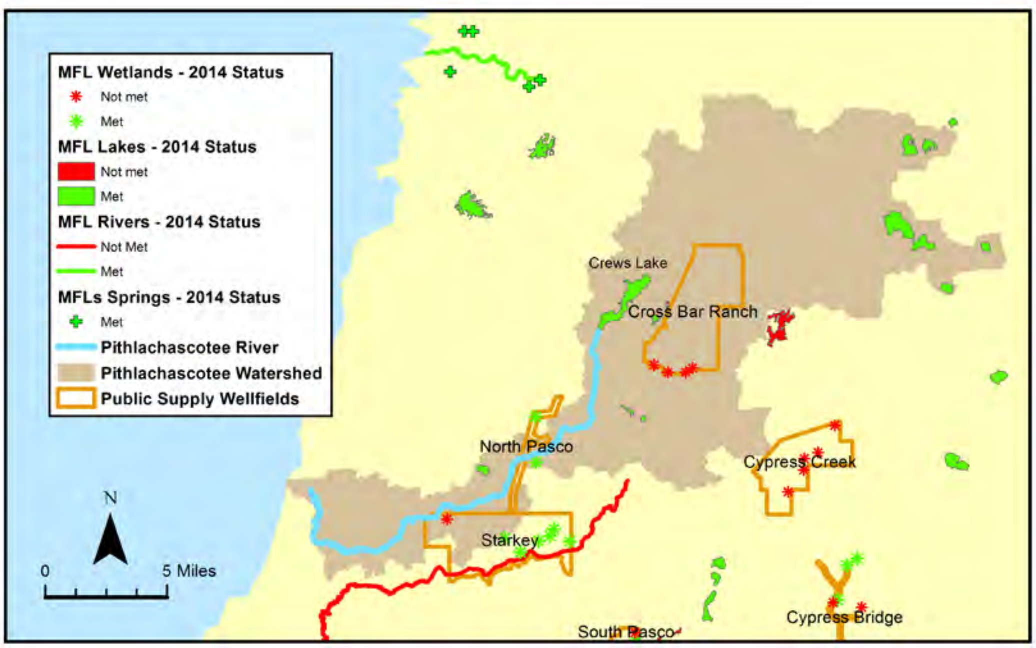


Figure 6-15. Recent status of established minimum flows and levels (and proposed minimum levels for Crews Lake) in the vicinity of the Pithlachascotee River.

As part of the Permit Recovery Plan required as part of the Consolidated Water Use Permit addressing withdrawals from its Central System Facilities, Tampa Bay Water has recently completed an analysis of recovery status of wetlands on or near the Starkey Wellfield (Tampa Bay Water 2016) that is currently being reviewed by District staff. This wetland assessment was conducted in conjunction with a study that documented up to six and three feet increases, respectively, in UFA system and surficial aquifer system groundwater levels, between periods preceding and following 65 percent reductions in withdrawals at the wellfield (Wise Consulting Group 2016).

The wetland assessment results indicate that 33 of 37 mesic-associated isolated cypress wetlands in the monitoring program, have met a hydrologically-based recovery metric similar to the criterion used by the District for establishing the Minimum Wetland Levels. Three of the four wetlands where the recovery metric was not met exhibited some hydrologic improvement and Tampa Bay Water has been recommended that these systems be categorized as “improved, but not fully recovered.” Classification of recovery status for the fourth wetland as “not fully recovered” was recommended, as was the completion of a site-specific assessment of the wetland to evaluate potential confounding effects of historical augmentation of the wetland with pumped groundwater.

6.3.6 Consideration of Sea Level Rise

The District uses projections of sea level change to help assess the need for and schedule any necessary reevaluations of established minimum flows and levels (Heyl and Basso 2015). District staff analyzed the effect of potential sea level rise on salinity-based habitat in the Pithlachascotee River to see if impacts associated with future flow reductions will be magnified toward the end of a twenty-year period (i.e., by 2035) that is consistent with our current regional water supply planning horizon and requirements of the Water Resources Act of 1972.

6.3.6.1 Historical sea level trends

Sea level has varied globally through time, oscillating both above and below the present level (Siddall et al. 2003). Sea level plays an important role in determining the amount of salinity-based habitat. Rising sea levels are, therefore, expected to alter available habitat for species with narrow salinity tolerances (Obeysekera et al. 2011). Locally, sea level has increased over the period of record; historical trends based on monthly measurements at Cedar Key (NOAA 2016a) and St. Petersburg (NOAA 2016b) reveal an average increase of 2.32 millimeters per year, which is equivalent to a change of 0.76 feet in 100 years (Table 6-6). Although seemingly small, through time this rate of change has the potential to result in significant impacts on low-lying coastal areas, and can produce varied alterations to salinity habitats of the Pithlachascotee River.

Table 6-6. Mean sea level trends as of May 2016.

NOAA Tide Station	Mean trend (mm/year)	Mean trend (ft/100year)
8727520 Cedar Key, Florida (NOAA 2016a)	1.97	0.65
8726520 St. Petersburg, Florida (NOAA 2016b)	2.66	0.87
Average	2.32	0.76

6.3.6.2 Incorporating Sea Level Change in Minimum Flows Assessment

Sea level changes with daily tides. As sea level rises during high tide, isohalines move inland. As sea level falls during low tide, isohalines move seaward. Long term changes in mean sea level (MSL) tend to mirror tidal changes, with increasing sea level resulting in the upstream movement of isohalines. This movement of isohalines associated with rising sea level will affect salinity-based habitats under both baseline and withdrawal-impacted flows by shifting isohalines upstream. However, river morphology has the potential to either increase or decrease the amount of habitat lost due to rising MSL.

For minimum flow status assessments, the District uses projections of sea level change that follow United States Army Corps of Engineers (USACE) guidance for the design of coastal projects. The USACE (2013) recommends using projections of future sea level based on three National Research Council (NRC 1987) scenarios. These include a low scenario based on continuing historical linear increases, an intermediate scenario (NRC Curve I) and a high scenario (NRC curve III).

6.3.6.3 Sea Level Rise Analysis Methods

For our Pithlachascotee River analyses, baseline flows needed to be recalculated under new sea level conditions. First, District staff used the USACE guidelines to estimate MSL in 2035, the end of our planning horizon. To estimate changes to MSL in the vicinity of the river, staff averaged values from the Cedar Key and St. Petersburg gages. Sea level changes relative to 1995, the midpoint of our baseline flow and gage height data, were considered. The average sea level rise expected between 1995 and 2035 is 0.09, 0.14, and 0.295 meters for low, intermediate, and high USACE projections. District staff added the USACE sea level rise values to gage height values for the Pithlachascotee River at Main Street gage from 1990 through 2000 data and recalculated isohaline locations based on these three increased sea level conditions.

Water column 2 psu isohalines are the most sensitive habitat response to flow, and thus form the basis for the proposed minimum flow for the lower, estuarine segment of the Pithlachascotee River (see Table 5-8 and 5-9). However, water column 2 psu isohalines are not predicted by tide gage height according to our regressions (see Section 4.5.2.1). Sea level change is incorporated into salinity-based habitat assessment by increasing tide gage height according to USACE projections. Therefore, when tide gage height is not a predictor of a particular habitat, District staff cannot predict the effect of sea level change on that habitat. This is the case for the 2 psu water column volume habitat: it is not sensitive to sea level rise because tide is not a significant predictor of the location of the 2 psu water column isohaline. Similarly, bottom area habitat is not predicted by tide gage height because it is dependent on the same water column isohaline that is used to predict water volume. This leaves vegetated shoreline distance as the only 2 psu salinity-based habitat dependent upon tide gage height and therefore upon sea level change. Therefore, our analyses of the effect of sea level change on salinity-based habitats in the Pithlachascotee River were based on the assessment of change in the length of vegetated shoreline associated with salinities of 2 psu or less. By inference, District staff can use this as a measure of the magnitude of changes we might expect to see in other salinity-based habitats.

6.3.6.4 Sea Level Rise Analysis Results

Rising sea levels are expected to alter baseline, i.e., not impacted by withdrawals, conditions by shifting isohalines upriver. Under baseline flows, sea level rise will cause the daily mean length of vegetated shoreline exposed to salinities of 2 psu or less to decrease by nine percent in Bock 1 and by three percent in Blocks 2 and 3 (Table 6-7). Compare this with decreases due to flow change, where historically, a 40 percent decrease in flow results in a seven percent decrease in habitat in Block 3 and an eight percent habitat decrease in Blocks 1 and 2. Taking into account the “new” baseline conditions created by sea level rise, reducing flow to 60 percent of baseline will result in 10 percent, nine percent, and eight percent decreased in habitat during Blocks 1, 2, and 3 respectively. These represent an increase of one to two percent more habitat lost due to equivalent flow reductions under future sea level conditions. The combined effect of sea level rise and loss of 40 percent of flow will reduce habitat by 20 percent, 13 percent, and 11 percent in each block.

Table 6-7. Effect of sea level rise and reduced flows on daily mean shoreline habitat by seasonal flow block for current (1995) and future (2035) sea level conditions. Baseline flows are shown where Flow = 100 percent. Decreases in habitat are shown as percent change due to reduced flows, sea level rise, and the combination of the two. Responses for only the highest sea level rise scenario are listed because this condition is expected to have the greatest consequences for salinity-based habitat. Likewise, only the smallest fraction of flow (60 percent) considered is shown here for simplicity.

Block	Time Period	Flow (percent)	Vegetated Shoreline (m)	Decrease Due to Flow (percent)	Decrease Due to Sea Level Rise (percent)	Decrease Due to Flow and Sea Level Rise (percent)
1	1995	100	3,437	0	0	0
1	2035	100	3,153	0	9	9
1	1995	60	3,175	8	0	8
1	2035	60	2,868	10	11	20
2	1995	100	5,078	0	0	0
2	2035	100	4,909	0	3	3
2	1995	60	4,707	8	0	8
2	2035	60	4,504	9	5	13
3	1995	100	5,148	0	0	0
3	2035	100	5,004	0	3	3
3	1995	60	4,820	7	0	7
3	2035	60	4,637	8	4	11

How does partitioning flows above and below 60 cfs, as was done for our development of recommended minimum flows for the lower Pithlachascotee River, affect the interaction between sea level rise and impacted flows? All Block 1 flows are below 60 cfs, so there is no change to projected block one flows. In Blocks 2 and 3, habitat decrease when flows are below 60 cfs is similar to Block 1 (where all flows are less than 60 cfs): in all three blocks, habitat is decreased by 10 percent under future sea level conditions when flow is at 60 percent of baseline and baseline flows are under 60 cfs (Table 6-8). When flows are greater than 60 cfs, there is no additional decrease in habitat under future sea level conditions.

Table 6-8. Effect of reduced flows on vegetated shoreline habitat when considering sea level change and partitioning season block flows above and below 60 cfs for current (1995) and future (2035) sea level conditions. Responses for only the highest sea level rise scenario are shown here because this condition is expected to have the greatest consequences for salinity-based habitat. Likewise, only the smallest fraction of flow (60 percent).

Block	Time period	Flow > 60 cfs?	Flow (percent)	Vegetated Shoreline (m)	Decrease Due to Flow (percent)
1	1995	No	100	3,437	0
1	2035	No	100	3,153	0
1	1995	No	60	3,175	8
1	2035	No	60	2,868	10
2	1995	Yes	100	6,522	0
2	2035	Yes	100	6,502	0
2	1995	Yes	60	6,319	3
2	2035	Yes	60	6,310	3
2	1995	No	100	4,938	0
2	2035	No	100	4,754	0
2	1995	No	60	4,551	9
2	2035	No	60	4,329	10
3	1995	Yes	100	6,275	0
3	2035	Yes	100	6,268	0
3	1995	Yes	60	6,197	1
3	2035	Yes	60	6,186	1
3	1995	No	100	4,903	0
3	2035	No	100	4,729	0
3	1995	No	60	4,520	8
3	2035	No	60	4,299	10

6.3.6.5 Sea Level Rise Analysis Discussion

Our purpose in analyzing the effect of potential sea level rise on habitat was to see if the effect of flow reductions will be magnified over a 20-year planning horizon, i.e., by 2035. In order to ask this question properly, District staff first established and accounted for the effect that sea level rise will have on baseline flows. After calculating 2035 baseline conditions, District staff predicted the potential change in salinity-based habitats relative to the new baseline conditions. District staff found that flow reductions will result in an additional one to two percent decrease in low-salinity habitat under 2035 sea levels (See Table 6-7). This pattern holds true when flows are below 60 cfs. When flows are above 60 cfs, rising sea level will not increase the effect of flow-based habitat reductions (see Table 6-8).

By inference, District staff might expect water column volume to be affected similarly, although in the particular case here, tide height was not a significant predictor of the location of the water column 2 psu isohaline. If the pattern shown for 2 psu vegetated shoreline holds for water volume habitat, then District staff would expect to see a one to two percent decrease in habitat for each reduction in flow. This would correspond to maximum flow reductions of 30 percent in Block 1 and 25 percent in

Blocks 2 and 3 (see Table 6-8). In conclusion, sea level rise is not expected to alter our need for development of an additional prevention or recovery strategy for the Pithlachascotee River, due to its negligible effect on amplifying the consequences of flow reductions on salinity-based habitats. These findings indicate that there is not currently an identified need to schedule a reevaluation of minimum flows that are proposed for adoption into District rules.

6.4 Summary of Minimum Flows Status Assessment

District staff evaluated the current status of the flow regime of the Pithlachascotee River, numerical modeling results and other supporting information to assess 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 for the upper and lower segments of the river.

Our minimum flows status assessment included: numerical modeling of flow impacts associated with current (74.3 mgd) and projected (90 mgd) withdrawal rates from Tampa Bay Water's Central System Facility wellfields; evaluation of the range of impacts predicted with the numeric model; consideration of numeric modeling uncertainty associated with input rainfall variation, the spatial distribution of wellfield withdrawals and intrinsic model error; aquifer water level changes in the surficial aquifer and UFA on Starkey wellfield, consideration of the usefulness of mean and median flow statistics for assessing flows; evaluation of trends in observed flows in the river and rainfall within Pasco County; consideration of status assessments for area water bodies with established minimum flows and levels; consideration of a wetland recovery assessment recently completed for Starkey Wellfield; and consideration of potential effects of various sea level rise on salinity-based habitats in the lower river. Based on this information District staff conclude that the minimum flows proposed for the upper and lower segments of the Pithlachascotee River are currently being met and are expected to be met during the coming 20-year planning period. Current and projected flows in the river are, however, near the minima associated with the proposed minimum flows for the upper river.
Because climate change, structural alterations and other changes in the watershed and groundwater basin contributing flows to the Pithlachascotee River, and because additional information relevant to minimum flows development may become available, the District is committed to periodic reevaluation and if necessary, revision of minimum flows for this priority water body that will presumably be incorporated into Chapter 40D-8, F.A.C. In support of this commitment, the District, in cooperation with the USGS, will continue to monitor and assess the status of flows in the river and continue to work with Tampa Bay Water on refinement of tools such as the INTB Model that were used for minimum flow development and assessment. Minimum flow status assessments will be completed by the District on an annual basis, on a five-year basis as part of the regional water supply planning process, and on an as-needed basis in association with permit and project activities. In the event that the need for recovery of minimum flows is identified for the Pithlachascotee River, the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution Area and the Hillsborough River Strategy (Rule 40D80-073, F.A.C.) would be applicable.

6.5 Miniumum Flows Implementation

District water use permits include, among other conditions, requirements that permitted water use will not lead to violation of adopted minimum flows and levels. In addition, the Florida Statutes require, as necessary, the adoption of recovery or prevention strategies to achieve recovery to established minimum flows or prevent existing flows from falling below the established minimum flows within a 20-year planning horizon.

Ongoing, periodic status assessments, like those described in preceding section of this chapter will be an important component of the implementation of minimum flows that are to be adopted for the Pithlachascotee River. Routine assessments of predicted flows based on updated groundwater modeling results will be critical to assessing potential withdrawal effects on the river. Gaged flows will also be critical for minimum flows implementation, with varying allowable percentages of flows for the lower river dependent upon withdrawal-corrected, lagged-flow recorded at the USGS Pithlachascotee River near New Port Richey, FL gage. Similarly, observed flow at the gage site will be used to potentially limit permitted surface water withdrawals from the upper river.

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